White Matter Heritability Using Diffusion Tensor Imaging in Neonatal Brains

Xiujuan Geng,¹ Elizabeth C. Prom-Wormley,⁵ Javier Perez,⁵ Thomas Kubarych,⁵ Martin Styner,^{1,2} Weili Lin,^{3,4} Michael C. Neale,⁵ and John H. Gilmore¹

¹Department of Psychiatry, University of North Carolina-Chapel Hill, Chapel Hill, USA

²Department of Computer Science, University of North Carolina-Chapel Hill, Chapel Hill, USA

³Department of Radiology, University of North Carolina-Chapel Hill, Chapel Hill, USA

⁴Biomedical Research Imaging Center, University of North Carolina-Chapel Hill, Chapel Hill, USA

⁵Virginia Institute for Psychiatric and Behavioral Genetics, Virginia Commonwealth University, Richmond, USA

Understanding genetic and environmental effects on white matter development in the first years of life is of great interest, as it provides insights into the etiology of neurodevelopmental disorders. In this study, the genetic and environmental effects on white matter were estimated using data from 173 neonatal twin subjects. Diffusion tensor imaging scans were acquired around 40 days after birth and were nonrigidly registered to a group-specific atlas and parcellated into 98 ROIs. A model of additive genetic, and common and specific environmental variance components was used to estimate overall and regional genetic and environmental contributions to diffusion parameters of fractional anisotropy, radial diffusivity, and axial diffusivity. Correlations between the regional heritability values and diffusion parameters were also examined. Results indicate that individual differences in overall white matter microstructure, represented by the average diffusion parameters over the whole brain, are heritable, and estimates are higher than found in studies in adults. Estimates of genetic and environmental variance components vary considerably across different white matter regions. Significant positive correlations between radial diffusivity heritability and radial diffusivity values are consistent with regional genetic variation being modulated by maturation status in the neonatal brain: the more mature the region is, the less genetic variation it shows. Common environmental effects are present in a few regions that tend to be characterized by low radial diffusivity. Results from the joint diffusion parameter analysis suggest that multivariate modeling approaches might be promising to better estimate maturation status and its relationship with genetic and environmental effects.

Keywords: heritability, genetic variation, environmental variation, magnetic resonance imaging (MRI), diffusion tensor imaging (DTI), white matter maturation, white matter atlas, neonates, fractional anisotropy, radial diffusivity, axial diffusivity

Twin studies provide important insights into the genetic basis of phenotypic variation of the human brain. Studies of adult twins show that genes play a significant role in the variability of global brain volumes, including total intracranial, total gray matter (GM), and white matter (WM) volumes (Peper et al., 2007; Posthuma et al., 2000; Schmitt et al., 2007), and local regional gray and white volumes (Hulshoff Pol et al., 2006; Thompson et al., 2001). Other brain measures, such as cortical thickness and surface area, are also highly heritable in adults (Panizzon et al., 2009; Schmitt et al., 2008). Not only structure, but also the 'default-mode' network (Glahn et al., 2010) and cognitive function, such as working memory (Blokland et al., 2011; Karlsgodt et al., 2010; Koten et al., 2009), have been shown to relate to genetic factors using functional magnetic resonance imaging (fMRI). A few studies suggest that global and regional GM and WM structures (Peper et al., 2009) and cortical networks (Schmitt et al., 2008) are also heritable in pediatric populations.

Little is known about genetic and environmental contributions to human brain development in the early years of life. The first years of life involve the most dynamic growth of brain structure and function during postnatal develop-

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ADDRESS FOR CORRESPONDENCE: Dr. Xiujuan Geng, Department of Psychiatry, 229 Medical School Wing B, University of North Carolina, Chapel Hill, NC 27514, USA. E-mail: xiujuan geng@med.unc.edu

ment (Gilmore et al., 2007, Knickmeyer et al., 2008). The degree to which genes and environment generate individual differences in early brain development is of fundamental importance in understanding developmental trajectories during childhood, and may help the early identification and prevention of various neurodevelopmental disorders (Gilmore et al., 2010; Schmitt et al., 2007). Our previous study in neonatal twins (Gilmore et al., 2010) revealed that the heritabilities of total intracranial volume (.73) and total WM volume (.85) were high, and similar to those reported in older children and adults, while GM volume heritability was lower (.56). However, it is not clear whether variation in WM microstructure, such as fiber organization and myelination, is under genetic or environmental control in early childhood.

WM maturation is a complex and lengthy process; the most significant period of myelination occurs between midgestation and the second postnatal year (Brody et al., 1987; Yakovlev and Lecours, 1967). DTI enables non-invasive estimation of WM microstructure and pathways by measuring water diffusion properties in brain tissues (Basser et al., 1994; Le Bihan et al., 2001). DTI-extracted parameters, such as apparent diffusion coefficients, including radial diffusivity (RD), axial diffusivity (AD), and fractional anisotropy (FA), are possible indicators of axonal organization, density, and degree of myelination (Beaulieu, 2002; Neil et al., 1998; Song et al., 2002). RD and AD describe the diffusion degree perpendicular to and parallel to fiber tracts, respectively, and the normalized parameter FA estimates the anisotropy degree of the diffusion process. DTI studies in adult twins have reported high heritability in the microstructure of the splenium and genu corpus callosum (Pfefferbaum et al., 2001), and of FA in bilateral frontal, parietal and left occipital lobes (Chiang et al., 2009). It has been shown that the whole brain WM FA and RD show significant genetic variability, with heritability values of .52 and .37, respectively (Kochunov et al., 2010). Genetic variation in AD was nonsignificant in that study, and estimates of heritability vary among different major fiber regions. A recent WM developmental study of persons aged 12 to 29 years indicated genetic variation in WM integrity (represented by FA), and that the effects vary with age (higher in adolescence than adulthood), gender, socioeconomic status, and IQ (Chiang et al., 2011). A study in nine-year-old children reported that RD and AD, rather than FA, were significantly influenced by genetic factors (Brouwer et al., 2010). Additional studies of larger samples are needed to clarify the pattern of results across ages, tracts, and DTI measures.

The aim of the present study was to assess the early genetic and environmental influences on the WM microstructure in neonates. We hypothesized that WM is highly heritable, that genetic influences vary in different brain regions, and that the non-uniformity in each individual might be related to the maturation pattern. Due to the inconsistent previous findings of genetic effects on different diffusion measures, the three commonly used parameters FA, RD, and AD, were analyzed in this study. Structural equation modeling was used to estimate global and regional genetic and environmental effects in a sample of neonatal twin pairs. It has been suggested that the diffusion measures are associated with WM development (Dubois et al., 2006, Gao et al., 2009). During the maturation process, decreases in RD may reflect axonal myelin synthesis and proliferation of glial cells. Increases in FA could reflect fiber organization, and may also be attributed to decreases in RD (Partridge et al., 2004). Therefore the correlation between heritability estimates and the level of RD were computed to explore whether regional genetic variation is modulated by the maturation degree in the first few months of life.

Methods

Subjects

The Institutional Review Board of the University of North Carolina (UNC) School of Medicine and Duke University Medical Center (DUMC) approved this study. Mothers with same-sex twin pregnancies were recruited from the outpatient OB-GYN clinics at UNC Hospitals and DUMC. Exclusion criteria included maternal HIV infection, major congenital abnormality on fetal ultrasound, and chromosomal abnormalities of fetuses. Informed consent was obtained from the parents of all subjects. For zygosity testing, polymerase chain reaction-short tandem repeat (PCR-STR) analysis of 14 loci was performed on DNA isolated from buccal swab cell collection (BRT Laboratories, Baltimore, MD). The study sample consisted of 173 individual participants comprising 63 complete same-sex twin pairs -31 monozygotic (MZ) and 32 dizygotic (DZ) - and 47 unpaired twins. Two twin pairs from a single mother are included, though treated as independent pairs in the statistical analysis. Demographic and clinical variables are presented in Table I.

Image Acquisition and DTI Preprocessing

All neonatal MRI scans were acquired on a head-only 3T scanner (Allegra, Siemens Medical Solutions, Erlangen, Germany) around 40 postnatal days of age (see Table 1). All subjects were scanned without sedation. Before neonates were imaged, they were fed, swaddled, and fitted with ear protection. Once asleep they were fitted with earplugs or earphones and placed in the MRI scanner with head in a vacuum-fixation device. Scans were performed with a neonatal nurse present, and a pulse oximeter to monitor heart rate and oxygen saturation. A single-shot echo-planar spin echo DTI sequence was used with the following variables: TR 5,200 ms, TE = 73 ms, slice thickness = 2 mm, in-plane resolution = $2 \times 2 \text{ mm}^2$, and 45 slices. One image without diffusion gradients (b = 0) and diffusion-weighted images (DWIs) along 6 gradient directions, with a b value of 1,000 mm²/sec, were acquired. The acquisition was repeated

| Gender | MZ twins | DZ twins | Single twin | Total | | | | | | |
|---|----------------|----------------|----------------|---------------|--|--|--|--|--|--|
| Male (%) | 36 (58.1) | 34 (53.1) | 17 (36.2) | 87 (50.3) | | | | | | |
| Female (%) | 26 (41.9) | 30 (46.9) | 30 (63.8) | 86 (49.7) | | | | | | |
| Ethnicity | | | | | | | | | | |
| Caucasian (%) | 42 (67.7) | 38 (59.4) | 39 (83.0) | 119 (68.8) | | | | | | |
| African American (%) | 14 (22.6) | 26 (40.6) | 7 (14.9) | 47 (27.2) | | | | | | |
| Other (%) | 6 (9.7) | 0 (0) | 1 (2.1) | 7 (4.0) | | | | | | |
| Mean gestational age (days) at birth (SD) | 241.9 (20.4) | 251.3 (16.1) | 247.4 (16.1) | 246.8 (18.1) | | | | | | |
| Mean gestational age (days) at MRI (SD) | 283.6 (13.4) | 291.0 (20.6) | 293.5 (24.0) | 289.0 (19.8) | | | | | | |
| Mean birth weight (g) (SD) | 2168.4 (579.4) | 2392.0 (513.2) | 2386.7 (470.4) | 2310.4 (534.8 | | | | | | |

TABLE 1 Demographic Characteristics for Particir

Note: MZ = monozygotic, DZ = dizygotic, SD = standard deviation

five times to improve signal-to-noise ratio. DWIs were screened offline for motion artifacts and for missing and corrupted sections using an automatic DWI quality control tool, DTIPrep (http://www.nitrc.org/projects/dtiprep). Diffusion images with large motion artifacts were excluded from the entire set of DWIs. The DWIs with more than 70% successful rate were retained for later analysis. After the offline screening, the five repeated sequences were combined into a single DWI volume and the diffusion maps, such as RD, AD, and FA, were then estimated using standard weighted least square fitting (Liu et al., 2010).

DTI Registration and White Matter Parcellation

All tensor images (173 in total) were first rigidly aligned and the average computed and used as the initial template. The original DTI data was affine-aligned to it, and a new average tensor image was computed for the updated template, which is sharper than the initial one. Affine registration was repeated three times; little change was found between the average images from the third and second iteration, indicating that the initial template converged after the third iteration. The affine-aligned tensors were then mapped to an iteratively updated group average with an unbiased group-wise tensor-based deformable registration method (Zhang et al., 2007). At each iteration, all input images were warped to the average of the registered tensors in the previous iteration. This deformable registration was repeated six times, allowing the convergence of the group average, that is, the template. The tensorbased rigid, affine, and non-rigid registrations were performed using a publicly available toolkit, DTITK (http://dtitk.sourceforge.net/pmwiki/pmwiki.php). The RD, AD, and FA maps (Figure 1) were then warped to the template space using their corresponding affine matrices and deformation fields estimated from the above registration process.

We adapted the recently developed WM atlas JHU-DTI-SS (a.k.a. 'Eve atlas', http://lbam.med.jhmi.edu/) (Oishi et al., 2009), to obtain a comprehensive WM parcellation for calculation of regional average diffusion parameters. The FA map of the atlas was affine-aligned and then deformably registered to the average FA maps of our warped neonatal DTI data. The 'Type II' WM parcellation with 130 labels was



FIGURE 1

The FA (fractional anisotropy), RD (radial diffusivity) and AD (axial diffusivity) maps of a typical original diffusion tensor imaging (DTI) data.

mapped to the neonatal space following the affine and nonrigid transformations with nearest neighbor interpolation. This parcellation included 52 gyri regions (including 44 superficial WM regions), 56 deep WM regions, 10 subcortical regions, and 12 other regions. The boundary of the cortex and WM of our DTI atlas was defined by an FA threshold of .1. Since most WM regions are not myelinated at birth, the FA values are lower compared to those in adults (Dubois et al., 2008). The boundary was used to define the superficial WM regions included in the corresponding gyri from the Type II parcellation. In this study, we included 44 superficial WM ROIs, 52 deep WM ROIs (bilateral inferior cerebral peduncle and medial lemniscus were excluded due to the very small coverage of the ROIs with less than 10 voxels in the neonatal atlas), and bilateral cerebellum WM, 98 WM ROIs in total. The abbreviations of each ROI can be found in the Appendix. For every registered individual diffusion map, the FA, RD, and AD were averaged over each ROI. Therefore, the three sets of 98 diffusion parameters from each subject were obtained (see Figure 2(a)) and ready for the following statistical analyses.

Estimation of Genetic and Environmental Effects

Genetic and environmental variation in the average whole brain (thresholded with FA > .1), left and right hemispheres, and ROI measures of WM integrity (FA, AD, and RD) were estimated using a classic univariate twin modeling



FIGURE 2

(a) Illustration of white matter regions of interest (ROIs) in the neonatal image space; (b) heritability values of FA, RD and AD over each ROI and their corresponding p values (normalized using -log(p), -log(0.05) = 1.3, and -log(0.0001) = 4). Note: see Appendix for ROI abbreviations; image left corresponds to brain left.

approach (Neale & Cardon, 1992). This approach utilizes MZ and DZ twin pair variances and covariances to estimate the proportion of total phenotypic variance due to additive genetic, shared environmental, and unique environmental influences. Additive genetic effects (A) refer to the additive effects of alleles at every locus; shared environmental effects (C) are those effects shared by twin pairs; and unique environment effects (E) refer to effects not shared by twin pairs and include measurement error. Univariate analysis parameterizes the total phenotypic variance as $\sigma^2_V = \sigma^2_A + \sigma^2_C$ + $\sigma^2_{\rm E}$. Twin covariances are parameterized as $\sigma^2_{\rm covMZ}$ = $\sigma^2_A + \sigma^2_C$ and $\sigma^2_{covDZ} = .5\sigma^2_A + \sigma^2_C$. The full ACE model and its submodels, (i.e. AE, CE, and E only) were fitted to test the significance of additive genetic and shared environmental effects on the three sets of imaging measures. Model fitting used maximum likelihood (Edwards, 1984) by calculating twice the negative log-likelihood of the raw data for each twin pair, and summing across all pairs. Because the variance component estimates are zero-bounded, the difference between an original model and its respective submodels follows a 50:50 mixture of zero, and a χ^2 distribution with degrees of freedom equal to the difference in model parameters (df = 1 for AE and CE models, df = 2 for an E-only model).

There were significant (p < .05) associations between diffusion measures and gestational age at MRI in most ROIs. Similarly, significant differences in mean intensity (p < .05) were detected by gender in approximately 5% of all positions. All analyses included sex and the linear effects of gestational age at the MRI scan as fixed effects in the means models. Prior to ACE submodel comparisons, saturated models were fitted to test for group differences in mean and variances, and to estimate cross-twin correlations by zygosity. Maximum likelihood analyses of individual observations were used for all analyses as implemented in OpenMx 1.1, a package for use within the R language (Boker et al., 2011).

Analysis of Relationship Between Heritability and Diffusion Measures

Mean FA, RD, and AD were calculated across the whole population over each ROI. Three linear regression analyses were performed on the mean FA and FA heritability, mean RD and RD heritability, and mean AD and AD heritability separately.

A single parameter may not be specific to maturation status. High FA might not indicate high maturation (e.g., splenium and genu of the corpus callosum have high FA values after birth, but are not myelinated until later years of age). In general, a high RD region where fibers follow similar directions might indicate a low myelination degree. However, regions with more complex fiber organization, such as crossing fibers, may also appear to have high RD, despite being highly myelinated. Since RD rather than AD has been shown to be better representative of changes in demyelination models (Song et al., 2003), we analyzed the data by considering both FA and RD. The ROIs were separated into four subgroups according to high/low FA (20 ROIs with the highest/lowest FA) and high/low RD (20 ROIs with the highest/lowest RD) values, and the genetic effects were summarized under the four conditions: HL, HH, LL and LH (see Table 3). HL (high FA and low RD) might be associated with high maturation; HH indicates regions that are well organized but have low maturation; LL may correspond to high maturation regions with complex

TABLE 2

Genetic and Common Environmental Contribution Estimates for Whole Brain, Left, and Right Hemisphere White Matter, Diffusion Tensor Imaging Parameters

| Measure | Mean | rMZ | rDZ | a ² [95% CI] | p-value | c ² [95% CI] | p-value |
|---------|------|-----|-----|-------------------------|---------|-------------------------|---------|
| WB- FA | 0.16 | .86 | .70 | .60 [.22, .91] | .0021 | .25 (0, .61) | .3402 |
| WB- RD | 1.21 | .86 | .76 | .53 [.19, .91] | .0021 | .34 (0, .65) | .1525 |
| WB- AD | 1.55 | .83 | .67 | .57 [.19, .90] | .0039 | .27 (0, .62) | .2805 |
| L- FA | 0.16 | .84 | .71 | .56 [.16, .89] | .0060 | .28 (0, .64) | .293 |
| L- RD | 1.21 | .84 | .73 | .45 [.09, .88] | .0151 | .39 (0, .70) | .1211 |

Note: a² = genetic contribution, c² = common environmental contribution, CI = confidenc interval, WB = whole brain, L = left, R = right, MZ = monozygotic, DZ = dizygotic

TABLE 3

Regional Heritability of FA and RD Under Four Conditions: High FA and Low RD; High FA and High RD; Low FA and Low RD; and Low FA and High RD

| | High FA | | | Low FA | | | |
|---------|---|--|---|---------------------------------------|-------------------------------------|-----------------------------------|--|
| Low RD | ROI (HL) | a ² _{RD} | a ² FA | ROI (LL) | a ² _{RD} | a ² FA | |
| | L PLIC R PLIC L ALIC R ALIC L RLIC R RLIC R CP R SCP | 0 .16 .14 .07 .30 .65* 0 .62* | .19 0 0 0 .34 .21 .12 | L Cerebel R Cerebel | .74* .78* | .66* .70* | |
| High RD | ROI (HH) | a^2_{RD} | a^2_{FA} | ROI (LH) | a^2_{RD} | a ² FA | |
| | R PTR L BCC R BCC L Tap | .79* .70* .77* 0 | .55* .69* .74* .60* | L A R A R LFO L MFO R MFO | .40* .40* .48 .70* .69* | .61* .33 .32 .11 .66* | |

Note: See Appendix for abbreviations of regions of interest (ROIs), a² = genetic contribution, L = left, R = right, HL = high-low, HH = high-high, LL = low-low, LH = low-high.

= p < .05.

fiber organization; and LH might represent a low degree of maturation.

Results

Both qualitative and quantitative tests suggested that the population distribution of most ROIs approximated a normal distribution. Similarly, there were no statistically significant differences in means and variances between MZ and DZ twins for most structures. Population means and variances are reported in Table 4.

Global Analysis

There was significant heritability across all three average diffusion parameters over whole brain WM (Table 2). FA had the highest heritability. .60, 95% CI [.22, .91], followed by AD, .57, 95% CI [.19, .90], and RD, .53, 95% CI [.19, .91]. There was significant heritability in both hemispheres of FA: left, .56, 95% CI [.16, .89], right, .60, 95% CI [.20, .90]; and RD: left, .45, 95% CI [.09, .88], right, .60, 95%

CI [.27, .93]. AD heritability was significant in the right hemisphere only, .68, 95% CI [.30, .92].

