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Within-subject test-retest reliability of the atlas-based cortical volume measurement in the rat brain: A voxel-based morphometry study

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Abstract

Background—Various neurological and psychological disorders are related to cortical volume changes in specific brain regions, which can be measured *in vivo* using structural magnetic resonance imaging (sMRI). There is an increasing interest in MRI studies using rat models, especially in longitudinal studies of brain disorders and pharmacologic interventions. However, morphometric changes observed in sMRI are only meaningful if the measurements are reliable. To date, a systematic evaluation of the test-retest reliability of the morphometric measures in the rat brain is still lacking.

New method—We rigorously evaluated the test-retest reliability of morphometric measures derived from the voxel-based morphometry (VBM) analysis. 37 Sprague-Dawley rats were scanned twice at an interval of six hours and the gray matter volume was estimated using the VBM-DARTEL method. The intraclass coefficient, percent volume change and Pearson correlation coefficient were used to evaluate the reliability in 96 subregions of the rat brain.

Results—Most subregions showed excellent test-retest reliabilities within an interval of 6 h while a few regions demonstrated lower reliability, especially in the retrosplenial granular cortex. The results were consistent between different methods of reliability assessment.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.jneumeth.2018.06.022>.

Comparison with existing method—To the best of our knowledge, this is the first study to quantify the test-retest reliability of the VBM measurements of the rat brain.

Conclusion—Atlas-based cortical volume of the rat brain can be reliably estimated using the VBM-DARTEL method in most subregions. However, findings in subregions with lower reliability must be interpreted with caution.

Keywords

Test-retest reliability; Voxel-based morphometry; Intraclass coefficient; Rat brain

1. Introduction

Rat models of brain diseases have been widely used in translational neuroscience studies due to low cost and stable behavior. Compared to the human study, rat models are particularly suitable for the investigation of longitudinal changes of brain structure and function associated with a specific disease or pharmacological intervention as the brain characteristics can be measured *in vivo* over the lifespan. Brain volume is an important indicator for macroscopic structural changes, which could be captured non-invasively using MRI not only in humans but also in animal models (Quallo et al., 2009; Badea et al., 2010; Ellegood et al., 2010, 2013; Powell et al., 2016; Steventon et al., 2016). Many studies used the deformation based morphometry (DBM) method to measure the whole brain volume alternations, which it is dependent on the accuracy of imaging registration (van Eede et al., 2013). Another category of method is voxel-based morphometry (Ashburner and Friston, 2000), which can objectively estimate the voxel-wise whole brain cortical volumes without any prior assumption (Chetelat et al., 2005; Baron et al., 2001). Recent development in this line of research includes the improved registration pipeline called diffeomorphic anatomical registration through exponentiated lie algebra (DARTEL) (Ashburner, 2007). The VBM-DARTEL analysis improves inter-subject alignment by registering individual structural images to an asymmetric template generated within each group, and has demonstrated great promise in the studies of human psychiatric and neurological disorders (Mak et al., 2011; Asami et al., 2012; Matsuda et al., 2012; Liu et al., 2014). The VBM-DARTEL analysis can be easily transposed to rat models and only requires some specific preprocessing for the rat MRI data. Recent studies have demonstrated the usefulness of this method in animal studies. For example, Sumiyoshi et al. reported that regional gray matter volume increased following 7 days of voluntary wheel running exercise in rats (Sumiyoshi et al., 2014); Suzuki et al. (2013, 2015) found structural abnormalities in the hippocampus in rat models of cardiopulmonary resuscitation and heart failure. Furthermore, it is also possible to relate macroscopic cortical volume/density measures with microscopic changes in the animal brain. A recent study demonstrated that the VBM signal is correlated with the dendritic spine density in the mice brain (Keifer et al., 2015), suggesting the physiological significance of VBM measurements.

