DOES MACROSCALE GREY MATTER MORPHOMETRY HAVE PERSONALITY?

Sofie L. Valk[1,2*]; Felix Hoffstaedter[1,2]; Julia A. Camilleri[1,2]; Peter Kochunov[3]; B.T. Thomas Yeo[4,5,6,7]; Simon B. Eickhoff[1,2]

[1)] Institute of Neuroscience and Medicine (INM-7: Brain and Behaviour), Research Centre Jülich, 52425 Jülich, Germany
[2)] Institute of Systems Neuroscience, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany
[3)] Maryland Psychiatric Research Center, University of Maryland School of Medicine, Baltimore, Maryland, USA.
[4)] Department of Electrical and Computer Engineering, Clinical Imaging Research Centre, Institute for Health and Memory Networks Program, National University of Singapore, Singapore, Singapore.
[5)] Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, MA, USA.
[6)] Centre for Cognitive Neuroscience, Duke-NUS Medical School, Singapore, Singapore.
[7)] NUS Graduate School for Integrative Sciences and Engineering, National University of Singapore, Singapore, Singapore.

Abstract

Personality traits are key indices of inter-individual variation in complex behaviors. Large-scale neuroimaging studies have reported inconsistent results on the association between personality and local grey matter structure. In three large-scale datasets of personality and cortical structure in twins and unrelated individuals (N=2824) we replicate both positive and null-results in personality neuroimaging. Positive results were observed between agreeableness, neuroticism, and openness in predominantly frontal regions in the twin-sample, where phenotypical correlations were driven by additive genetic factors. In addition, spatial patterns of genetic correlation between cortical thickness and openness were mirrored by phenotypic patterns in all samples. Last, using a multivariate approach, we identified a robust, heritable, relation between a latent personality component, emphasizing extraversion and openness, and a unique cortical thickness signature stretching from unimodal to heteromodal cortices. While our observations provide evidence of a genetic origin of correlations between grey matter and personality, associations were weak and highlighted robustness of whole-brain spatial patterns in relation to latent personality components, rather than single regions and traits.

“Personality” is an individuals’ characteristic set of cognitive, emotional and behavioral patterns. Behavioral science ascertains personality structure using a statistical construct that parcellates the individual variability in goals, cognition, and emotion into independent components (Mischel W 2004). The most well-known personality taxonomy is the Big Five Personality inventory (McCrae RR and PT Costa, Jr. 1997; John OP and S Srivastava 1999). The Five-factor personality structure (NEO- Five-Factor-Inventory – NEO-FFI) (McCrae RR and PT Costa, Jr. 1985, 1987) is a variance portioning approach to derive five orthogonal dimensions or traits of agreeableness (friendly/compassionate vs. challenging/detached), conscientiousness (efficient/organized vs. easy-going/careless), extraversion (outgoing/ energetic vs. solitary/reserved), neuroticism (sensitive/nervous vs. secure/confident), and openness (inventive/curious vs. consistent/cautious). Importantly, personality is related to health, wellbeing, and reproductive success (Alvergne A et al. 2010; Strickhouser JE et al. 2017). For example personality traits have been linked to the quality of social relationships (Asendorpf JB and S Wilpers 1998), job performance (Rothmann S and EP Coetzer 2003), and risk for mental disorders (Miller JD et al. 2001; Trull TJ 2013).

Personality has both stable as well as malleable features as a function of ageing (Harris MA et al. 2016; Penke L and M Jokela 2016; Damian RI et al. 2019) and the strongest predictor of personality is the personality of biological parents. Indeed, personality traits are heritable with about 50% of the variance attributable to additive genetic factors (Bouchard TJ, Jr. 1994; Jang KL et al. 1996; Loehlin JC et al. 1998; Bouchard TJ, Jr. and JC Loehlin 2001; Bouchard TJ, Jr. and M McGue 2003; Vukasovic T and D Bratko 2015). Genome-wide association studies (GWAS) have reported several genetic variants associated with personally traits (de Moor MH et al. 2012; van den Berg SM et al. 2016; Lo MT et al. 2017). However, results point to a large number of genetic variants with individually tiny effects that explain the heritability of personality (Verweij KJ et al. 2012; Consortium GoP 2015; van den Berg SM *et al.* 2016). Evolutionary causes for variability in personality traits have been suggested to be due to

balancing selection, where selection pressures in different directs affected the same traits enabling adaptation to changing environmental demands (Penke L and M Jokela 2016).

Next to these developments in behavioral genetics, the relationship between personality and brain structure has also been investigated using magnetic resonance imaging (MRI) (DeYoung CG et al. 2010; Bjornebekk A et al. 2013; Nostro AD et al. 2017; Riccelli R et al. 2017). While various studies found some phenotypic relationship between brain structure and variations in personality traits, the findings have been inconsistent (DeYoung CG *et al.* 2010; Bjornebekk A *et al.* 2013; Riccelli R *et al.* 2017). For instance, researchers failed to observe significant relations between personality and various markers of brain structure using the largest sample to date (Avinun R et al. BioArchiv June 4th). At the same time, using a similarly sized sample with monozychotic and dyzychotic twins, Owens and colleagues (Owens MM et al. 2019) report significant phenotypic relationships between personality and cortical structure. Here they observed associations between agreeableness, conscientiousness, neuroticism, and openness with dorsolateral prefrontal cortex morphometry.

This positive phenotypic relationship may be due to shared genetic factors which are enhanced in genetically related samples. Specifically, phenotypic correlation between two traits can be driven by shared genetic factors such as pleiotropy where a gene exerts phenotypic effects on both traits. However, significant genetic correlations may also be driven by sample biases, such as assortative mating and population stratification (Solovieff N et al. 2013). On the other hand, phenotypic correlation may be also be driven by shared environmental factors including nutrition, upbringing, stress, education and others. Genetic correlation analysis can separate between shared additive and environmental factors by using the contrast in kinship between individuals (monozychotic twins ~100% and dizychotic twins and siblings ~50% genetic similarity) to calculate the extent to which correlation between two traits varies as a function of genetic proximity.

In the current study we combined neuroimaging and behavioral genetics to investigate to shared genetic basis of personality traits and grey mater macrostructure. We combined three large-scale publicly available datasets to assess multi-site robustness of associations between personality and cortical thickness. We captured variations in brain morphometry using an atlas-based approach (Schaefer A et al. 2018) leading to more a homogeneous and biologically meaningful representation than common summary measures based on macro-anatomy (Eickhoff SB et al. 2018). Here, we first investigated the robustness of cortical thickness measurements, as well as NEO-FFI intercorrelations across three different samples. We then evaluated the phenotypic relation between personality and cortical thickness in three samples of unrelated individuals and assessed their consistency. Next, we evaluated personality – cortical thickness relationships in a twin-based sample. The twin-structure of this sample enabled the analysis of shared genetic variance between personality and cortical thickness. Analysis of heritability and co-heritability was performed using maximum likelihood variance-decomposition methods using Sequential Oligogenic Linkage Analysis Routines (www.solar-eclipse-genetics.org; Solar Eclipse 8.4.0.). Heritability (h^2) is the total additive genetic variance and genetic (ρ_g) correlations were estimated using bivariate polygenic analyses. estimated the genetic correlation between personality and cortical thickness in this sample. Lastly, we used a multivariate approach (partial least squares) to evaluate whether latent relationships between personality traits and cortical brain structure exist, and assessed its genetic basis.

Results

Replicability of NEO five-factor personality and cortical thickness measurements.

As we used three independent large-scale samples: The Human Connectome Project sample (HCP), the enhanced Nathan Kline Institute – Rockland sample (eNKI) and the Brain Genomics Superstruct Project (GSP), we first tested whether distributions of personality traits and cortical thickness were comparable across samples. First, we assess the distributions of personality scores and cortical thickness across samples as well as comparability between samples. Indeed, all personality scores were normally distributed (Figure 1A). Following we verified whether the correlational structure between personality trait scores (Figure 1B) was comparable across samples. Indeed, NEO-FFI intercorrelations were highly correlated (r>0.95) across samples (Table 1), indicating that the different dimensions of personality had a similar structure relative to each other across samples. At the same time, the mean of most traits differed significantly across samples (Supplementary Table 1). Last, we assessed whether regional of thickness (Figure 1C) was similar across samples using unpaired two-sample t-test. Indeed, after controlling for global thickness, there were no significant differences between samples (Supplementary figure 1).

	HCP	**GSP**	**eNKI**
HCP	1		
GSP	0.99 [0.91 1]	1	
eNKI	0.95 [0.81 1]	0.94 [0.80 0.99]	1

Table 1. Internal structure of the NEO-FFI is highly replicable across samples. Spearman correlations ± 95% CI of the intercorrelation between personality traits across samples of unrelated individuals.

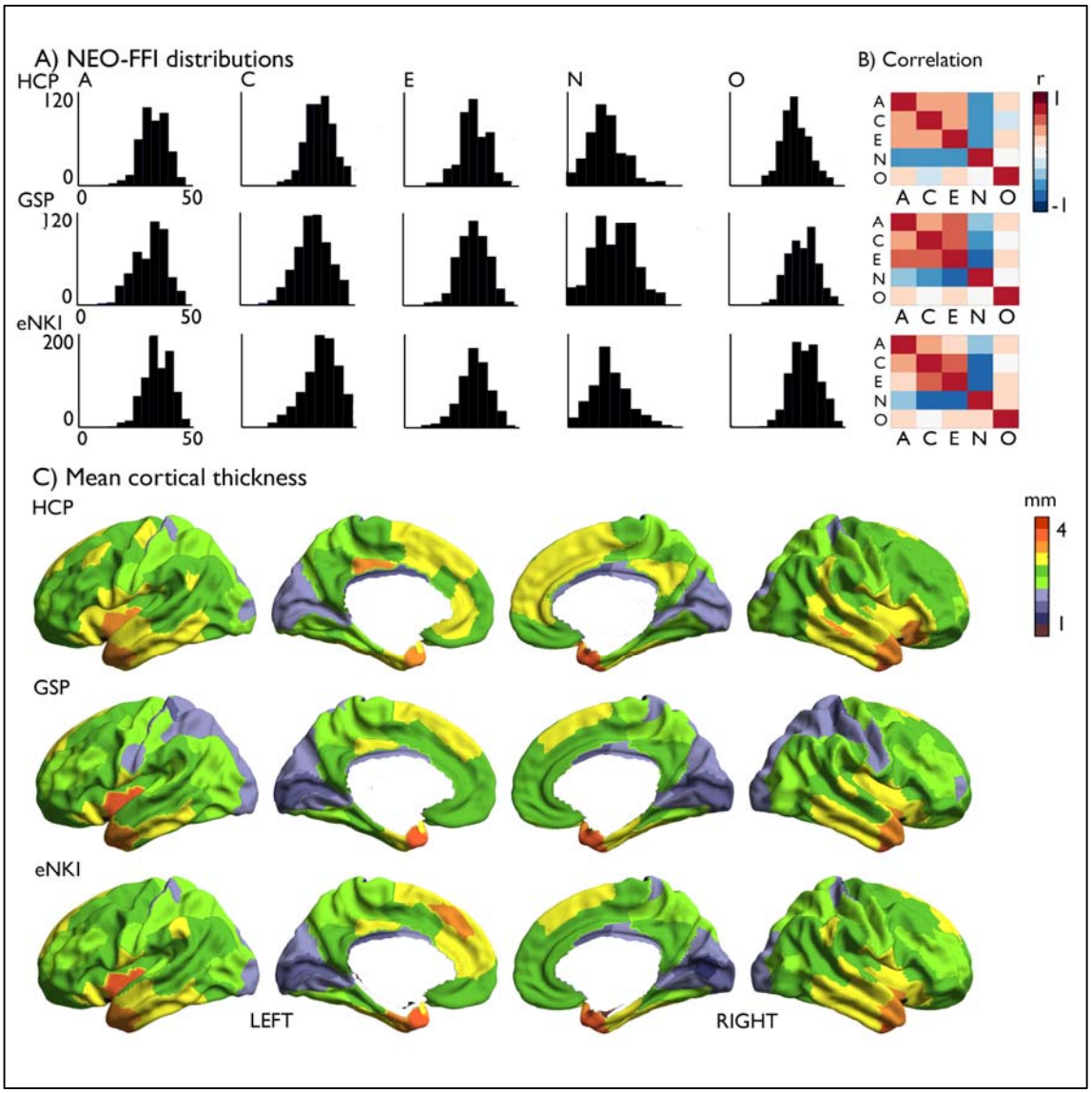


Figure 1. Distribution of NEO-FFI scores, their intercorrelation, and parcel-wise cortical thickness in three independent samples. A). Distributions of NEO-FFI scores in three unrelated samples (HCP; GSP; eNKI). B). Intercorrelation of personality trait scores in each sample. C). Distribution of mean parcel-wise thickness in mm in the three unrelated samples.

Phenotypical correlation between NEO-FFI and cortical thickness in three samples.

Next, we sought to assess whether there is a phenotypical correlation between personality and cortical thickness which is replicable across samples. First, we selected unrelated individuals from the HCP sample (n=419), as well as GSP sample (n=926) and eNKI sample (n=792). Then we correlated each personality trait with cortical thickness at each parcel, which we corrected for multiple comparisons using FDR (controlling for the number of parcels as well

as number of datasets). We did not find significant relationships between NEO-FFI traits and parcel-wise cortical thickness in any of the samples. Also, trend-level ($p<0.01$) relationships between NEO-FFI traits and cortical thickness did not overlap between samples (Figure 2, Supplementary Table 2). Combining samples while controlling for site also did not generate significant results (Supplementary Figure 2). Following, we assessed phenotypic correlation between personality traits and parcel-wise cortical thickness in the complete HCP sample (n=1106 including 286 MZ-twins and 170 DZ-twins). Here we observed significant (FDR, corrected for number of parcels) correlations between agreeableness, neuroticism, and openness and local cortical thickness. Specifically, agreeableness related negatively to variations in thickness in left lateral and medial prefrontal cortex (FDR$p<0.0125$). Neuroticism related positively to thickness in dorsolateral frontal areas and left posterior operculum, and negatively to thickness in posterior mid-temporal cortex and occipital regions (FDR$p<0.015$). Openness related negatively to thickness in bilateral ventrolateral cortex, and positively to left inferior temporal regions, right temporal pole, and right cuneus (FDR$p<0.01$) (Supplementary Table 2). Though we observed little reliability across samples (Supplementary Table 2), the spatial distributions of phenotypic correlations showed some consistency across samples (Supplementary table 3), especially in openness. At the same time, in line with phenotypic behavioral intercorrelations, we observed considerable overlap of phenotypic correlation between personality trait and cortical thickness across traits (Supplementary table 4). Though findings remained similar when controlling for intelligence, post-hoc analysis showed that the relation between cortical thickness and personality was partially mediated by intelligence (Supplementary table 5).

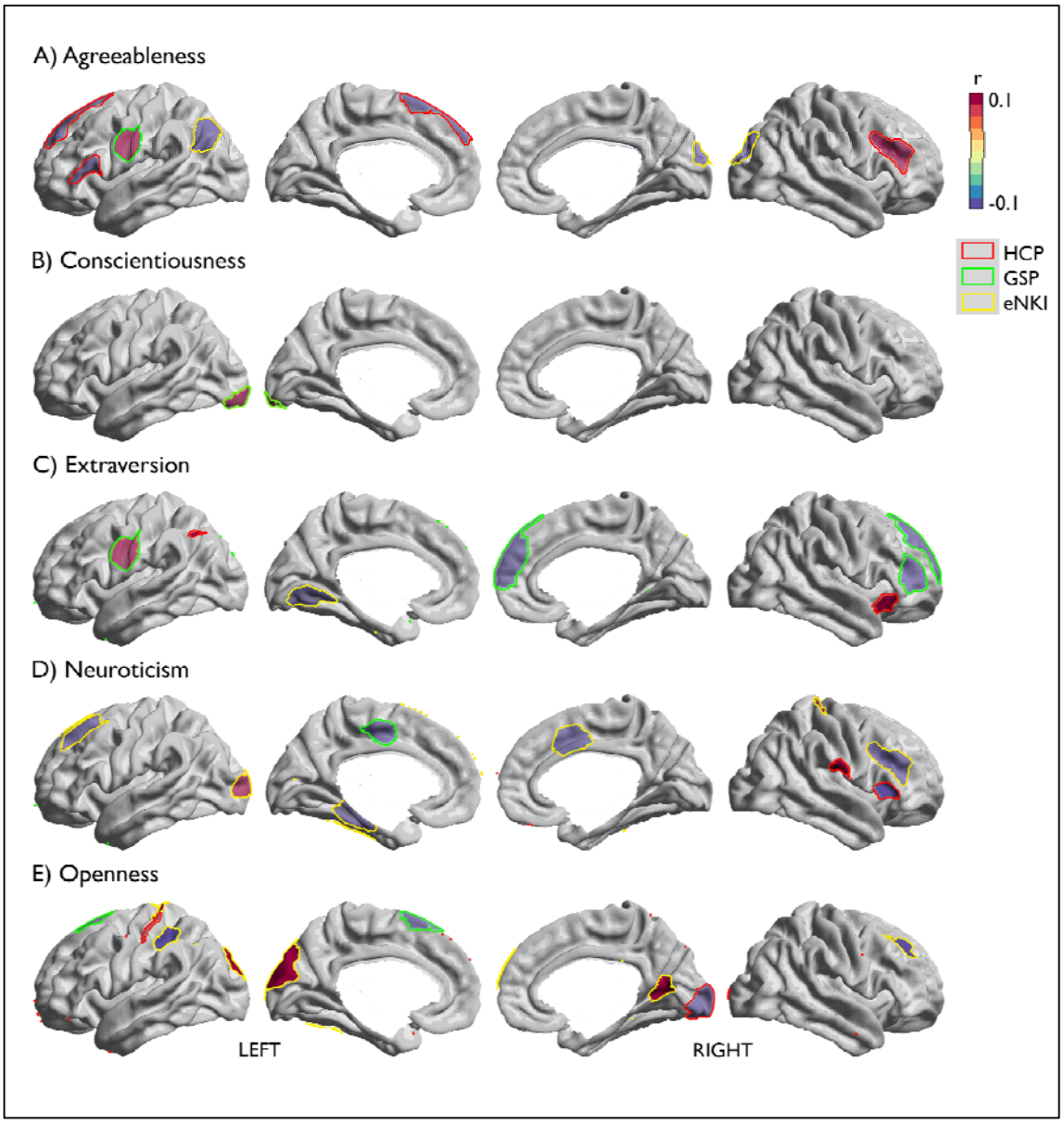


Figure 2. No consistent phenotypic relationship between cortical thickness and personality. Findings in each sample are displayed at p<0.01, positive Spearman's ρ is displayed in red, whereas negative spearman's ρ is displayed in blue. Findings are outlined with specific color per sample (red=HCP unrelated subsample; green=GSP, yellow= eNKI). Multiple comparisons were accounted for by using FDRp<0.05 correcting for the number of parcels (200), as well as number of samples (3).