Regional Analysis

The regional diffusion parameters of each ROI are listed in Table 4. The mean FA values range from .11 to .38; D varies within $0.79 \sim 1.65 \times 10^{-3} \text{ mm}^2 \text{s}^{-1}$, and AD varies between $1.09 \sim 2.17 \times 10^{-3} \text{ mm}^2 \text{s}^{-1}$. Posterior limb of internal capsule (PLIC), retrolenticular part of internal capsule (RLIC), and the splenium and genu of the corpus callosum show larger FA values. PLIC, pontine crossing tracts, corticospinal tracts, midbrain, anterior limb of internal capsule (ALIC), and RLIC have smaller RD than other regions. These findings are consistent with our previous early WM developmental study focused on the major fiber bundles (Geng et al., 2011). Superficially located WM in cortical regions has lower FA values compared to deep WM.

Among the majority of ROIs, MZ twin pairs had increased correlations of FA, RD, and AD compared with DZ twin pairs, suggesting significant additive genetic effects. In general, heritability shows heterogeneity over WM tissue (Figure 2b). There are about half of the ROIs with high heritability (A > .50, p < .05) on RD (49 ROIs), AD (42 ROIs), and FA (42 ROIs) measures. Many fewer ROIs show high common environment effects (C > .50, p < .05) for RD (10 ROIs), AD (7 ROIs) and FA (3 ROIs) (Table 4).

For FA heritability, left posterior corona radiata shows the highest genetic variation (A = .82). There are seven regions with relatively high RD heritability estimates with A > .80: superficial WM regions in left middle and inferior occipital gyrus, right pre-cuneus, and right inferior temporal gyrus, and deep WM regions of right sagittal stratum, right splenium of corpus callosum, and left posterior corona radiata. The corresponding RD values in these regions are relatively high (between 1.19 and 1.30).

For AD heritability, right posterior corona radiata show the highest genetic variation with A = .92. For the estimates of environmental variation, WM in the left inferior temporal gyrus has the highest FA environmental variation with C = .69. Bilateral external capsule and left PLIC have relatively high RD environmental variation with C > .7, and right external capsule shows the highest value of C = .82. Left external capsule and WM in left angular gyrus show the highest environmental variation of AD with C = .71.

Relationships Between Heritability and Diffusion Measures

There is no correlation between FA heritability and mean FA throughout the 98 ROIs (Figure 3). There is a significant positive correlation between RD heritability and mean RD (r = .17, $p < 10^{-5}$), and a significant positive correlation between AD heritability and mean AD (r = .05, p = .02).

Genetic variation in FA and RD under the four conditions, HL, HH, LL, and LH, is described in Table 3. We note that ROIs with high FA and low RD include major

TABLE 4 (a)

| Genetic and Common | Environmental | Contribution | Estimates of | Averaged FA | Over Superficial | and Deep ' | White Matter | Regions of |
|--------------------|---------------|--------------|--------------|-------------|-------------------------|------------|--------------|------------|
| nterest | | | | | | | | |

| S.P. 0.15 0.43 | ROI (Left) | FA | Variance (10 ⁻³) | rMZ | rDZ | a ² [95% CI] | p of a ² | c ² [95% CI] | p of c ² |
|--|--------------|------|------------------------------|-----|-----------|-------------------------|---------------------|-------------------------|---------------------|
| S.Cmg 0.15 0.16 .74 .37 .87 .07 .08 .0269* .05 .05 .05 .05 .05 .05 .05 .05 .05 .05 .05 .05 .05 .05 .05 .05 .06 .07 .03 .03 .06 .07 .03 .05 .05 .05 .05 .05 .05 .05 .05 .05 .06 | S_SP | 0.15 | 0.43 | .77 | .58 | .47 [.00, .85] | .0507 | .29 [.00, .68] | .3088 |
| 5.SF 0.15 0.52 76 59 57.107,861 0.244" 20.100,.061 .4701 S.F 0.14 0.42 4.66 52 10.10,.071 .7388 49.10,.071 .13142 S.F 0.14 0.42 4.66 52 .10140,.711 .7388 49.10,.071 .10000 S.A 0.12 0.18 4.8 .15 .461,.071 .10000 .371 .00100,.391 .10000 .371,.0010,.391 .10000 .371,.0010,.391 .10000 .371,.0010,.391 .10000 .371,.0010,.391 .10000 .371,.0010,.391 .10000 .371,.0010,.391 .10000 .371,.0010,.391 .10000 .371,.0010,.391 .10000 .371,.0010,.391 .440 .331<.00,.491 | S_Cing | 0.15 | 0.16 | .74 | .37 | .67 [.08, .83] | .0269* | .05 [.00, .54] | .8826 |
| S.MF 0.11 0.35 76 58 4.4 [00, 22] .1048 .30 [00, 70] .1111 S.PF 0.14 0.42 .42 .57 [100, 83] .0482 .15 [1111] .015 .000, .01 .011 .015 .010, .01 .011 .015 .010, .01 .0100< | S_SF | 0.15 | 0.52 | .76 | .59 | .57 [.07, .86] | .0249* | .20 [.00, .60] | .4701 |
| S,F 0.14 0.42 .62 .55 .10.[00,71] .7308 .49[0,71] .1191 S,FPC 0.15 0.34 .48 .42 .75 [00, 38] .0422 .15 [00, 00, 71] .0401 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .501 .0000 .401000 .401000 .401000 .401000 .4010000 .4010000 .4010000 .4010000 .4010000 .4010000 .4010000 .4010000 .4010000 <t< td=""><td>S_MF</td><td>0.11</td><td>0.35</td><td>.76</td><td>.58</td><td>.43 [.00, .82]</td><td>.1048</td><td>.30 [.00, .70]</td><td>.3142</td></t<> | S_MF | 0.11 | 0.35 | .76 | .58 | .43 [.00, .82] | .1048 | .30 [.00, .70] | .3142 |
| S.PrC 0.15 0.34 68 4/2 57 [00, 33] 0.482" .15 [00, 60] .6010 S.PrC 0.14 0.26 .67 .27 .73 [23, 85] .00449 .00100, 30] .0000 S.A 0.12 0.15 .44 .114 .41 [18, 77] .0147 .0000 .2215 S.L 0.13 0.17 .74 .66 .68 [29, 81] .0037 .0010, .31 .2015 S.Fu 0.12 0.16 .47 .28 .21 [0000 .22 [0010, .31] .2005 S.Fu 0.13 0.32 .43 .28 .42 [21, .30, .43] .3671 .15 [00, .58] .4645 S.MO 0.14 0.21 .50 .34 .35 [00, .67] .3671 .15 [00, .38] .4645 S.Fro 0.13 0.32 .43 .36 [00, .67] .3671 .15 [00, .68] .4645 S.Fro 0.12 .30 .32 .30 .31 [00, .67] .3671 .31 [00, .60] .3671< | S_IF | 0.14 | 0.42 | .62 | .55 | .10 [.00, .71] | .7308 | .49 [.00, .71] | .1181 |
| 5, PaC 0.14 0.26 .47 27 77, 12, 9, 85 0.048 .00, 100, 28 1.0000 5, PrC 0.12 0.36 .44 .14 .41, 18, 70 .0145 .00, 100, 26 1.0000 5, PrC 0.12 0.13 0.17 .74 .36 .00, 12 .36 .36 .13 .010, 0.45 1.0000 5, Fu 0.12 0.16 .47 .28 .27, 100, 62 .536.3 .13, 0.54 .120, 0.48 1.0000 5, Fu 0.12 0.14 0.37 .41 .57 .00, 60 .421 .151, 00, 48 1.0000 5, MO 0.14 0.21 .50 .44 .351, 00, 49 .362 .461, 00, 34 1.0000 5, MT 0.14 0.25 .67 .63 .0100, 47 1.0000 .461, 00, 31 1.1000 5, MT 0.15 0.43 .464 .41 .451, 82, 74 .460, 00, 31 1.0000 5, MT 0.15 0.457 | S_PrC | 0.15 | 0.34 | .68 | .42 | .57 [.00, .83] | .0482* | .15 [.00, .60] | .6010 |
| S.A. 0.12 0.36 | S_PoC | 0.14 | 0.26 | .67 | .27 | .73 [.29, .85] | .0048* | .00 [.00, .36] | 1.0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | S_A | 0.12 | 0.36 | .64 | .14 | .61 [.18, .79] | .0145* | .00 [.00, .29] | 1.0000 |
| S.C. 0.14 0.24 38 37 001 (00, 59) 1,0000 37 (00, 56) 2815 S.L 0.12 0.17 47 26 6612, 81 0.0000 0.010, 0.31 1.0000 S.G 0.12 0.17 47 26 481, 0000 0.120, 0.51 1.0000 S.MO 0.14 0.37 47 27 0.0.43 1.0000 481, 10000 S.MO 0.14 0.22 43 28 481, 00, 691 3.010, 0.33 1.00, 0.44 1.0000 4.41 1.0000 5.17 0.14 0.22 0.00 0.00, 0.41 1.0000 5.17 0.14 0.49 4.5 0.00 0.00, 0.31 1.0000 5.16 0.000 0.100, 0.31 1.0000 5.1 0.000 0.000, 0.31 1.0000 5.1 0.000 0.000, 0.31 0.0000 5.1 5.4 0.010, 0.31 0.000 0.000, 0.31 0.0000 5.3 0.000 5.3 0.000 0.000, 0.00, 0.000 0.000, 0.000 0.00 | S_PrCu | 0.12 | 0.18 | .48 | .15 | .46 [.00, .67] | .1514 | .00 [.00, .45] | 1.0000 |
| S_L 0.13 0.17 //4 0.06 281 (2), 431 0.037 0.035 <th< td=""><td>S_Cu</td><td>0.14</td><td>0.24</td><td>.38</td><td>.37</td><td>.00 [.00, .59]</td><td>1.0000</td><td>.37 [.00, .56]</td><td>.2815</td></th<> | S_Cu | 0.14 | 0.24 | .38 | .37 | .00 [.00, .59] | 1.0000 | .37 [.00, .56] | .2815 |
| 3 50 0.14 0.17 41 27 20 0.00 23 300 10 0.01 0.02 100 100 41 0.02 100 <td>S_L</td> <td>0.13</td> <td>0.17</td> <td>./4</td> <td>.06</td> <td>.08 [.29, .81]</td> <td>.0037*</td> <td>.00[.00, .31]</td> <td>1.0000</td> | S_L | 0.13 | 0.17 | ./4 | .06 | .08 [.29, .81] | .0037* | .00[.00, .31] | 1.0000 |
| 2 SD 0.13 0.32 31 32 00 [00, 39] 10000 20 [00, 18] 10000 SMO 0.14 0.21 53 53 0.15 0.24 66 24 72 [30, 84] 0037 00 [00, 38] 1.0604 SJT 0.14 0.25 67 6.3 0.0100, 47] 1.0000 66 [0, 76] 0.09 67 1.64 5. SLFO 0.12 0.30 52 50 1.31 [00, 70] 6976 42 [00, 67] 1.1644 S.MO 0.13 0.40 6.1 52 1.11 [00, 71] 7265 48 [00, 70] 1.33 S.MO 0.13 0.35 39 22 0.9 [00, 55] 4437 23 [00, 50] 5.91 S.SCP 0.13 0.37 38 34 0.0 [00, 78] 1.0000 33 [00, 60] 333 [00, 60] 333 [00, 60] 333 [00, 60] 332 [00, 60] 332 [00, 60] 332 [00, 60] 332 [00, 60] 332 [00, 60] 332 [00, 60] 332 [00, 60] 332 [00, 60]< | S_FU | 0.12 | 0.16 | .47 | .28 | .27 [.00, .62] | .5363 | .13[.00, .54] | ./484 |
| a Mo 0 14 0.21 23 24 142 1201 | 5_50 | 0.14 | 0.37 | .01 | .37 | .00 [.00, .36] | 2125 | .02[.00, .75] | 1 0000 |
| $ \begin{array}{c} 2 \mbox{Sr} & 0.15 & 0.24 & 0.4 & 0.4 & 0.72 (190, 44] & 0.003 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 1.0000 & 0.01 (0, 0.34) & 0.010 & 0.01 (0, 0.34) & 0.010 & 0.01 (0, 0.34) & 0.010 & 0.01 (0, 0.34) & 0.010 & 0.01 (0, 0.34) & 0.010 & 0.01 (0, 0.34) & 0.010 & 0.01 (0, 0.34) & 0.000 & 0.01 (0, 0.34)$ | 3_10 S_MO | 0.13 | 0.32 | .43 | .20 | 35 [00 40] | 2671 | 15[00, 58] | 6645 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | S ST | 0.14 | 0.21 | .50 | .34 | 72 [30 84] | .3071 | 00[00,34] | 1 0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | S IT | 0.13 | 0.24 | .00 | .24 | 00[00 47] | 1 0000 | 69 [24 80] | 1.0000 |
| | S_MT | 0.14 | 0.49 | .07 | -0.06 | 60 [19 76] | 0109* | 00 [00 .31] | 1.0000 |
| | S LFO | 0.12 | 0.30 | .52 | .50 | .13 [.00, .70] | .6998 | .42 [.00, .67] | .1644 |
| | S MFO | 0.13 | 0.40 | .61 | .52 | .11 [.00, .71] | .7265 | .48 [.00, .70] | .1338 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | S_SM | 0.12 | 0.34 | .60 | .14 | .56 [.02, .74] | .0420* | .00 [.00, .40] | 1.0000 |
| S_Cerebel 0.13 0.19 .70 2.4 .66 (17), .60) .013** .00 (.00, .39) (1.000) D_CF 0.18 0.37 .38 .34 .00 (.00, .53) 1.000 .33 (.00, .53) .2522 D_CP 0.25 0.41 .55 .21 .58 (.03, .77) .04 (.10, .53) .7656 D_PUC 0.34 0.47 .54 .50 .770 .56 (.17, .66) .358 (.10, .77) .24 (.10, .62) .4750 D_ACR 0.16 0.72 .76 .66 .45 (.10, .83) .0900 .28 (.10, .69) .3558 D_SCR 0.19 0.72 .64 .50 .59 (.10, .48) .00 (.10, .43) 1.0000 D_CGG 0.18 0.37 .68 .42 (.48) .00 (.10, .43) 1.0000 D_CGH 0.15 0.39 .57 .56 .04 (.0, .64) .8920 .52 (.10, .70) .0827 D_FSF 0.17 .648 .86 .61 (.10, .63) .92540 .9100, .53 (.1000 < | S_R | 0.13 | 0.35 | .39 | .22 | .09 [.00, .55] | .8457 | .23 [.00, .50] | .5911 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | S_Cerebel | 0.13 | 0.19 | .70 | .24 | .66 [.17, .80] | .0139* | .00 [.00, .39] | 1.0000 |
| D_SCP 0.21 0.37 4.43 3.33 3.77 100, 681 3.733 1.10(.00, 53] 7.7656 D_ALIC 0.22 0.52 5.51 5.4 0.0(00, 58] 1.0000 4.9(.00, 66] .9931 D_PIUC 0.34 0.47 5.4 5.0 1.9(.00, 23] 2.21(.00, 62] .21(.00, 62] .4750 D_ACR 0.16 0.72 .76 6.6 4.5(.0) .300900 .28(.00, 69) .3558 D_SCR 0.19 0.72 .64 .50 .59(.04, 84] .001(.00, 43] 1.0000 D_CGG 0.18 0.74 .81 42 .848, 10, 81] .001(.00, 43] 1.0000 D_CGG 0.18 0.37 .68 42 .481, 10, 81] .0223* .001(.00, 43] 1.0000 D_SF 0.17 .048 .86 .61 .481, 09, 88] .015* .41(.00, 57] .2929 D_SF 0.17 .048 .86 .61 .481, 09, 88] .015* <t< td=""><td>D_CST</td><td>0.18</td><td>0.37</td><td>.38</td><td>.34</td><td>.00 [.00, .53]</td><td>1.0000</td><td>.33 [.00, .53]</td><td>.2522</td></t<> | D_CST | 0.18 | 0.37 | .38 | .34 | .00 [.00, .53] | 1.0000 | .33 [.00, .53] | .2522 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | D_SCP | 0.21 | 0.37 | .43 | .33 | .37 [.00, .68] | .3733 | .10 [.00, .53] | .7656 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_CP | 0.25 | 0.41 | .55 | .21 | .58 [.03, .77] | .0411* | .00 [.00, .36] | .9931 |
| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$ | D_ALIC | 0.22 | 0.52 | .51 | .54 | .00 [.00, .58] | 1.0000 | .49 [.00, .66] | .0605 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_PLIC | 0.34 | 0.47 | .54 | .50 | .19 [.00, .72] | .5649 | .38 [.00, .67] | .2213 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_PTR | 0.25 | 0.92 | .79 | .51 | .56 [.07, .86] | .0263* | .21 [.00, .62] | .4750 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_ACR | 0.16 | 0.72 | .76 | .66 | .45 [.00, .83] | .0900 | .28 [.00, .69] | .3558 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_SCR | 0.19 | 0.72 | .64 | .50 | .59 [.04, .84] | .0371* | .14 [.00, .57] | .6107 |
| $ \begin{array}{c c GC \\ D_{C}GH \\ D_$ | D_PCR | 0.18 | 0.74 | .81 | .42 | .82 [.36, .90] | .0008* | .00 [.00, .43] | 1.0000 |
| $ \begin{array}{c} D_{CGH} & 0.15 & 0.37 & .37 & .36 & .04 [.00, .66] & .8920 & .32 [.00, .70] & .0622 \\ D_{SLF} & 0.17 & 0.68 & .36 & .61 & .48 [.09, .88] & .0157^* & .34 [.00, .69] & .2172 \\ D_{SLF} & 0.17 & 0.68 & .36 & .61 & .48 [.09, .88] & .0157^* & .34 [.00, .69] & .2172 \\ D_{SFO} & 0.20 & 0.54 & .49 & .40 & .54 [.00, .75] & .1699 & .03 [.00, .53] & .9256 \\ D_{SS} & 0.22 & 0.65 & .71 & .20 & .70 [.32, .84] & .0039^* & .00 [.00, .81] & .1000 \\ D_{FC} & 0.19 & 0.33 &36 & .42 & .03 [.00, .63] & .9427 & .37 [.00, .58] & .2584 \\ D_{UF} & 0.20 & 0.47 & .63 & .01 & .62 [.23, .80] & .0099^* & .00 [.00, .21] & 1.0000 \\ D_{FC} & 0.20 & 0.47 & .63 & .01 & .62 [.23, .80] & .0099^* & .00 [.00, .53] & .2584 \\ D_{UF} & 0.20 & 0.47 & .63 & .01 & .62 [.23, .80] & .0099^* & .00 [.00, .53] & .10000 \\ D_{GCC} & 0.29 & 1.01 & .79 & .51 & .72 [.19, .87] & .0073^* & .06 [.00, .53] & 1.0000 \\ D_{GCC} & 0.29 & 1.01 & .79 & .51 & .72 [.19, .87] & .0073^* & .06 [.00, .53] & 1.0000 \\ D_{SCC} & 0.22 & 1.01 & .79 & .51 & .72 [.19, .87] & .0073^* & .06 [.00, .37] & 1.0000 \\ D_{SCC} & 0.27 & 0.68 & .79 & .45 & .68 [.15, .86] & .0124^* & .08 [.00, .55] & .7846 \\ D_{Tap} & 0.22 & 1.51 & .82 & .46 & .00 [.00, .43] & 1.0000 & .46 [.00, .63] & .1064 \\ D_{Tap} & 0.22 & 1.51 & .82 & .46 & .60 [.14, .88] & .0105^* & .20 [.00, .61] & .4993 \\ S_{Cing} & 0.14 & 0.06 & .67 & .15 & .60 [.00, .74] & .3824 & .28 [.00, .55] & .37846 \\ S_{Cing} & 0.14 & 0.06 & .47 & .15 & .60 [.05, .76] & .0334^* & .00 [.00, .43] & 1.0000 \\ S_{F} & 0.13 & 0.34 & .76 & .67 & .30 [.00, .81] & .1796 & .46 [.00, .77] & .0602 \\ S_{Cing} & 0.14 & 0.06 & .47 & .15 & .60 [.05, .76] & .0334^* & .00 [.00, .43] & .10000 \\ S_{F} & 0.13 & 0.34 & .76 & .64 & .69 [.25, .85] & .0304^* & .21 [.00, .63] & .4889 \\ S_{MF} & 0.12 & 0.38 & .76 & .24 & .69 [.25, .85] & .0304^* & .21 [.00, .63] & .4889 \\ S_{F} & 0.13 & 0.46 & .79 & .47 & .55 [.05, .85] & .0304^* & .21 [.00, .63] & .4889 \\ S_{F} & 0.13 & 0.46 & .79 & .47 & .55 [.05, .85] & .0304^* & .21 [.00, .63] & .4889 \\ S_{F} & 0.13 & 0.46 & .79 &$ | D_CGC | 0.18 | 0.37 | .68 | .42 | .68 [.10, .81] | .0235* | .00 [.00, .46] | 1.0000 |
| D_rS1 0.28 0.43 .39 .36 .00 0.00 .370 .36 0.00 .370 .36 0.00 .370 .36 0.00 .370 .34 0.00 .69 2772 D_FFO 0.19 0.93 .50 0.5 .39 10.0 .22 .06 .31 .00 0.00 .43 1.0000 D_FC 0.19 0.33 .36 .42 .03 100, .63 .9427 .37 100, .58 .258 D_FC 0.20 0.45 .34 .48 .00 100, .50 1.0000 .42 .00, .60 .0723 D_MCP 0.20 0.45 .34 .48 .00 .00, .50 1.0000 .42 .00, .60 .0723 D_MCP 0.20 0.45 .34 .48 .00 .00 .00 .00 .00 .03 1.0000 D_SCC 0.23 .833 .75 .24 .69 .24, .82 | | 0.15 | 0.39 | .57 | .50 | .04 [.00, .68] | .8920 | .52[.00, .70] | .0827 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | | 0.20 | 0.43 | .37 | .30 | .00 [.00, .60] | .7707 | 34[00, 57] | .2727 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | | 0.17 | 0.00 | .00 | .01 | 39 [00 42] | 1763 | .34 [.00, .07] | 1 0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | | 0.17 | 0.73 | .30 | .03 | 54 [00, .02] | 1699 | 03[00, 53] | 9256 |
| D_EC 0.19 0.33 3.6 .42 0.3 0.06,33 9427 .37 0.0,58 .2584 D_UF 0.20 0.47 .63 .01 .622,38,00 .0090* .00[.00,.21] 1.0000 D_PCT 0.20 0.56 .34 .48 .00[.00,.50] 1.0000 .42[.00,.60] .0020* .00[.00,.53] 1.0000 D_MCP 0.20 0.49 .66 .35 .66[.00,.80] .0480* .00[.00,.53] 1.0000 D_GCC 0.29 1.01 .79 .51 .72[.19,.87] .0073* .06[.00,.52] .8504 D_BCC 0.23 0.83 .75 .24 .69[.24,.82] .0065* .00[.00,.55] .7846 D_RUIC 0.27 0.55 .41 .62 .00[.00,.74] .3824 .28[.00,.65] .3497 D_MIDrain 0.18 0.24 .57 .48 .29[.00,.74] .3824 .28[.00,.65] .3497 S_SP 0.13 0.34 | D SS | 0.22 | 0.65 | .17 | 20 | 70[32 84] | .00.39* | 00 [00 . 28] | 1,0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_SS D_EC | 0.19 | 0.33 | .36 | .42 | .03 [.00, .63] | .9427 | .37 [.00, .58] | .2584 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D UF | 0.20 | 0.47 | .63 | .01 | .62 [.23, .80] | .0090* | .00 [.00, .21] | 1.0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | DPCT | 0.20 | 0.56 | .34 | .48 | .00 [.00, .50] | 1.0000 | .42 [.00, .60] | .0723 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_MCP | 0.20 | 0.49 | .66 | .35 | .66 [.00, .80] | .0480* | .00 [.00, .53] | 1.0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_GCC | 0.29 | 1.01 | .79 | .51 | .72 [.19, .87] | .0073* | .06 [.00, .52] | .8504 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_BCC | 0.23 | 0.83 | .75 | .24 | .69 [.24, .82] | .0065* | .00 [.00, .37] | 1.0000 |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_SCC | 0.27 | 0.68 | .79 | .45 | .68 [.15, .86] | .0124* | .08 [.00, .55] | .7846 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_RLIC | 0.27 | 0.55 | .41 | .62 | .00 [.00, .63] | 1.0000 | .46 [.00, .63] | .1064 |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_Tap | 0.22 | 1.51 | .82 | .46 | .60 [.14, .88] | .0105* | .20 [.00, .61] | .4993 |
| ROI (Right)FAVariance (10 ⁻³)rMZrDZa² [95% CI]p of a²c² [95% CI]p of c²S_SP0.130.34.76.67.30 [.00, .81].1796.46 [.00, .77].0802S_Cing0.140.06.67.15.60 [.05, .76].0342*.00 [.00, .43]1.0000S_SF0.150.52.86.60.72 [.26, .90].0020*.11 [.00, .53].6988S_MF0.120.38.76.24.69 [.25, .82].0064*.00 [.00, .37]1.0000S_IFC0.150.35.68.52.53 [.04, .86].0339*.24 [.00, .63].4887S_PCC0.140.28.59.36.58 [.00, .79].0861.06 [.00, .56].8499S_A0.120.19.36.13.33 [.00, .57].3261.00 [.00, .42]1.0000S_PCu0.110.27.32.08.28 [.00, .55].3766.00 [.00, .51].9088S_L0.110.13.52.34.56 [.00, .76].1360.02 [.00, .51].9088S_SO0.140.24.55.22.47 [.00, .67].2186.00 [.00, .51].9588S_MO0.140.24.55.22.47 [.00, .67].2186.00 [.00, .51].9588S_NO0.140.24.55.22.47 [.00, .67].2186.00 [.00, .51].9588S_MO0.140.24.55.22.47 [.00, .67].2186.00 [. | D_Midbrain | 0.18 | 0.24 | .57 | .48 | .29 [.00, .74] | .3824 | .28 [.00, .65] | .3497 |
| S_SP 0.13 0.34 .76 .67 .30 [.00, .81] .1796 .46 [.00, .77] .0802 S_Cing 0.14 0.06 .67 .15 .60 [.05, .76] .0342* .00 [.00, .43] 1.0000 S_SF 0.15 0.52 .86 .60 .72 [.26, .90] .0020* .11 [.00, .53] .6988 S_MF 0.12 0.38 .76 .24 .69 [.25, .82] .0064* .00 [.00, .37] 1.0000 S_IF 0.13 0.46 .79 .47 .55 [.05, .85] .0304* .21 [.00, .63] .4887 S_PrC 0.15 0.35 .68 .52 .53 [.04, .86] .0339* .24 [.00, .63] .3781 S_PoC 0.14 0.28 .59 .36 .58 [.00, .77] .0861 .06 [.00, .42] 1.0000 S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .42] 1.0000 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9889 S_L 0.11 | ROI (Right) | FA | Variance (10 ⁻³) | rMZ | rDZ | a ² [95% CI] | p of a ² | c² [95% Cl] | p of c ² |
| S_Cing 0.14 0.06 .67 .15 .60 [.05, .76] .0342* .00 [.00, .43] 1.0000 S_SF 0.15 0.52 .86 .60 .72 [.26, .90] .0020* .11 [.00, .53] .6988 S_MF 0.12 0.38 .76 .24 .69 [.25, .82] .0064* .00 [.00, .37] 1.0000 S_IF 0.13 0.46 .79 .47 .55 [.05, .85] .0304* .21 [.00, .63] .3781 S_PoC 0.14 0.28 .59 .36 .58 [.00, .79] .0861 .06 [.00, .56] .8499 S_A 0.12 0.19 .36 .13 .33 [.00, .57] .3261 .00 [.00, .42] 1.0000 S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .39] 1.0000 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9988 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9589 S_GO 0.14 | S_SP | 0.13 | 0.34 | .76 | .67 | .30 [.00, .81] | .1796 | .46 [.00, .77] | .0802 |
| S_SF 0.15 0.52 .86 .60 .72 [.26, .90] .0020* .11 [.00, .53] .6988 S_MF 0.12 0.38 .76 .24 .69 [.25, .82] .0064* .00 [.00, .37] 1.0000 S_PrC 0.13 0.46 .79 .47 .55 [.05, .85] .0304* .21 [.00, .63] .4887 S_PrC 0.15 0.35 .68 .52 .53 [.04, .86] .0339* .24 [.00, .63] .3781 S_PoC 0.14 0.28 .59 .36 .58 [.00, .79] .0861 .06 [.00, .56] .8499 S_A 0.12 0.19 .36 .13 .33 [.00, .57] .3261 .00 [.00, .42] 1.0000 S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .51] .9088 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9588 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .2186 .00 [.00, .53] .10000 S_Fu 0.12 | S_Cing | 0.14 | 0.06 | .67 | .15 | .60 [.05, .76] | .0342* | .00 [.00, .43] | 1.0000 |
| S_MF 0.12 0.38 .76 .24 .69 [.25, .82] .0064* .00 [.00, .37] 1.0000 S_IF 0.13 0.46 .79 .47 .55 [.05, .85] .0304* .21 [.00, .63] .4887 S_PrC 0.15 0.35 .68 .52 .53 [.04, .86] .0339* .24 [.00, .63] .3781 S_PoC 0.14 0.28 .59 .36 .58 [.00, .79] .0861 .06 [.00, .56] .8499 S_A 0.12 0.19 .36 .13 .33 [.00, .57] .3261 .00 [.00, .42] 1.0000 S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .51] .9088 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9088 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9589 S_O 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_IO 0.14 <t< td=""><td>S_SF</td><td>0.15</td><td>0.52</td><td>.86</td><td>.60</td><td>.72 [.26, .90]</td><td>.0020*</td><td>.11 [.00, .53]</td><td>.6988</td></t<> | S_SF | 0.15 | 0.52 | .86 | .60 | .72 [.26, .90] | .0020* | .11 [.00, .53] | .6988 |
| S_IF 0.13 0.46 .79 .47 .55 [.05, .85] .0304* .21 [.00, .63] .4887 S_PrC 0.15 0.35 .68 .52 .53 [.04, .86] .0339* .24 [.00, .63] .3781 S_PoC 0.14 0.28 .59 .36 .58 [.00, .79] .0861 .06 [.00, .56] .8499 S_A 0.12 0.19 .36 .13 .33 [.00, .57] .3261 .00 [.00, .42] 1.0000 S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .51] .9088 S_Lu 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .53] .9501 S_Fu 0.12 0.19 .64 .64 .36 [.00, .78] .2251 .29 [.00, .67] .3268 S_SO 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_MO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .51] .0000 S_MO 0.14 < | S_MF | 0.12 | 0.38 | .76 | .24 | .69 [.25, .82] | .0064* | .00 [.00, .37] | 1.0000 |
| S_PrC 0.15 0.35 .68 .52 .53 [.04, .86] .0339* .24 [.00, .63] .3781 S_PoC 0.14 0.28 .59 .36 .58 [.00, .79] .0861 .06 [.00, .56] .8499 S_A 0.12 0.19 .36 .13 .33 [.00, .57] .3261 .00 [.00, .42] 1.0000 S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .39] 1.0000 S_Cu 0.12 0.24 .43 .17 .32 [.00, .59] .4966 .05 [.00, .51] .9088 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .53] .9501 S_Fu 0.12 0.19 .64 .64 .36 [.00, .78] .2251 .29 [.00, .67] .3268 S_SO 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_IO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .51] .0000 S_ST 0.17 <t< td=""><td>S_IF</td><td>0.13</td><td>0.46</td><td>.79</td><td>.47</td><td>.55 [.05, .85]</td><td>.0304*</td><td>.21 [.00, .63]</td><td>.4887</td></t<> | S_IF | 0.13 | 0.46 | .79 | .47 | .55 [.05, .85] | .0304* | .21 [.00, .63] | .4887 |
| S_PoC 0.14 0.28 .59 .36 .58 [.00, .79] .0861 .06 [.00, .56] .8499 S_A 0.12 0.19 .36 .13 .33 [.00, .57] .3261 .00 [.00, .42] 1.0000 S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .42] 1.0000 S_Cu 0.12 0.24 .43 .17 .32 [.00, .59] .4966 .05 [.00, .51] .9088 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9088 S_Fu 0.12 0.19 .64 .64 .36 [.00, .78] .2251 .29 [.00, .67] .3268 S_SO 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_IO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .51] .0500 S_MO 0.14 0.24 .57 .46 .42 [.00, .75] .2301 .16 [.00, .61] .6075 S_IT 0.17 | S_PrC | 0.15 | 0.35 | .68 | .52 | .53 [.04, .86] | .0339* | .24 [.00, .63] | .3781 |
| S_A 0.12 0.19 .36 .13 .33 [.00, .57] .3261 .00 [.00, .42] 1.0000 S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .39] 1.0000 S_Cu 0.12 0.24 .43 .17 .32 [.00, .59] .4966 .05 [.00, .51] .9088 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9088 S_Fu 0.12 0.19 .64 .64 .36 [.00, .78] .2251 .29 [.00, .67] .3268 S_SO 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_IO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .53] 1.0000 S_MO 0.14 0.24 .57 .46 .42 [.00, .75] .2301 .16 [.00, .61] .6075 S_ST 0.17 0.28 .45 .57 .00 [.00, .65] 1.0000 .55 [.00, .70] .0603 S_ITT 0.14 <t< td=""><td>S_PoC</td><td>0.14</td><td>0.28</td><td>.59</td><td>.36</td><td>.58 [.00, .79]</td><td>.0861</td><td>.06 [.00, .56]</td><td>.8499</td></t<> | S_PoC | 0.14 | 0.28 | .59 | .36 | .58 [.00, .79] | .0861 | .06 [.00, .56] | .8499 |
| S_PrCu 0.11 0.27 .32 .08 .28 [.00, .55] .3766 .00 [.00, .39] 1.0000 S_Cu 0.12 0.24 .43 .17 .32 [.00, .59] .4966 .05 [.00, .51] .9088 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .51] .9088 S_Fu 0.12 0.19 .64 .64 .36 [.00, .76] .2251 .29 [.00, .67] .3268 S_SO 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_IO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .53] 1.0000 S_MO 0.14 0.24 .57 .46 .42 [.00, .75] .2301 .16 [.00, .61] .6075 S_ST 0.17 0.28 .45 .57 .00 [.00, .65] 1.0000 .55 [.00, .70] .0603 S_IT 0.14 0.20 .56 .43 .23 [.00, .72] .4923 .33 [.00, .66] .3141 S_MT 0.15 <td< td=""><td>S_A</td><td>0.12</td><td>0.19</td><td>.36</td><td>.13</td><td>.33 [.00, .57]</td><td>.3261</td><td>.00 [.00, .42]</td><td>1.0000</td></td<> | S_A | 0.12 | 0.19 | .36 | .13 | .33 [.00, .57] | .3261 | .00 [.00, .42] | 1.0000 |
| S_Cu 0.12 0.24 .43 .17 .32 [.00, .59] .4966 .05 [.00, .51] .9088 S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .53] .9501 S_Fu 0.12 0.19 .64 .64 .36 [.00, .78] .2251 .29 [.00, .67] .3268 S_SO 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_IO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .53] 1.0000 S_MO 0.14 0.24 .57 .46 .42 [.00, .75] .2301 .16 [.00, .61] .6075 S_ST 0.17 0.28 .45 .57 .00 [.00, .65] 1.0000 .55 [.00, .70] .0603 S_ITT 0.14 0.20 .56 .43 .23 [.00, .72] .4923 .33 [.00, .66] .3141 S_MT 0.15 0.41 .66 .42 .51 [.00, .79] .1172 .14 [.00, .62] .6692 S_LFO 0.12 | S_PrCu | 0.11 | 0.27 | .32 | .08 | .28 [.00, .55] | .3766 | .00[.00, .39] | 1.0000 |
| S_L 0.11 0.13 .52 .34 .56 [.00, .76] .1360 .02 [.00, .53] .9501 S_Fu 0.12 0.19 .64 .64 .36 [.00, .78] .2251 .29 [.00, .67] .3268 S_SO 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_IO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .53] 1.0000 S_MO 0.14 0.24 .57 .46 .42 [.00, .75] .2301 .16 [.00, .61] .6075 S_ST 0.17 0.28 .45 .57 .00 [.00, .65] 1.0000 .55 [.00, .70] .0603 S_ITT 0.14 0.20 .56 .43 .23 [.00, .72] .4923 .33 [.00, .66] .3141 S_MT 0.15 0.41 .66 .42 .51 [.00, .79] .1172 .14 [.00, .62] .6692 S_LFO 0.12 0.32 .60 .43 .32 [.00, .74] .3436 .27 [.00, .65] .3929 S_MFO 0.13 <td< td=""><td>S_Cu</td><td>0.12</td><td>0.24</td><td>.43</td><td>.17</td><td>.32[.00, .59]</td><td>.4966</td><td>.05[.00, .51]</td><td>.9088</td></td<> | S_Cu | 0.12 | 0.24 | .43 | .17 | .32[.00, .59] | .4966 | .05[.00, .51] | .9088 |
| S_ru 0.12 0.17 .04 .04 .36 [.00, .78] .2251 .29 [.00, .67] .3268 S_SO 0.14 0.30 .61 .47 .67 [.03, .82] .0408* .02 [.00, .51] .9589 S_IO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .53] 1.0000 S_MO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .53] 1.0000 S_MO 0.14 0.24 .57 .46 .42 [.00, .75] .2301 .16 [.00, .61] .6075 S_ST 0.17 0.28 .45 .57 .00 [.00, .65] 1.0000 .55 [.00, .70] .0603 S_IT 0.14 0.20 .56 .43 .23 [.00, .72] .4923 .33 [.00, .66] .3141 S_MT 0.15 0.41 .66 .42 .51 [.00, .79] .1172 .14 [.00, .62] .6692 S_LFO 0.12 0.32 .60 .43 .32 [.00, .74] | 5_L 5_E | 0.11 | 0.13 | .52 | .34 | .56 [.00, ./6] | .1360 | .02[.00, .53] | .9501 |
| S_SC 0.14 0.30 .61 .47 .67 [.03, 82] .0408 .02 [.00, .51] .9589 S_IO 0.14 0.24 .55 .22 .47 [.00, .67] .2186 .00 [.00, .53] 1.0000 S_MO 0.14 0.24 .57 .46 .42 [.00, .75] .2301 .16 [.00, .61] .6075 S_ST 0.17 0.28 .45 .57 .00 [.00, .65] 1.0000 .55 [.00, .70] .0603 S_IT 0.14 0.20 .56 .43 .23 [.00, .72] .4923 .33 [.00, .66] .3141 S_MT 0.15 0.41 .66 .42 .51 [.00, .79] .1172 .14 [.00, .62] .6692 S_LFO 0.12 0.32 .60 .43 .32 [.00, .74] .3436 .27 [.00, .65] .3929 S_MFO 0.13 0.27 .72 .30 .66 [.07, .80] .0306* .00 [.00, .49] 1.0000 | s_ru | 0.12 | 0.19 | .04 | .04 17 | .30 [.UU, ./8] | .2251 | .27[.00, .07] | .3208 |
| S_IO 0.14 0.24 .55 .22 .44 [.00, .67] .2186 .00 [.00, .53] 1.0000 S_MO 0.14 0.24 .57 .46 .42 [.00, .75] .2301 .16 [.00, .61] .6075 S_ST 0.17 0.28 .45 .57 .00 [.00, .65] 1.0000 .55 [.00, .70] .0603 S_IT 0.14 0.20 .56 .43 .23 [.00, .72] .4923 .33 [.00, .66] .3141 S_MT 0.15 0.41 .66 .42 .51 [.00, .79] .1172 .14 [.00, .62] .6692 S_LFO 0.12 0.32 .60 .43 .32 [.00, .74] .3436 .27 [.00, .65] .3929 S_MFO 0.13 0.27 .72 .30 .66 [.07, .80] .0306* .00 [.00, .49] 1.0000 | 3_3U | 0.14 | 0.30 | .01 | .4/ | .07 [.U3, .82] | .0408 | .02 [.00, .51] | .7587 |
| S_INC 0.14 0.24 .37 .40 .42 [.00, 73] .2301 .16 [.00, .61] .6073 S_ST 0.17 0.28 .45 .57 .00 [.00, .65] 1.0000 .55 [.00, .70] .6603 S_IT 0.14 0.20 .56 .43 .23 [.00, .72] .4923 .33 [.00, .66] .3141 S_MT 0.15 0.41 .66 .42 .51 [.00, .79] .1172 .14 [.00, .62] .6692 S_LFO 0.12 0.32 .60 .43 .32 [.00, .74] .3436 .27 [.00, .65] .3929 S_MFO 0.13 0.27 .72 .30 .66 [.07, .80] .0306* .00 [.00, .49] 1.0000 | s_iu | 0.14 | 0.24 | .55 | .22 | .47 [.00, .67] | .2180 2201 | .00[.00, .53] | 1.0000 |
| S_IT 0.14 0.20 .56 .43 .23 [.00, .72] .4923 .33 [.00, .66] .3141 S_MT 0.15 0.41 .66 .42 .51 [.00, .79] .1172 .14 [.00, .62] .6692 S_LFO 0.12 0.32 .60 .43 .32 [.00, .74] .3436 .27 [.00, .65] .3929 S_MFO 0.13 0.27 .72 .30 .66 [.07, .80] .0306* .00 [.00, .49] 1.0000 | S ST | 0.14 | 0.24 | .57 | .+0 | 00[00 45] | 1 0000 | 55 [00 70] | .007.3 |
| S_MT 0.15 0.41 .66 .42 .51 [.00, .72] .172 .14 [.00, .62] .6692 S_LFO 0.12 0.32 .60 .43 .32 [.00, .74] .3436 .27 [.00, .65] .3929 S_MFO 0.13 0.27 .72 .30 .66 [.07, .80] .0306* .00 [.00, .49] 1.0000 | S IT | 0.17 | 0.20 | .43 | .37 | 23 [00 72] | 4923 | .33[00 66] | 3141 |
| S_LFO 0.12 0.32 .60 .43 .32 [.00, .74] .14 [.00, .02] .605 .3929 S_MFO 0.13 0.27 .72 .30 .66 [.07, .80] .0306* .00 [.00, .49] 1.0000 | S MT | 0.15 | 0.41 | 66 | .42 | .51 [00 79] | .1172 | .14[00 62] | 6692 |
| S_MFO 0.13 0.27 .72 .30 .66 [.07, .80] .0306* .00 [.00, .49] 1.0000 | S LFO | 0.12 | 0.32 | .60 | .43 | .32 [.0074] | .3436 | .27 [.0065] | .3929 |
| | S_MFO | 0.13 | 0.27 | .72 | .30 | .66 [.07, .80] | .0306* | .00 [.00, .49] | 1.0000 |