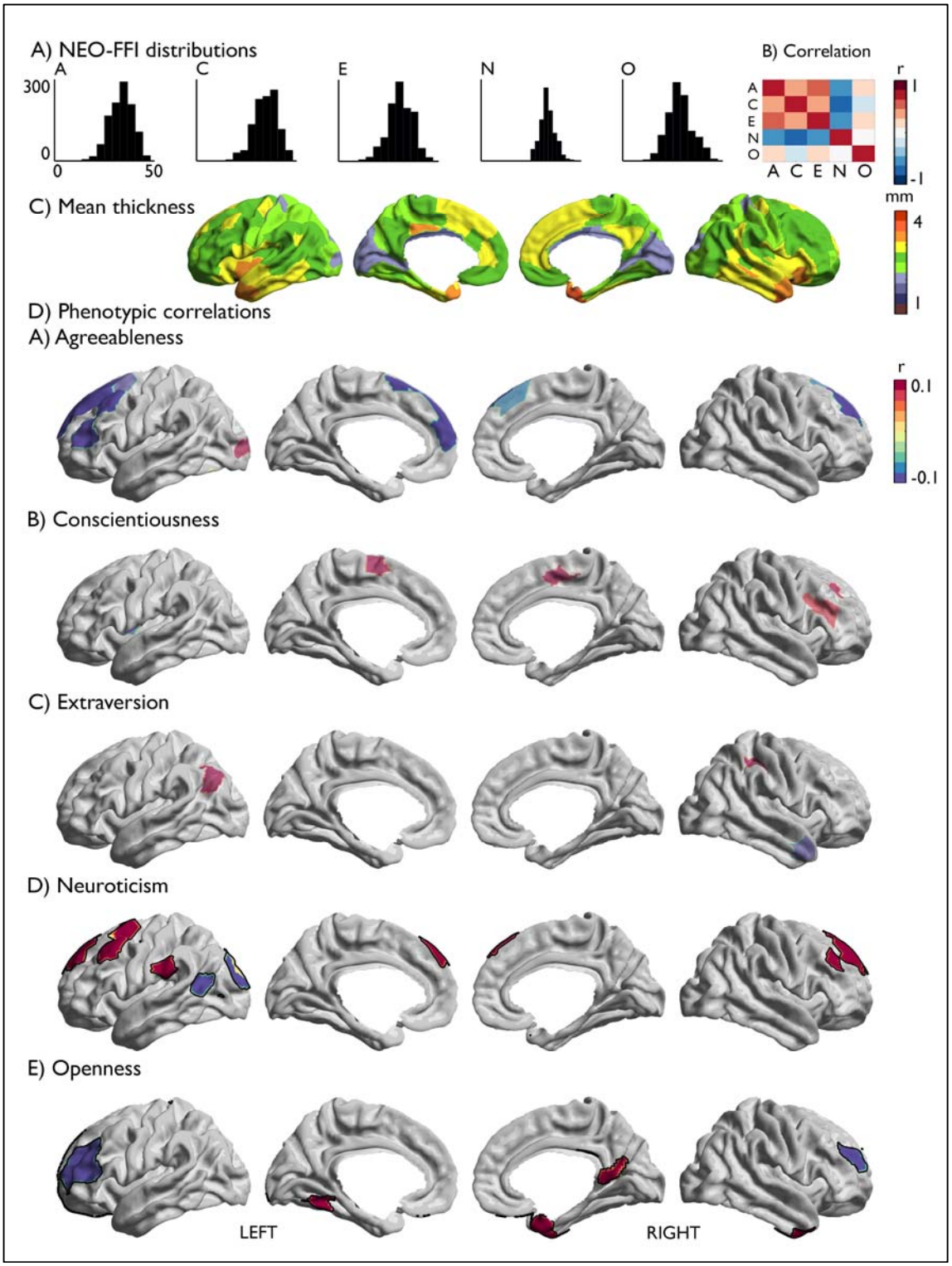


Figure 3. Significant relation between personality traits and local cortical thickness in the related HCP sample. Findings in each sample are displayed at $p<0.01$, positive Spearman's ρ is displayed in red, whereas negative spearman's ρ is displayed in blue. Multiple comparisons were accounted for by using FDR$p<0.05$ correcting for the number of parcels (200).

Genetic correlation of personality traits and brain structure

Subsequently, we sought to understand whether the phenotypic correlations observed in the twin-sample might be due to shared genetic effects on grey matter brain structure and personality traits. All personality traits were significantly heritable in our current sample (Figure 4A, Supplementary Table 6), and we next confirmed cortical thickness to be heritable in our parcel-based approach (Figure 4B, Supplementary Table 7). This enabled us to perform genetic correlation analyses between personality traits and cortical structure. Agreeableness showed genetic correlation (FDR $p<0.05$) with cortical thickness in left posterior superior/mid temporal sulcus ('7Networks_LH_Default_Temp_5') ($r=0.03$; $\rho_g = 0.60$, $p<0.0005$; $\rho_e = -0.15$, $p<0.01$), right superior frontal cortex extending to mid cingulate ('7Networks_RH_SalVentAttn_Med_3') ($r=-0.04$; $\rho_g = -0.55$, $p<0.0004$; $\rho_e =0.18$, $p<0.005$), and right dorsolateral frontal cortex ('7Networks_RH_Default_PFCm_6') ($r=-0.02$; $\rho_g = -0.51$, $p<0.0006$; $\rho_e =0.21$, $p<0.0004$). Quantitative functional decoding using the BrainMap database(Fox PT et al. 2014) (Supplementary Fig. 3) indicated that the left posterior superior-mid temporal sulcus was related to various forms of language processing ($p<0.05$), whereas the left superior frontal / mid cingulate parcel was related to action imagination and execution, as well as cognition and perception, and the dorsolateral prefrontal cortex was found implicated in cognitive tasks involving memory and reasoning. Second, we observed a genetic correlation (FDR $p<0.01$) between extraversion and left TPJ thickness ('7Networks_LH_Default_Temp_9') ($\rho=0.1$, $p<0.001$; $\rho_g = 0.49$ $p<0.00005$; $\rho_e = -0.11$, $p<0.05$). Quantitative functional decoding showed the TPJ to be activated above chance by (socio-) cognitive tasks and hence should be implicated in cognitive and social cognitive processing ($p<0.05$). Next to socio-cognitive processing, the TPJ, was implicated in cognition related to reasoning and language (Supplementary figure 3). Lastly, though we observed significant genetic correlation between intelligence (total cognitive score) and personality

traits (Supplementary table 11), genetic correlations between personality and cortical thickness remained similar when controlling for intelligence (Supplementary figure 5).

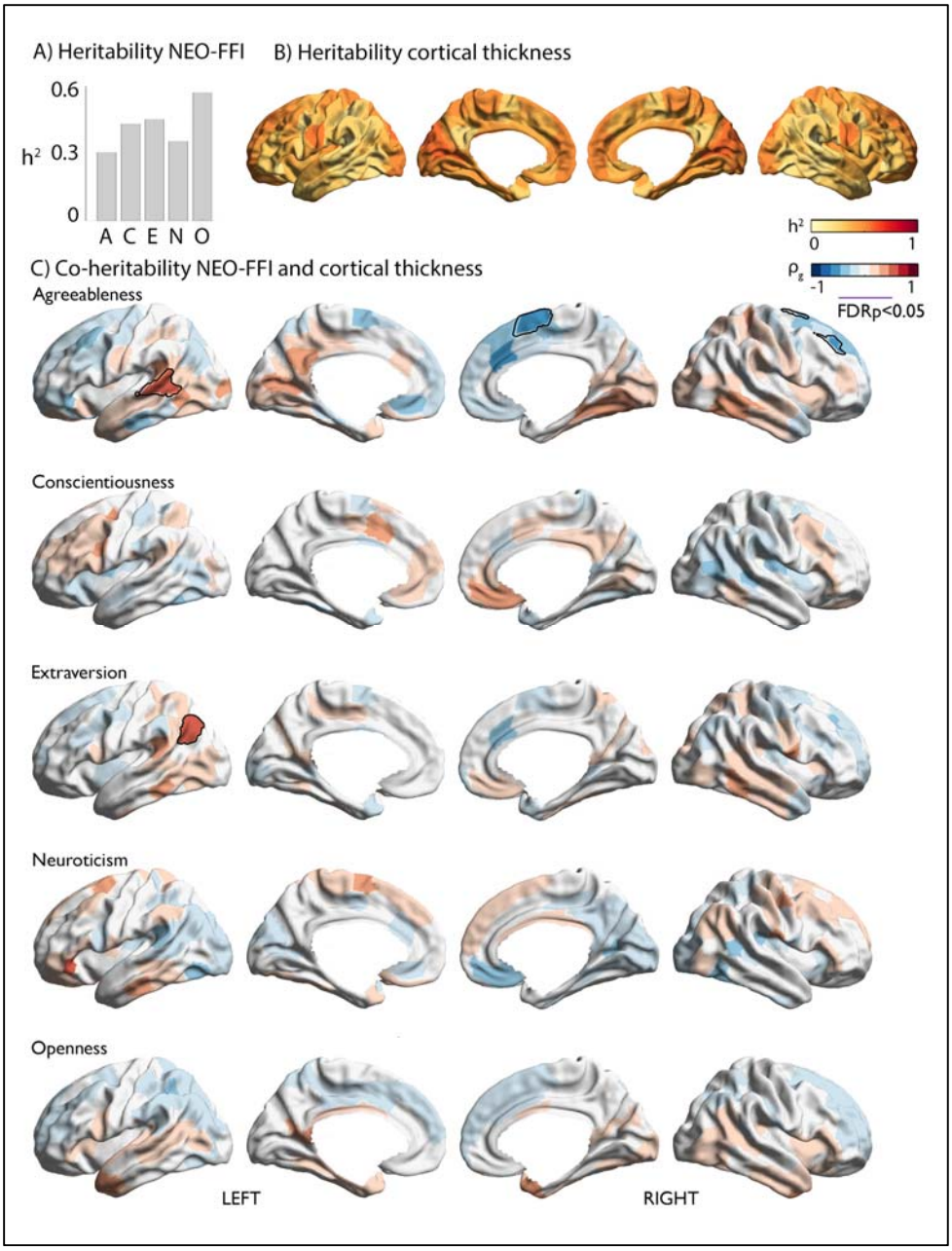


Figure 4. Genetic correlation between personality traits and cortical thickness. Upper panel depicts the heritability of A) personality and B) cortical thickness, see supplementary table 5 and 6 for exact heritability values. Lower panels are genetic correlation between cortical thickness and personality traits, here red values indicate positive associations whereas blue values indicate negative genetic correlation between parcel-wise thickness and personality traits. Findings at FDRp<0.05 are outlined in black.

Correspondence of genetic and phenotypic correlations

Following, we assessed whether we could uncover correspondence between phenotypic and genetic correlations (Cheverud's conjuncture) within the HCP sample, as well as whether genetic correlations related to phenotypic correlations across samples. 11 of 22 previously observed significant (FDRp<0.05) phenotypic correlations in the complete HCP sample also show genetic correlations at p<0.05 (Supplementary table 8). At the same time, observed significant genetic correlations (based on Figure 4) were not consistently associated with phenotypic correlations, both within the HCP sample as in the GSP and eNKI samples (Supplementary table 9). We did not observe significant genetic correlations between cortical thickness and Conscientiousness, Neuroticism, and Openness, or significant environmental correlations between cortical thickness and any of the personality traits (Supplementary figure 5).

We then explored whether genetic correlations mirrored phenotypical correlations (Table 3). Here we observed that indeed spatial patterns of genetic correlations across the cortex showed strong (r=0.46-0.71) positive correlations with spatial patterns of phenotypic correlations both within the complete HCP sample, as well as in the unrelated subsample. However, these patterns only extended out of sample for openness, where both phenotypical patterns between openness and cortical thickness in GSP (r=0.18 [0.04 0.32]) and eNKI (0.34 [0.23 0.46]) both showed positive correlations with genetic correlation patterns in HCP.

	HCP all	**HCP un**	**GSP**	**eNKI**
Agreeableness	0.59 [0.49 0.67]	0.37 [0.23 0.51]	-0.04 [-0.18 0.10]	-0.14 [-0.27 0.02]
Conscientiousness	0.52 [0.38 0.63]	0.26 [0.13 0.40]	0.04 [-0.11 0.17]	0.01 [-0.12 0.16]
Extraversion	0.46 [0.32 0.58]	0.37 [0.26 0.48]	0.08 [-0.06 0.22]	0.12 [-0.03 0.25]
Neuroticism	0.58 [0.47 0.67]	0.35 [0.22 0.47]	-0.06 [-0.19 0.09]	-0.03 [-0.15 0.10]
Openness	0.71 [0.62 0.78]	0.43 [0.31 0.54]	0.18 [0.04 0.32]	0.34 [0.23 0.46]

Table 3. Correlation of phenotypic and genetic correlation across samples. Spearman's correlation [95% confidence interval] between spatial distribution of genetic correlation based

on the HCP related sample, and phenotypic correlation in the HCP related sample (HCP all), HCP unrelated subsample (HCP un), GSP sample, and eNKI sample.

Latent structures between personality traits and cortical thickness.

As we observed phenotypic (Figure 1, Figure 2) and genetic and environmental correlations between personality traits (Supplementary Table 11 and 12), as well as spatial overlap in brain-personality correspondences (Supplementary table 4), we investigated whether when using multivariate data-driven approach (partial least squares; PLS), personality could be related to cortical thickness. First, we assessed the existence of latent structures based on personality traits and cortical thickness in the unrelated GSP and eNKI samples combined. We observed that out of five possible components, the second component significantly ($p<0.001$) explained 30% of shared variance between cortical thickness and personality in eNKI and GSP. The behavioral salience component was predominantly driven by openness and extraversion. In the GSP sample we observed the component related to a factor with on the one hand complex cognition and harm avoidance (caution) and on the other hand reward seeking and instability (exploration) (Supplementary table 14). The brain salience component had low loadings (BSR<-2) in occipital and posterior insular regions and high loadings (BSR>2) in frontal and inferior parietal and TPJ regions. Running post-hoc analysis of the spatial distribution, we observed that whereas visual and sensorimotor networks had relatively low saliencies, ventral attention, frontoparietal and default mode regions had relatively high saliencies. This was mirrored by a positive relation (r=0.48 [0.37 0.58]) between the brain saliency component and principal gradient of functional organization(Margulies DS et al. 2016). Importantly, the component remained robust when controlling for intelligence. We could replicate the positive association between behavioral salience and brain salience, by projecting the saliencies on brain and behavioral data of the HCP sample (r=0.08 [0.01 0.14]). Indeed, both brain and behavioral scores were highly heritable in HCP; brain score (h2r = 0.74, 0.03): behavioral score (h2r = 0.52, 0.05). Last, performing genetic correlation on the

brain score and the behavioral score component showed a trending positive correlation (ρ_g = 0.11, p<0.09; ρ_e = 0.02, p>0.5). Last, we could reproduce a similar second latent factor in the HCP sample (Supplementary figure 7, supplementary table 14).

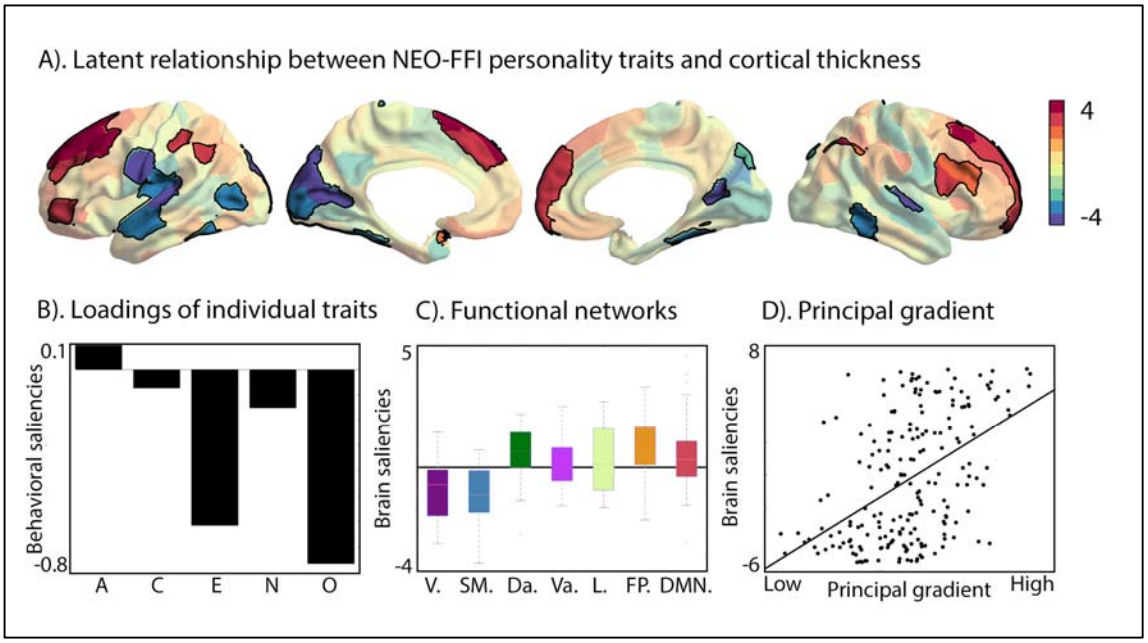


Figure 5. Latent cortical thickness informed factor of personality traits. A. Bootstrap ratio of the second brain saliency that showed significant robustness, where parcel-wise saliencies of p<0.05 are highlighted. Red indicates a positive association whereas blue indicates a negative association; B. Loadings of the individual traits; C. Relation to functional networks (Yeo BT et al. 2011) and D. Relation to functional gradient (Margulies DS *et al.* 2016).

Discussion

Personality traits are highly heritable, suggesting a genetic basis for personality. Variance in macroscale brain structure is also highly heritable, but though behavior is ultimately enabled by brain structure, but there is inconclusive evidence of covariance between personality traits and local grey matter macrostructure. To assess the relationship between personality traits and cortical thickness we assembled three independent large and representative datasets containing human structural MRI and personality assessments. Our analysis showed that phenotypic correlations are inconsistent across samples, and only significant in the HCP sample which included monozychotic and dyzychotic twins. In this sample phenotypic correspondences between personality and cortical thickness are mirrored by genetic correlations, suggesting a shared genetic basis of personality and cortical thickness. At the same time, significant genetic associations between personality traits and cortical thickness were not reflected in phenotypic correlations across samples. Only in case of openness we observed that spatial distributions of genetic correlations reflect phenotypic correlations out of sample. Using a multivariate approach, we identified a robust, heritable, latent dimension of personality – cortical thickness correspondence, most strongly related to openness and extraversion. The cortical thickness signature of this component featured a pattern from unimodal to heteromodal association cortices, suggesting a system-level relationship between personality and cortical thickness. In sum, while our observations indicate that in the twin-based sample phenotypic correlations related to shared genetic effects on cortical thickness and personality, effects were small and distributed across the cortical mantle. Second, we observed only robustness across samples in latent personality components in relation to whole-brain spatial patterns, suggesting neurobiological mechanisms underlying personality are shared not trait specific.