| TABLE 4 | (a) |
|----------|-----|
| Continue | |

| ROI (Left) | FA | Variance (10 ⁻³) | rMZ | rDZ | a ² [95% CI] | p of a ² | c ² [95% CI] | p of c ² |
|------------|------|------------------------------|-----|-----|-------------------------|---------------------|-------------------------|---------------------|
| S_SM | 0.13 | 0.30 | .49 | .44 | .19 [.00, .69] | .6058 | .30 [.00, .61] | .3503 |
| S_R | 0.13 | 0.15 | .33 | .71 | .00 [.00, .36] | 1.0000 | .50 [.16, .67] | .0127* |
| S_Cerebel | 0.12 | 0.18 | .66 | .37 | .70 [.15, .83] | .0176* | .00 [.00, .41] | 1.0000 |
| D_CST | 0.21 | 0.67 | .32 | .28 | .21 [.00, .59] | .6496 | .12 [.00, .48] | .7313 |
| D_SCP | 0.23 | 0.39 | .40 | .41 | .12 [.00, .67] | .7549 | .32 [.00, .59] | .3034 |
| D_CP | 0.26 | 0.46 | .19 | .04 | .21 [.00, .50] | .4849 | .00 [.00, .34] | 1.0000 |
| D_ALIC | 0.22 | 0.49 | .35 | .54 | .00 [.00, .55] | 1.0000 | .47 [.00, .64] | .0561 |
| D_PLIC | 0.38 | 0.57 | .39 | .50 | .00 [.00, .63] | 1.0000 | .50 [.00, .66] | .0794 |
| D_PTR | 0.22 | 0.74 | .78 | .56 | .55 [.08, .87] | .0220* | .23 [.00, .62] | .3993 |
| D_ACR | 0.16 | 0.98 | .78 | .75 | .34 [.00, .83] | .1195 | .43 [.00, .76] | .0907 |
| D_SCR | 0.19 | 0.52 | .71 | .44 | .73 [.19, .84] | .0116* | .00 [.00, .44] | 1.0000 |
| D_PCR | 0.17 | 0.90 | .69 | .42 | .63 [.02, .83] | .0414* | .07 [.00, .54] | .7943 |
| D_CGC | 0.17 | 0.29 | .68 | .30 | .71 [.26, .83] | .0071* | .00 [.00, .34] | 1.0000 |
| D_CGH | 0.17 | 0.31 | .20 | .24 | .05 [.00, .56] | .9114 | .22 [.00, .47] | .5347 |
| D_FxST | 0.23 | 0.35 | .52 | .03 | .47 [.00, .69] | .0623 | .00 [.00, .36] | 1.0000 |
| D_SLF | 0.17 | 0.64 | .70 | .61 | .33 [.00, .81] | .1935 | .39 [.00, .73] | .1536 |
| D_SFO | 0.13 | 0.39 | .64 | .26 | .64 [.03, .79] | .0391* | .00 [.00, .47] | 1.0000 |
| D_IFO | 0.21 | 0.42 | .70 | .31 | .74 [.38, .86] | .0018* | .00 [.00, .27] | 1.0000 |
| D_SS | 0.21 | 0.56 | .81 | .41 | .76 [.25, .86] | .0056* | .00 [.00, .43] | 1.0000 |
| D_EC | 0.20 | 0.39 | .58 | .61 | .14 [.00, .73] | .6380 | .48 [.00, .72] | .1062 |
| D_UF | 0.17 | 0.24 | .57 | .23 | .58 [.00, .75] | .0535 | .00 [.00, .44] | 1.0000 |
| D_PCT | 0.17 | 0.59 | .46 | .44 | .21 [.00, .71] | .5761 | .31 [.00, .62] | .2992 |
| D_MCP | 0.21 | 0.59 | .78 | .23 | .79 [.52, .89] | .0002** | .00 [.00, .22] | 1.0000 |
| D_GCC | 0.29 | 0.76 | .73 | .58 | .52 [.05, .86] | .0321* | .25 [.00, .63] | .3288 |
| D_BCC | 0.27 | 1.04 | .74 | .39 | .74 [.30, .85] | .0035* | .00 [.00, .37] | 1.0000 |
| D_SCC | 0.30 | 0.67 | .83 | .42 | .73 [.18, .87] | .0073* | .05 [.00, .55] | .8821 |
| D_RLIC | 0.30 | 0.58 | .63 | .46 | .34 [.00, .75] | .3234 | .25 [.00, .63] | .4010 |
| D_Tap | 0.18 | 1.71 | .78 | .43 | .79 [.30, .88] | .0024* | .00 [.00, .43] | 1.0000 |
| D Midbrain | 0.17 | 0.23 | .51 | .38 | .22 [.00, .69] | .5572 | .28 [.00, .61] | .3862 |



FIGURE 3

Correlation plots between mean diffusion parameters (RD, AD and FA) and their heritability values over 98 white matter ROIs.

projection fibers with known earlier maturation after birth (Kinney et al., 1988). All these regions show low genetic effect on FA, and most of these regions show low genetic effect on RD (except for right RLIC and right superior cerebral peduncle). ROIs with high FA and high RD include bilateral body corpus callosum, right posterior thalamic radiation, and left tapetum. All these regions have high FA heritability, and all but left tapetum has high RD heritability. ROIs with low FA and low RD include bilateral cerebellum with high RD and FA heritability. ROIs with low FA and low RD include bilateral cerebellum with high RD and FA heritability. ROIs with low FA and high RD include a few superficial WM regions in bilateral lingual gyrus, bilateral middle frontal orbital gyrus, and right lateral frontal orbital gyrus.

Discussion

Genetic Effects Related to Overall White Matter Microstructure

This is the first twin study to assess the genetic and environmental contributions to WM microstructure measured by DTI in neonates. The heritability estimates for DTI measures averaged over the whole brain WM (FA = .60, RD = .53, and AD = .57) were higher than those reported for an adult population (FA = .52, RD = .37). Further, no significant genetic effects were detected for AD in the adult study (Kochunov et al., 2010). WM development is a complex process that continues into adulthood. During the long maturation process, different environmental

TABLE 4 (b)

| Genetic and Common | Environmental (| Contribution | Estimates of | Average F | RD Over S | Superficial a | and Deep ' | White Matter | Regions of |
|--------------------|-----------------|--------------|--------------|-----------|-----------|---------------|------------|--------------|------------|
| nterest | | | | | | | | | |

| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .1737 .6538 .2203 .0810 .1047 |
|--|--|
| S_Cring 1.20 0.57 .80 .58 .69 (23, 89) 0.001" .12 (00, 53) .45 S_FF 1.28 1.04 .79 .68 .34 (00, .83) 10.00 .45 (00, .76) .08 S_FC 1.16 0.99 .76 .73 .57 (10, .84) .0991 .45 (00, .73) .01 S_PCC 1.16 0.99 .76 .73 .60 .43 (00, .85) .0651 .34 (00, .74) .02 S_PCC 1.16 0.99 .76 .73 .40 (14, .81) .0035' .44 (00, .74) .42 .50 .51 (10, .72) .55 .51 .51 (11, .34 (10, .76) .3064' .28 (00, .66) .35 .55 .51 (11, .34 (10, .76) .3064' .28 (00, .61) .35 (11, .34 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) .44 (10, .76) | .6538 .2203 .0810 .1047 |
| S.SF 1.30 1.57 .91 .78 62 30, 49 .0001** .30, 100, .61 .22 S.JFF 1.24 0.99 .76 .76 .37 100, .83 .1060 .45 100, .76 .78 S.PC 1.15 0.69 .73 .60 .43 100, .85 .90651 .34 100, .76 .78 S.PC 1.15 0.69 .73 .60 .43 100, .85 .94 .44 .0032* .44 .0033* .14 .40 .74 .74 .75 .76 .76 .376 .364 .41 .0032* .44 .40 .44 .41 .42 .41 .40 .44 .43 .40 .43 .44 .44 .44 .42 .40 .41 .41 .44 .40 .43 .40 .41 .41 .42 .40 .43 .40 .43 .40 .43 .41 .40 .41 .41 .41 .41 .41 .41 .41 .41 .41 .41 .41 .41 <td>.2203 .0810 .1047</td> | .2203 .0810 .1047 |
| S,MF 1.28 1.04 .79 .68 .34 (00,.83) 1.060 .45 (1,00,.76) .086 S,PC 1.16 0.90 .87 .76 .50 (21,.92) .0008* .39 (100,.67) .085 S,PC 1.15 0.69 .73 .60 .43 (100,.85) .0651 .34 (100,.73) .10 S,PC 1.26 0.91 .81 .53 .68 (23,.99) .0032* .49 (108,.74) .02 S,PCu 1.20 0.77 .61 .44 .33 (100,.76) .3084 .28 (100,.66) .35 S,L 1.30 1.21 .62 .06 .64 (14,.72) .0369* .00 (10,.04) .100 S,SO 1.23 0.85 .67 .48 .58 (20,.82) .0011** .00 (100,.29) .100 S,MO 1.22 .84 .45 .86 (43,.92) .0001** .00 (100,.41) .100 S,MT 1.23 .85 .66 .65 .19 (10,.76) .4459 .36 (10,.71) <td>.0810</td> | .0810 |
| S, F 1.24 0.99 .76 .76 .37 100, .84 .0991 .40 100, .73 .10 S, PrC 1.15 0.69 .73 .60 .43 100, .85 .0651 .34 100, .70 .17 S, A 1.37 1.22 .88 .73 .40 1.4, 81 .0035' .44 100, .70 .41 S, PrCu 1.26 0.91 .81 .53 .48 .1033' .14 .100 .58 S, Lu 1.30 1.21 .62 .06 .54 .104, .72 .3084'''''''''''''''''''''''''''''''''''' | .1047 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | ()()'' * |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .0834 |
| S.A 1.3/ 1.22 .88 .73 .40 .14.81 .0032' .44 .108, 74 .100, 53 S.PrCu 1.20 0.77 .61 .44 .33 .00, 76 .3084 .28 .00, 63 .358 S.L 1.30 1.21 .62 .06 .54 .14, 72 .3084 .28 .00, 40 1.00 S.Fu 1.27 0.88 .59 .59 .37 .00, 83 .0479''' .1611 .34 .00, 70 .84 S.DO 1.22 1.20 .81 .42 .84 .53 .91 .0001''' .00 .00, 76 .00 .00 .91 .00 .91 .00 .91 .00 .91 .00 .91 .00 .91 .00 .91 .00 .91 .00 .91 .00 .92 .00 .91 .00 .91 .00 .91 .00 .91 .91 .91 .91 .91 .91 .91 .91 .91 .91 .91 .93 .93 .91 <td< td=""><td>.1741</td></td<> | .1741 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .0232* |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .5837 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .3574 |
| S_SO 1.22 0.00 1.27 1.37 1.37 1.01 <th< td=""><td>1820</td></th<> | 1820 |
| SIO 1.27 1.20 1.81 1.42 1.84 [53, 91] 0.00 [00, 29] 1.00 S.MO 1.28 1.05 .84 .45 .86 [43, 92] 0.00 [00, .41] 1.00 S.T 1.21 0.85 .66 .65 .19 [00, .76] .4459 .50 [00, .76] .475 S.T 1.27 0.88 .65 .62 .33 [00, .80] .2243 .36 [00, .71] .17 S.MT 1.31 1.38 .80 .53 .66 [19, .80] .0066* .11 [00, .50] .48 S_MFO 1.30 1.37 .83 .61 .70 [28, 91] .0013* .15 [00, .53] .57 S_Cerebel 1.04 .60 .71 .37 .73 [20, .86] .0362* .43 [00, .73] .07 S_Cerebel 1.04 .60 .35 .71 .49 .59 [08, .86] .0328* .17 [00, .66] .50 D_CP 1.08 .031 .58 .36 .52 [00, .76] .1441 .08 [00, | 6051 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | 1 0000 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | 1.0000 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | .0725 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .1735 |
| S_LFO 1.27 1.02 .78 .59 .57 [07, 86] .0263* .19 [00, 60] .48 S_MFO 1.30 1.37 .83 .61 .70 [28, 91] .0013* .15 [.00, 59] .54 S_SM 1.28 1.17 .82 .59 .60 [.19, 90] .0050* .23 [.00, 59] .34 S_Cerebel 1.04 0.60 .71 .37 .74 [.20, 85] .0094* .00 [.00, .44] 1.00 D_CST 1.08 0.48 .69 .41 .44 [.00, .79] .1547 .21 [.00, .66] .50 D_CP 1.08 0.31 .58 .36 .52 [.00, .76] .1441 .08 [.00, 58] .79 D_ALC 0.99 0.45 .78 .75 .14 [.00, .54] .389 .66 [.28, 84] .00 D_PLIC 0.83 0.24 .79 .69 .00 [.00, 45] .10000 .74 [.31, 83] .00 D_FRT 1.26 1.60 .74 .71 .78 .33 [.30, 34] .0000*** .12 [.00, .61] .26 D_FCR 1.21 | .6952 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .4802 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | .5758 |
| S.R1.250.87.80.72.39 [03, 86]0.362*.43 [00, 73].07S_Cerebel1.040.60.71.37.74 [20, .85].0094*.00 [.00, .44]1.00D_CST1.080.48.69.41.44 [.00, .79].1547.21 [.00, .66].50D_CP1.060.35.71.49.59 [.08, .86].023*.17 [.00, .58].51D_CP1.080.31.58.36.52 [.00, .76].1441.08 [.00, .58].79D_ALIC0.990.45.78.75.14 [.00, .54].3899.66 [.28, .84].00D_PLIC0.830.24.79.69.00 [.00, .45]1.0000.74 [.31, .83].00D_PCR1.352.03.89.76.50 [.19, .91].005*.38 [.00, .68].11D_SCR1.211.99.91.69.63 [.30, .94].0000***.28 [.00, .61].26D_CCR1.332.38.93.52.80 [.42, .96].0000***.28 [.00, .61].26D_CCR1.332.38.93.52.33 [.00, .80].2103.37 [.00, .72].18D_CGH1.120.36.70.52.33 [.00, .80].2103.37 [.00, .74].18D_FKST1.110.79.61.16.56 [.00, .74].0564.00 [.00, .46].99D_SF1.261.51.92.72.51 [.23, .83].0002*.00 [.00, .46].99 <td>.3423</td> | .3423 |
| S_Cerebel 1.04 0.60 .71 .37 .74 [.20, .85] .0094* .00 [.00, .44] 1.00 D_CST 1.08 0.48 .69 .41 .44 [.00, .79] .1547 .21 [.00, .66] .50 D_SCP 1.06 0.35 .71 .49 .59 [.08, .86] .0238* .17 [.00, .58] .51 D_CP 1.08 0.31 .58 .36 .52 [.00, .76] .14411 .08 [.00, .58] .79 D_ALIC 0.99 0.45 .78 .75 .14 [.00, .54] .3899 .66 [.28, .84] .00 D_PLIC 0.83 0.24 .79 .69 .00 [.00, .45] 1.0000 .74 [.31, .83] .00 D_ACR 1.35 2.03 .89 .76 .50 [.19, .91] .0015* .38 [.00, .68] .11 D_SCR 1.21 1.99 .91 .69 .63 [.30, .94] .0000** .28 [.00, .61] .26 D_CGG 1.13 0.71 .78 .43 .73 [.25, .84] .0056* .00 [.00, .41] .100 D_CGG 1.90 | .0718 |
| D_CST1.080.48.69.41.44 [.00, .79]1.547.21 [.00, .66].50D_SCP1.060.35.71.49.59 [.08, .86].0238*.17 [.00, .58].51D_CP1.080.31.58.36.52 [.00, .76].1441.08 [.00, .58].79D_ALIC0.990.45.78.75.14 [.00, .54].3899.66 [.28, .84].00D_PLIC0.830.24.79.69.00 [.00, .45]1.0000.74 [.31, .83].00D_FTR1.261.60.74.11.66 [.15, .80].0154*.00 [.00, .45]1.00D_ACR1.352.03.89.76.50 [.19, .91].0015*.38 [.00, .68].11D_SCR1.211.99.91.69.63 [.30, .94].0000***.28 [.00, .61].26D_PCR1.332.38.93.52.80 [.42, .96].0000***.12 [.00, .51].64D_CGC1.190.71.78.43.73 [.25, .84].0056*.00 [.00, .41]1.00D_CGH1.120.36.70.52.33 [.00, .80].2103.37 [.00, .72].18D_FSC1.080.93.72.40.76 [.23, .86].0066*.00 [.00, .46].99D_IFO1.100.58.60.64.42 [.00, .83].1087.31 [.00, .68].19D_SS1.241.03.72.40.76 [.23, .86].0066*.00 [.00, .46].99 </td <td>1.0000</td> | 1.0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .5035 |
| D_CP' 1.08 0.31 .58 .36 .52 [100, .76] .1441 .08 [100, .58] .79 D_ALIC 0.99 0.45 .78 .75 .14 [100, 54] .3899 .66 [28, .84] .00 D_PTR 1.26 1.60 .74 .11 .66 [.15, .80] .0154* .00[.00, .45] 1.000 D_ACR 1.35 2.03 .89 .76 .50 [.19, .91] .0015* .38 [.00, .68] .11 D_SCR 1.21 1.99 .91 .69 .63 [.30, .94] .0000*** .28 [.00, .61] .64 D_CGC 1.19 0.71 .78 .43 .73 [.25, .84] .0056* .00 [.00, .44] 1.00 D_CGH 1.12 0.36 .70 .52 .33 [.00, .80] .2103 .37 [.00, .72] .18 D_SFS 1.11 0.79 .61 .16 .56 [.00, .74] .0545 .00 [.00, .46] .00 D_SFO 1.08 0.93 .72 .40 .76 [.23, .86] .0066* .00 [.00, .39] 1.00 D_SS 1.24 1.0 | .5190 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .7945 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .0031* |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .0044* |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | 1142 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | 2622 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | .2022 |
| D_CGH1.120.36.70.52.33 [.00, .80].2103.37 [.00, .72].18D_FxST1.110.79.61.16.56 [.00, .74].0545.00 [.00, .46]1.00D_SLF1.261.51.92.72.51 [.23, .93].0002*.41 [.00, .68].08D_SFO1.080.93.72.40.76 [.23, .86].0066*.00 [.00, .46].99D_IFO1.100.58.60.64.42 [.00, .83].1087.31 [.00, .68].19D_SS1.241.03.75.45.78 [.33, .88].0022*.00 [.00, .39]1.00D_EC1.090.61.78.85.10 [.00, .42].4503.73 [.42, .87].00D_UF1.020.19.45.57.00 [.00, .56]1.0000.51 [.01, .67].04D_PCT0.880.21.69.35.51 [.00, .79].1058.15 [.00, .64].65D_MCP1.090.75.72.57.06 [.00, .65].7955.62 [.06, .78].03D_GCC1.251.66.71.43.66 [.06, .83].0304*.05 [.00, .54].87D_SCC1.271.19.82.48.66 [.18, .88].0065*.15 [.00, .54].62D_RLIC1.010.50.59.67.30 [.00, .79].2899.37 [.00, .70].17D_Tap1.564.44.60.49.00 [.00, .65].10000.56 [.00, .71].07 <td>1 0000</td> | 1 0000 |
| D_FxST1.110.79.61.16.56 [.00, .74].0545.00 [.00, .46]1.00D_SLF1.261.51.92.72.51 [.23, .93].0002*.41 [.00, .68].08D_SFO1.080.93.72.40.76 [.23, .86].0066*.00 [.00, .46].99D_IFO1.100.58.60.64.42 [.00, .83].1087.31 [.00, .68].19D_SS1.241.03.75.45.78 [.33, .88].0022*.00 [.00, .39]1.00D_EC1.090.61.78.85.10 [.00, .42].4503.73 [.42, .87].00D_UF1.020.19.45.57.00 [.00, .46].65.04D_PCT0.880.21.69.35.51 [.00, .79].1058.15 [.00, .64].65D_MCP1.090.75.72.57.06 [.00, .65].7955.62 [.06, .78].03D_GCC1.251.66.71.43.66 [.06, .83].0304*.05 [.00, .54].87D_SCC1.271.19.82.48.66 [.18, .88].0065*.15 [.00, .43]1.00D_RLIC1.010.50.59.67.30 [.00, .79].2899.37 [.00, .70].17D_Tap1.56.4.44.60.49.00 [.00, .65].10000.56 [.00, .71].07D_Midbrain.960.13.55.57.07 [.00, .69].8247.48 [.00, .68].09 | 1873 |
| D_SLF1.261.51.92.72.51.23, .93.0002*.41.00, .68.08D_SFO1.080.93.72.40.76.23, .86.0066*.00.00, .46.99D_IFO1.100.58.60.64.42.00, .83.1087.31.00, .68.19D_SS1.241.03.75.45.78.33, .88.0022*.00.00, .0391.00D_EC1.090.61.78.85.10.00, .42.4503.73.42, .87.00D_UF1.020.19.45.57.00.00, .561.0000.51.51.04D_PCT0.880.21.69.35.51.00, .79.1058.15.00.64.65D_MCP1.090.75.72.57.06.00, .65.7955.62.06, .78.03D_GCC1.251.66.71.43.66.06, .83.0304*.05.00.54.87D_BCC1.271.19.82.48.66.66.88.0065*.15.00.62D_RLIC1.010.50.59.67.30.00, .79.2899.37.00.07.17D_Tap1.56.444.60.49.00.60.651.0000.56.00, .71.07D_Midbrain.960.13.55.57.07.69.8247.48 <td>1.0000</td> | 1.0000 |
| D_SFO 1.08 0.93 .72 .40 .76 [.23, .86] .0066* .00 [.00, .46] .99 D_IFO 1.10 0.58 .60 .64 .42 [.00, .83] .1087 .31 [.00, .68] .19 D_SS 1.24 1.03 .75 .45 .78 [.33, .88] .0022* .00 [.00, .39] 1.00 D_EC 1.09 0.61 .78 .85 .10 [.00, .42] .4503 .73 [.42, .87] .00 D_UF 1.02 0.19 .45 .57 .00 [.00, .56] 1.0000 .51 [.01, .67] .04 D_PCT 0.88 0.21 .69 .35 .51 [.00, .65] .7955 .62 [.06, .78] .03 D_GCC 1.25 1.66 .71 .43 .66 [.06, .83] .0304* .05 [.00, .54] .87 D_BCC 1.40 2.13 .73 .31 .70 [.17, .82] .0127* .00 [.00, .43] 1.00 D_SCC 1.27 1.19 .82 .48 .66 [.18, .88] .0065* .15 [.00, .58] .62 D_RLIC 1.01 0.50< | .0837 |
| D_IFO1.100.58.60.64.42 [.00, .83].1087.31 [.00, .68].19D_SS1.241.03.75.45.78 [.33, .88].0022*.00 [.00, .39]1.00D_EC1.090.61.78.85.10 [.00, .42].4503.73 [.42, .87].00D_UF1.020.19.45.57.00 [.00, .56]1.0000.51 [.01, .67].04D_PCT0.880.21.69.35.51 [.00, .65].7955.62 [.06, .78].03D_GCC1.251.66.71.43.66 [.06, .83].0304*.05 [.00, .54].87D_SCC1.271.19.82.48.66 [.18, .88].0065*.15 [.00, .68].62D_RLIC1.010.50.59.67.30 [.00, .79].2899.37 [.00, .70].17D_Tap1.56.4.44.60.49.00 [.00, .65]1.0000.56 [.00, .71].07D_Midbrain.960.13.55.57.07 [.00, .69].8247.48 [.00, .68].09 | .9906 |
| D_SS 1.24 1.03 .75 .45 .78 [.33, .88] .0022* .00 [.00, .39] 1.00 D_EC 1.09 0.61 .78 .85 .10 [.00, .42] .4503 .73 [.42, .87] .00 D_UF 1.02 0.19 .45 .57 .00 [.00, .56] 1.0000 .51 [.01, .67] .04 D_PCT 0.88 0.21 .69 .35 .51 [.00, .65] .7955 .62 [.06, .78] .03 D_GCC 1.25 1.66 .71 .43 .66 [.06, .83] .0304* .05 [.00, .54] .87 D_BCC 1.40 2.13 .73 .31 .70 [.17, .82] .0127* .00 [.00, .43] 1.00 D_SCC 1.27 1.19 .82 .48 .66 [.18, .88] .0065* .15 [.00, .54] .87 D_RLIC 1.01 0.50 .59 .67 .30 [.00, .79] .2899 .37 [.00, .70] .17 D_Tap 1.56 4.44 .60 .49 .00 [.00, .65] .10000 .56 [.00, .71] .07 D_Midbrain .96 0 | .1994 |
| D_EC 1.09 0.61 .78 .85 .10 [.00, .42] .4503 .73 [.42, .87] .00 D_UF 1.02 0.19 .45 .57 .00 [.00, .56] 1.0000 .51 [.01, .67] .04 D_PCT 0.88 0.21 .69 .35 .51 [.00, .79] .1058 .15 [.00, .64] .65 D_MCP 1.09 0.75 .72 .57 .06 [.00, .65] .7955 .62 [.06, .78] .03 D_GCC 1.25 1.66 .71 .43 .66 [.06, .83] .0304* .05 [.00, .43] .87 D_BCC 1.40 2.13 .73 .31 .70 [.17, .82] .0127* .00 [.00, .43] 1.00 D_SCC 1.27 1.19 .82 .48 .66 [.18, .88] .0065* .15 [.00, .58] .62 D_RLIC 1.01 0.50 .59 .67 .30 [.00, .79] .2899 .37 [.00, .70] .17 D_Tap 1.56 4.44 .60 .49 .00 [.00, .65] 1.0000 .56 [.00, .71] .07 D_Midbrain .96 0. | 1.0000 |
| D_UF 1.02 0.19 .45 .57 .00 [.00, .56] 1.0000 .51 [.01, .67] .04 D_PCT 0.88 0.21 .69 .35 .51 [.00, .79] .1058 .15 [.00, .64] .65 D_MCP 1.09 0.75 .72 .57 .06 [.00, .65] .7955 .62 [.06, .78] .03 D_GCC 1.25 1.66 .71 .43 .66 [.06, .83] .0304* .05 [.00, .43] .87 D_BCC 1.40 2.13 .73 .31 .70 [.17, .82] .0127* .00 [.00, .43] 1.00 D_SCC 1.27 1.19 .82 .48 .66 [.18, .88] .0065* .15 [.00, .58] .62 D_RLIC 1.01 0.50 .59 .67 .30 [.00, .79] .2899 .37 [.00, .70] .17 D_Tap 1.56 4.44 .60 .49 .00 [.00, .65] 1.0000 .56 [.00, .71] .07 D_Midbrain .96 0.13 .55 .57 .07 [.00, .69] .8247 .48 [.00, .68] .09 POL (Right) RD < | .0003** |
| D_PCT 0.88 0.21 .69 .35 .51 [.00, .79] .1058 .15 [.00, .64] .65 D_MCP 1.09 0.75 .72 .57 .06 [.00, .65] .7955 .62 [.06, .78] .03 D_GCC 1.25 1.66 .71 .43 .66 [.06, .83] .0304* .05 [.00, .43] .87 D_BCC 1.40 2.13 .73 .31 .70 [.17, .82] .0127* .00 [.00, .43] 1.00 D_SCC 1.27 1.19 .82 .48 .66 [.18, .88] .0065* .15 [.00, .70] .17 D_RLIC 1.01 0.50 .59 .67 .30 [.00, .79] .2899 .37 [.00, .70] .17 D_Tap 1.56 4.44 .60 .49 .00 [.00, .65] 1.0000 .56 [.00, .71] .07 D_Midbrain .96 0.13 .55 .57 .07 [.00, .69] .8247 .48 [.00, .68] .09 POL (Right) RD Variance (10 ⁻³) rMZ rDZ a^2 [95% CI] p.6 a^2 c^2 [95% CI] p.6f | .0453* |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | .6521 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | .0336* |
| D_BCC 1.40 2.13 .73 .31 $.76(17, 52)$ $.0127$ $.00(100, 43)$ 1.00 D_SCC 1.27 1.19 .82 .48 .66[18, 88] $.0062^{+0}$ $.15[.00, .58]$.62 D_RLIC 1.01 0.50 .59 .67 .30[.00, .79] .2899 .37[.00, .70] .17 D_Tap 1.56 4.44 .60 .49 .00[.00, .65] 1.0000 .56[.00, .71] .07 D_Midbrain .96 0.13 .55 .57 .07[.00, .69] .8247 .48[.00, .68] .09 POL (Right) RD Variance (10 ⁻³) rMZ rDZ a^2 [95% CI p.64 ² c^2 [95% CI p.61 | .0743 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | 6247 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | 1703 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | .0735 |
| POI (Right) PD Variance (10 ⁻³) rM7 rD7 a^2 [95% CI] p of a^2 c^2 [95% CI] p of | .0958 |
| | p of c ² |
| S SP 1 27 1 26 85 58 64[22 90] 0030* 19[00 57] 46 | 4672 |
| S Cing 1.23 0.34 .71 .42 .66 [05 82] 0.338* 0.4100 .551 .90 | .9068 |
| S SF 1.29 1.58 .89 .79 .52 [.19, 91] .0017* .36 [.00, 67] .14 | .1424 |
| S MF 1.28 1.02 .86 .77 .37 .06 .84 .0214* .49 .02, .75 .04 | .0403* |
| S_IF 1.27 1.26 .85 .80 .26 [.00, .70] .1013 .57 [.14, .82] .01 | .0156* |
| S_PrC 1.16 0.87 .86 .79 .45 [.16, .90] .0027* .43 [.00, .70] .05 | .0555 |
| S_PoC 1.14 0.66 .75 .61 .63 [.23, .90] .0036* .21 [.00, .56] .37 | .3759 |
| S_A 1.32 0.94 .82 .66 .40 [.02, .86] .0374* .42 [.00, .73] .09 | .0907 |
| S_PrCu 1.29 1.24 .83 .49 .84[.39, .91] .0003** .00[.00, .43] .99 | .9999 |
| S_Cu 1.17 0.74 .78 .64 .46 [.03, .86] .0370* .34 [.00, .68] .16 | .1688 |
| S_L 1.23 0.74 .84 .34 .72 [.14, .85] .0135* .03 [.00, .56] .94 | .9410 |
| 5_ru 1.26 0.86 .49 .59 .43[.00,.81] .1559 .25[.00,.65] .33 | .3306 |
| 5_50 1.23 0.93 .57 .60 .47[.00,.84] .0851 .27[.00,.65] .26 | .2624 |
| i∪ i.∠o 0.73 .67 .49 .46[.00,81] .1106 .17[.00,.63] .49 | .4753 |
| 5_mic 1.27 0.72 .77 .03 .04(113,.00) .0113 .27(100,.02] .20 | 2617 |
| 5_{51} 1.7 0.70 .70 .30 [00, 04] .000 .45 [00, 73] 1.00 | .2617 |
| SMT 1.31 1.21 .84 .59 .68[.25, 90] 0025* 15[.00, 24] 55 | .2617 .0570 1.0000 |
| S LFO 1.30 1.41 .86 .65 .48 [.08, 88] .0201* .34 [.00, .68] .21 | .2617 .0570 1.0000 .5567 |
| | .2617 .0570 1.0000 .5567 .2128 |

| Continue | | | | | | | | |
|------------|------|------------------------------|-----|-----|-------------------------|---------------------|-------------------------|---------------------|
| ROI (Left) | FA | Variance (10 ⁻³) | rMZ | rDZ | a ² [95% CI] | p of a ² | c ² [95% CI] | p of c ² |
| S_SM | 1.26 | 0.97 | .85 | .79 | .41 [.11, .85] | .0085* | .46 [.02, .72] | .0401* |
| S_R | 1.25 | 0.70 | .70 | .72 | .25 [.00, .78] | .3354 | .45 [.00, .74] | .0951 |
| S_Cerebel | .99 | 0.47 | .84 | .45 | .78 [.33, .91] | .0006* | .06 [.00, .49] | .8161 |
| D_CST | .93 | 0.26 | .72 | .46 | .27 [.00, .78] | .3329 | .40 [.00, .73] | .2248 |
| D_SCP | 1.06 | 0.40 | .58 | .34 | .62 [.00, .78] | .0517* | .00 [.00, .46] | 1.0000 |
| D_CP | 1.01 | 0.24 | .11 | .31 | .00 [.00, .46] | 1.0000 | .22 [.00, .44] | .2952 |
| D_ALIC | .98 | 0.38 | .71 | .74 | .07 [.00, .48] | .7200 | .69 [.30, .83] | .0025* |
| D_PLIC | .79 | 0.23 | .76 | .62 | .16 [.00, .69] | .4411 | .57 [.06, .80] | .0308* |
| D_PTR | 1.30 | 2.34 | .82 | .33 | .79 [.33, .88] | .0014* | .00 [.00, .43] | 1.0000 |
| D_ACR | 1.36 | 2.29 | .93 | .75 | .50 [.24, .94] | .0001** | .40 [.00, .68] | .0872 |
| D_SCR | 1.21 | 1.60 | .90 | .71 | .62 [.28, .93] | .0002** | .28 [.00, .61] | .2643 |
| D_PCR | 1.42 | 2.83 | .94 | .58 | .77 [.42, .97] | .0000*** | .17 [.00, .53] | .4981 |
| D_CGC | 1.18 | 0.52 | .78 | .62 | .51 [.07, .87] | .0229* | .28 [.00, .65] | .2844 |
| D_CGH | 1.11 | 0.28 | .52 | .50 | .14 [.00, .70] | .6795 | .39 [.00, .66] | .1910 |
| D_FxST | 1.06 | 0.58 | .70 | .01 | .71 [.36, .86] | .0028* | .00 [.00, .16] | 1.0000 |
| D_SLF | 1.27 | 1.66 | .91 | .76 | .53 [.25, .94] | .0001** | .39 [.00, .67] | .0830 |
| D_SFO | 1.10 | 0.66 | .65 | .52 | .55 [.00, .82] | .0718 | .14 [.00, .60] | .6323 |
| D_IFO | 1.08 | 0.53 | .72 | .64 | .42 [.00, .86] | .0521 | .37 [.00, .70] | .1165 |
| D_SS | 1.23 | 1.05 | .76 | .24 | .84 [.64, .92] | .0001** | .00 [.00, .16] | 1.0000 |
| D_EC | 1.05 | 0.58 | .82 | .87 | .03 [.00, .29] | .8060 | .82 [.58, .90] | .0000*** |
| D_UF | 1.00 | 0.16 | .71 | .70 | .00 [.00, .41] | 1.0000 | .69 [.30, .80] | .0038* |
| D_PCT | .89 | 0.25 | .75 | .45 | .40 [.00, .82] | .1218 | .32 [.00, .72] | .3019 |
| D_MCP | 1.05 | 0.61 | .65 | .45 | .08 [.00, .70] | .7969 | .51 [.00, .72] | .1332 |
| D_GCC | 1.16 | 0.87 | .62 | .61 | .29 [.00, .79] | .2856 | .38 [.00, .71] | .1491 |
| D_BCC | 1.32 | 2.00 | .75 | .41 | .77 [.29, .87] | .0035* | .00 [.00, .41] | 1.0000 |
| D_SCC | 1.19 | 0.96 | .83 | .50 | .82 [.39, .89] | .0005** | .00 [.00, .40] | 1.0000 |
| D_RLIC | .98 | 0.45 | .71 | .60 | .65 [.12, .86] | .0182* | .11 [.00, .53] | .6695 |
| D_Tap | 1.65 | 5.72 | .83 | .52 | .62 [.18, .89] | .0054* | .20 [.00, .59] | .4611 |
| D_Midbrain | .94 | 0.09 | .51 | .41 | .00 [.00, .60] | 1.0000 | .46 [.00, .63] | .1594 |

TABLE 4 (b)

exposures likely play a role in neuronal plasticity and influence the WM integrity of individuals (Bengtsson et al., 2005). Therefore, genetic variation might decrease with development and aging. The higher heritability estimates for diffusion measures, especially for RD and AD (for RD, $A_{Left} = .45$, $A_{Right} = .60$; for AD, $A_{Left} = .43$, $A_{Right} =$.68), may correspond to WM microstructure asymmetries in adults (Jahanshad et al., 2010), and to brain structural asymmetries that appear in neonates (Gilmore et al., 2007).

Heterogeneous Heritability Across Regions of Interest Results from regional ACE analysis indicate that the magnitude of genetic effects differs across WM regions. About half of the regions analyzed show high heritability in the diffusion measures. Among RD measures, the regions with the largest magnitude of heritability include left middle (.86) and left inferior occipital WM (.84), right inferior temporal (.84), and right pre-cuneus WM, part of the superior parietal lobule (.84). There was no significant genetic contribution for several major WM fiber bundles, such as bilateral uncinate fasciculus RD. Interestingly, the WM regions with the highest RD heritability have low FA heritability (A = .23–.48), whereas the uncinate fasciculus shows relatively high FA heritability (left/right: .62/.58).

The inconsistent genetic effects on RD and FA over several WM regions suggest that these two measures reflect distinct WM biological properties that are shaped differently by genetic and environmental effects. Future multivariate approaches focusing on the shared genetic and environmental effects between these measures could help elucidate this relationship.