In the current study focused on the relationship between individual differences in personality traits and local grey matter anatomy, using compressed surface-based MRI data based on the parcellation scheme of Schaefer et al. Using compressed features of structural MRI has been suggested to both to improve signal-to-noise of brain measures, assuming the cortex can be subdivided in cortical areas that bridge different features such as connectivity and structure (cf. Eickhoff et al. (Eickhoff SB *et al.* 2018) and Genon et al. (Genon S et al. 2018)), as well as to optimize analysis scalability in our genetic analyses. The Schaefer parcellation is derived using functional MRI data from ~1500 subjects, by integrating local approaches that detect abrupt transitions in functional connectivity patterns and global approaches that cluster similar functional connectivity patterns (Schaefer A *et al.* 2018). Previous research found that the Schaefer parcellation showed convergence with partitions based on structure alone (Varikuti DP et al. 2018). A combination of within-area micro circuitry, proxied by brain morphometry, and between-area connectivity enables each area to perform a unique set of computations (Van Essen DC and MF Glasser 2018). Therefore, a parcellation approach that considers both local and global connectivity benefits structural image analysis, as it reduces signal-to-noise both within individual as across individuals and make control for multiple comparisons more straightforward (Genon S *et al.* 2018). Based on the findings in our study we suggest our approach might be a fruitful first exploratory step to further investigate the relation between brain structure and behavior, and locate neural mechanisms of interest. Future studies can then verify these results by exploring more specific genetic mechanisms, as well as neuroanatomical features. For example, in line with our multivariate observations, there is converging evidence that inter-individual differences in topological integrative features of multi-modal areas are more important for higher-order cognitive functions, such as intelligence, than local features only (Seidlitz J et al. 2018).

Both cortical thickness distributions as well as personality trait structure were comparable across samples. Indeed, all samples showed a comparable intercorrelation of personality traits, with neuroticism consistently negatively related to all other traits. Second, we observed strong correspondence between spatial distribution of cortical thickness across the three samples, with relative thick anterior insular regions, and thinning in occipital regions. However, in line with a recent report (Avinun R *et al*. BioArchiv June 4th), we did not observe consistent correspondence between personality traits and cortical thickness in three-large scale unrelated samples. Possibly sources of difference such as age are known to show moderate associations with both brain structure and personality (Ferschmann L et al. 2018) cannot explain lack of correspondence between personality traits and cortical thickness as the HCP and GSP sample both entail young adults. Also, when combining all samples, creating a sample size of over 2000 individuals, we only observed associations at trend-level. At the same time, we were able to replicate previous observations of significant relationships between cortical thickness and personality traits in the related HCP sample. Indeed, correspondence between frontal regions and personality traits of agreeableness, neuroticism, and openness are also reported using a non-parcel-based method by Owens and colleagues (Owens MM *et al.* 2019).

The lacking relationship between personality traits and brain structure is in line with the previous finding of Kharabian Masouleh et al. (Kharabian Masouleh S et al. 2019), reporting little robust correspondence between complex behavior and local brain structure. Though our samples all were from WEIRD (Western, educated, industrialized, rich, and democratic) populations (Laajaj R et al. 2019), it is possible that functional processes underlying the responses were not comparable across samples. The observation that a more genetically homogeneous group shows stronger phenotypic correlation between personality traits and grey matter structure could have multiple explanations. First, personality is a complex psychological construct where various biological processes could underlie the behavioral

phenotype. Thus, multiple functional processes, related to variation in grey matter structure, could underlie a complex trait such as personality. It is possible that due to their genetic similarity power is increased to observe similar mappings, for example by interacting with intelligence. Second, confounding environmental and noise effects vary across samples. Indeed, the trait with least environmental sources of variation, openness, showed some correspondence across samples. Third, it could be that the Big five personality traits are not the optimal mapping of traits to be reflected consistently in local grey matter brain structure. Indeed, in line with previous studies(Vukasovic T and D Bratko 2015; Lo MT *et al.* 2017), we observed phenotypic and genetic correlation between personality traits. As in our study, Vukasovic T and D Bratko (2015) as well as Lo and colleagues(Lo MT *et al.* 2017) consistently report neuroticism to be negatively genetically correlated with all other personality traits. Other genetic correlation patterns are less consistent, e.g., we did not observe a genetic correlation between extraversion and openness (Lo MT *et al.* 2017). These correlation analyses highlight latent genetic relationships between various personality traits. Exploiting the intercorrelation between personality traits using partial least squares (McIntosh AR and NJ Lobaugh 2004; Zoller D et al. 2017) we observed a robust latent factor of personality and cortical thickness. Notably, this factor was predominantly driven by openness, followed by extraversion. This factor showed some overlap with the genetic component of personality identified by Lo et al. (Lo MT *et al.* 2017) where extraversion and openness showed similar loadings. Its corresponding cortical thickness signature followed a pattern from unimodal to transmodal cortices, one of the most stable patterns of genetic, functional and microstructural cortical organization (Huntenburg JM et al. 2018). This suggests that variation in personality is related to local alterations in global processing hierarchies, linking external oriented cognitive operations with internal thought. Indeed, recent work has shown functional hierarchies are related to ASD, a pervasive neurodevelopmental condition with abnormal behavior both in sensory as well as higher-cognitive behavioral domains (Hong SJ

et al. 2019). As the relation between personality traits brain structure is longitudinally related to developmental effects (Ferschmann L *et al.* 2018), it is possible personality relates to the interrelation of regions, rather than local structure.

To assess whether phenotypic correlations between personality traits and macroscale grey matter structure reflected shared genetic processes we performed genetic correlation analysis in the twin sample. The strength of genetic correlations is strongly dependent on the heritability of each of the correlated markers. In our sample, between 30% and 60% (on average 42%) of variance in personality traits was explained by additive genetic factors. This is in line with previous studies using twin and family samples(Jang KL *et al.* 1996) as well as genome-wide approaches (Lo MT *et al.* 2017). A recent meta-analysis (Vukasovic T and D Bratko 2015) confirmed that an average 40% of the variance in personality traits is of genetic origin. Also, conform previous studies (Panizzon MS et al. 2009; Kremen WS et al. 2010; Winkler AM et al. 2010; Eyler LT et al. 2012; Strike LT et al. 2018), we observe high (h2>0.4) heritability of cortical thickness, with highest values in primary sensory areas. The heritability patterns highlight high heritability of cortical thickness in unimodal cortices, whereas variance in association cortices is on average less influenced by genetic factors (Panizzon MS *et al.* 2009; Kremen WS *et al.* 2010; Eyler LT *et al.* 2012; Fjell AM et al. 2015; Hofer E and e al. 2018; Strike LT *et al.* 2018; Teeuw J et al. 2018).

Though our genetic correlation analyses revealed a genetic link of agreeableness and extraversion to brain structure, these correlations were not mirrored by phenotypic correlation both within sample as well as across samples, questioning the robustness of these observations.

Indeed, though overall patterns of genetic correlations corresponded to phenotypic correlations more strongly than environmental correlations, regions that showed genetic correlations at FDR-corrected thresholds were outliers, as typical values of genetic correlation

ranged between -0.4 and 0.4. The observed correspondence between phenotypic and genetic correlations between cortical thickness and personality traits within the HCP sample is in line with Cheverud's conjuncture. This assumption asserts that the use of phenotypic correlations as proxies for genetic correlations and has been confirmed in other human traits (Sodini SM et al. 2018). However, inversely, given that phenotypic correlations between personality and brain structure are low across samples, the genetic correlation between brain structure and personality traits is likely also low. Indeed, comparing genetic correlations with phenotypic correlations out of sample, only the spatial distribution of genetic correlation in openness was robustly related to phenotypic spatial distribution in all three samples. Coincidently openness had highest heritability in the HCP sample, indicating that the largest proportion of variance in openness is not driven by environmental mechanisms or chance.

The observed genetic correlation between cortical thickness and personality is likely due to mediated pleiotropy (a gene affects A which affects B), rather than linkage disequilibrium or biological pleiotropy. Here the genetic mechanism would affect grey matter macrostructure and associated function and, as a consequence, personality. Alternatively, it could be that genetic variation affects brain function which in turn modulates both macroscale structure as well as personality, or a genetic mechanism affects an unknown biological factor which in turn affects personality and brain structure. On the other hand, genetic correlation patterns did not replicate across samples. Assuming that genetic correlation patterns of the other personality traits are meaningful, there are various explanations for lack of association between genetic correlation and phenotypic correlation out of sample. First, it could be lack of power. Indeed extraversion, the second-most heritable trait, showed also positive correspondence between genetic correlation and phenotypic correlation out of sample at sub-threshold level. Second, it is possible that similar functional processes have diverging neural signatures across samples. (Part of) variation in personality is due to rare genetic variants

(Penke L and M Jokela 2016; Boyle EA et al. 2017; Hill WD et al. 2018) which could lead to differences between samples leading to variable patterns of brain-behavior correspondences. Further research needs to identify the functional implications of the impact rare variants on variance in complex behaviors. Third, it might be that traits probed are not comparable across samples due to challenges in operationalize personality reliably. Indeed, we observed some difference between samples both in variance of personality traits, as well as for intelligence, and age. Follow up mediation analysis showed that associations between personality traits and cortical thickness in the HCP sample are partially mediated by intelligence. While patterns of genetic correlation between cortical thickness and personality remained similar when controlling for intelligence, this suggest an interaction between intelligence, personality, and macroscale grey matter structure in the HCP sample.

In the current study we focused on the phenotypic and genetic relation of local cortical thickness with personality trait. Our results only showed weak correlations, if at all. However, these correlations were linked to genetic correlations, suggesting that if there is a correlation between brain structure and personality traits, this is likely due to shared, additive, genetic effects. Nevertheless, personality is relevant factor for life functioning, and related to mental and physical health (Asendorpf JB and S Wilpers 1998; Miller JD *et al.* 2001; Rothmann S and EP Coetzer 2003; Trull TJ 2013). Due to limitations in the twin-design, we could not account for shared environmental effects. As only 40% of personality variance is heritable, it is likely that part of individual difference in personality are due to non-genetic effects. For example, family environment, peer-groups, as well as development shape personality (Nakao K et al. 2000; Hopwood CJ et al. 2011). Future studies accounting for shared environment might be able to uncover environmental effects on covariance between personality and brain structure. In similar vein, the current focus has been on grey matter macrostructure. Though our latent models indeed suggest that part of the variance in personality traits can be

explained by grey matter structure, variance in personality traits is also accounted for by both static and dynamic brain functional variations (Dubois J et al. 2018; Wu X et al. 2019). Indeed recent work has shown genetics underlying structure and function are dissociable in heteromodal association cortices (Bertolero MA et al. arXiv). As we observed a strong multivariate link between heteromodal association cortices and personality traits, it would be interesting to explore the genetic relation between function and personality, as well as structural modalities other than cortical thickness such as surface area, and white matter structure.

In sum, we demonstrate that phenotypic correlations between personality traits and local cortical thickness are inconsistent across samples. At the same time, we did observe phenotypic associations between personality traits and cortical thickness in a twin sample, which were partially mediated by intelligence. In this sample phenotypic correspondence between personality and cortical thickness was reflected by genetic correlations. Only in case of openness we observed that spatial distributions of genetic correlations reflect phenotypic correlations out of sample. Last, using a multivariate approach, we identified a robust, heritable, latent dimension of personality and cortical thickness, related to openness and extraversion. While our results suggest a genetic origin of correlations between grey matter and personality, associations were weak and highlighted system-level patterns, rather than localized effects. Our observations might inform further studies bridging the relation between complex behavior, brain, and genetic architecture.

Materials and methods

HCP sample:

Participants and study design

For our analysis we used the publicly available data from the Human Connectome Project S1200 release (HCP; http://www.humanconnectome.org/), which comprised data from 1206 individuals (656 females), 298 MZ twins, 188 DZ twins, and 720 singletons, with mean age 28.8 years (SD = 3.7, range = 22–37). We included for whom the scans and data had been released (humanconnectome.org) after passing the HCP quality control and assurance standards (Marcus DS et al. 2013). The full set of inclusion and exclusion criteria are described elsewhere(Glasser MF et al. 2013; Van Essen DC et al. 2013). After removing individuals with missing structural imaging or behavioral data our sample consisted of 1106 individuals (including 286 MZ-twins and 170 DZ-twins) with mean age of 28.8 years (SD =3.7, range =22-37).

Structural imaging processing

MRI protocols of the HCP are previously described in(Glasser MF *et al.* 2013; Van Essen DC *et al.* 2013). The pipeline used to obtain the Freesurfer-segmentation is described in detail in a previous article (Glasser MF *et al.* 2013) and is recommended for the HCP-data. The pre-processing steps included co-registration of T1 and T2 scans, B1 (bias field) correction, and segmentation and surface reconstruction using FreeSurfer version 5.3-HCP to estimate cortical thickness.

Behavioral assessment

The NEO-FFI personality traits were assessed using the NEO-Five-Factors-Inventory (NEO-FFI)(McCrae RR and PT Costa 2004). The NEO-FFI is composed of a subset of 60-items extracted from the full-length 240-item NEO-PI-R. For each item, participants reported their

level of agreement on a 5-point Likert scale, from strongly disagree to strongly agree. The NEO instruments have been previously validated in USA and several other countries(McCrae RR and A Terracciano 2005).

As a proxy for IQ we used the NIH Toolbox Cognition(Weintraub S et al. 2013), 'total composite score'. The Cognitive Function Composite score is derived by averaging the normalized scores of each of the Fluid and Crystallized cognition measures, then deriving scale scores based on this new distribution. Higher scores indicate higher levels of cognitive functioning. Participant score is normed to those in the entire NIH Toolbox Normative Sample (18 and older), regardless of age or any other variable, where a score of 100 indicates performance that was at the national average and a score of 115 or 85, indicates performance 1 SD above or below the national average.

For post-hoc analysis on the brain saliency we used the behavioral scores as reported in the HCP data dictionary unrestricted variables, for details please see (https://wiki.humanconnectome.org/display/PublicData/HCP+Data+Dictionary+Public-+Updated+for+the+1200+Subject+Release#HCPDataDictionaryPublic-Updatedforthe1200SubjectRelease-Instrument:SocialRelationships).

Measure	**n**	**mean±SD (range)**
Males/Females	506/600	-
Age	1106	28.8±3.7 (22-36)
Intelligence (Composite score)	1089	121.9±14.6 (84.6-153.4)
Agreeableness	1106	33.5±5.8
Conscientiousness	1106	34.5±5.9
Extraversion	1106	30.7±6
Neuroticism	1106	16.6±7.4
Openness	1106	28.3±6.2

Table 4. Behavioral characteristics of the full HCP sample. Behavioral characteristics for gender, age, intelligence as well as the NEO-FFI scores in the HCP sample including twins.

Measure	n	mean±SD (range)
Males/Females	195/224	-
Age	419	28.6±3.7 (22-36)
Intelligence (Composite score)	1089	121.6±14.7 (84.6-153.4)
Agreeableness	419	33.1±5.7
Conscientiousness	419	34.6±5.8
Extraversion	419	30.5±6
Neuroticism	419	17.2±7.8
Openness	419	28.7±5.9

Table 5. Behavioral characteristics of the unrelated HCP sample. Behavioral characteristics for gender, age, intelligence as well as the NEO-FFI scores in the HCP sample of unrelated individuals.

GSP sample

Participants and study design

To evaluate the cross-sample reproducibility of observations we additionally investigated correspondence between personality and cortical brain structure in the Brain Genomics Superstruct Project (GSP) (Holmes AJ et al. 2015). Participants provided written informed consent in accordance with guidelines established by the Partners Health Care Institutional Review Board and the Harvard University Committee on the Use of Human Subjects in Research (See Supplementary Appendix A in (Holmes AJ *et al.* 2015)).

Structural imaging processing

All imaging data were collected on matched 3T Tim Trio scanners (Siemens Healthcare, Erlangen, Germany) at Harvard University and Massachusetts General Hospital using the vendor-supplied 12-channel phased-array head coil. Structural data included a high-resolution (1.2mm isotropic) multi-echo T1-weighted magnetization-prepared gradient-echo image (multi-echo MPRAGE23, see further: (Holmes AJ *et al.* 2015)). The low participant burden resulting from the use of multi-echo MPRAGE anatomical scans makes this sequence well

suited for high-throughput studies. The morphometric features derived through conventional 6-min 1mm MPRAGE and the 2-min 1.2mm multi-echo MPRAGE are highly consistent (r2>0.9 for most structures)24 suggesting that rapid acquisition multi-echo MPRAGE can be used for many purposes in place of longer anatomical scans without degradation of the quantitative morphometric estimates. Rapid acquisition is also beneficial because it lessens the opportunity for within-scan motion.

Behavioral markers.

The NEO-FFI personality traits were assessed using the NEO-Five-Factors-Inventory (NEO-PI-R)(Costa PT and RR McCrae 1992), the full-length 240-item NEO-PI-R. For each item, participants reported their level of agreement on a 5-point Likert scale, from strongly disagree to strongly agree. The NEO instruments have been previously validated in USA and several other countries(McCrae RR and A Terracciano 2005). As a proxy for IQ we used the estimated IQ derived through the OPIE3 formula(Schoenberg MR et al. 2002). Reported values are in integers and binned. For post-hoc analysis on the partial least squares behavioral saliency we used the behavioral data from (https://static1.squarespace.com/static/5b58b6da7106992fb15f7d50/t/5b68650d8a922db3bb807a90/1533568270847/GSP_README_140630.pdf).

Measure	**n**	**mean±SD (range)**
Males/Females	536/390	-
Age	926	21.6±3.9 (19-35)
Estimated IQ	892	108.7±8.1 (77-129)
Agreeableness	926	32.0±6.6
Conscientiousness	926	31.7±7.2
Extraversion	926	30.7±6.5
Neuroticism	926	20.3±8.8
Openness	926	31.6±6.1

Table 6. Behavioral characteristics of the GSP sample. Behavioral characteristics for gender, age, intelligence as well as the NEO-FFI scores in the GSP sample.

eNKI sample:

Participants and study design

To evaluate the cross-sample reproducibility of observations we additionally investigated correspondence between personality and cortical brain structure in the enhanced Nathan Kline Institute-Rockland Sample (NKI). The sample was made available by the Nathan-Kline Institute (NKY, NY, USA), as part of the '*enhanced NKI-Rockland sample*' (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3472598/). All approvals regarding human subjects' studies were sought following NKI procedures. Scans were acquired from the International Neuroimaging Data Sharing Initiative (INDI) online database http://fcon_1000.projects.nitrc.org/indi/enhanced/studies.html

For our phenotypical analyses, we selected individuals with personality and imaging data. Our sample for phenotypical correlations consisted of 792 (494 females) individuals with mean age of 41.1 years (SD =20.3, range =12-85). Please see Table 7 for demographic characteristics.

Measure	**n**	**mean±SD (range)**
Males/Females	298/494	-
Age	792	41.1±20.3 (12-85)
Intelligence (WASI)	792	101.9±13.3 (65-141)
Agreeableness	792	34.3±6.0
Conscientiousness	792	33.9±7.4
Extraversion	792	30.0±6.4

Neuroticism	792	18.5±8.1
Openness	792	31.9±6.3

Table 7. Behavioral characteristics of the eNKI sample. Behavioral characteristics for gender, age, intelligence as well as the NEO-FFI scores in the eNKI sample.

Structural imaging processing

3D magnetization-prepared rapid gradient-echo imaging (3D MP-RAGE) structural scans(Mugler JP, 3rd and JR Brookeman 1990) were acquired using a 3.0 T Siemens Trio scanner with TR=2500 ms, TE=3.5 ms, Bandwidth=190 Hz/Px, field of view=256 × 256 mm, flip angle=8°, voxel size=1.0 × 1.0 × 1.0 mm. More details on image acquisition are available at http://fcon_1000.projects.nitrc.org/indi/enhanced/studies.html. All T1 scans were visually inspected to ensure the absence of gross artefacts and subsequently pre-processed using the Freesurfer software library (http://surfer.nmr.mgh.harvard.edu/) Version 5.3.0(Fischl B 2012).

Behavioral markers.

The NEO-FFI personality traits were assessed using the NEO-FFI3(McCrae RR and PT Costa 2004). The NEO-FFI-3 is a 60-item psychological personality inventory that assesses based on the five-factor model: Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Participants are asked to select the response that best represents their opinion on a 5-point scale: 0-Strongly Agree, 1-Agree, 2-Neutral, 3-Disagree, 4-Strongly Disagree. The NEO instruments have been previously validated in USA and several other countries(McCrae RR and A Terracciano 2005).

For intelligence we used the Wechsler Abbreviated Scale of Intelligence (WASI-II)(Wechsler D 1999), full scale IQ. The WASI is a general intelligence, or IQ test designed to assess

specific and overall cognitive capabilities and is individually administered to children, adolescents and adults (ages 6-89). It is a battery of four subtests: Vocabulary (31-item), Block Design (13-item), Similarities (24-item) and Matrix Reasoning (30-item). In addition to assessing general, or Full Scale, intelligence, the WASI is also designed to provide estimates of Verbal and Performance intelligence consistent with other Wechsler tests. Specifically, the four subtests comprise the full scale and yield the Full Scale IQ (FSIQ-4).

Parcellation approach

In all three samples, we used a parcellation scheme(Schaefer A *et al.* 2018) based on the combination of a local gradient approach and a global similarity approach using a gradient-weighted Markov Random models. The parcellation has been extensively evaluated with regards to stability and convergence with histological mapping and alternative parcellations. In the context of the current study, we focus on the granularity of 200 parcels, as averaging will improve signal-to-noise. 200 parcels are close to granularity used in Enigma (Desikan-atlas, 68 parcels) while at the same time providing more anatomical detail in functionally heterogeneous regions such as parietal and frontal cortex. In order to improve signal-to-noise and improve analysis speed, we opted to average unsmoothed structural data within each parcel. Thus, cortical thickness of each ROI was estimated as the trimmed mean (10 percent trim).

Reproducibility and phenotypic correlation analysis.

Between-sample comparison of the cortical thickness estimations are performed using paired t-tests, within each region while controlling for global thickness effects. For our phenotypical analysis between local cortical thickness and personality traits we performed Spearman correlation analysis, controlling for the same variables as in the genetic analysis, namely age,

sex, age × sex interaction, age^2, age^2 × sex interaction, as well as global thickness effects when investigating brain structure. Results were corrected for multiple comparisons using Benjamin-Hochberg FDR(Benjamini Y and Y Hochberg 1995) at whole-brain analysis, where we corrected for number of analysis within the current step and report FDR thresholds. Bonferroni correction was applied when investigating behavior or in post-hoc brain analysis, here we corrected for number of analysis x ROIs. Post-hoc we also controlled for a proxy for intelligence, total cognitive score(Weintraub S *et al.* 2013) or comparable measures in the GSP(Schoenberg MR *et al.* 2002) and eNKI samples.

Heritability and genetic correlation analysis

To investigate the heritability and genetic correlation of brain structure and personality traits, we analyzed 200 parcels of cortical thickness, as well as personality trait score of each subject in a twin-based heritability analysis. As in previous studies(Glahn DC et al. 2010), the quantitative genetic analyses were conducted using Sequential Oligogenic Linkage Analysis Routines (SOLAR)(Almasy L and J Blangero 1998). SOLAR uses maximum likelihood variance-decomposition methods to determine the relative importance of familial and environmental influences on a phenotype by modeling the covariance among family members as a function of genetic proximity. This approach can handle pedigrees of arbitrary size and complexity and thus, is optimally efficient with regard to extracting maximal genetic information. To ensure that our traits, behavioral as well as of cortical thickness parcels, conform to the assumptions of normality, an inverse normal transformation was applied for all behavioral and neuroimaging traits(Glahn DC *et al.* 2010).

Heritability (h^2) represents the portion of the phenotypic variance (σ^2_p) accounted for by the total additive genetic variance (σ^2_g), i.e., $h^2 = \sigma^2_g/\sigma^2_p$. Phenotypes exhibiting stronger covariances between genetically more similar individuals than between genetically less

similar individuals have higher heritability. Within SOLAR, this is assessed by contrasting the observed covariance matrices for a neuroimaging measure with the structure of the covariance matrix predicted by kinship. Heritability analyses were conducted with simultaneous estimation for the effects of potential covariates. For this study, we included covariates including age, sex, age × sex interaction, age^2, age^2 × sex interaction. Post-hoc we also controlled for a proxy for intelligence, total cognitive score(Weintraub S *et al.* 2013). When investigating cortical thickness, we additionally controlled for global thickness effects (mean cortical thickness).

To determine if variations in personality and brain structure were influenced by the same genetic factors, genetic correlation analyses were conducted. More formally, bivariate polygenic analyses were performed to estimate genetic (ρ_g) and environmental (ρ_e) correlations, based on the phenotypical correlation (ρ_p), between brain structure and personality with the following formula: $\rho_p = \rho_g\sqrt{(h^2_1 h^2_2)} + \rho_e\sqrt{[(1 - h^2_1)(1 - h^2_2)]}$, where h^2_1 and h^2_2 are the heritability's of the parcel-based cortical thickness and the various behavioral traits. The significance of these correlations was tested by comparing the log likelihood for two restricted models (with either ρ_g or ρ_e constrained to be equal to 0) against the log likelihood for the model in which these parameters were estimated. A significant genetic correlation (corrected for multiple comparisons using Benjamin-Hochberg FDR(Benjamini Y and Y Hochberg 1995) in case of whole-brain analysis and Bonferroni correction when investigating behavior or in post-hoc brain analysis) is evidence suggesting that (a proportion of) both phenotypes are influenced by a gene or set of genes(Almasy L et al. 1997).

Functional decoding

All significant parcels were in a last step functionally characterized using the Behavioral Domain meta-data from the BrainMap database using forward inference

(http://www.brainmap.org(Laird AR et al. 2009; Laird AR et al. 2011)). To do so, volumetric counterparts of the surface-based parcels were identified. In particular, we identified those meta-data labels (describing the computed contrast [behavioral domain]) that were significantly more likely than chance to result in activation of a given parcel(Fox PT *et al.* 2014; Nostro AD *et al.* 2017; Genon S *et al.* 2018). That is, functions were attributed to the identified neurogenetic effects by quantitatively determining which types of experiments are associated with activation in the respective parcellation region. Significance was established using a binomial test ($p < 0.05$, corrected for multiple comparisons using false discovery rate (FDR)).

Mediation analysis

In short, mediation analysis is an important tool in the behavioral sciences for investigating the role of intermediate variables that lie in the path between a treatment and an outcome variable. The influence of the intermediate variable on the outcome is often explored using a linear structural equation model (LSEM), with model coefficients interpreted as possible effects. Here we performed single-level mediation analysis combined with bootstrap-based significant testing using the function 'mediation.m' from the Mediation toolbox download from https://github.com/canlab/MediationToolbox (Wager TD et al. 2008; Wager TD et al. 2009). We controlled for effects of global thickness, age and gender, and used ranked variables of personality traits, intelligence and local brain structure.

Partial least squares

PLS is a multivariate data-driven statistical technique that aims to maximize the covariance between two matrices by deriving *latent components* (LCs), which are optimal linear combinations of the original matrices(McIntosh AR and NJ Lobaugh 2004; Zoller D *et al.* 2017). We applied PLS to the cortical thickness and personality measures of all participants.

Each LC is characterized by a distinct cortical thickness pattern (called brain *saliences*) and a distinct behavioral profile (called behavioral *saliences*). By linearly projecting the brain and behavioral measures of each participant onto their respective saliences, we obtain individual-specific brain and behavioral *composite scores* for each LC. By construction, PLS seeks to find saliences that maximize across-participant covariance between the brain and behavioral composite scores. The number of significant LCs was determined by a permutation (1000 permutations). The p-values (from the permutation test) for the LCs were corrected for multiple comparisons using a false discovery rate (FDR) of $p < 0.05$. To interpret the LCs, we computed Pearson's correlations between behavioral composite scores for each LC and behavioral measures not included in the analysis. A large positive (or negative) correlation for a particular behavioral measure for a given LC indicates greater importance of the behavioral measure for the LC(Kebets V et al. BioArchiv).

Acknowledgements

We would like to thank the various contributors to the open access databases that our data was downloaded from. Specifically; HCP data were provided by the Human Connectome Project, Washington University, the University of Minnesota, and Oxford University Consortium (Principal Investigators: David Van Essen and Kamil Ugurbil;1U54MH091657) funded by the 16 NIH Institutes and Centers that support the NIH Blueprint for Neuroscience Research; and by the McDonnell Center for Systems Neuroscience at Washington University. GSP data were provided by the Brain Genomics Superstruct Project of Harvard University and the Massachusetts General Hospital, (Principal Investigators: Randy Buckner, Joshua Roffman, and Jordan Smoller), with support from the Center for Brain Science Neuroinformatics Research Group, the Athinoula A. Martinos Center for Biomedical Imaging, and the Center for Human Genetic Research. 20 individual investigators at Harvard and MGH generously contributed data to the overall project.

For enhanced NKI, we would like to thank the principal support for the enhanced NKI-RS project is provided by the NIMH BRAINS R01MH094639-01 (PI Milham). Funding for key personnel was also provided in part by the New York State Office of Mental Health and Research Foundation for Mental Hygiene. Funding for the decompression and augmentation of administrative and phenotypic protocols provided by a grant from the Child Mind Institute (1FDN2012-1). Additional personnel support provided by the Center for the Developing Brain at the Child Mind Institute, as well as NIMH R01MH081218, R01MH083246, and R21MH084126. Project support also provided by the NKI Center for Advanced Brain Imaging (CABI), the Brain Research Foundation (Chicago, IL), and the Stavros Niarchos Foundation.

References

Almasy L, Blangero J. 1998. Multipoint quantitative-trait linkage analysis in general pedigrees. Am J Hum Genet. 62:1198-1211.

Almasy L, Dyer TD, Blangero J. 1997. Bivariate quantitative trait linkage analysis: pleiotropy versus co-incident linkages. Genet Epidemiol. 14:953-958.

Alvergne A, Jokela M, Lummaa V. 2010. Personality and reproductive success in a high-fertility human population. Proc Natl Acad Sci U S A. 107:11745-11750.

Asendorpf JB, Wilpers S. 1998. Personality effects on social relationships. Journal of Personality and Social Psychology. 74:1531-1544.

Avinun R, Isreal S, Knodt AR, Hariri AR. BioArchiv June 4th. No evidence for associations between big five personality traits and variability in brain gray or white matter.

Benjamini Y, Hochberg Y. 1995. Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. Journal of the Royal Statistical Society Series B (Methodological). 57:289-300.

Bertolero MA, Sizemore Blevins A, Baum LG, Gur RC, Gur RE, Roalf DR, Satterthwaite TD, Bassett DS. arXiv. The network architecture of the human brain is modularly encoded in the genome.

Bjornebekk A, Fjell AM, Walhovd KB, Grydeland H, Torgersen S, Westlye LT. 2013. Neuronal correlates of the five factor model (FFM) of human personality: Multimodal imaging in a large healthy sample. Neuroimage. 65:194-208.

Bouchard TJ, Jr. 1994. Genes, environment, and personality. Science. 264:1700-1701.

Bouchard TJ, Jr., Loehlin JC. 2001. Genes, evolution, and personality. Behav Genet. 31:243-273.

Bouchard TJ, Jr., McGue M. 2003. Genetic and environmental influences on human psychological differences. J Neurobiol. 54:4-45.

Boyle EA, Li YI, Pritchard JK. 2017. An Expanded View of Complex Traits: From Polygenic to Omnigenic. Cell. 169:1177-1186.

Consortium GoP. 2015. Meta-analysis of genome-wide association studies for neuroticism, and the polygenic association with major depressive disorder. JAMA Psychiatry.

Costa PT, McCrae RR. 1992. NEO PI-R Professional Manual: Psychological Assessment Resources, Inc.

Damian RI, Spengler M, Sutu A, Roberts BW. 2019. Sixteen going on sixty-six: A longitudinal study of personality stability and change across 50 years. J Pers Soc Psychol. 117:674-695.

de Moor MH, Costa PT, Terracciano A, Krueger RF, de Geus EJ, Toshiko T, Penninx BW, Esko T, Madden PA, Derringer J, Amin N, Willemsen G, Hottenga JJ, Distel MA, Uda M, Sanna S, Spinhoven P, Hartman CA, Sullivan P, Realo A, Allik J, Heath AC, Pergadia ML, Agrawal A, Lin P, Grucza R, Nutile T, Ciullo M, Rujescu D, Giegling I, Konte B, Widen E, Cousminer DL, Eriksson JG, Palotie A, Peltonen L, Luciano M, Tenesa A, Davies G, Lopez LM, Hansell NK, Medland SE, Ferrucci L, Schlessinger D, Montgomery GW, Wright MJ, Aulchenko YS, Janssens AC, Oostra BA, Metspalu A, Abecasis GR, Deary IJ, Raikkonen K, Bierut LJ, Martin NG, van Duijn CM, Boomsma DI. 2012. Meta-analysis of genome-wide association studies for personality. Molecular psychiatry. 17:337-349.

DeYoung CG, Hirsh JB, Shane MS, Papademetris X, Rajeevan N, Gray JR. 2010. Testing predictions from personality neuroscience. Brain structure and the big five. Psychol Sci. 21:820-828.

Dubois J, Galdi P, Han Y, Paul LK, Adolphs R. 2018. Resting-state functional brain connectivity best predicts the personality dimension of openness to experience. Personal Neurosci. 1.

Eickhoff SB, Constable RT, Yeo BTT. 2018. Topographic organization of the cerebral cortex and brain cartography. Neuroimage. 170:332-347.
Eyler LT, Chen CH, Panizzon MS, Fennema-Notestine C, Neale MC, Jak A, Jernigan TL, Fischl B, Franz CE, Lyons MJ, Grant M, Prom-Wormley E, Seidman LJ, Tsuang MT, Fiecas MJ, Dale AM, Kremen WS. 2012. A comparison of heritability maps of cortical surface area and thickness and the influence of adjustment for whole brain measures: a magnetic resonance imaging twin study. Twin Res Hum Genet. 15:304-314.
Ferschmann L, Fjell AM, Vollrath ME, Grydeland H, Walhovd KB, Tamnes CK. 2018. Personality Traits Are Associated With Cortical Development Across Adolescence: A Longitudinal Structural MRI Study. Child Dev. 89:811-822.
Fischl B. 2012. FreeSurfer. Neuroimage. 62:774-781.
Fjell AM, Grydeland H, Krogsrud SK, Amlien I, Rohani DA, Ferschmann L, Storsve AB, Tamnes CK, Sala-Llonch R, Due-Tonnessen P, Bjornerud A, Solsnes AE, Haberg AK, Skranes J, Bartsch H, Chen CH, Thompson WK, Panizzon MS, Kremen WS, Dale AM, Walhovd KB. 2015. Development and aging of cortical thickness correspond to genetic organization patterns. Proc Natl Acad Sci U S A. 112:15462-15467.
Fox PT, Lancaster JL, Laird AR, Eickhoff SB. 2014. Meta-analysis in human neuroimaging: computational modeling of large-scale databases. Annu Rev Neurosci. 37:409-434.
Genon S, Reid A, Langner R, Amunts K, Eickhoff SB. 2018. How to Characterize the Function of a Brain Region. Trends Cogn Sci. 22:350-364.
Glahn DC, Winkler AM, Kochunov P, Almasy L, Duggirala R, Carless MA, Curran JC, Olvera RL, Laird AR, Smith SM, Beckmann CF, Fox PT, Blangero J. 2010. Genetic control over the resting brain. Proc Natl Acad Sci U S A. 107:1223-1228.
Glasser MF, Sotiropoulos SN, Wilson JA, Coalson TS, Fischl B, Andersson JL, Xu J, Jbabdi S, Webster M, Polimeni JR, Van Essen DC, Jenkinson M, Consortium WU-MH. 2013. The minimal preprocessing pipelines for the Human Connectome Project. Neuroimage. 80:105-124.
Harris MA, Brett CE, Johnson W, Deary IJ. 2016. Personality stability from age 14 to age 77 years. Psychol Aging. 31:862-874.
Hill WD, Arslan RC, Xia C, Luciano M, Amador C, Navarro P, Hayward C, Nagy R, Porteous DJ, McIntosh AM, Deary IJ, Haley CS, Penke L. 2018. Genomic analysis of family data reveals additional genetic effects on intelligence and personality. Molecular psychiatry. 23:2347-2362.
Hofer E, al. e. 2018. Genetic Determinants of Cortical Structure (Thickness, Surface Area and Volumes) among Disease Free Adults in the CHARGE Consortium. bioRxiv preprint first posted online Sep 9, 2018; doi: http://dxdoiorg/101101/409649.
Holmes AJ, Hollinshead MO, O'Keefe TM, Petrov VI, Fariello GR, Wald LL, Fischl B, Rosen BR, Mair RW, Roffman JL, Smoller JW, Buckner RL. 2015. Brain Genomics Superstruct Project initial data release with structural, functional, and behavioral measures. Sci Data. 2:150031.
Hong SJ, Vos de Wael R, Bethlehem RAI, Lariviere S, Paquola C, Valk SL, Milham MP, Di Martino A, Margulies DS, Smallwood J, Bernhardt BC. 2019. Atypical functional connectome hierarchy in autism. Nat Commun. 10:1022.
Hopwood CJ, Donnellan MB, Blonigen DM, Krueger RF, McGue M, Iacono WG, Burt SA. 2011. Genetic and environmental influences on personality trait stability and growth during the transition to adulthood: a three-wave longitudinal study. J Pers Soc Psychol. 100:545-556.
Huntenburg JM, Bazin PL, Margulies DS. 2018. Large-Scale Gradients in Human Cortical Organization. Trends Cogn Sci. 22:21-31.
Jang KL, Livesley WJ, Vernon PA. 1996. Heritability of the big five personality dimensions and their facets: a twin study. J Pers. 64:577-591.