Substantial Shared Environmental Effects in Specific Regions of Interest

Bilateral PLIC, ALIC, external capsule, uncinate fasciculus, and left middle cerebellar peduncle show high shared environmental effects in RD ranging from .57 to .82. The AD of bilateral external capsule, middle cerebellar peduncle, and inferior frontal occipital fasciculus also has a large proportion of shared environmental effects, ranging between .47 and .71. Shared environmental effects are substantial for the RD measure of bilateral external capsule (left/right: .73/.82). Located between the putamen and claustrum, and lateral to the internal capsule, the external capsule is believed to contain association fibers, such as the superior longitudinal fasciculus, inferior frontal occipital fasciculus, and commissural fibers, and is not devoid of projection fibers. Together with PLIC and ALIC, the external capsule may have started myelination earlier prenatally than other association fibers (Kinney et al., 1988). Prenatal neurohormonal and uterine environment could affect the maturation process, which might lead to pronounced shared environmental variation in the maturation process. The significant genetic contributions in these regions observed in adults (Kochunov et al., 2010) may indicate the canalization effect (Gilmore

TABLE 4 (c)

| Genetic and Common | Environmental Con | ntribution Estimates | of Average A | D Over Superficial a | and Deep White | Matter Regions of |
|--------------------|--------------------------|----------------------|--------------|----------------------|----------------|-------------------|
| nterest | | | | | | |