John OP, Srivastava S. 1999. The Big Five Trait taxonomy: History, measurement, and theoretical perspectives. In: Pervin LA, John OP, editors. Handbook of Personality: Theory and Research. Guilford Press p 102-138.
Kebets V, Holmes AJ, Orban C, Tang S, Li J, Sun N, Kong R, Poldrack RA, Yeo BT. BioArchiv. Somatosensory-Motor dysconnectivity spans multiple transdiagnosic dimensions of psychopathology.
Kharabian Masouleh S, Eickhoff SB, Hoffstaedter F, Genon S, Alzheimer's Disease Neuroimaging I. 2019. Empirical examination of the replicability of associations between brain structure and psychological variables. elife.
Kremen WS, Prom-Wormley E, Panizzon MS, Eyler LT, Fischl B, Neale MC, Franz CE, Lyons MJ, Pacheco J, Perry ME, Stevens A, Schmitt JE, Grant MD, Seidman LJ, Thermenos HW, Tsuang MT, Eisen SA, Dale AM, Fennema-Notestine C. 2010. Genetic and environmental influences on the size of specific brain regions in midlife: the VETSA MRI study. Neuroimage. 49:1213-1223.
Laajaj R, Macours K, Pinzon Hernandez DA, Arias O, Gosling SD, Potter J, Rubio-Codina M, Vakis R. 2019. Challenges to capture the big five personality traits in non-WEIRD populations. Science Advances. 5.
Laird AR, Eickhoff SB, Fox PM, Uecker AM, Ray KL, Saenz JJ, Jr., McKay DR, Bzdok D, Laird RW, Robinson JL, Turner JA, Turkeltaub PE, Lancaster JL, Fox PT. 2011. The BrainMap strategy for standardization, sharing, and meta-analysis of neuroimaging data. BMC Res Notes. 4:349.
Laird AR, Eickhoff SB, Kurth F, Fox PM, Uecker AM, Turner JA, Robinson JL, Lancaster JL, Fox PT. 2009. ALE Meta-Analysis Workflows Via the Brainmap Database: Progress Towards A Probabilistic Functional Brain Atlas. Front Neuroinform. 3:23.
Lo MT, Hinds DA, Tung JY, Franz C, Fan CC, Wang Y, Smeland OB, Schork A, Holland D, Kauppi K, Sanyal N, Escott-Price V, Smith DJ, O'Donovan M, Stefansson H, Bjornsdottir G, Thorgeirsson TE, Stefansson K, McEvoy LK, Dale AM, Andreassen OA, Chen CH. 2017. Genome-wide analyses for personality traits identify six genomic loci and show correlations with psychiatric disorders. Nat Genet. 49:152-156.
Loehlin JC, McCrae RR, Costa PT, John OP. 1998. Heritabilities of Common and Measure-Specific Components of the Big Five Personality Factors. Journal of Research in Personality. 32:431-453.
Marcus DS, Harms MP, Snyder AZ, Jenkinson M, Wilson JA, Glasser MF, Barch DM, Archie KA, Burgess GC, Ramaratnam M, Hodge M, Horton W, Herrick R, Olsen T, McKay M, House M, Hileman M, Reid E, Harwell J, Coalson T, Schindler J, Elam JS, Curtiss SW, Van Essen DC, Consortium WU-MH. 2013. Human Connectome Project informatics: quality control, database services, and data visualization. Neuroimage. 80:202-219.
Margulies DS, Ghosh SS, Goulas A, Falkiewicz M, Huntenburg JM, Langs G, Bezgin G, Eickhoff SB, Castellanos FX, Petrides M, Jefferies E, Smallwood J. 2016. Situating the default-mode network along a principal gradient of macroscale cortical organization. Proc Natl Acad Sci U S A. 113:12574-12579.
McCrae RR, Costa PT. 2004. A contemplated revision of the NEO Five-Factor Inventory. Pers Individ Dif. 36:587-596.
McCrae RR, Costa PT, Jr. 1985. Updating Norman's "Adequate Taxonomy": intelligence and personality dimensions in natural language and in questionnaires. J Pers Soc Psychol. 49:710-721.
McCrae RR, Costa PT, Jr. 1987. Validation of the five-factor model of personality across instruments and observers. J Pers Soc Psychol. 52:81-90.
McCrae RR, Costa PT, Jr. 1997. Personality trait structure as a human universal. Am Psychol. 52:509-516.

McCrae RR, Terracciano A. 2005. Personality profiles of cultures: aggregate personality traits. J Pers Soc Psychol. 89:407-425.
McIntosh AR, Lobaugh NJ. 2004. Partial least squares analysis of neuroimaging data: applications and advances. Neuroimage. 23 Suppl 1:S250-263.
Miller JD, Lynam DR, Widiger TA, Leukefeld C. 2001. Personality disorders as extreme variants of common personality dimensions: can the Five-Factor Model adequately represent psychopathy? J Pers. 69:253-276.
Mischel W. 2004. Toward an integrative science of the person. Annu Rev Psychol. 55:1-22.
Mugler JP, 3rd, Brookeman JR. 1990. Three-dimensional magnetization-prepared rapid gradient-echo imaging (3D MP RAGE). Magn Reson Med. 15:152-157.
Nakao K, Takaishi J, Tatsuta K, Katayama H, Iwase M, Yorifuji K, Takeda M. 2000. The influences of family environment on personality traits. Psychiatry Clin Neurosci. 54:91-95.
Nostro AD, Muller VI, Reid AT, Eickhoff SB. 2017. Correlations Between Personality and Brain Structure: A Crucial Role of Gender. Cereb Cortex. 27:3698-3712.
Owens MM, Hyatt CS, Gray JC, Carter NT, MacKillop J, Miller JD, Sweet LH. 2019. Cortical morphometry of the five-factor model of personality: findings from the Human Connectome Project full sample. Soc Cogn Affect Neurosci. 14:381-395.
Panizzon MS, Fennema-Notestine C, Eyler LT, Jernigan TL, Prom-Wormley E, Neale M, Jacobson K, Lyons MJ, Grant MD, Franz CE, Xian H, Tsuang M, Fischl B, Seidman L, Dale A, Kremen WS. 2009. Distinct genetic influences on cortical surface area and cortical thickness. Cereb Cortex. 19:2728-2735.
Penke L, Jokela M. 2016. The evolutionary genetics of personality revisited. Current Opinion in Psychology. 7:104-109.
Riccelli R, Toschi N, Nigro S, Terracciano A, Passamonti L. 2017. Surface-based morphometry reveals the neuroanatomical basis of the five-factor model of personality. Soc Cogn Affect Neurosci. 12:671-684.
Rothmann S, Coetzer EP. 2003. The big five personality dimensions and job performance. SA Journal of Industrial Psychology. 29.
Schaefer A, Kong R, Gordon EM, Laumann TO, Zuo XN, Holmes AJ, Eickhoff SB, Yeo BTT. 2018. Local-Global Parcellation of the Human Cerebral Cortex from Intrinsic Functional Connectivity MRI. Cereb Cortex. 28:3095-3114.
Schoenberg MR, Scott JG, Duff K, Adams RL. 2002. Estimation of WAIS-III intelligence from combined performance and demographic variables: development of the OPIE-3. Clin Neuropsychol. 16:426-437.
Seidlitz J, Vasa F, Shinn M, Romero-Garcia R, Whitaker KJ, Vertes PE, Wagstyl K, Kirkpatrick Reardon P, Clasen L, Liu S, Messinger A, Leopold DA, Fonagy P, Dolan RJ, Jones PB, Goodyer IM, Consortium N, Raznahan A, Bullmore ET. 2018. Morphometric Similarity Networks Detect Microscale Cortical Organization and Predict Inter-Individual Cognitive Variation. Neuron. 97:231-247 e237.
Sodini SM, Kemper KE, Wray NR, Trzaskowski M. 2018. Comparison of Genotypic and Phenotypic Correlations: Cheverud's Conjecture in Humans. Genetics. 209:941-948.
Solovieff N, Cotsapas C, Lee PH, Purcell SM, Smoller JW. 2013. Pleiotropy in complex traits: challenges and strategies. Nat Rev Genet. 14:483-495.
Strickhouser JE, Zell E, Krizan Z. 2017. Does personality predict health and well-being? A metasynthesis. Health Psychol. 36:797-810.
Strike LT, Hansell NK, Couvy-Duchesne B, Thompson PM, de Zubicaray GI, McMahon KL, Wright MJ. 2018. Genetic Complexity of Cortical Structure: Differences in Genetic and Environmental Factors Influencing Cortical Surface Area and Thickness. Cereb Cortex.
Teeuw J, Brouwer RM, Koenis MMG, Swagerman SC, Boomsma DI, Hulshoff Pol HE. 2018. Genetic Influences on the Development of Cerebral Cortical Thickness During

Childhood and Adolescence in a Dutch Longitudinal Twin Sample: The Brainscale Study. Cereb Cortex.
Trull TJ. 2013. Dimensional models of personality: the five-factor model and the DSM-5. Dialogues Clin Neurosci. 15:135-146.
van den Berg SM, de Moor MH, Verweij KJ, Krueger RF, Luciano M, Arias Vasquez A, Matteson LK, Derringer J, Esko T, Amin N, Gordon SD, Hansell NK, Hart AB, Seppala I, Huffman JE, Konte B, Lahti J, Lee M, Miller M, Nutile T, Tanaka T, Teumer A, Viktorin A, Wedenoja J, Abdellaoui A, Abecasis GR, Adkins DE, Agrawal A, Allik J, Appel K, Bigdeli TB, Busonero F, Campbell H, Costa PT, Smith GD, Davies G, de Wit H, Ding J, Engelhardt BE, Eriksson JG, Fedko IO, Ferrucci L, Franke B, Giegling I, Grucza R, Hartmann AM, Heath AC, Heinonen K, Henders AK, Homuth G, Hottenga JJ, Iacono WG, Janzing J, Jokela M, Karlsson R, Kemp JP, Kirkpatrick MG, Latvala A, Lehtimaki T, Liewald DC, Madden PA, Magri C, Magnusson PK, Marten J, Maschio A, Mbarek H, Medland SE, Mihailov E, Milaneschi Y, Montgomery GW, Nauck M, Nivard MG, Ouwens KG, Palotie A, Pettersson E, Polasek O, Qian Y, Pulkki-Raback L, Raitakari OT, Realo A, Rose RJ, Ruggiero D, Schmidt CO, Slutske WS, Sorice R, Starr JM, St Pourcain B, Sutin AR, Timpson NJ, Trochet H, Vermeulen S, Vuoksimaa E, Widen E, Wouda J, Wright MJ, Zgaga L, Generation S, Porteous D, Minelli A, Palmer AA, Rujescu D, Ciullo M, Hayward C, Rudan I, Metspalu A, Kaprio J, Deary IJ, Raikkonen K, Wilson JF, Keltikangas-Jarvinen L, Bierut LJ, Hettema JM, Grabe HJ, Penninx BW, van Duijn CM, Evans DM, Schlessinger D, Pedersen NL, Terracciano A, McGue M, Martin NG, Boomsma DI. 2016. Meta-analysis of Genome-Wide Association Studies for Extraversion: Findings from the Genetics of Personality Consortium. Behav Genet. 46:170-182.
Van Essen DC, Glasser MF. 2018. Parcellating Cerebral Cortex: How Invasive Animal Studies Inform Noninvasive Mapmaking in Humans. Neuron. 99:640-663.
Van Essen DC, Smith SM, Barch DM, Behrens TE, Yacoub E, Ugurbil K, Consortium WU-MH. 2013. The WU-Minn Human Connectome Project: an overview. Neuroimage. 80:62-79.
Varikuti DP, Genon S, Sotiras A, Schwender H, Hoffstaedter F, Patil KR, Jockwitz C, Caspers S, Moebus S, Amunts K, Davatzikos C, Eickhoff SB. 2018. Evaluation of non-negative matrix factorization of grey matter in age prediction. Neuroimage. 173:394-410.
Verweij KJ, Yang J, Lahti J, Veijola J, Hintsanen M, Pulkki-Raback L, Heinonen K, Pouta A, Pesonen AK, Widen E, al. e. 2012. Maintenance of genetic variation in human personality: testing evolutionary models by estimating heritability due to common causal variants and investigating the effect of distant inbreeding. Evolution. 66:3288-3251.
Vukasovic T, Bratko D. 2015. Heritability of personality: A meta-analysis of behavior genetic studies. Psychol Bull. 141:769-785.
Wager TD, Davidson ML, Hughes BL, Lindquist MA, Ochsner KN. 2008. Prefrontal-subcortical pathways mediating successful emotion regulation. Neuron. 59:1037-1050.
Wager TD, Waugh CE, Lindquist M, Noll DC, Fredrickson BL, Taylor SF. 2009. Brain mediators of cardiovascular responses to social threat: part I: Reciprocal dorsal and ventral sub-regions of the medial prefrontal cortex and heart-rate reactivity. Neuroimage. 47:821-835.
Wechsler D. 1999. Wechsler Abbreviated Scale of Intelligence. San Antonio, TX.: The Psychological Corporation.
Weintraub S, Dikmen SS, Heaton RK, Tulsky DS, Zelazo PD, Bauer PJ, Carlozzi NE, Slotkin J, Blitz D, Wallner-Allen K, Fox NA, Beaumont JL, Mungas D, Nowinski CJ, Richler J, Deocampo JA, Anderson JE, Manly JJ, Borosh B, Havlik R, Conway K, Edwards E, Freund L, King JW, Moy C, Witt E, Gershon RC. 2013. Cognition assessment using the NIH Toolbox. Neurology. 80:S54-64.
Winkler AM, Kochunov P, Blangero J, Almasy L, Zilles K, Fox PT, Duggirala R, Glahn DC. 2010. Cortical thickness or grey matter volume? The importance of selecting the phenotype for imaging genetics studies. Neuroimage. 53:1135-1146.

Wu X, He H, Shi L, Xia Y, Zuang K, Feng Q, Zhang Y, Ren Z, Wei D, Qiu J. 2019. Personality traits are related with dynamic functional connectivity in major depression disorder: A resting-state analysis. J Affect Disord. 245:1032-1042.
Yeo BT, Krienen FM, Sepulcre J, Sabuncu MR, Lashkari D, Hollinshead M, Roffman JL, Smoller JW, Zollei L, Polimeni JR, Fischl B, Liu H, Buckner RL. 2011. The organization of the human cerebral cortex estimated by intrinsic functional connectivity. J Neurophysiol. 106:1125-1165.
Zoller D, Schaer M, Scariati E, Padula MC, Eliez S, Van De Ville D. 2017. Disentangling resting-state BOLD variability and PCC functional connectivity in 22q11.2 deletion syndrome. Neuroimage. 149:85-97.

DOES MACROSCALE GREY MATTER MORPHOMETRY HAVE PERSONALITY?
- SUPPLEMENTARY MATERIAL -

Sofie L. Valk[1,2*]; Felix Hoffstaedter[1,2]; Julia Camilleri[1,2]; Peter Kochunov[3]; B.T. Thomas Yeo[4,5,6,7]; Simon B. Eickhoff[1,2]

[1)] Institute of Neuroscience and Medicine (INM-7: Brain and Behaviour), Research Centre Jülich, 52425 Jülich, Germany
[2)] Institute of Systems Neuroscience, Heinrich Heine University Düsseldorf, 40225 Düsseldorf, Germany
[3)] Maryland Psychiatric Research Center, University of Maryland School of Medicine, Baltimore, Maryland, USA.
[4)] Department of Electrical and Computer Engineering, Clinical Imaging Research Centre, Institute for Health and Memory Networks Program, National University of Singapore, Singapore, Singapore.
[5)] Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, MA, USA.
[6)] Centre for Cognitive Neuroscience, Duke-NUS Medical School, Singapore, Singapore.
[7)] NUS Graduate School for Integrative Sciences and Engineering, National University of Singapore, Singapore, Singapore.

HCPu vs GSP (*df* 1343)					
mean	2,95 **	7,07 **	-0,43	-6,38 **	-8,42 **
std	6,33	6,82	6,38	8,47	6,01
GSP vs eNKI (*df* 1716)					
mean	-7,66 **	-6,19 **	2,11 *	4,36**	-0,79
std	6,31	7,30	6,47	8,46	6,16
HCPu vs eNKI (*df* 1209)					
mean	-3,50 **	1,57	1,31	-2,90 **	-8,69 **
std	5,88	6,90	6,28	7,99	6,12

Supplementary table 1. Difference in personality trait means between samples. Two sample t-tests measuring difference personality trait distribution across samples. ** indicates Bonferroni corrected p<0.05, corrected for number of analysis (traits x samples), whereas * indicates p<0.05.

Agreeableness	**HCP all**	**HCP unrelated**	**GSP**	**eNKI**
7Networks_LH_Cont_PFCl_4	-0.11	-0.07	0.04	-0.02
7Networks_LH_Default_PFC_7	-0.11	-0.12 *	0.02	0.01
7Networks_LH_Default_PFC_9	-0.12	-0.15 **	-0.01	0.05
7Networks_LH_Default_PFC_11	-0.12	-0.10 *	-0.01	-0.03
7Networks_LH_Default_PFC_12	-0.10	-0.02	0.08 *	0.01
7Networks_LH_Default_PFC_13	-0.11	-0.14 **	-0.02	-0.01
7Networks_RH_Default_PFCm_5	-0.11	-0.08	-0.06	0.04

Neuroticism	**HCP all**	**HCP unrelated**	**GSP**	**eNKI**
7Networks_LH_Vis_14	-0.11	-0.08	0.07 *	-0.01
7Networks_LH_DorsAttn_FEF_2	0.10	0.09	0.07 *	0.00
7Networks_LH_SalVentAttn_ParOper_2	0.10	0.08	-0.03	0.01
7Networks_LH_Default_Temp_6	-0.11	-0.13 *	0.06	-0.01
7Networks_LH_Default_PFC_9	0.11	0.15 **	0.03	-0.02
7Networks_LH_Default_PFC_11	0.10	0.11 *	0.00	-0.05
7Networks_RH_Cont_PFCl_6	0.10	0.05	0.07 *	-0.03
7Networks_RH_Default_PFCm_5	0.12	0.11 *	-0.01	-0.04

Openness	**HCP all**	**HCP unrelated**	**GSP**	**eNKI**
7Networks_LH_Vis_1	0.10	0.08	0.05	-0.01
7Networks_LH_SalVentAttn_PFCl_1	-0.11	-0.11 *	0.02	-0.06
7Networks_LH_Cont_PFCl_3	-0.11	-0.11 *	0.01	-0.07 *
7Networks_LH_Cont_PFCl_4	-0.12	-0.12 *	0.02	-0.01
7Networks_RH_Limbic_TempPole_1	0.11	0.07	0.02	0.00
7Networks_RH_Cont_PFCl_5	-0.10	-0.09	0.05	-0.09 *
7Networks_RH_Default_PCC_1	0.10	0.07	-0.03	-0.00

Supplementary table 2. Inconsistent pattern of phenotypic correlations across samples. Robustness of phenotypical association between parcels that showed significant phenotypic correlation in the related HCP sample and the corresponding personality trait. ** indicates Bonferroni corrected p<0.05 (corrected for number of ROIs per trait), whereas * indicates p<0.05. Nomenclature of the regions is based on the official parcel names of the Schaefer 200 – 7 networks parcel solution.

Agreeableness	**HCP un**	**HCP all**	**GSP**	**Conscientiousness**	**HCP un**	**HCP all**	**GSP**
HCP all	0.66 **	1			0.44 **	1	
GSP	0.23 **	0.06	1		0.05	0.09	1
eNKI	-0.13	-0.28 **	-0.05		0.03	0.16 *	-0.07
Extraversion	**HCP un**	**HCP all**	**GSP**	**Neuroticism**	**HCP un**	**HCP all**	**GSP**
HCP all	0.70 **	1			0.67 **	1	
GSP	0.09	0.04	1		-0.05	-0.08	1
eNKI	0.03	0.22 **	0.1		0.04	-0.04	0.03
Openness	**HCP un**	**HCP all**	**GSP**				
HCP all	0.61 **						
GSP	0.05	0.21 **	1				
eNKI	0.25 **	0.43 **	0.09				

Supplementary table 3. Correlation between spatial patterns of phenotypical correlation between personality and cortical thickness across samples. To assess whether sub-threshold patterns of phenotypic correlations were similar across samples we correlated the spatial distributions of Spearman r-values for each personality trait and cortical thickness across samples. ** indicates Bonferroni corrected p<0.05 (corrected for number of tests per personality trait), whereas * indicates p<0.05.