| S.S.P 1.43 1.18 40 4.46 4.41 (10, 45) 0.0195 1.11 (10, 0, 41) 1.000 S.Fr 1.59 1.03 0.71 7.8 38 (27, 74) 100107 33 (10, 0, 41) 1.000 S.Fr 1.59 1.03 0.71 7.8 38 (27, 74) 100107 33 (10, 0, 41) 1.000 S.Fr 1.54 0.66 4.5 3.5 1.71 3.81 0.0149 3.81 (0, 0, 74) 1.12 1.1154 S.Fr 1.44 0.66 4.5 7.5 0.81 (0, 44) 0.333 1.1154 3.81 0.013 3.81 0.013 3.81 0.013 3.81 0.013 3.81 0.013 3.81 0.013 3.81 0.013 3.81 0.013 3.81 0.013 3.81 0.010 3.81 0.010 3.81 0.010 3.81 0.010 3.81 0.010 3.81 0.010 3.81 0.010 3.81 0.010 3.81 0.010 3.81 0.000 3.81 0.001 3.81 0.001 3.81 0.001 3.81 0.001 | ROI (Left) | AD | Variance (10 ⁻³) | rMZ | rDZ | a ² [95% CI] | p of a ² | c ² [95% CI] | $p 	ext{ of } c^2$ |
|--|------------------|------|------------------------------|-----------|-----------|-------------------------------|---------------------|----------------------------|---------------------|
| S.C.m.g 1.50 0.46 .77 .48 .79 [33, 83] 0.027 .00 [00, 44] 1.167 S.MF 1.51 0.66 .45 .57 .25 .26 .00017 .35.44 .42 [00, 027] .35.44 .42 [00, 04] .1637 S.PFC 1.44 0.66 .48 .75 .26 [00, 79] .26.44 .41 [00, 64] .1518 S.PC 1.42 0.53 .66 .60 .27 [00, 79] .26.44 .41 [00, 64] .3331 .151 .333 .21 [00, 79] .26.44 .41 [00, 64] .3332 .21 [00, 79] .25.44 .151 .332 .26 [00, 64] .4333 .21 [00, 79] .354 .12 [00, 64] .3332 .21 [00, 79] .354 .12 [00, 64] .3332 .21 [00, 64] .3333 .21 [00, 78] .3332 .21 [00, 78] .3333 .21 [00, 78] .3333 .21 [00, 38] .10000 .331 .0000 .331 .0000 .331 .0000 .331 .0000 .331 .0000 .331 | S_SP | 1.63 | 1.18 | .80 | .46 | .64 [.10, .85] | .0195* | .11 [.00, .56] | .7195 |
| S.S.F 1.59 1.03 .91 .78 188 180 0011 33 100, 721 1220 S.F.C 1.51 0.66 .65 .59 .60, 70 .834 .41 .00, 721 .1210 S.F.C 1.51 0.69 .83 .61 .4210, 721 .1210 S.P.C 1.42 0.53 .66 .60 .264 .0033 .010, .41 .3310, .41 .210, .41 .3310, .41 .3310, .41 .210, .41 .3310, .41 .210, .41 .3310, .41 .210, .41 .3310, .41 .410, .33110, .41 .410, .41 .410, .41 .410, .41 .410, .41< | S_Cing | 1.50 | 0.46 | .77 | .48 | .79 [.30, .88] | .0023* | .00 [.00, .44] | 1.0000 |
| S.MF 1.51 0.66 .45 .59 .25 1.61 0.66 .45 .59 .25 .17 1.00 .61 .338 S.P.C 1.42 0.53 .66 .67 .59 .26 .17 1.00 .71 .338 | S_SF | 1.59 | 1.03 | .91 | .78 | .58 [.27, .94] | .0001** | .33 [.00, .64] | .1657 |
| S.F. 1.51 0.49 4.31 4.91 4.90 8.90 1.252 1.71 1.33 S.P.GC 1.42 0.69 7.8 7.5 7.6 7.6 7.6 7.6 7.6 7.6 7.6 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 7.7 7.8 | S_MF | 1.51 | 0.66 | .65 | .59 | .25 [.00, .77] | .3544 | .42 [.00, .72] | .1270 |
| S.Pr.C. 1.44 0.68 31 | S_IF | 1.51 | 0.69 | .63 | .61 | .49 [.00, .80] | .1252 | .17 [.00, .61] | .5356 |
| S. Foc. 1.42 0.53 .56 .50 .57 .42 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .100 .71 .700 .71 .700 .700 .710 .710 .700 < | S_PrC | 1.44 | 0.66 | .81 | ./5 | .52[.17, .90] | .0049* | .34 [.00, .65] | .1510 |
| S.A. Cu 1.64 0.76 | S_PoC | 1.42 | 0.53 | .66 | .60 | .29 [.00, .79] | .2684 | .41[.00, .73] | .1154 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | S_A | 1.03 | 0.92 | ./8 | ./5 | .08 [.00, .46] | .0330 | ./ [[.35, .85] | .0014* |
| 1 1 1 1 0 10 10 10 10 100 <th< td=""><td>S_FICU</td><td>1.51</td><td>0.90</td><td>.75</td><td>.45</td><td>16[00_66]</td><td>.0033</td><td>30[00,40]</td><td>2002</td></th<> | S_FICU | 1.51 | 0.90 | .75 | .45 | 16[00_66] | .0033 | 30[00,40] | 2002 |
| S.F. 151 0.90 50 42 51 100.791 1354 12100.581 67722 S.SO 154 1.15 73 33 761.35, 861 0.0021* 0.0100.351 1.0000 S.MO 154 1.04 76 32 751.30, 861 0.0021* 0.0100.351 1.0000 S.TT 151 0.72 62 56 391.00, 751 3732 281.00, 651 4333 S.TT 151 0.75 .73 .49 .610.831 .6427 1.31<0.591 | S_Cu | 1.47 | 1 40 | .47 | .30 | 41 [00 63] | 0801 | .30[.00, .30] | 1 0000 |
| S 50 152 0.08 45 34 46 104, 40 0.084 0.000, 48 1.0000 S/IO 154 1.15 73 33 76 (35, 46) 0.003* 0.00, 0.0, 38 1.0000 S.MO 156 1.04 76 32 75 (30, 86) 0.003* 0.00, 0.0, 38 1.0000 S.MT 157 153 0.75 53 30 (00, 78) 2.33 24 (00, 64) .3340 S.MT 167 102 .59 .52 .46 (00, 79) 1.602 .18 (00, 42) .58 .58 S.MT 1.52 0.73 .72 .42 .37 (00, 80) .866 .00 (00, 00) .0000 .500 | S Eu | 1.51 | 0.90 | .50 | 42 | 51 [00 79] | 1354 | 12[00 58] | 6732 |
| SiDe 1.54 1.15 7.3 3.33 7.6 [35, 86] 0.0021* 0.00 [00, 35] 1.0000 S,ST 1.51 0.72 6.2 5.6 3.9 [00, 78] 2.183 2.4 [00, 6.5] 4.333 S,MT 1.67 1.05 7.5 3.00 3.01 (0.75] 3.732 2.8 [00, 6.6] 4.333 S,MT 1.67 1.05 7.5 3.00 3.8 [02, 83] 0.422 1.31 (00, 59] .6511 S,MFO 1.57 1.02 .52 .46 (10, 79] 1.1602 .81 (00, 62] .1330 S,MFO 1.57 1.02 .57 .52 .46 (10, 79] 1.1602 .81 (00, 72] .1002 .81 (00, 72] .1330 S,MFO 1.50 .61 .44 (10, 72] .6532 .09 (100, 57] .75792 D,CP 1.44 0.41 .64 .64 (100, 72] .6453 .47 (100, 71] .75792 D,CP 1.44 0.41 .64 (100, 72] .64 (100, 72] .64 (100, 72] .757 | S SO | 1.52 | 0.88 | .65 | .34 | .66 [.04, .80] | .0384* | .00 [.00, .48] | 1.0000 |
| S,MO 1.56 1.04 7.6 3.2 7.5 [30, 66] .00024 .001 (00, 36] 1.4333 S,IT 1.58 0.75 .53 .50 .30 (100, 75] .372 28 (20, 44) .3334 S,IT 1.57 0.75 .73 .49 .61 (103, 83) .0427 .13 (00, .59) .65 (100, .59) .53 (100, .51) .75 .58 (100, 71) .1602 .18 (00, .62) .73 (100, .53) .53 (100, .51) .73 (100, .51) .73 (100, .51) .73 (100, .51) .73 (100, .51) .73 (100, .51) .75 (100, .51) .74 (100, .51) .75 (100 | s_io | 1.54 | 1.15 | .73 | .33 | .76 [.35, .86] | .0021* | .00 [.00, .35] | 1.0000 |
| S,ST 1.51 0.72 4.22 5.64 .39 [00, 78] .2183 .24 [00, 46] .4330 S,MT 1.67 1.58 0.75 .53 .50 .30 [00, 77] .3732 .28 [00, 46] .3340 S,MFO 1.57 1.02 .59 .52 .46 [10, 79] .1662 .39 [00, 60] .53 S,MFO 1.52 0.93 .72 .46 [10, 83] .0423 .99 [100, 60] .53 S,Cerebal 1.26 0.71 .60 .41 .45 [100, 83] .0532 .99 [100, 76] .788 C,CP 1.40 .64 .59 .55 .67 [100, 64] .824 [100, 71] .710 .788 C,CP 1.64 .033 .52 .80 [00, 74] .0300 .51 [100, 0.51] .771 .788 C,CP 1.43 1.46 .67 .01 .61 [100, 71] .711 [17] D,ACR 1.71 1.51 .87 .74 .44 [15, 90] .03001 .41 [00, 00] .4 | S_MO | 1.56 | 1.04 | .76 | .32 | .75 [.30, .86] | .0036* | .00 [.00, .38] | 1.0000 |
| S.IT 1.58 0.75 5.3 50 .30 [00, 75] .372 22 [00, .64] .3340 S.MT 1.57 1.05 .75 .58 .46 [103, 83] .0389 .10 [00, .59] .6511 S.MTO 1.57 1.02 .59 .46 [00, 79] .1602 .18 [00, .50] .7301 S.MT 1.52 0.71 .60 .41 .65 [00, 80] .0566 .00 [00, .50] .10000 S.Cerebel 1.26 0.55 .66 .46 .40 [00, 78] .1441 .5100, .61 .6267 .52 (00, .64] .627 .52 (00, .64] .627 .52 (00, .64] .627 .52 (00, .57] .744 .44 [10, 71] .510 .710 .410 .620 .511 .711 .600 .51 .710 (00, .64] .520 .510 .710 .643 .710 .721 .4450 .711 .710 .721 .4450 .711 .711 .711 .711 .711 .711 .711 .711 .711 <td< td=""><td>S_ST</td><td>1.51</td><td>0.72</td><td>.62</td><td>.56</td><td>.39 [.00, .78]</td><td>.2183</td><td>.24 [.00, .65]</td><td>.4333</td></td<> | S_ST | 1.51 | 0.72 | .62 | .56 | .39 [.00, .78] | .2183 | .24 [.00, .65] | .4333 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | S_IT | 1.58 | 0.75 | .53 | .50 | .30 [.00, .75] | .3732 | .28 [.00, .64] | .3340 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | S_MT | 1.67 | 1.05 | .75 | .50 | .58 [.02, .83] | .0427 | .13 [.00, .59] | .6511 |
| $ \begin{array}{c} S, MeO \\ S, SM \\ S, SM \\ 1.52$ | S_LFO | 1.51 | 0.75 | .73 | .49 | .61 [.03, .83] | .0389 | .10 [.00, .56] | .7301 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | S_MFO | 1.57 | 1.02 | .59 | .52 | .46 [.00, .79] | .1602 | .18[.00, .62] | .5350 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | S_SM | 1.52 | 0.93 | ./2 | .62 | .37 [.00, .83] | .1056 | .39[.00, .72] | .1105 |
| Decked 1.20 0.30 1.30 < | S_K S_Corobol | 1.50 | 0.71 | .00 | .41 | 40[00, 20] | .0300 | .00[.00, .50] | 7592 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | | 1.20 | 0.55 | .00 | .40 | .80[.00, .82] | .0332 | .09[.00, .37] 52[00 71] | .7362 |
| $ \begin{array}{c} C_{C} P & 1 & a \\ D, AUC & 0.35 & 56 & 51 & 33 & 58 [00, 76] & 1196 & 01 [00, 54] & 9704 \\ D, PUC & 1.45 & 0.20 & 59 & 38 & 00 [00, 61] & 1.0000 & 51 [00, 67] & 1107 \\ D, PUC & 1.45 & 0.20 & 59 & 38 & 00 [00, 61] & 1.0000 & 51 [00, 67] & 1107 \\ D, AUC & 1.71 & 1.51 & 87 & 74 & 44 [15, 90] & 0.030^{+} & 44 [00, 71] & 0.539 \\ D, SCR & 1.71 & 1.51 & 87 & 74 & 44 [15, 90] & 0.030^{+} & 44 [00, 71] & 0.539 \\ D, SCR & 1.73 & 2.06 & 91 & 55 & 70 [32, 93] & 0.001^{-} & 19 [00, 67] & 4285 \\ D, CGC & 1.56 & 0.61 & 80 & 39 & 77 [33, 86] & 0.001^{-} & 19 [00, 67] & 4285 \\ D, CGC & 1.56 & 0.61 & 80 & 39 & 76 [33, 76] & 0.007^{+} & 23 [00, 44] & 4717 \\ D, ExST & 1.65 & 0.77 & 67 & 37 & 36 & 56 [13, 27] & 0.008^{+} & 34 [00, 64] & 1584 \\ D, FCR & 1.73 & 2.06 & 91 & 55 & 70 [32, 53] & 0.001^{-} & 01 [00, 47] & 1000 \\ D, CGH & 1.46 & 0.87 & 77 & 47 & 36 & 56 [13, 292] & 0.008^{+} & 34 [00, 64] & 1584 \\ D, FC & 1.46 & 0.87 & 77 & 67 & 36 & 56 [13, 292] & 0.008^{+} & 34 [00, 64] & 1584 \\ D, FC & 1.46 & 0.87 & 77 & 1.57 & 367 & 368 & 368 [12, 814] & 0.0143^{+} & 40 [00, 47] & 1000 \\ D, JFO & 1.46 & 0.87 & 77 & 1.3 & 28 [00, 57] & 3586 & 40 [00, 38] & 0.016^{+} \\ D, DC & 1.46 & 0.87 & 77 & 1.3 & 28 [00, 57] & 3581 & 0.01 [00, 38] & 0.016^{+} \\ D, DC & 1.46 & 0.83 & .69 & .80 & .70 [13, 88] & 0.0160 \\ D, JFC & 1.40 & 0.23 & .21 & .13 & 28 [00, 577] & .3551 & .00 [00, 38] & 0.016^{+} \\ D, DC & 1.46 & 0.63 & .76 & .81 & .28 [00, 577] & .3551 & .00 [00, 38] & 0.016^{+} \\ D, CC & 1.98 & 1.41 & .62 & .28 & .57 [00, .74] & 1.0253 & .01 [00, .56] & .9748 \\ D, BCC & 1.98 & 1.41 & .62 & .28 & .57 [00, .74] & 1.0253 & .01 [00, .47] & .2620 \\ D, MCC & 1.46 & 0.63 & .77 & .78 & .41 & .78 [.32, 87] & .0024^{+} & .00 [.00, .47] & .2620 \\ D, MCC & 1.52 & 0.41 & .63 & .51 & .33 [00, .67] & .35 [00, .71] & .2551 \\ D, MCHorian & 1.26 & 0.07 & .48 & .71 [.48 & .56 [00, .83] & .35 [00, .71] & .2627 \\ D, MCHorian & 1.26 & 0.07 & .74 & .48 & .50 [00, .63] & .735 & .35 [00, .71] & .2788 \\ C, RO (Right) & AD & Variance (10^{-3}) & rMZ & .72 & .23 [$ | | 1.40 | 0.00 | .57 | .55 | 48 [00 78] | 1441 | 15[00,61] | 6225 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D CP | 1.60 | 0.39 | .00 | .33 | 58 [00 76] | 1196 | 01[00_54] | 9704 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D ALIC | 1.40 | 0.35 | .68 | .51 | .14 [.00, .72] | .6453 | .47 [.00, .71] | .1210 |
| $ \begin{array}{c} D_{PTR} \\ D_{ACR} & 171 & 151 & 87 & 7.4 & 41 (15) \\ D_{CR} & 1.60 & 1.61 & 90 & 61 & 63 (27, 93) \\ D_{CR} & 1.60 & 1.61 & 90 & 61 & 63 (27, 93) \\ D_{CR} & 1.73 & 2.06 & 91 & 55 & 70 (22, 93) \\ D_{CGC} & 1.56 & 0.61 & .80 & .39 & 71 (33, 88) & 0.017^* & .19 [0.0, 57] & .4825 \\ D_{CGC} & 1.56 & 0.61 & .80 & .39 & .78 (33, 88) & 0.017^* & .00 (0.0, .41) & 1.0000 \\ D_{CGH} & 1.41 & 0.30 & .54 & .36 & .36 (0.0, 75] & .2981 & .23 (0.0, 64] & .4711 \\ D_{FST} & 1.65 & 0.77 & .67 & .07 & .66 (13, 76] & .01008^* & .34 (0.0, 64] & .10000 \\ D_{SFF} & 1.58 & 1.02 & .88 & .66 & .55 (23, 92] & .0008^* & .34 (0.0, 64] & .1804 \\ D_{SFO} & 1.48 & 0.41 & .81 & .69 & .39 (0.8, 84] & .0143^* & .47 (0.3, 7.3] & .0391^* \\ D_{SS} & 1.71 & 0.66 & .66 & .37 & .77 (13, 33] & .0144^* & .00 (0.0, .45] & .10000 \\ D_{CC} & 1.46 & 0.53 & .69 & .80 & .04 (1.0, .45] & .8128 & .71 (.33, .83] & .0016^* \\ D_{VF} & 1.40 & 0.23 & .21 & .13 & .28 (0.0, 57] & .4860 & .00 (0.0, .48] & .10001 \\ D_{CC} & 1.46 & 0.53 & .69 & .80 & .04 (1.0, .45] & .3551 & .40 (0.0, .74] & .2620 \\ D_{MC} & 1.40 & 0.33 & .76 & .41 & .27 (0.0, .77] & .3551 & .40 (0.0, .74] & .2620 \\ D_{MC} & 1.40 & 0.33 & .74 & .66 & .00 (0.0, .74] & .10000 & .72 (25, .81] & .0071^* \\ D_{SCC} & 1.98 & 1.41 & .62 & .28 & .57 (1.00, .74] & .1253 & .01 [0.0, .56] & .9848 \\ D_{SCC} & 1.98 & 1.41 & .62 & .28 & .57 (0.0, .74] & .1253 & .01 [0.0, .56] & .9848 \\ D_{SCC} & 1.98 & 1.41 & .62 & .28 & .57 (0.0, .74] & .1253 & .01 [0.0, .56] & .9848 \\ D_{SCC} & 1.98 & 1.41 & .63 & .51 & .33 (0.0, .60] & .10000 & .38 [0.0, .07] & .2879 \\ D_{Midbrain} & 1.26 & .0.9 & .34 & .77 (2.4, .87] & .0.043^* & .0.0 [0.0, .47] & 1.0000 \\ D_{SC} & 1.98 & .215 & .64 & .288 & .57 [0.0, .74] & .1253 & .01 [0.0, .56] & .9848 \\ D_{SCC} & 1.98 & .0.41 & .73 & .33 (0.0, .60] & .10000 & .38 [0.0, .62] & .27879 \\ D_{Midbrain} & 1.26 & .0.9 & .34 & .77 & .42 & .35 & .00 (.0, .61 & .0001^* & .35 [0.0, .61] & .9974 \\ D_{RIC} & 1.53 & 0.0.1 & .78 & .41 & .78 [3.2, 0.7] & .964 & .00 [0.0, .41] & .0000 \\ S_{Crn} & 1.59 & 0.$ | D PLIC | 1.45 | 0.20 | .59 | .38 | .00 [.00, .61] | 1.0000 | .51 [.00, .67] | .1107 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_PTR | 1.83 | 1.46 | .67 | 01 | .58 [.03, .74] | .0394* | .00 [.00, .47] | 1.0000 |
| D_SCR 1.60 1.61 .90 .61 631 (27, 93) 0002** .26 (D0, 61) .3366 D_CGC 1.56 0.61 .80 .39 .79 (1.33, 28) 00017* .00 (1.00, 41) 1.0000 D_CGG 1.56 0.61 .80 .39 .79 (1.33, 28) .0017* .00 (1.00, 41) 1.0000 D_SLF 1.58 1.02 .88 .66 .55 (23, .92) .0019* .00 (0.0, 47) 1.0000 D_SLF 1.58 1.02 .88 .66 .37 (7) (1.3, 78) .0194* .00 (0.0, 43) 1.0000 D_FCC 1.44 0.41 .81 .69 .39 (1.08, 84) .0143* .47 (1.03, 73) .0391* D_SC 1.44 0.53 .69 .80 .04 (1.00, 45] .8128 .71 (1.33, 83) .0010* .0000 .00 (25, 81) .0001 .000, .38] 1.0000 .00 (25, 81) .0001 .00 (25, 81) .0011* .0001 .00 (25, 81) .0011* .001* .001* .001* .001* .001* .001* .001* .001* .001* .001* <td>D_ACR</td> <td>1.71</td> <td>1.51</td> <td>.87</td> <td>.74</td> <td>.44 [.15, .90]</td> <td>.0030*</td> <td>.44 [.00, .71]</td> <td>.0539</td> | D_ACR | 1.71 | 1.51 | .87 | .74 | .44 [.15, .90] | .0030* | .44 [.00, .71] | .0539 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_SCR | 1.60 | 1.61 | .90 | .61 | .63 [.27, .93] | .0002** | .26 [.00, .61] | .3366 |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$ | D_PCR | 1.73 | 2.06 | .91 | .55 | .70 [.32, .93] | .0001** | .19 [.00, .57] | .4825 |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | D_CGC | 1.56 | 0.61 | .80 | .39 | .79 [.33, .88] | .0017* | .00 [.00, .41] | 1.0000 |
| $ D_{FX1} $ 1.65 0.77 .67 .07 .66 1.07 .60 1.13, .61 .0190" .00 [100, .37] 1.0000 D_SLF $ 1.58 1.02 .88 .66 .55 [23, .92] .0008" .34 [00, .64] .1584 D_SFO 1.46 0.87 .77 .26 .68 [12, .81] .0194" .00 [00, .47] 1.0000 D_EC 1.46 0.53 .69 .80 .04 [00, .57] .4001 .00, .45] 1.0000 D_EC 1.46 0.53 .69 .80 .04 [00, .57] .4860 .00 [00, .45] 1.0000 D_EC 1.46 0.53 .69 .80 .04 [00, .57] .4860 .00 [00, .38] 1.0000 D_EC 1.46 0.63 .74 .66 .00 [00, .47] 1.0000 .70 [25, .81] .0071" D_SCC 1.98 1.41 .62 .28 .57 [00, .77] .3551 .40 [00, .74] .2260 D_SCC 1.98 1.41 .62 .28 .57 [00, .74] .1253 .01 [00, .56] .9948 D_SCC 1.98 1.41 .62 .28 .57 [00, .74] .1253 .01 [00, .56] .9948 D_SCC 1.98 1.41 .63 .51 .33 (00, 80] .2239 .35 [00, .71] .2082 D_SCC 1.91 0.91 .80 .34 .77 [21, .86] .0063" .00 [00, .57] .2974 D_RLC 1.53 0.41 .63 .51 .33 (00, 80] .2239 .35 [00, .71] .2082 D_Tap 2.17 3.67 .42 .35 .00 [10, .68] .7350 .35 [00, .62] .2788 RO (Right) AD Variance (10-3) MZ rDZ a2 [95% C] p of a2 c2 [95% C] p of c2 S.SF 1.56 1.01 .78 .41 .78 [32, .87] .0024" .00 [00, .40] 1.0000 S.SG 1.5, .00, .62] .2788 S.FF 1.59 1.04 .86 .75 .50 [15, .00] .024" .00 [00, .40] 1.0000 S.SF 1.59 1.04 .86 .75 .50 [15, .00] .0047" .36 [00, .67] .1515 S.FF 1.59 1.04 .86 .75 .50 [15, .00] .0047" .36 [00, .67] .1515 S.FF 1.59 1.04 .86 .75 .50 [15, .00] .0047" .36 [00, .60] .0010, .61] .0000 S.SF 1.50 0.83 .76 .72 .23 [00, .78] .3293 .48 [00, .76] .0715 S.PFC 1.45 0.59 .81 .80 .39 (02, .86] .3737 .43 [00, .73] .0686 S.PC 1.40 0.55 .69 .54 .71 [26, .89] .0042" .00 [00, .41] .10000 S.PC 1.40 0.55 .69 .54 .71 [27, .81] .0041" .20 [00, .41] .3000 S.PFC 1.45 0.83 .54 .50 .29 [10, .76] .3771 .32 [00, .64] .2768 S.PC 1$ | D_CGH | 1.41 | 0.30 | .54 | .36 | .36 [.00, .75] | .2981 | .23 [.00, .64] | .4717 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_FxS1 | 1.65 | 0.77 | .6/ | .07 | .60 [.13, ./6] | .0190* | .00[.00, .37] | 1.0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_SLF | 1.58 | 1.02 | .88 | .00 | .55 [.23, .92] | .0008* | .34 [.00, .64] | .1584 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | | 1.40 | 0.87 | .// | .20 | .00[.12,.01] 39[08_84] | .0194* | .00[.00, .47] | 0391* |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | | 1.40 | 0.41 | .01 | 37 | 70[13_83] | .0143 | 00[00_45] | 1 0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_SS D_EC | 1.46 | 0.53 | .69 | .80 | .04 [.00, .45] | .8128 | .71 [.33, .83] | .0016* |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D UF | 1.40 | 0.23 | .21 | .13 | .28 [.00, .57] | .4860 | .00 [.00, .38] | 1.0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_PCT | 1.17 | 0.20 | .76 | .41 | .27 [.00, .77] | .3551 | .40 [.00, .74] | .2620 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_MCP | 1.46 | 0.63 | .74 | .66 | .00 [.00, .47] | 1.0000 | .70 [.25, .81] | .0071* |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_GCC | 1.98 | 1.41 | .62 | .28 | .57 [.00, .74] | .1253 | .01 [.00, .56] | .9848 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_BCC | 1.98 | 2.15 | .64 | .28 | .63 [.03, .78] | .0413* | .00 [.00, .47] | 1.0000 |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | D_SCC | 1.91 | 0.91 | .80 | .34 | .77 [.21, .86] | .0063* | .00 [.00, .51] | .9974 |
| D_latg 2.17 3.67 42 .35 .00 [.00,.60] 1.0000 .38 [.00,.57] .2879 D_Midbrain 1.26 0.09 .48 .40 .13 [.00,.68] .7350 .35 [.00,.62] .2788 ROI (Right) AD Variance (10 ⁻³) rMZ rDZ a² [95% Cl] p of a² c² [95% Cl] p of c² S_SP 1.56 1.01 .78 .41 .78 [.32,.87] .0024* .00 [.00,.40] 1.0000 S_Ging 1.54 0.34 .71 .48 .56 [.00,.83] .0528* .16 [.00,.62] .6139 S_SF 1.59 1.04 .86 .75 .50 [.15, 90] .0047* .36 [.00,.67] .1515 S_MF 1.52 0.62 .81 .73 .25 [.00,.72] .1863 .55 [.09,.80] .023* S_PrC 1.45 0.59 .81 .80 .39 [.02,.86] .0373* .43 [.00,.73] .0686 S_PrC 1.40 .055 .69 .54 | D_RLIC | 1.53 | 0.41 | .63 | .51 | .33 [.00, .80] | .2239 | .35 [.00, .71] | .2082 |
| Dinitiation 1.26 0.09 .48 .40 1.3 [.00, .86] .7330 .33 [.00, .82] .2788 ROI (Right) AD Variance (10 ⁻³) rMZ rDZ a² [95% C] p of a² c² [95% C] p of c² S_SF 1.56 1.01 .78 .41 .78 [.32, .87] .0024* .00 [.00, .40] 1.0000 S_Grig 1.54 0.34 .71 .48 .56 [.00, .83] .0528* .16 [.00, .62] .6139 S_MF 1.52 0.62 .81 .73 .25 [.00, .72] .1863 .55 [.09, .80] .0236* S_IF 1.53 0.83 .76 .72 .23 [.00, .78] .3293 .48 [.00, .76] .0715 S_PrC 1.45 0.59 .81 .80 .39 [.02, .86] .0373* .43 [.00, .73] .0686 S_PrC 1.46 0.55 .69 .54 .73 [.26, .89] .0042* .00 [.00, .44] .00000 S_L 1.12 .76 .39 .77 [.27 | D_Tap | 2.17 | 3.67 | .42 | .35 | .00[.00, .60] | 1.0000 | .38[.00, .57] | .2879 |
| ROI (Right)ADVariance (10 ⁻³)rMZrDZa² [95% CI]p of a²c² [95% CI]p of c²S_SP1.561.01.78.41.78 [.32, .87].0024*.00 [.00, .40]1.0000S_Cing1.540.34.71.48.56 [.00, .83].0528*.16 [.00, .62].6139S_SF1.591.04.86.75.50 [.15, .90].0047*.36 [.00, .67].1515S_MF1.520.62.81.73.25 [.00, .72].1863.55 [.09, .80].0236*S_IF1.530.83.76.72.23 [.00, .78].3293.48 [.00, .76].0715S_PC1.450.59.81.80.39 [.02, .86].0373*.43 [.00, .73].0686S_PcC1.400.55.69.54.73 [.26, .89].0042*.07 [.00, .47].7673S_A1.570.82.80.56.54 [.11, .88].0149*.26 [.00, .63].3178S_PcLu1.521.12.76.39.77 [.27, .87].0041*.00 [.00, .44]1.0000S_Cu1.400.88.62.46.51 [.00, .80].1149.15 [.00, .60].5861S_L1.460.87.74.14.63 [.07, .77].0292*.00 [.00, .47].10000S_So1.510.97.60.45.71 [.15, .86].0169*.03 [.00, .66].2561S_ID1.540.83.54.50.29 [.00, .76].3771 | D_IVIIdbrain | 1.26 | 0.09 | .48 | .40 | .13[.00, .68] | .7350 | .35 [.00, .62] | .2788 |
| S_SP 1.56 1.01 .78 .41 .78 [.32, .87] .0024* .00 [.00, .40] 1.0000 S_Cing 1.54 0.34 .71 .48 .56 [.00, .83] .0528* .16 [.00, .62] .6139 S_SF 1.59 1.04 .86 .75 .50 [.15, .90] .0047* .36 [.00, .67] .1515 S_MF 1.52 0.62 .81 .73 .25 [.00, .72] .1863 .55 [.09, .80] .0236* S_IF 1.53 0.83 .76 .72 .23 [.00, .78] .3293 .48 [.00, .76] .0715 S_PrC 1.45 0.59 .81 .80 .39 [.02, .86] .0373* .43 [.00, .73] .0686 S_PrC 1.40 0.55 .69 .54 .73 [.26, .89] .0042* .07 [.00, .47] .7673 S_Cu 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.40 | ROI (Right) | AD | Variance (10 ⁻³) | rMZ | rDZ | a ² [95% CI] | p of a ² | c ² [95% Cl] | p of c ² |
| S_Cing 1.54 0.34 .71 .48 .56 [00, .83] .0528* .16 [.00, .62] .6139 S_SF 1.59 1.04 .86 .75 .50 [.15, .90] .0047* .36 [.00, .67] .1515 S_MF 1.52 0.62 .81 .73 .25 [.00, .72] .1863 .55 [.09, .80] .0236* S_Fr 1.53 0.83 .76 .72 .23 [.00, .78] .3293 .48 [.00, .76] .0715 S_PrC 1.45 0.59 .81 .80 .39 [.02, .86] .0373* .43 [.00, .47] .7673 S_A 1.57 0.82 .80 .56 .54 [.11, .88] .0149* .26 [.00, .63] .3178 S_Cu 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.46 0.87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .47] .1000 S_Fu 1.50 0.78 .40 .53 .36 [.00, .79] .2774 .27 [.00, .64] .2968 S_SO 1.51 <t< td=""><td>S_SP</td><td>1.56</td><td>1.01</td><td>.78</td><td>.41</td><td>.78 [.32, .87]</td><td>.0024*</td><td>.00 [.00, .40]</td><td>1.0000</td></t<> | S_SP | 1.56 | 1.01 | .78 | .41 | .78 [.32, .87] | .0024* | .00 [.00, .40] | 1.0000 |
| S_SF 1.59 1.04 .86 .75 .50 [.15, .90] .004/* .36 [.00, .67] .1515 S_MF 1.52 0.62 .81 .73 .25 [.00, .72] .1863 .55 [.09, .80] .0236* S_IF 1.53 0.83 .76 .72 .23 [.00, .78] .3293 .48 [.00, .76] .0715 S_PrC 1.45 0.59 .81 .80 .39 [.02, .86] .0373* .43 [.00, .73] .0686 S_PoC 1.40 0.55 .69 .54 .73 [.26, .89] .0042* .07 [.00, .47] .7673 S_A 1.57 0.82 .80 .56 .54 [.11, .88] .0149* .26 [.00, .63] .3178 S_PrCu 1.52 1.12 .76 .39 .77 [.27, .87] .0041* .00 [.00, .44] 1.0000 S_Cu 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.46 .87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .42] .00100 S_Fu 1.50 | S_Cing | 1.54 | 0.34 | .71 | .48 | .56 [.00, .83] | .0528* | .16 [.00, .62] | .6139 |
| S_MF 1.52 0.62 .81 .73 .25 [.00, .72] .1863 .55 [.09, .80] .0236* S_IF 1.53 0.83 .76 .72 .23 [.00, .78] .3293 .48 [.00, .76] .0715 S_PrC 1.45 0.59 .81 .80 .39 [.02, .86] .0373* .43 [.00, .73] .0686 S_PoC 1.40 0.55 .69 .54 .73 [.26, .89] .0042* .07 [.00, .47] .7673 S_A 1.57 0.82 .80 .56 .54 [.11, .88] .0149* .26 [.00, .63] .3178 S_PrCu 1.52 1.12 .76 .39 .77 [.27, .87] .0041* .00 [.00, .44] 1.0000 S_Cu 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.46 0.87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .44] .0000 S_Fu 1.50 0.78 .40 .53 .36 [.00, .76] .3771 .32 [.00, .64] .2968 S_LO 1.51 | S_SF | 1.59 | 1.04 | .86 | .75 | .50[.15, .90] | .0047* | .36 [.00, .67] | .1515 |
| S_IP 1.33 0.83 .76 .72 .23 [.00, 76] .3293 .46 [.00, 76] .0715 S_PrC 1.45 0.59 .81 .80 .39 [.02, .86] .0373* .43 [.00, .73] .0686 S_PrC 1.40 0.55 .69 .54 .73 [.26, .89] .0042* .07 [.00, .47] .7673 S_A 1.57 0.82 .80 .56 .54 [.11, .88] .0149* .26 [.00, .63] .3178 S_PrCu 1.52 1.12 .76 .39 .77 [.27, .87] .0041* .00 [.00, .44] 1.0000 S_Cu 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.46 0.87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .47] 1.0000 S_Fu 1.50 0.78 .40 .53 .36 [.00, .79] .2774 .27 [.00, .64] .2968 S_SO 1.51 0.97 .60 .45 .71 [.15, .86] .0169* .03 [.00, .66] .2561 S_MO 1.54 | S_MF | 1.52 | 0.62 | .81 | ./3 | .25 [.00, .72] | .1863 | .55[.09, .80] | .0236* |
| S_PrC 1.40 0.57 .61 .60 .57 [.02, .60] .0573 .40 [.00, .73] .0000 S_PoC 1.40 0.55 .69 .54 .73 [.26, .89] .0042* .07 [.00, .47] .7673 S_A 1.57 0.82 .80 .56 .54 [.11, .88] .0149* .26 [.00, .63] .3178 S_PrCu 1.52 1.12 .76 .39 .77 [.27, .87] .0041* .00 [.00, .44] 1.0000 S_Cu 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.46 0.87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .47] 1.0000 S_Fu 1.50 0.78 .40 .53 .36 [.00, .79] .2774 .27 [.00, .64] .2968 S_SO 1.51 0.97 .60 .45 .71 [.15, .86] .0169* .03 [.00, .46] .8963 S_IO 1.54 0.83 .54 .50 .29 [.00, .76] .3771 .32 [.00, .66] .2561 S_MO 1.54 | S_IF | 1.53 | 0.63 | ./0 | ./2 | .23 [.00, .76] | .3273 | .40[.00, .70] | .0715 |
| S_A 1.57 0.52 0.57 1.54 1.51(2), 0.71 1.042 0.01(20, 0.71) 1.073 S_A 1.57 0.82 80 56 54 [11, 88] 0.0142* 2.6 [00, 6.3] 3.178 S_PrCu 1.52 1.12 .76 .39 .77 [.27, 87] 0.041* 0.0 [.00, .44] 1.0000 S_Cu 1.40 0.88 .62 .46 .51 [.00, 80] .1149 .15 [.00, .60] .5861 S_L 1.46 0.87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .47] 1.0000 S_Fu 1.50 0.78 .40 .53 .36 [.00, .79] .2774 .27 [.00, .64] .2968 S_SO 1.51 0.97 .60 .45 .71 [.15, 86] .0169* .03 [.00, .46] .8963 S_IOD 1.54 0.83 .54 .50 .29 [.00, .76] .3771 .32 [.00, .66] .2561 S_MO 1.54 0.81 .64 .51 .41 [.00, .81] .1601 .27 [.00, .67] .3218 S_ST 1.53 0.57< | S PoC | 1.45 | 0.57 | .01 | .00 | 73 [26 89] | .0373 | .43[.00, .73] | .0000 |
| S_PrCu 1.52 1.12 .76 .39 .77 [.27, .87] .0041* .00 [.00, .44] 1.0000 S_Cu 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.46 0.87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .47] 1.0000 S_Fu 1.50 0.78 .40 .53 .36 [.00, .79] .2774 .27 [.00, .64] .2968 S_SO 1.51 0.97 .60 .45 .71 [.15, .86] .0169* .03 [.00, .46] .8963 S_IO 1.54 0.83 .54 .50 .29 [.00, .76] .3771 .32 [.00, .66] .2561 S_MO 1.54 0.81 .64 .51 .41 [.00, .81] .1601 .27 [.00, .67] .3218 S_ST 1.53 0.57 .78 .62 .51 [.09, .87] .0198* .30 [.00, .65] .2365 S_IT 1.59 0.80 .65 .23 .73 [.39, .86] .0025* .00 [.00, .22] 1.0000 S_LFO 1.55 | S_10C | 1.40 | 0.82 | 80 | 56 | 54 [11 88] | .0042 0149* | 26[00, 63] | 3178 |
| S_Cu 1.40 0.88 .62 .46 .51 [.00, .80] .1149 .15 [.00, .60] .5861 S_L 1.46 0.87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .47] 1.0000 S_Fu 1.50 0.78 .40 .53 .36 [.00, .79] .2774 .27 [.00, .64] .2968 S_SO 1.51 0.97 .60 .45 .71 [.15, .86] .0169* .03 [.00, .46] .8963 S_IO 1.54 0.83 .54 .50 .29 [.00, .76] .3771 .32 [.00, .66] .2561 S_MO 1.54 0.81 .64 .51 .41 [.00, .81] .1601 .27 [.00, .65] .2318 S_ST 1.53 0.57 .78 .62 .51 [.09, .87] .0198* .30 [.00, .65] .2365 S_IT 1.59 0.80 .65 .23 .73 [.39, .86] .0025* .00 [.00, .22] 1.0000 S_MT 1.64 0.90 .77 .49 .67 [.14, .86] .0139* .09 [.00, .54] .7431 S_LFO 1.55 < | S PrCu | 1.52 | 1.12 | .76 | .39 | .77 [.27, .87] | .0041* | .00 [.00, .44] | 1.0000 |
| S_L 1.46 0.87 .74 .14 .63 [.07, .77] .0292* .00 [.00, .47] 1.0000 S_Fu 1.50 0.78 .40 .53 .36 [.00, .79] .2774 .27 [.00, .64] .2968 S_SO 1.51 0.97 .60 .45 .71 [.15, .86] .0169* .03 [.00, .46] .8963 S_IO 1.54 0.83 .54 .50 .29 [.00, .76] .3771 .32 [.00, .66] .2561 S_MO 1.54 0.81 .64 .51 .41 [.00, .81] .1601 .27 [.00, .67] .3218 S_ST 1.53 0.57 .78 .62 .51 [.09, .87] .0198* .30 [.00, .65] .2365 S_IT 1.59 0.80 .65 .23 .73 [.39, .86] .0025* .00 [.00, .22] 1.0000 S_MT 1.64 0.90 .77 .49 .67 [.14, .86] .0139* .09 [.00, .54] .7431 S_LFO 1.55 1.11 .79 .59 .41 [.00, .83] .1081 .31 [.00, .71] .2834 S_MFO 1.58 | S Cu | 1.40 | 0.88 | .62 | .46 | .51 [.00, .80] | .1149 | .15 [.00, .60] | .5861 |
| S_Fu 1.50 0.78 .40 .53 .36 [.00, .79] .2774 .27 [.00, .64] .2968 S_SO 1.51 0.97 .60 .45 .71 [.15, .86] .0169* .03 [.00, .46] .8963 S_IO 1.54 0.83 .54 .50 .29 [.00, .76] .3771 .32 [.00, .66] .2561 S_MO 1.54 0.81 .64 .51 .41 [.00, .81] .1601 .27 [.00, .67] .3218 S_ST 1.53 0.57 .78 .62 .51 [.09, .87] .0198* .30 [.00, .65] .2365 S_IT 1.59 0.80 .65 .23 .73 [.39, .86] .0025* .00 [.00, .22] 1.0000 S_MT 1.64 0.90 .77 .49 .67 [.14, .86] .0139* .09 [.00, .54] .7431 S_LFO 1.55 1.11 .79 .59 .41 [.00, .83] .1081 .31 [.00, .71] .2834 S_MFO 1.58 1.20 .67 .51 .58 [.00, .80] .0703 .08 [.00, .58] .8005 S_SM 1.53 < | s_L | 1.46 | 0.87 | .74 | .14 | .63 [.07, .77] | .0292* | .00 [.00, .47] | 1.0000 |
| S_SO 1.51 0.97 .60 .45 .71 [.15, .86] .0169* .03 [.00, .46] .8963 S_IO 1.54 0.83 .54 .50 .29 [.00, .76] .3771 .32 [.00, .66] .2561 S_MO 1.54 0.81 .64 .51 .41 [.00, .81] .1601 .27 [.00, .67] .3218 S_ST 1.53 0.57 .78 .62 .51 [.09, .87] .0198* .30 [.00, .65] .2365 S_IT 1.59 0.80 .65 .23 .73 [.39, .86] .0025* .00 [.00, .22] 1.0000 S_MT 1.64 0.90 .77 .49 .67 [.14, .86] .0139* .09 [.00, .54] .7431 S_LFO 1.55 1.11 .79 .59 .41 [.00, .83] .1081 .31 [.00, .71] .2834 S_MFO 1.58 1.20 .67 .51 .58 [.00, .80] .0703 .08 [.00, .58] .8005 S_SM 1.53 0.74 .79 .63 .60 [.18, .8 | S_Fu | 1.50 | 0.78 | .40 | .53 | .36 [.00, .79] | .2774 | .27 [.00, .64] | .2968 |
| S_IO 1.54 0.83 .54 .50 .29 [.00, .76] .3771 .32 [.00, .66] .2561 S_MO 1.54 0.81 .64 .51 .41 [.00, .81] .1601 .27 [.00, .67] .3218 S_ST 1.53 0.57 .78 .62 .51 [.09, .87] .0198* .30 [.00, .65] .2365 S_IT 1.59 0.80 .65 .23 .73 [.39, .86] .0025* .00 [.00, .22] 1.0000 S_MT 1.64 0.90 .77 .49 .67 [.14, .86] .0139* .09 [.00, .54] .7431 S_LFO 1.55 1.11 .79 .59 .41 [.00, .83] .1081 .31 [.00, .71] .2834 S_MFO 1.58 1.20 .67 .51 .58 [.00, .80] .0703 .08 [.00, .58] .8005 S_SM 1.53 0.74 .79 .63 .60 [.18, .89] .0071* .21 [.00, .58] .3878 | S_SO | 1.51 | 0.97 | .60 | .45 | .71 [.15, .86] | .0169* | .03 [.00, .46] | .8963 |
| S_MO 1.54 0.81 .64 .51 .41 [.00, .81] .1601 .27 [.00, .67] .3218 S_ST 1.53 0.57 .78 .62 .51 [.09, .87] .0198* .30 [.00, .65] .2365 S_IT 1.59 0.80 .65 .23 .73 [.39, .86] .0025* .00 [.00, .22] 1.0000 S_MT 1.64 0.90 .77 .49 .67 [.14, .86] .0139* .09 [.00, .54] .7431 S_LFO 1.55 1.11 .79 .59 .41 [.00, .83] .1081 .31 [.00, .71] .2834 S_MFO 1.58 1.20 .67 .51 .58 [.00, .80] .0773 .08 [.00, .58] .8005 S_SM 1.53 0.74 .79 .63 .60 [.18, .89] .0071* .21 [.00, .58] .3878 | S_IO | 1.54 | 0.83 | .54 | .50 | .29 [.00, .76] | .3771 | .32 [.00, .66] | .2561 |
| S_S1 1.53 0.57 .78 .62 .51(09,.87) .0198* .30(.00,.65) .2365 S_IT 1.59 0.80 .65 .23 .73(.39,.86) .0025* .00(.00,.22) 1.0000 S_MT 1.64 0.90 .77 .49 .67[.14,.86] .0139* .09[.00,.54] .7431 S_LFO 1.55 1.11 .79 .59 .41[.00,.83] .1081 .31[.00,.71] .2834 S_MFO 1.58 1.20 .67 .51 .58[.00,.80] .0773 .08[.00,.58] .8005 S_SM 1.53 0.74 .79 .63 .60[.18,.89] .0071* .21[.00,.58] .3878 | S_MO | 1.54 | 0.81 | .64 | .51 | .41 [.00, .81] | .1601 | .27 [.00, .67] | .3218 |
| s_in i.37 0.60 .65 .23 ./3[.37, 36] .0025* .00[.00, .22] 1.0000 S_MT 1.64 0.90 .77 .49 .67 [.14, .86] .0139* .09 [.00, .54] .7431 S_LFO 1.55 1.11 .79 .59 .41 [.00, .83] .1081 .31 [.00, .71] .2834 S_MFO 1.58 1.20 .67 .51 .58 [.00, .80] .0703 .08 [.00, .58] .8005 S_SM 1.53 0.74 .79 .63 .60 [.18, .89] .0071* .21 [.00, .58] .3878 | 5_51 s_itt | 1.53 | 0.5/ | ./8 | .62 | .51[.09, .87] | .0198* | .30 [.00, .65] | .2365 |
| S_INT 1.04 0.70 .77 .47 .07 [.14,.06] .0137 .07 [.00,.54] .7431 S_LFO 1.55 1.11 .79 .59 .41 [.00,.83] .1081 .31 [.00,.71] .2834 S_MFO 1.58 1.20 .67 .51 .58 [.00,.80] .0703 .08 [.00,.58] .8005 S_SM 1.53 0.74 .79 .63 .60 [.18,.89] .0071* .21 [.00,.58] .3878 | 5_11 S_MT | 1.37 | 0.00 | כט. דד | .23 | ./3[.37,.80] | .0025* | .00[.00, .22] | 1.0000 |
| S_EI C 1.55 1.11 .77 .57 .41 [.00, .03] .1001 .51 [.00, .71] .2634 S_MFO 1.58 1.20 .67 .51 .58 [.00, .80] .0703 .08 [.00, .58] .8005 S_SM 1.53 0.74 .79 .63 .60 [.18, .89] .0071* .21 [.00, .58] .3878 | | 1.04 | 0.70 | .77 | .47 59 | .07 [.14, .00] 41 [00 83] | 1081 | 31[00 71] | ./431 282/ |
| S_SM 1.53 0.74 .79 .63 .60 [.18, .89] .0071* .21 [.00, .58] .3878 | S MFO | 1.58 | 1.20 | .67 | .51 | .58 [.0080] | .0703 | .08 [.0058] | .8005 |
| | S_SM | 1.53 | 0.74 | .79 | .63 | .60 [.18, .89] | .0071* | .21 [.00, .58] | .3878 |