HCP unrelated	**A**	**C**	**E**	**N**	**O**
Agreeableness	1				
Conscientiousness	-0.09	1			
Extraversion	0.18 *	0.14	1		
Neuroticism	-0.38 **	-0.09	-0.29 **	1	
Openness	0.10	-0.00	0.08	-0.19 *	1

HCP related	**A**	**C**	**E**	**N**	**O**
Agreeableness	1				
Conscientiousness	-0.13	1			
Extraversion	0.34 **	0.23 *	1		
Neuroticism	-0.58 **	-0.15 *	-0.50 **	1	
Openness	0.50 **	-0.38	0.05	-0.19 *	1

GSP	**A**	**C**	**E**	**N**	**O**
Agreeableness	1				
Conscientiousness	0.15 *	1			
Extraversion	0.26 **	0.23 *	1		
Neuroticism	-0.28 **	-0.40 **	-0.48 **	1	
Openness	-0.06 **	0.05	0.18 *	0.07	1

eNKI	**A**	**C**	**E**	**N**	**O**
Agreeableness	1				
Conscientiousness	0.09	1			
Extraversion	-0.01	0.39 **	1		
Neuroticism	-0.29 **	-0.20 *	-0.24 **	1	
Openness	-0.27 **	0.10	0.23 **	0.32 **	1

Supplementary table 4. Little specificity of spatial patterns of phenotypic correlations within samples. We assessed whether patterns brain-personality trait correspondences were specific for each personality trait in each sample. ** indicates Bonferroni corrected p<0.05 (corrected for number of tests per personality trait), whereas * indicates p<0.05. A= agreeableness, C = conscientiousness, E= extraversion, N=neuroticism, O=openness.

	X > M	M > Y	X > Y unmediated	X > Y	X > Y mediated
7Networks_LH_Cont_PFCl_4					
mean	4,1927	-0,0728	-3,95	-4,2537	-0,3037
std	1,3378	0,0277	1,2262	1,2307	0,1537
p	0,0007	0,0071	0,0015	0,0009	0,0162
7Networks_LH_Default_PFC_7					
mean	4,1641	-0,1137	-3,465	-3,9369	-0,4719
std	1,332	0,0318	1,3845	1,3912	0,2018
p	0,0023	0,0003	0,0129	0,0041	0,005
7Networks_LH_Default_PFC_9					
mean	4,1891	-0,0924	-3,9936	-4,38	-0,3864
std	1,3401	0,0312	1,374	1,3812	0,1825
p	0,004	0,0029	0,0014	0,0003	0,0131
7Networks_LH_Default_PFC_11					
mean	4,1476	-0,1819	-4,7158	-5,4693	-0,7535
std	1,3647	0,0294	1,3357	1,3523	0,2773
p	0,0014	0,0003	0,0002	0,0003	0,003
7Networks_LH_Default_PFC_12					
mean	4,1476	-0,0836	-2,8679	-3,2146	-0,3466
std	1,3306	0,0282	1,3769	1,3866	0,1653
p	0,002	0,0044	0,0364	0,0227	0,0131
7Networks_LH_Default_PFC_13					
mean	4,2008	-0,0715	-3,95	-4,2472	-0,2972
std	1,3327	0,0306	1,3694	1,3723	0,1592
p	0,0027	0,0205	0,0012	0,0007	0,0432
7Networks_RH_Default_PFCm_5					
mean	4,1516	-0,1474	-3,2194	-3,8306	-0,6112
std	1,3437	0,0293	1,3178	1,3424	0,234
p	0,0009	0,0003	0,0129	0,0039	0,0021

Supplementary table 5a. Mediation of phenotypic relationship of agreeableness with cortical thickness by intelligence (total cognitive score). For each mediation test the relation between personality and intelligence (X > M), intelligence and brain (M > Y), relationship between personality and brain unmediated (residual), relationship between personality > brain, and mediated relationship between personality and brain (X>M * M>Y). Nomenclature of the regions is based on the official parcel names of the Schaefer 200 – 7 networks parcel solution.

7Networks_LH_Vis_14					
mean	-3,4579	-0,0164	-3,6376	-3,5826	0,055
std	1,0132	0,0308	0,9672	0,9621	0,1111
p	0,0019	0,5795	0,0002	0,0002	0,5324
7Networks_LH_DorsAttn_FEF_2					
mean	-3,4821	-0,0758	2,8688	3,1337	0,2649
std	1,0069	0,031	1,0646	1,0658	0,1376
p	0,0003	0,0162	0,0074	0,0038	0,0107
7Networks_LH_SalVentAttn_ParOper_2					
mean	-3,4836	0,0713	3,2862	3,0383	-0,2479
std	1,018	0,0287	1,0193	1,0116	0,1258
p	0,0003	0,0131	0,0004	0,0028	0,0213
7Networks_LH_Default_Temp_6					
mean	-3,4613	0,069	-2,79	-3,028	-0,238
std	1,0095	0,0303	1,0612	1,057	0,128
p	0,0017	0,0228	0,0063	0,003	0,0412
7Networks_LH_Default_PFC_9					
mean	-3,4868	-0,0906	3,426	3,7433	0,3173
std	1,005	0,0309	1,0523	1,0506	0,1481
p	0,0008	0,0041	0,0003	0,0003	0,0033
7Networks_LH_Default_PFC_11					
mean	-3,4751	-0,1853	2,2229	2,8674	0,6445
std	1,0102	0,03	1,0431	1,0576	0,2171
p	0,0006	0,0004	0,0382	0,0119	0,0005
7Networks_RH_Cont_PFCl_6					
mean	-3,4729	-0,087	3,1641	3,4667	0,3026
std	1,0009	0,0306	1,0333	1,0331	0,1419
p	0,0003	0,0041	0,002	0,0005	0,0025
7Networks_RH_Default_PFCm_5					
mean	-3,491	-0,1449	3,0807	3,5878	0,5071
std	1,0269	0,0292	1,0248	1,0284	0,1864
p	0,0006	0,0003	0,0014	0,0007	0,0004

Supplementary table 5b. Mediation of phenotypic relationship of neuroticism with cortical thickness by intelligence (total cognitive score). For each mediation test the relation between personality and intelligence (X > M), intelligence and brain (M > Y), relationship between personality and brain unmediated (residual), relationship between personality > brain, and mediated relationship between personality and brain (X>M * M>Y). Nomenclature of the regions is based on the official parcel names of the Schaefer 200 – 7 networks parcel solution.

7Networks_LH_Vis_1					
mean	9,5516	0,07	2,9474	3,6178	0,6703
std	1,1722	0,0328	1,4448	1,4028	0,3298
p	0,0004	0,0281	0,0451	0,014	0,024
7Networks_LH_SalVentAttn_PFCl_1					
mean	9,555	-0,1021	-2,6757	-3,6512	-0,9755
std	1,173	0,0309	1,2662	1,2363	0,3206
p	0,0005	0,001	0,0315	0,0035	0,0013
7Networks_LH_Cont_PFCl_3					
mean	9,5113	-0,0457	-3,5776	-4,0116	-0,4341
std	1,1724	0,0295	1,3229	1,3032	0,2865
p	0,0003	0,1136	0,0083	0,0034	0,1318
7Networks_LH_Cont_PFCl_4					
mean	9,5422	-0,056	-4,2244	-4,757	-0,5326
std	1,1536	0,0276	1,1796	1,1658	0,2702
p	0,0004	0,0437	0,0003	0,0003	0,0496
7Networks_RH_Limbic_TempPole_1					
mean	9,5439	0,0853	4,4995	5,3135	0,814
std	1,1616	0,0346	1,4554	1,4421	0,3461
p	0,0004	0,0162	0,0017	0,0004	0,0131
7Networks_RH_Cont_PFCl_5					
mean	9,5311	-0,091	-3,0622	-3,9291	-0,8669
std	1,1608	0,0314	1,2414	1,2225	0,3194
p	0,0004	0,002	0,0129	0,0015	0,0025
7Networks_RH_Default_PCC_1					
mean	9,5402	0,1268	2,448	3,657	1,2089
std	1,1672	0,0333	1,4864	1,4742	0,3505
p	0,0004	0,0004	0,0954	0,014	0,0002

Supplementary table 5c. Mediation of phenotypic relationship of neuroticism with cortical thickness by intelligence (total cognitive score). For each mediation test the relation between personality and intelligence (X > M), intelligence and brain (M > Y), relationship between personality and brain unmediated (residual), relationship between personality > brain, and mediated relationship between personality and brain (X>M * M>Y). Nomenclature of the regions is based on the official parcel names of the Schaefer 200 – 7 networks parcel solution.

Personality trait	**Heritability**	**SE**	**p**
Agreeableness	0.29	0.07	0.0000
Conscientiousness	0.43	0.06	0.0000
Extraversion	0.43	0.05	0.0000
Neuroticism	0.37	0.06	0.0000
Openness	0.58	0.05	0.0000

Supplementary table 6. Heritability of personality traits. Heritability of personality traits computed using Solar 8.4.0. Here we report heritability values, standard error, as well as p-values.

ROIS	Heritability	SE	p
'7Networks_LH_Vis_1'	0.3960	0.0506	0.0000
'7Networks_LH_Vis_2'	0.3280	0.0555	0.0000
'7Networks_LH_Vis_3'	0.1523	0.0586	0.0036
'7Networks_LH_Vis_4'	0.4836	0.0439	0.0000
'7Networks_LH_Vis_5'	0.4083	0.0522	0.0000
'7Networks_LH_Vis_6'	0.4480	0.0501	0.0000
'7Networks_LH_Vis_7'	0.4963	0.0470	0.0000
'7Networks_LH_Vis_8'	0.2402	0.0513	0.0000
'7Networks_LH_Vis_9'	0.4775	0.0471	0.0000
'7Networks_LH_Vis_10'	0.5194	0.0463	0.0000
'7Networks_LH_Vis_11'	0.3290	0.0522	0.0000
'7Networks_LH_Vis_12'	0.4718	0.0516	0.0000
'7Networks_LH_Vis_13'	0.5551	0.0466	0.0000
'7Networks_LH_Vis_14'	0.4452	0.0519	0.0000
'7Networks_LH_SomMot_1'	0.4736	0.0497	0.0000
'7Networks_LH_SomMot_2'	0.2755	0.0555	0.0000
'7Networks_LH_SomMot_3'	0.5145	0.0480	0.0000
'7Networks_LH_SomMot_4'	0.3997	0.0531	0.0000
'7Networks_LH_SomMot_5'	0.2452	0.0547	0.0000
'7Networks_LH_SomMot_6'	0.5276	0.0462	0.0000
'7Networks_LH_SomMot_7'	0.2888	0.0575	0.0000
'7Networks_LH_SomMot_8'	0.2808	0.0589	0.0000
'7Networks_LH_SomMot_9'	0.3392	0.0544	0.0000
'7Networks_LH_SomMot_10'	0.5155	0.0479	0.0000
'7Networks_LH_SomMot_11'	0.2151	0.0550	0.0000
'7Networks_LH_SomMot_12'	0.3585	0.0543	0.0000
'7Networks_LH_SomMot_13'	0.3296	0.0584	0.0000
'7Networks_LH_SomMot_14'	0.3638	0.0514	0.0000
'7Networks_LH_SomMot_15'	0.4356	0.0492	0.0000
'7Networks_LH_SomMot_16'	0.4002	0.0578	0.0000
'7Networks_LH_DorsAttn_Post_1'	0.3267	0.0586	0.0000
'7Networks_LH_DorsAttn_Post_2'	0.2151	0.0535	0.0000
'7Networks_LH_DorsAttn_Post_3'	0.3442	0.0544	0.0000
'7Networks_LH_DorsAttn_Post_4'	0.3499	0.0561	0.0000
'7Networks_LH_DorsAttn_Post_5'	0.2148	0.0550	0.0000
'7Networks_LH_DorsAttn_Post_6'	0.2283	0.0590	0.0000
'7Networks_LH_DorsAttn_Post_7'	0.4602	0.0527	0.0000

'7Networks_LH_DorsAttn_Post_8'	0.3059	0.0551	0.0000
'7Networks_LH_DorsAttn_Post_9'	0.4502	0.0506	0.0000
'7Networks_LH_DorsAttn_Post_10'	0.4682	0.0529	0.0000
'7Networks_LH_DorsAttn_FEF_1'	0.2673	0.0550	0.0000
'7Networks_LH_DorsAttn_FEF_2'	0.3613	0.0562	0.0000
'7Networks_LH_DorsAttn_PrCv_1'	0.1866	0.0585	0.0005
'7Networks_LH_SalVentAttn_ParOper_1'	0.1303	0.0574	0.0096
'7Networks_LH_SalVentAttn_ParOper_2'	0.2800	0.0527	0.0000
'7Networks_LH_SalVentAttn_ParOper_3'	0.2185	0.0581	0.0000
'7Networks_LH_SalVentAttn_FrOper_1'	0.3500	0.0537	0.0000
'7Networks_LH_SalVentAttn_FrOper_2'	0.4083	0.0535	0.0000
'7Networks_LH_SalVentAttn_FrOper_3'	0.4316	0.0528	0.0000
'7Networks_LH_SalVentAttn_FrOper_4'	0.2426	0.0610	0.0000
'7Networks_LH_SalVentAttn_PFCl_1'	0.4391	0.0476	0.0000
'7Networks_LH_SalVentAttn_Med_1'	0.3362	0.0589	0.0000
'7Networks_LH_SalVentAttn_Med_2'	0.3337	0.0577	0.0000
'7Networks_LH_SalVentAttn_Med_3'	0.2462	0.0571	0.0000
'7Networks_LH_Limbic_OFC_1'	0.2963	0.0532	0.0000
'7Networks_LH_Limbic_OFC_2'	0.3585	0.0556	0.0000
'7Networks_LH_Limbic_TempPole_1'	0.3385	0.0583	0.0000
'7Networks_LH_Limbic_TempPole_2'	0.3692	0.0498	0.0000
'7Networks_LH_Limbic_TempPole_3'	0.2432	0.0529	0.0000
'7Networks_LH_Limbic_TempPole_4'	0.4492	0.0520	0.0000
'7Networks_LH_Cont_Par_1'	0.2170	0.0570	0.0000
'7Networks_LH_Cont_Par_2'	0.2715	0.0536	0.0000
'7Networks_LH_Cont_Par_3'	0.0448	0.0556	0.2068
'7Networks_LH_Cont_Temp_1'	0.1930	0.0574	0.0003
'7Networks_LH_Cont_PFCl_1'	0.2604	0.0512	0.0000
'7Networks_LH_Cont_PFCl_2'	0.2964	0.0557	0.0000
'7Networks_LH_Cont_PFCl_3'	0.3926	0.0532	0.0000
'7Networks_LH_Cont_PFCl_4'	0.2659	0.0547	0.0000
'7Networks_LH_Cont_PFCl_5'	0.4091	0.0501	0.0000
'7Networks_LH_Cont_PFCl_6'	0.2063	0.0572	0.0001
'7Networks_LH_Cont_pCun_1'	0.3744	0.0516	0.0000
'7Networks_LH_Cont_Cing_1'	0.5313	0.0487	0.0000
'7Networks_LH_Cont_Cing_2'	0.3678	0.0568	0.0000
'7Networks_LH_Default_Temp_1'	0.2854	0.0595	0.0000
'7Networks_LH_Default_Temp_2'	0.2831	0.0547	0.0000
'7Networks_LH_Default_Temp_3'	0.3428	0.0543	0.0000

'7Networks_LH_Default_Temp_4'	0.1930	0.0585	0.0004
'7Networks_LH_Default_Temp_5'	0.2131	0.0585	0.0001
'7Networks_LH_Default_Temp_6'	0.2821	0.0539	0.0000
'7Networks_LH_Default_Temp_7'	0.3019	0.0572	0.0000
'7Networks_LH_Default_Temp_8'	0.2422	0.0561	0.0000
'7Networks_LH_Default_Temp_9'	0.2643	0.0520	0.0000
'7Networks_LH_Default_PFC_1'	0.3635	0.0525	0.0000
'7Networks_LH_Default_PFC_2'	0.2708	0.0581	0.0000
'7Networks_LH_Default_PFC_3'	0.1493	0.0560	0.0032
'7Networks_LH_Default_PFC_4'	0.5135	0.0459	0.0000
'7Networks_LH_Default_PFC_5'	0.3168	0.0578	0.0000
'7Networks_LH_Default_PFC_6'	0.3310	0.0538	0.0000
'7Networks_LH_Default_PFC_7'	0.5053	0.0483	0.0000
'7Networks_LH_Default_PFC_8'	0.3889	0.0572	0.0000
'7Networks_LH_Default_PFC_9'	0.4656	0.0478	0.0000
'7Networks_LH_Default_PFC_10'	0.3767	0.0515	0.0000
'7Networks_LH_Default_PFC_11'	0.4263	0.0481	0.0000
'7Networks_LH_Default_PFC_12'	0.4694	0.0486	0.0000
'7Networks_LH_Default_PFC_13'	0.4649	0.0493	0.0000
'7Networks_LH_Default_PCC_1'	0.3913	0.0550	0.0000
'7Networks_LH_Default_PCC_2'	0.2794	0.0537	0.0000
'7Networks_LH_Default_PCC_3'	0.3900	0.0539	0.0000
'7Networks_LH_Default_PCC_4'	0.3922	0.0556	0.0000
'7Networks_LH_Default_PHC_1'	0.4640	0.0536	0.0000
'7Networks_RH_Vis_1'	0.3649	0.0531	0.0000
'7Networks_RH_Vis_2'	0.3496	0.0569	0.0000
'7Networks_RH_Vis_3'	0.3773	0.0566	0.0000
'7Networks_RH_Vis_4'	0.5840	0.0417	0.0000
'7Networks_RH_Vis_5'	0.2794	0.0551	0.0000
'7Networks_RH_Vis_6'	0.4662	0.0502	0.0000
'7Networks_RH_Vis_7'	0.5079	0.0463	0.0000
'7Networks_RH_Vis_8'	0.4341	0.0539	0.0000
'7Networks_RH_Vis_9'	0.5773	0.0433	0.0000
'7Networks_RH_Vis_10'	0.4768	0.0535	0.0000
'7Networks_RH_Vis_11'	0.2379	0.0536	0.0000
'7Networks_RH_Vis_12'	0.5188	0.0479	0.0000
'7Networks_RH_Vis_13'	0.4779	0.0490	0.0000
'7Networks_RH_Vis_14'	0.4356	0.0522	0.0000
'7Networks_RH_Vis_15'	0.2731	0.0558	0.0000

'7Networks_RH_SomMot_1'	0.4370	0.0532	0.0000
'7Networks_RH_SomMot_2'	0.3421	0.0590	0.0000
'7Networks_RH_SomMot_3'	0.3498	0.0573	0.0000
'7Networks_RH_SomMot_4'	0.3403	0.0554	0.0000
'7Networks_RH_SomMot_5'	0.1911	0.0576	0.0003
'7Networks_RH_SomMot_6'	0.2971	0.0572	0.0000
'7Networks_RH_SomMot_7'	0.4346	0.0501	0.0000
'7Networks_RH_SomMot_8'	0.1921	0.0546	0.0001
'7Networks_RH_SomMot_9'	0.3351	0.0603	0.0000
'7Networks_RH_SomMot_10'	0.1718	0.0602	0.0016
'7Networks_RH_SomMot_11'	0.3010	0.0532	0.0000
'7Networks_RH_SomMot_12'	0.4576	0.0501	0.0000
'7Networks_RH_SomMot_13'	0.3075	0.0531	0.0000
'7Networks_RH_SomMot_14'	0.3848	0.0524	0.0000
'7Networks_RH_SomMot_15'	0.3496	0.0590	0.0000
'7Networks_RH_SomMot_16'	0.2815	0.0593	0.0000
'7Networks_RH_SomMot_17'	0.4880	0.0494	0.0000
'7Networks_RH_SomMot_18'	0.3781	0.0504	0.0000
'7Networks_RH_SomMot_19'	0.4382	0.0534	0.0000
'7Networks_RH_DorsAttn_Post_1'	0.2420	0.0563	0.0000
'7Networks_RH_DorsAttn_Post_2'	0.2431	0.0565	0.0000
'7Networks_RH_DorsAttn_Post_3'	0.3086	0.0533	0.0000
'7Networks_RH_DorsAttn_Post_4'	0.2197	0.0572	0.0000
'7Networks_RH_DorsAttn_Post_5'	0.1940	0.0576	0.0002
'7Networks_RH_DorsAttn_Post_6'	0.3929	0.0523	0.0000
'7Networks_RH_DorsAttn_Post_7'	0.1424	0.0564	0.0047
'7Networks_RH_DorsAttn_Post_8'	0.3550	0.0542	0.0000
'7Networks_RH_DorsAttn_Post_9'	0.3334	0.0539	0.0000
'7Networks_RH_DorsAttn_Post_10'	0.4139	0.0513	0.0000
'7Networks_RH_DorsAttn_FEF_1'	0.3090	0.0586	0.0000
'7Networks_RH_DorsAttn_FEF_2'	0.2329	0.0569	0.0000
'7Networks_RH_DorsAttn_PrCv_1'	0.3154	0.0553	0.0000
'7Networks_RH_SalVentAttn_TempOccPar_1'	0.2310	0.0572	0.0000
'7Networks_RH_SalVentAttn_TempOccPar_2'	0.1702	0.0549	0.0008
'7Networks_RH_SalVentAttn_TempOccPar_3'	0.2479	0.0547	0.0000
'7Networks_RH_SalVentAttn_PrC_1'	0.1571	0.0568	0.0022
'7Networks_RH_SalVentAttn_FrOper_1'	0.2728	0.0570	0.0000
'7Networks_RH_SalVentAttn_FrOper_2'	0.5003	0.0520	0.0000

'7Networks_RH_SalVentAttn_FrOper_3'	0.3183	0.0530	0.0000
'7Networks_RH_SalVentAttn_FrOper_4'	0.2536	0.0567	0.0000
'7Networks_RH_SalVentAttn_Med_1'	0.2638	0.0558	0.0000
'7Networks_RH_SalVentAttn_Med_2'	0.4131	0.0515	0.0000
'7Networks_RH_SalVentAttn_Med_3'	0.3440	0.0594	0.0000
'7Networks_RH_Limbic_OFC_1'	0.4121	0.0566	0.0000
'7Networks_RH_Limbic_OFC_2'	0.3526	0.0496	0.0000
'7Networks_RH_Limbic_OFC_3'	0.3785	0.0545	0.0000
'7Networks_RH_Limbic_TempPole_1'	0.1799	0.0560	0.0005
'7Networks_RH_Limbic_TempPole_2'	0.3495	0.0556	0.0000
'7Networks_RH_Limbic_TempPole_3'	0.5059	0.0498	0.0000
'7Networks_RH_Cont_Par_1'	0.1538	0.0562	0.0021
'7Networks_RH_Cont_Par_2'	0.1959	0.0554	0.0001
'7Networks_RH_Cont_Par_3'	0.1328	0.0566	0.0081
'7Networks_RH_Cont_Temp_1'	0.2258	0.0600	0.0000
'7Networks_RH_Cont_PFCv_1'	0.2109	0.0579	0.0001
'7Networks_RH_Cont_PFCl_1'	0.2699	0.0546	0.0000
'7Networks_RH_Cont_PFCl_2'	0.3055	0.0549	0.0000
'7Networks_RH_Cont_PFCl_3'	0.3266	0.0515	0.0000
'7Networks_RH_Cont_PFCl_4'	0.4177	0.0506	0.0000
'7Networks_RH_Cont_PFCl_5'	0.3271	0.0519	0.0000
'7Networks_RH_Cont_PFCl_6'	0.3110	0.0512	0.0000
'7Networks_RH_Cont_PFCl_7'	0.3489	0.0573	0.0000
'7Networks_RH_Cont_pCun_1'	0.2582	0.0545	0.0000
'7Networks_RH_Cont_PFCmp_1'	0.4633	0.0479	0.0000
'7Networks_RH_Cont_PFCmp_2'	0.4163	0.0537	0.0000
'7Networks_RH_Cont_PFCmp_3'	0.2755	0.0573	0.0000
'7Networks_RH_Cont_PFCmp_4'	0.4503	0.0546	0.0000
'7Networks_RH_Default_Par_1'	0.2263	0.0589	0.0000
'7Networks_RH_Default_Par_2'	0.2045	0.0563	0.0001
'7Networks_RH_Default_Par_3'	0.1980	0.0561	0.0001
'7Networks_RH_Default_Temp_1'	0.3255	0.0543	0.0000
'7Networks_RH_Default_Temp_2'	0.3169	0.0556	0.0000
'7Networks_RH_Default_Temp_3'	0.4308	0.0562	0.0000
'7Networks_RH_Default_Temp_4'	0.2967	0.0533	0.0000
'7Networks_RH_Default_Temp_5'	0.2504	0.0595	0.0000
'7Networks_RH_Default_PFCv_1'	0.3596	0.0550	0.0000
'7Networks_RH_Default_PFCm_1'	0.2831	0.0532	0.0000
'7Networks_RH_Default_PFCm_2'	0.2488	0.0552	0.0000

'7Networks_RH_Default_PFCm_3'	0.3565	0.0609	0.0000
'7Networks_RH_Default_PFCm_4'	0.5538	0.0463	0.0000
'7Networks_RH_Default_PFCm_5'	0.4769	0.0474	0.0000
'7Networks_RH_Default_PFCm_6'	0.3159	0.0539	0.0000
'7Networks_RH_Default_PFCm_7'	0.1779	0.0539	0.0003
'7Networks_RH_Default_PCC_1'	0.3857	0.0577	0.0000
'7Networks_RH_Default_PCC_2'	0.4159	0.0549	0.0000
'7Networks_RH_Default_PCC_3'	0.2319	0.0547	0.0000

Supplementary table 7. Heritability of cortical thickness. Heritability of cortical thickness calculated using solar 8.4.0. regions are named according to the Schaefer 200 atlas, based on 7-networks. Here we report heritability values, standard errors (SE), and p-values. Nomenclature of the regions is based on the official parcel names of the Schaefer 200 – 7 networks parcel solution.

	rho_e	**p**	**rho_g**	**p**
Agreeableness				
7Networks_LH_Cont_PFCl_4	-0.12	0.04	-0.08	0.61
7Networks_LH_Default_PFC_7	-0.01	0.84	-0.22	0.06
7Networks_LH_Default_PFC_9	-0.05	0.44	-0.21	0.08
7Networks_LH_Default_PFC_11	0.01	0.90	-0.36	0.004
7Networks_LH_Default_PFC_12	-0.04	0.53	-0.17	0.17
7Networks_LH_Default_PFC_13	-0.02	0.72	-0.26	0.03
7Networks_RH_Default_PFCm_5	0.03	0.64	-0.33	0.005
Neuroticism				
7Networks_LH_Vis_14	-0.08	0.22	-0.18	0.12
7Networks_LH_DorsAttn_FEF_2	-0.03	0.69	0.27	0.03
7Networks_LH_SalVentAttn_ParOper_2	0.10	0.10	0.06	0.65
7Networks_LH_Default_Temp_6	-0.09	0.12	-0.10	0.49
7Networks_LH_Default_PFC_9	0.08	0.23	0.17	0.13
7Networks_LH_Default_PFC_11	0.01	0.84	0.19	0.09
7Networks_RH_Cont_PFCl_6	0.03	0.63	0.26	0.04
7Networks_RH_Default_PFCm_5	0.04	0.54	0.21	0.05
Openness				
7Networks_LH_Vis_1	-0.05	0.46	0.25	0.005
7Networks_LH_SalVentAttn_PFCl_1	-0.01	0.83	-0.20	0.02
7Networks_LH_Cont_PFCl_3	-0.03	0.69	-0.18	0.05
7Networks_LH_Cont_PFCl_4	-0.13	0.05	-0.15	0.17
7Networks_RH_Limbic_TempPole_1	-0.01	0.94	0.37	0.005
7Networks_RH_Cont_PFCl_5	-0.05	0.40	-0.16	0.10
7Networks_RH_Default_PCC_1	0.00	0.99	0.19	0.05

Supplementary Table 8. Phenotypic correlations in the complete HCP sample show some genetic correlation. Using the regions that showed significant phenotypic correlation in the complete HCP sample, we explored whether these regions also had a genetic relationship

with the respective personality trait. Nomenclature of the regions is based on the official parcel names of the Schaefer 200 – 7 networks parcel solution.

	HCP all	HCP unrelated	GSP	eNKI
Agreeableness:				
7Networks_LH_Default_Temp_5	0.03	-0.06	-0.04	-0.03
7Networks_RH_SalVentAttn_Med_3	-0.04	-0.04	-0.01	-0.01
7Networks_RH_Default_PFCm_6	-0.02	0.04	0.02	-0.03
Extraversion:				
7Networks_LH_Default_Temp_9	0.10 *	0.06	0.02	0.02

Supplementary Table 9. No robust phenotypic association between personality and cortical thickness in regions that showed significant genetic correlation between personality trait and cortical thickness. Using the regions that showed significant genetic correlation, we explored whether these regions also had a phenotypic relationship with the respective personality trait in all samples. ** indicates a Bonferroni corrected at p<0.05, whereas * indicates p<0.05.

Intelligence (h2r=0.75)	**r**	ρ_g	ρ_e
Agreeableness	0.10 **	0.31(0.09) **	-0.09(0.07)
Conscientiousness	-0.11 **	-0.26(0.07) **	0.11(0.07)
Extraversion	-0.03	-0.06(0.07)	0.01(0.07)
Neuroticism	-0.11 **	-0.22(0.08) **	0.01(0.07)
Openness	0.24 **	0.37(0.06) **	-0.002(0.07)

Supplementary table 10. Phenotypic and genetic correlation between personality traits and intelligence. Genetic correlation between intelligence (total cognitive score) and personality traits using solar 8.4.0. ** indicates a Bonferroni corrected at p<0.05 (controlled for number of analysis), whereas * indicates p<0.05.

Personality trait	**A**	**C**	**E**	**N**	**O**
Agreeableness	1				
Conscientiousness	0.04 (0.13)				
Extraversion	0.38 (0.12) **	0.33(0.09) **			
Neuroticism	-0.14 (0.14)	-0.27(0.10) *	-0.31(0.10) *		
Openness	0.17 (0.11)	-0.24 (0.09) *	0.05(0.09)	-0.01(0.10)	

Supplementary table 11. Genetic correlation of personality traits. Genetic correlation across personality traits using solar 8.4.0. ** indicates a Bonferroni corrected at p<0.05, controlled for number of analysis (10), whereas * indicates p<0.05.

Personality trait	**A**	**C**	**E**	**N**	**O**
Agreeableness	1				
Conscientiousness	0.32 (0.06) **				
Extraversion	0.26 (0.06) **	0.24(0.06) **			
Neuroticism	-0.41(0.06) **	-0.51(0.05) **	-0.39(0.06) **		
Openness	0.06 (0.06)	0.01 (0.07)	0.14(0.07) *	0.02(0.07)	

Supplementary table 12. Environmental correlation of personality traits. Environmental correlation across personality traits using solar 8.4.0. ** indicates a Bonferroni corrected at p<0.05, controlled for number of analysis (10), whereas * indicates p<0.05.

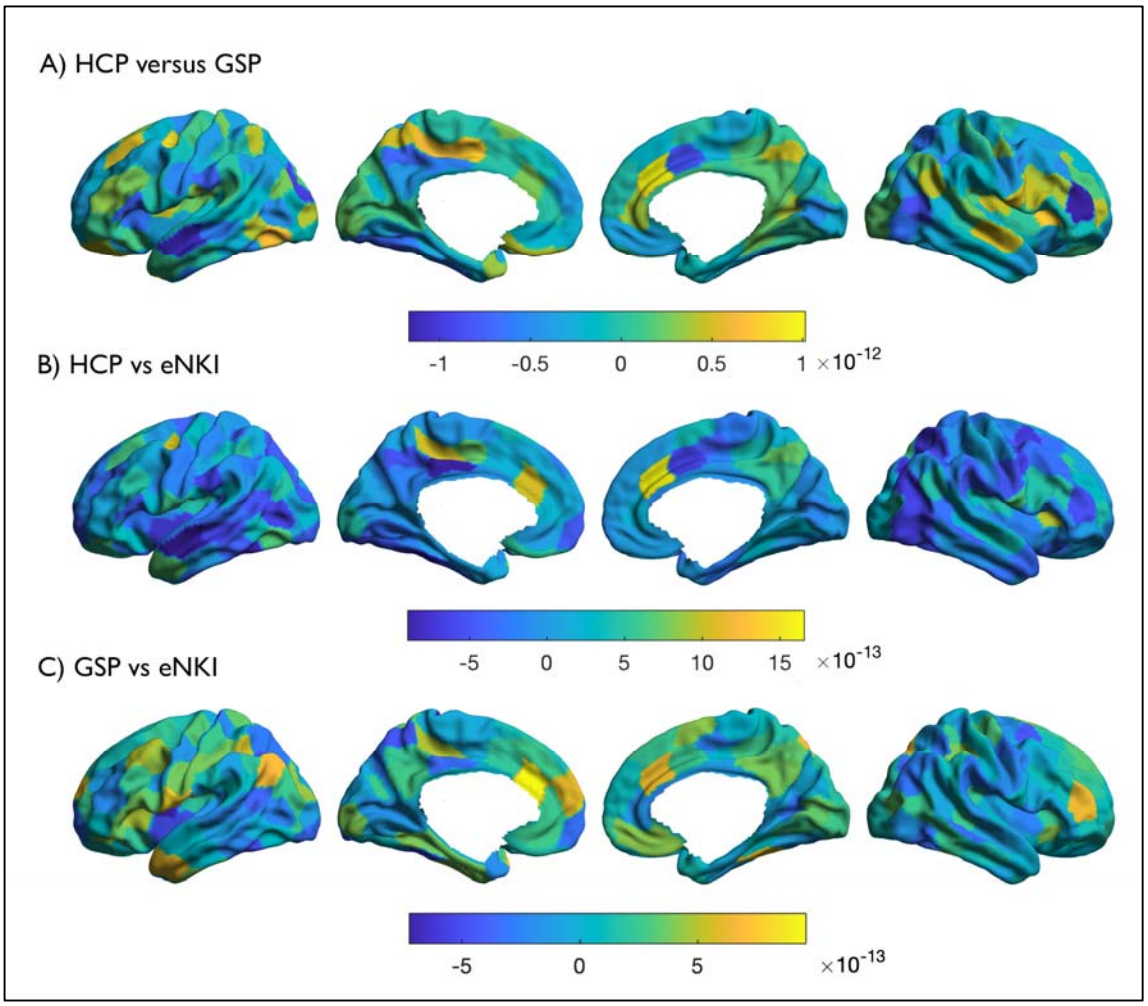
Top correlations for LV2: (GSP)	Spearman's rho
Barratt_1complex	*0.25*
TCI_HarmAvoidance	*0.16*
POMS_T_ConfusionBewilderment	*-0.11*
DOSPERT_taking	*-0.13*

Barratt_2mot	*-0.13*
BISBAS_BIS	*-0.14*
NEO_N	*-0.16*
Barratt_1mot	*-0.16*
EstIQ_Shipley_Int_Bin	*-0.18*
Shipley_Vocab_Raw	*-0.19*
BISBAS_BAS_Drive	*-0.20*
TCI_Novelty	*-0.22*
POMS_T_VigorActivity	*-0.22*
Barratt_1instability	*-0.24*
BISBAS_BAS_Reward	*-0.24*
MindWandering_Freq	*-0.25*
BISBAS_BAS_Fun	*-0.29*
TCI_RewardDependence	*-0.32*
NEO_E	*-0.41*
NEO_O	*-0.85*

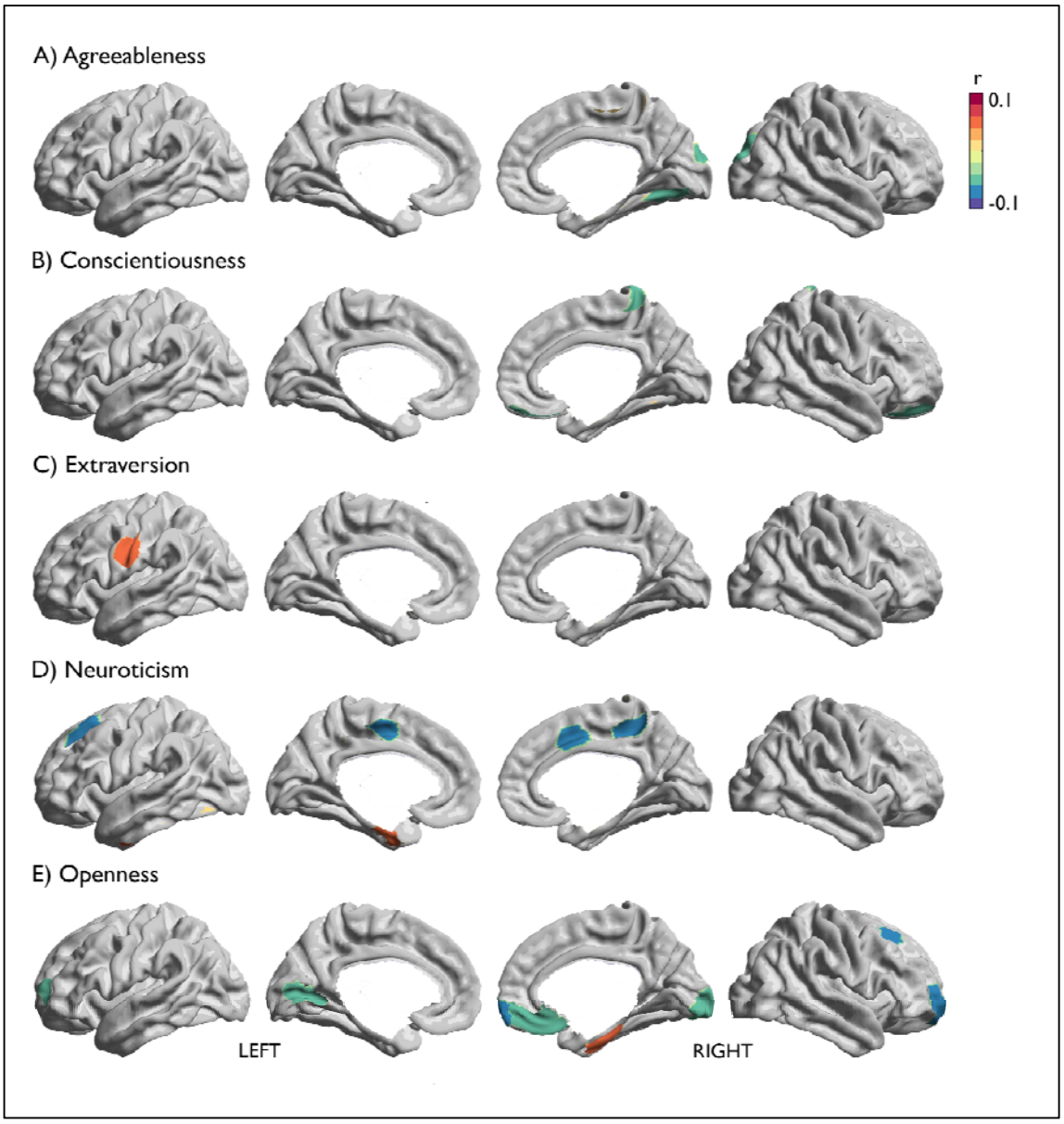
Supplementary table 13. Post-hoc correlation between significant personality component and behavior in GSP sample. Behavior was based on the available behavioral scores in the GSP sample.