| TABLE 4 | (c) |
|----------|-----|
| Continue | |

| ROI (Left) | FA | Variance (10 ⁻³) | rMZ | rDZ | a ² [95% CI] | p of a ² | c ² [95% CI] | p of c ² | | |
|------------|------|------------------------------|-----|-----|-------------------------|---------------------|-------------------------|---------------------|--|--|
| S_R | 1.49 | 0.64 | .62 | .55 | .25 [.00, .73] | .4529 | .31 [.00, .65] | .3034 | | |
| S_Cerebel | 1.19 | 0.41 | .82 | .45 | .76 [.27, .89] | .0024* | .04 [.00, .49] | .8844 | | |
| D_CST | 1.24 | 0.27 | .44 | .45 | .00 [.00, .52] | 1.0000 | .44 [.00, .62] | .0753 | | |
| D_SCP | 1.51 | 0.45 | .48 | .24 | .57 [.00, .76] | .0531 | .00 [.00, .37] | 1.0000 | | |
| D_CP | 1.54 | 0.19 | .22 | .14 | .16 [.00, .49] | .7418 | .05 [.00, .40] | .8872 | | |
| D_ALIC | 1.38 | 0.28 | .70 | .45 | .31 [.00, .77] | .3003 | .34 [.00, .71] | .3005 | | |
| D_PLIC | 1.48 | 0.19 | .59 | .39 | .00 [.00, .65] | 1.0000 | .53 [.00, .69] | .1199 | | |
| D_PTR | 1.81 | 2.28 | .78 | .18 | .74 [.32, .85] | .0023* | .00 [.00, .36] | 1.0000 | | |
| D_ACR | 1.74 | 1.50 | .92 | .70 | .50 [.22, .93] | .0002** | .42 [.00, .69] | .0845 | | |
| D_SCR | 1.61 | 1.46 | .87 | .62 | .71 [.31, .92] | .0004** | .16 [.00, .55] | .5437 | | |
| D_PCR | 1.82 | 2.41 | .93 | .46 | .92 [.52, .95] | .0000*** | .00 [.00, .40] | 1.0000 | | |
| D_CGC | 1.50 | 0.54 | .71 | .47 | .61 [.08, .85] | .0262* | .13 [.00, .56] | .6275 | | |
| D_CGH | 1.44 | 0.24 | .71 | .52 | .50 [.00, .85] | .0504 | .25 [.00, .64] | .3480 | | |
| D_FxST | 1.53 | 0.50 | .68 | .19 | .73 [.40, .86] | .0020* | .00 [.00, .20] | 1.0000 | | |
| D_SLF | 1.61 | 1.30 | .91 | .69 | .64 [.32, .95] | .0000*** | .28 [.00, .60] | .2363 | | |
| D_SFO | 1.35 | 0.67 | .75 | .48 | .64 [.11, .85] | .0187* | .11 [.00, .55] | .7131 | | |
| D_IFO | 1.48 | 0.42 | .80 | .74 | .34 [.02, .78] | .0392* | .50 [.08, .77] | .0251* | | |
| D_SS | 1.71 | 0.78 | .74 | .03 | .76 [.48, .88] | .0005** | .00 [.00, .16] | 1.0000 | | |
| D_EC | 1.40 | 0.47 | .81 | .76 | .14 [.00, .54] | .4040 | .66 [.27, .84] | .0036* | | |
| D_UF | 1.29 | 0.18 | .53 | .25 | .53 [.00, .73] | .1011 | .00 [.00, .45] | 1.0000 | | |
| D_PCT | 1.14 | 0.14 | .72 | .29 | .61 [.00, .80] | .0653 | .06 [.00, .61] | .8752 | | |
| D_MCP | 1.45 | 0.63 | .58 | .58 | .00 [.00, .39] | 1.0000 | .58 [.18, .72] | .0157* | | |
| D_GCC | 1.88 | 0.65 | .56 | .57 | .14 [.00, .72] | .6441 | .46 [.00, .70] | .1029 | | |
| D_BCC | 1.96 | 1.64 | .70 | .29 | .74 [.33, .86] | .0034* | .00 [.00, .32] | 1.0000 | | |
| D_SCC | 1.90 | 0.66 | .68 | .53 | .49 [.00, .81] | .0955 | .20 [.00, .65] | .4868 | | |
| D_RLIC | 1.57 | 0.32 | .61 | .51 | .43 [.00, .79] | .1708 | .22 [.00, .64] | .4350 | | |
| D_Tap | 2.16 | 3.76 | .76 | .46 | .54 [.02, .84] | .0397* | .20 [.00, .63] | .4904 | | |
| D_Midbrain | 1.21 | 0.08 | .42 | .57 | .00 [.00, .48] | 1.0000 | .49 [.03, .65] | .0392* | | |

Note: See Appendix for abbreviations of regions of interest (ROIs); FA = fractional anisotropy, RD = radial diffusivity, AD = axial diffusivity, $a^2 = genetic contribution$, $c^2 = common environmental contribution$, MZ = monozygotic, DZ = dizygotic, CI = confidence interval, S = superficial white matter, D = deep white matter. The unit of RD and AD traits is $10^{-3}mm^2s^{-1}$; other measures are unitless; genetic or environmental effects with $p \le .0005$ are highlighted.

 $^{*} = .0005 , <math>^{**} = .00001 , <math>^{***} p \le .00001$.

et al., 2010; Lenroot & Giedd, 2008). For example, cumulative genetic effects determine the endpoint of development, while early trajectories of development may be influenced more by environmental factors.

Relationships Between Genetic Variation and Maturation Status

The significant correlations between heritability and the mean diffusion levels of RD and AD suggest that genetic variation in WM microstructure may be modulated by maturation status in neonates. Membrane proliferation, one major WM maturation process, would lead to decreased RD and AD, and unchanged FA; fiber myelination, another major maturation process, would correspond to decreased RD, increased FA, and unchanged AD (Dubois et al., 2008). Studies in animal models that manipulate cerebral myelination levels showed that RD is highly sensitive to regional demyelination (Song et al., 2003). Infant WM development studies (Gao et al., 2009, Geng et al., 2011) observed significant increases in FA and significant reductions in RD and AD during the development of the first years of life. The positive correlation (r = .17, p < .00001) between RD heritability estimates and mean levels of RD suggests that fibers with higher maturation in neonates are possibly influenced more by prenatal common or unique environmental factors.

There was no significant association between estimates of heritability for FA and the average FA value across all ROIs. Fibers with higher FA values may not necessarily correspond to higher maturation degree in terms of myelination compared to other fibers at the same time point. Dense well-organized fibers (e.g., corpus callosum) may present high FA values when unmyelinated. Measures taking into account complex fiber structures based on high angular resolution diffusion imaging techniques may better reflect fiber maturation. With the current data acquisition limitation, joint analysis of FA and RD may reflect the maturation status better than univariate analyses of each measure. After separating the WM into four groups, based on high and low mean values of FA and RD, we noticed that major projection fibers fall in the HL group, consistent with previous infant WM maturation studies (Dubois et al., 2006; Yakovlev & Lecours, 1967). These projection fibers show low heritability estimates of RD and FA in general. Cerebellum is in the LL group with high genetic effect. The HH group includes the corpus callosum and thalamocortical fibers, which are less mature than the HL group and show high heritability estimates. The LH group contains several superficial WM regions with higher genetic control compared to the HL

group. These analyses show a promising beginning to the study of genetic and environmental variation in neuronal maturation.

It is possible that differences in heritability across regions could be driven by changes in the reliability of the measures. The reliability of the measures is likely to be higher in regions with higher FA values. If differences in heritability were driven by the reliability of the measures, a positive correlation, rather than no correlation, would be detected between FA and FA heritability. It is also possible that the sample size of this study may be insufficient to detect significant additive genetic effects, which may explain the lack of significant heritability for some measures. Clarification of these issues is expected to be addressed as sample size increases over time and as longitudinal data become available in our ongoing longitudinal study.

We adapted a recently developed WM atlas for singletons with 130 ROIs to parcellate our neonatal DTI images automatically in twins. WM differences between non-twins and twins may be apparent, especially among neonates. Subsequently, we warped the twin atlas used in this study together with the ROIs to our population-specific atlas, which is expected to reduce any effect caused by using the non-twin atlas. Compared to tractography-based approaches, which may only focus on major or more visible fiber tracts, our approach has a wider coverage of the WM. Due to the relatively low signal-to-noise ratio of the neonatal data (smaller brain size and shorter scanning time constrained by the baby's sleeping time), the voxel-based DTI analysis used by several DTI heritability studies in pediatric and adult groups may prove difficult to apply to neonatal brain image data. The ROI-based average regional measure used here is one way to overcome this limitation, as it decreases spatial resolution to increase data reliability. Future efforts to optimize the neonatal DTI atlas are expected to decrease measurement variability.

While there were significant mean differences for ROIs by gender, specific models testing the contribution of sex to the etiology of WM development could not be tested due to the absence of opposite-sex DZ twin pairs. Consequently, these results cannot resolve questions of genetic and environmental heterogeneity by gender in the development of WM. Nevertheless, these results provide comprehensive insight into the genetic and environmental contributions to WM during early human development.

The statistical tests of the genetic and environmental components (shown in Table 4) were not corrected for multiple comparisons. In the present context we do not seek to establish the statistical significance of the most heritable region, which would be analogous to, for example, correcting the p-value of the most significant SNP association in a genome-wide association study. Instead we wish to report the parameter estimates across a large number of different regions. A Q-Q plot would show that there is ample evidence of departure from the expectation under

Conclusion

We have conducted the first twin study of neonatal brain WM microstructure with DTI. In general, substantial heritability of the average DTI parameters was found over the whole-brain WM and is higher than that which has been reported for adults. Genetic and environmental effects are heterogeneous and display a wide range in magnitude over different WM regions. Significant positive correlation between heritability and diffusion measures suggests that regional genetic effects may be modulated by maturation status of the neonatal brain-the more mature the region, the less heritable its variation. Common environmental effects are present in fewer regions that tend to be characterized by low RD. Our joint diffusion parameter analysis suggests that multivariate modeling approaches that jointly analyze the diffusion parameters are promising approaches to estimating maturation status and its relationship with genetic and environmental effects.

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Appendix

List of Abbreviations of Regions of Interest (ROIs)

A, Angular gyrus

- ACR, Anterior corona radiata
- ALIC, Anterior limb of internal capsule

BCC, Body of corpus callosum

Cerebel, Cerebellum cortex

- CGC, Cingulum (cingulate gyrus)
- CGH, Cingulum (hippocampus)

Cing, Cingulate gyrus

CP, Cerebral peduncle

CST, Corticospinal tract

Cu, Cuneus

EC, External capsule

Fu, Fusiform gyrus

Fx/ST, Fornix (cres)/Stria terminalis (cannot be resolved

with current resolution)

GCC, Genu of corpus callosum

IF, Inferior frontal gyrus

IFO, Inferior fronto-occipital fasciculus

IO, Inferior occipital gyrus

IT, Inferior temporal gyrus

L, Lingual gyrus

LFO, Lateral fronto-orbital gyrus

MCP, Middle cerebellar peduncle

MF, Middle frontal gyrus

MFO, Middle fronto-orbital gyrus

Midbrain

MO, Middle occipital gyrus

MT, Middle temporal gyrus

PCR, Posterior corona radiata

PCT, Pontine crossing tract (a part of MCP)

PLIC, Posterior limb of internal capsule

PoC, Post-central gyrus

PrC, Pre-central gyrus

PrCu, Pre-cuneus

PTR, Posterior thalamic radiation (includes optic radiation)

r peduncle

R, Rectus gyrus

RLIC, Retrolenticular part of internal capsule

SCC, Splenium of corpus callosum

SCP, Superior

SCR, Superior corona radiate SF, Superior frontal gyrus SFO, Superior fronto-occipital fasciculus (could be a part of ALIC) SLF, Superior longitudinal fasciculus SM, Supramarginal gyrus SO, Superior occipital gyrus SP, Superior parietal lobule SS, Sagittal stratum (includes ILF and IFO) ST, Superior temporal gyrus Tap, Tapetum UF, Uncinate fasciculus