HCP first latent component			**HCP second latent component**	
NEOFAC_N	0.64		*NEOFAC_N*	0.72
AngHostil_Unadj	0.46		*Loneliness_Unadj*	0.54
PercStress_Unadj	0.44		*PercStress_Unadj*	0.54
Loneliness_Unadj	0.39		*Sadness_Unadj*	0.51
AngAffect_Unadj	0.38		*AngHostil_Unadj*	0.45
PercReject_Unadj	0.35		*FearAffect_Unadj*	0.45
Sadness_Unadj	0.33		*AngAffect_Unadj*	0.42
PercHostil_Unadj	0.30		*NEOFAC_O*	0.40
AngAggr_Unadj	0.29		*PSQI_DayEnthusiasm*	0.40
FearAffect_Unadj	0.28		*PercReject_Unadj*	0.40
CogCrystalComp_Unadj	-0.24		*PSQI_Comp7*	0.35
PosAffect_Unadj	-0.33		*NEOFAC_A*	-0.33
MeanPurp_Unadj	-0.33		*Friendship_Unadj*	-0.38
Friendship_Unadj	-0.35		*EmotSupp_Unadj*	-0.38
LifeSatisf_Unadj	-0.36		*SelfEff_Unadj*	-0.40
SelfEff_Unadj	-0.36		*PosAffect_Unadj*	-0.41
EmotSupp_Unadj	-0.36		*LifeSatisf_Unadj*	-0.43
NEOFAC_E	-0.50		*MeanPurp_Unadj*	-0.46
NEOFAC_O	-0.53		*NEOFAC_E*	-0.56
NEOFAC_A	-0.68		*NEOFAC_C*	-0.71

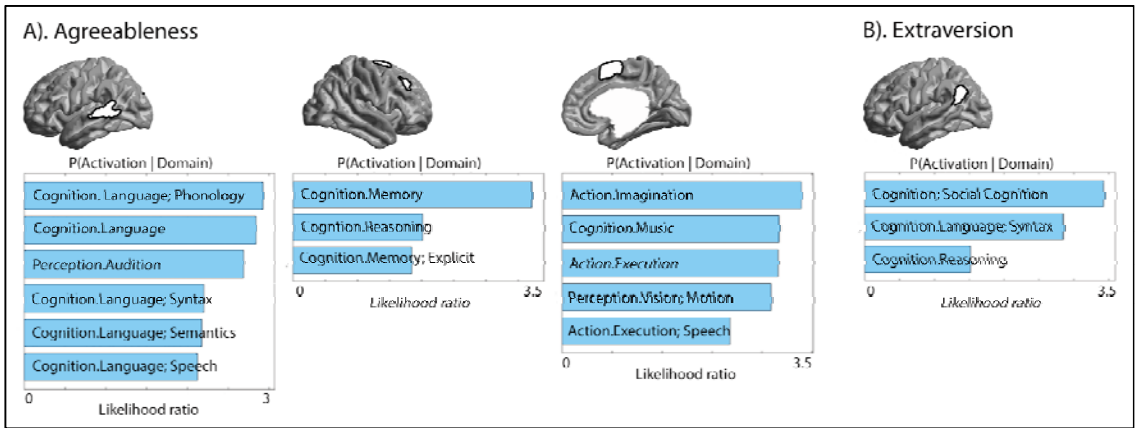
Supplementary table 14. Post-hoc correlation between significant personality component 1 and 2 and behavior in HCP sample. Using the behavioral saliency of the two components ($p<0.05$) in HCP we assessed their relation to behavioral scores in HCP. All correlations were significant at Bonferroni level $p<0.05$ correcting for the number of tests (20 x 2).



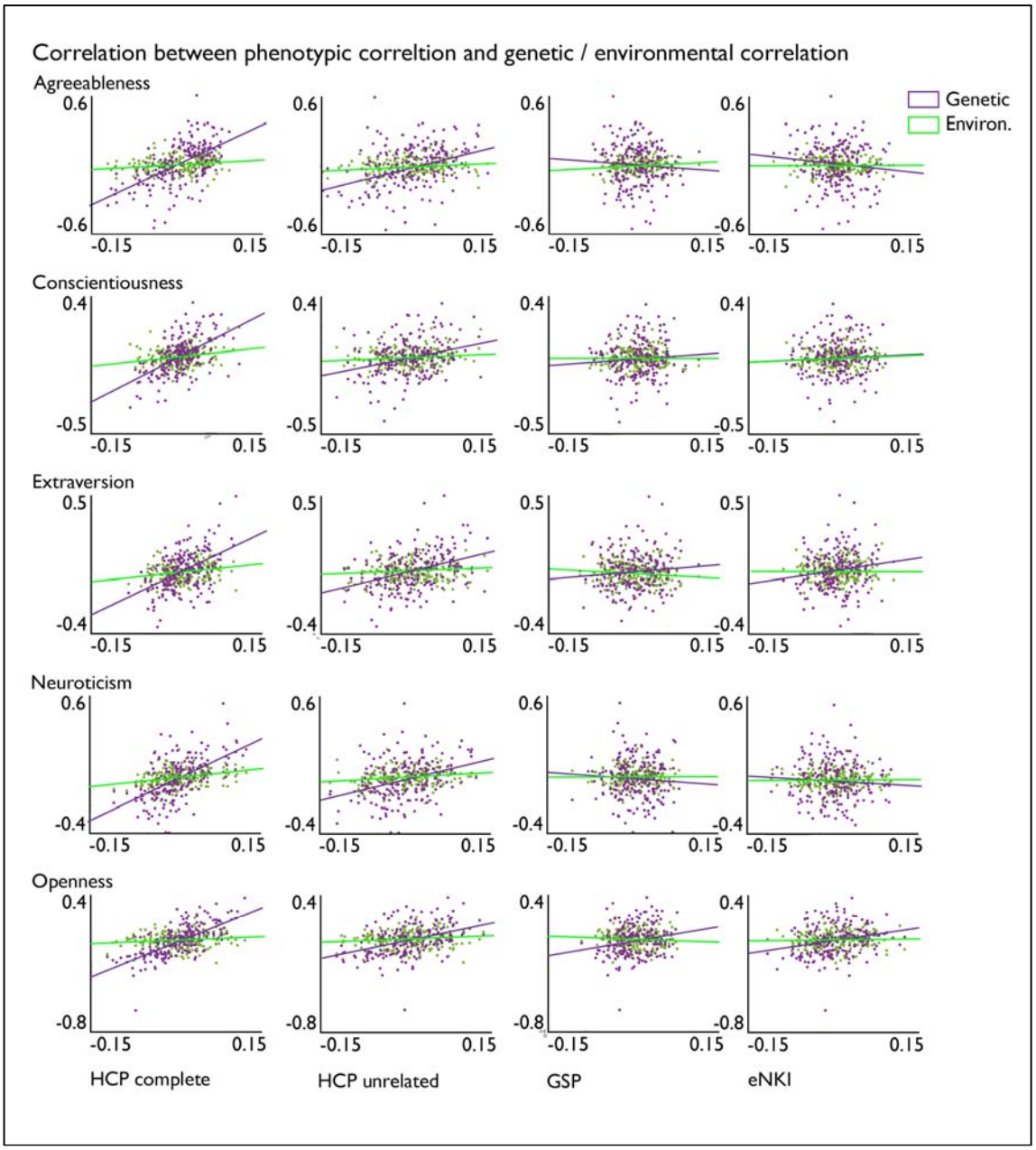
Supplementary figure 1. Comparability of parcel-wise cortical thickness values across samples. To test whether the distribution of cortical thickness is comparable across samples, we performed an unpaired Students t-test for each parcel between the three unrelated samples (HCP, GSP and eNKI). Distributions of t-statistics are visualized above.



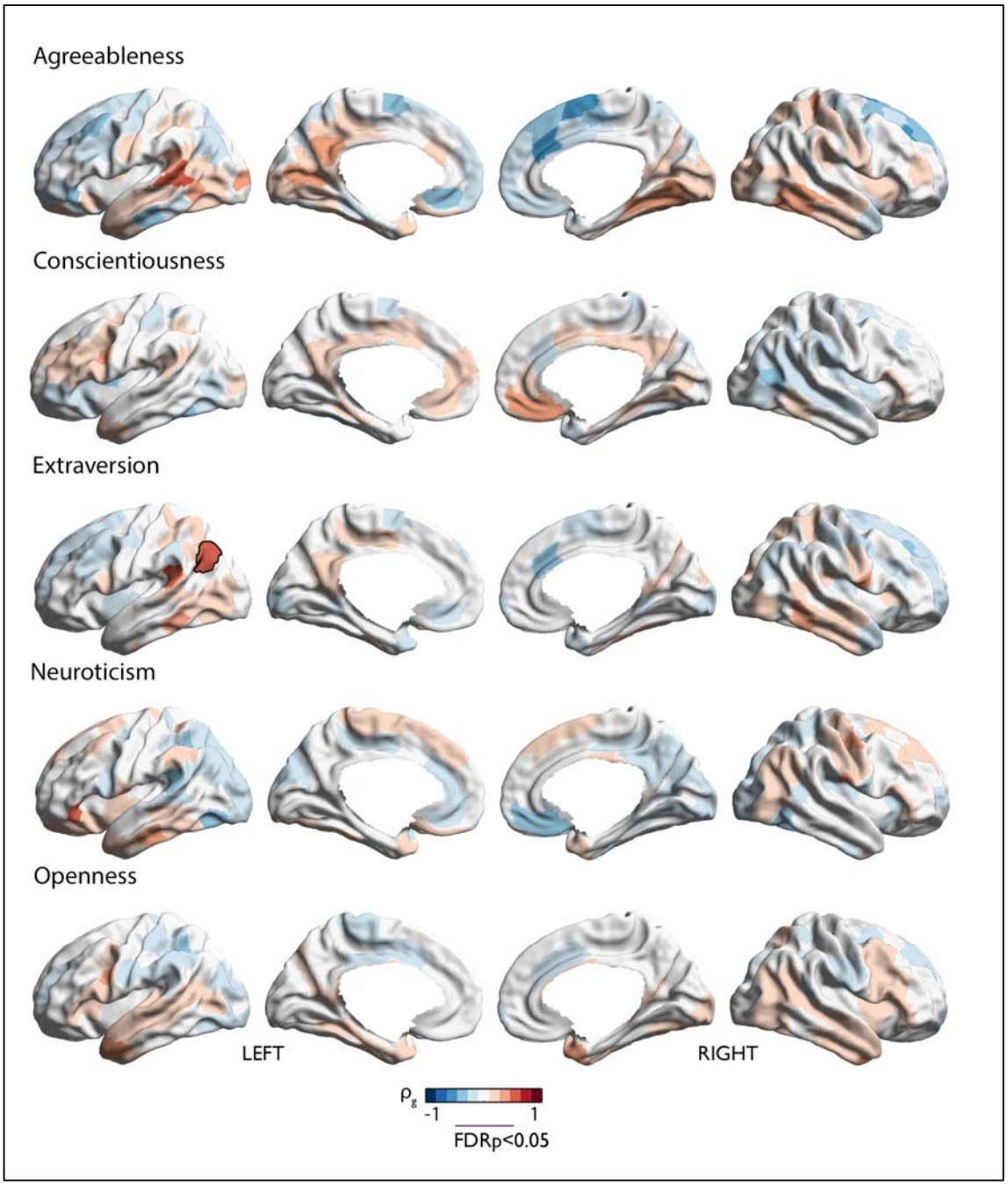
Supplementary figure 2. No significant phenotypic correlation in complete sample of 2137 individuals from three different datasets. Phenotypic correlation between personality traits and cortical thickness in largest sample to data by combining HCP unrelated sub-sample, GSP and eNKI. Trends are displayed at $p<0.01$, observations at FDR $p<0.05$ correcting for number of parcels have a black outline (none present).



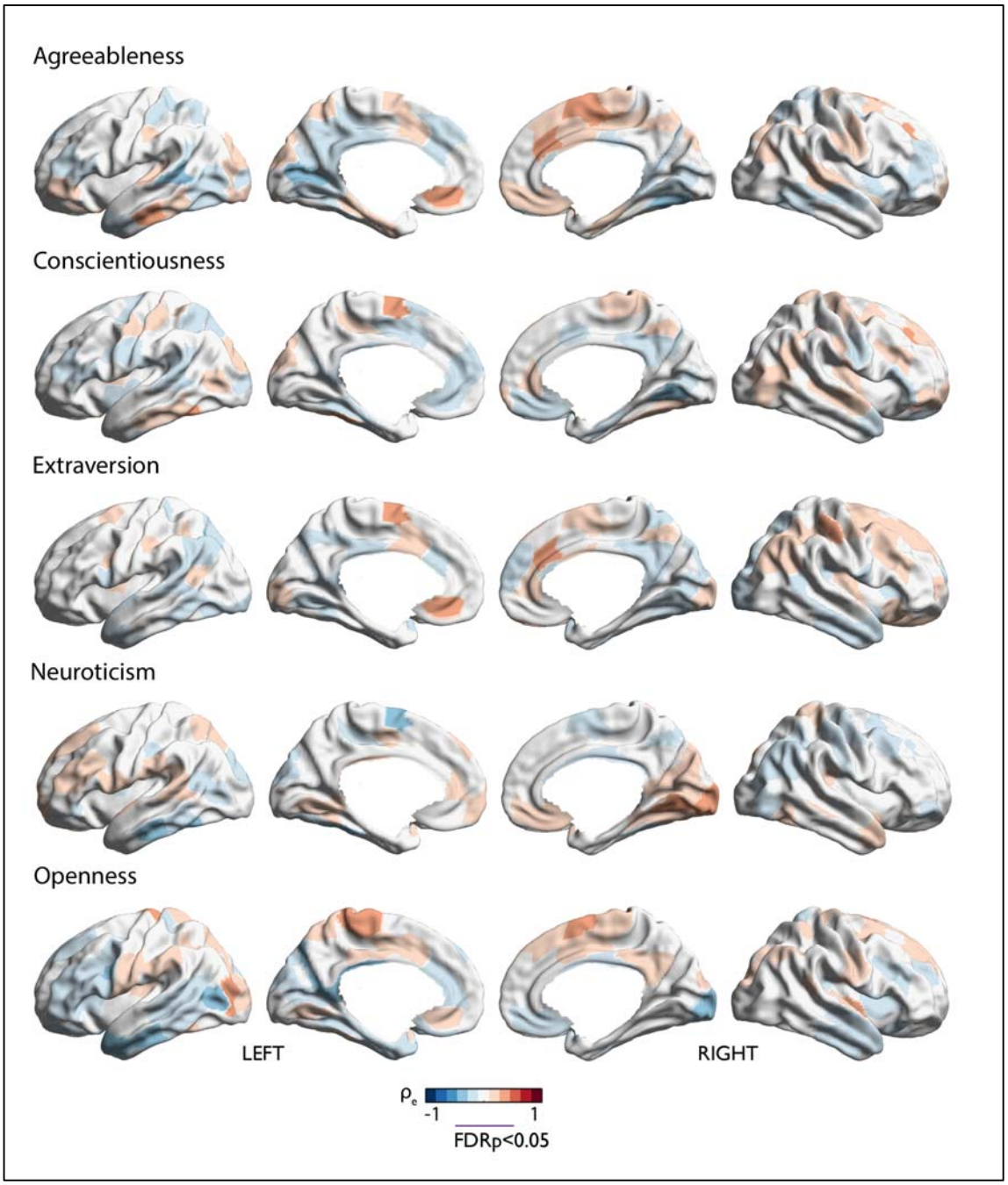
Supplementary figure 3. Genetic correlates between cortical thickness and personality traits functionally relate to (socio-) cognitive and language processing. Quantitative functional decomposition of neurogenetic markers of personality based on the FDR-corrected clusters of phenotypical relationships of Figure 4.



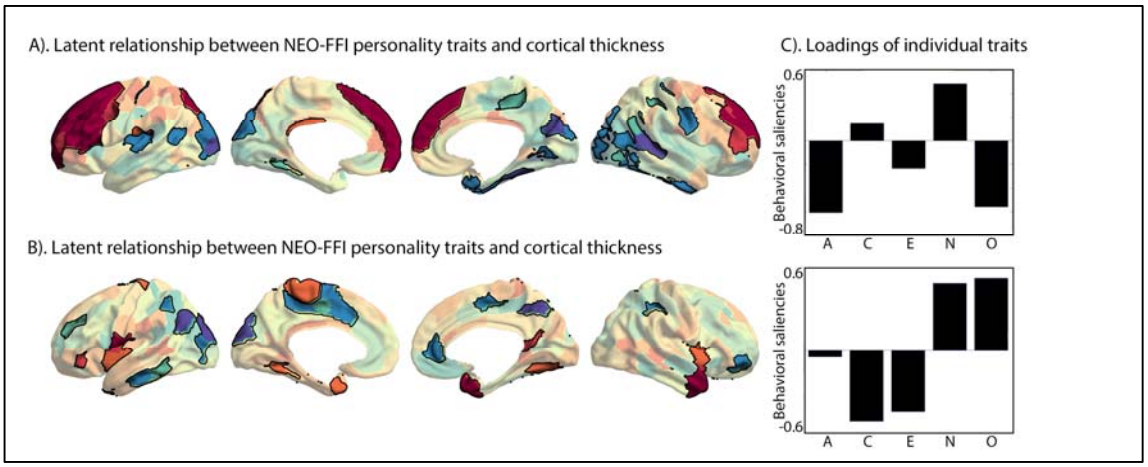
Supplementary figure 4. Correlation between cortex-wide spatial distributions of phenotypic and genetic/environmental correlation. Scatterplots of the correlation between spatial patterns of phenotypic correlation between personality traits and cortical thickness (X-axis) and genetic correlation between personality and cortical thickness (Y-axis).



Supplementary figure 5. Genetic correlations between personality traits and cortical thickness controlled for total cognitive score. Red values indicate positive genetic correlation whereas blue values indicate negative genetic correlation between parcel-wise thickness and personality traits. Findings at FDRp<0.05 are outlined in black.



Supplementary figure 6. Environmental correlations between personality traits and cortical thickness. Red values indicate positive environmental correlation whereas blue values indicate negative environmental correlation between parcel-wise thickness and personality traits. Findings at FDRp<0.05 are outlined in black.



Supplementary figure 7. Two latent relationships between personality traits and cortical thickness in HCP sample. Brain saliencies are depicted on the brain, where saliencies of $p<0.05$ are highlighted. Red indicates a positive association whereas blue indicates a negative association.