A vital question that has yet to be addressed is whether VBM measurements are reliable for quantitative studies of the rat brain. High within-subject test-retest reliability is a prerequisite of all imaging biomarkers. Identifying brain regions where cortical volume can be reliably measured will inform the interpretability of findings, particularly in longitudinal

and cross-sectional MRI studies. Due to its critical importance, the test-retest reliability of structural and functional MRI measures was carefully examined in the human brain (Zuo and Xing, 2014; Andellini et al., 2015; Laumann et al., 2015; Mueller et al., 2015; Seiger et al., 2015). However, to date, the test-retest reliability of MRI measures in the rat brain has not been systematically evaluated, limiting the usage of MRI for quantitative analyses of brain anatomy in rat models. To address this challenge, here, we studied the rat brain using a test-retest design and examined the reliability of cortical volume derived from the VBM-DARTEL analysis. The intraclass coefficient (ICC), percent volume change (PVC) and Pearson correlation coefficient (PCC) were calculated to comprehensively evaluate the test-retest reliability of the cortical volume of each subregion in the rat brain. We also investigated how the test-retest reliability of cortical volume measurements might be affected by choices of data processing parameters such as smoothing (Shen and Sterr, 2013).

2. Material and methods

2.1. Animals

Thirty-seven 10-week-old Sprague-Dawley rats (male, 240–260 g; Charles River, Beijing, China) were used in the experiment. All rats were housed in a temperature-controlled home cage ($25^{\circ}\text{C} \pm 2$) with a 12 h light-night alternation (6 p.m. – 6 a.m. light off); the rats could freely access food and water at all times. All animal procedures were in accordance with the Animal Research: Reporting of In Vivo Experiments (ARRIVE) guidelines and approved by the ethical committee and the Institutional Review Board of Capital Medical University.

2.2. Experimental design

Test-retest reliability can be divided into two categories based on the interval between the repeated measures: long-term reliability implies repeated measurements within a few weeks or longer; short-term reliability duplicates measurements within a few hours. Long-term reliability of VBM measurements can be affected by various factors, including measurement noise, data processing methods, biological changes in the brain, stability of MRI equipment over time, and consistency of data collection procedure, etc. In the present study, we evaluated the short-term reliability of the VBM-DARTEL results by scanning the subjects twice at a short interval of 6 h, thus the influence of variance due to MRI equipment, data collection procedure, and possible biological changes was minimized.

2.3. MRI image acquisition

Prior to the MRI scan, each rat was placed into an inhalation chamber and administered preoperative anesthesia containing 5% isoflurane (mixed with oxygen and air). The anesthetized rat was then positioned in the MRI scanner bed, with the head immobilized by a tooth bar. A continuous flow of 1.5% isoflurane was used to retain anesthesia. After the preparations, the rat brain was scanned in a 7.0 T Bruker MRI scanner (16-cm horizontal diameter, equipped with transmit volume coil and a surface coil, Germany). High resolution structural images were acquired using RARE T2-weighted sequences: repetition time (TR) = 9000 ms, effect echo time (TE_{eff}) = 48 ms, RARE factor = 8, average number = 8, number of coronal slices = 54, slice thickness = 0.5 mm, slice gap = 0, field of view (FOV) = $32 \times 32 \text{ mm}^2$, matrix size = 256×256 voxels, voxel size = $125 \times 125 \mu\text{m}^2$. During the scan, the rats'

respiration rate was continuously monitored, and the isoflurane might be slightly adjusted to maintain a safe respiration rate (40–50 breaths per minute). The structural MRI scanning procedure of each rat lasted about forty minutes. The signal to noise ratio (SNR) is an important quality control index for structural MRI studies and there exist many ways for the calculation of SNR, such as those reported by Solis-Najera et al. (2015), Pohmann et al. (2016). In the present study, we selected a simple but effective approach for the calculation of SNR, which is defined as the ratio of the mean image intensity in the brain divided by the standard deviation of the intensity at background (Sumiyoshi et al., 2014). The SNR was evaluated for the test and the retest imaging data, respectively.

2.4. Image processing

The VBM-DARTEL analysis was performed using statistical parameter mapping software (SPM 8, Wellcome Department of Cognitive Neurology, London, UK), and the detailed procedures were similar to the previous study (Sumiyoshi et al., 2014). First, the original T2-weighted images (0.125 mm resolution) were resized with a scale factor of 10 (Biedermann et al., 2012) to roughly match the size of the rat brain template. The transformed images thus have a spatial resolution of 1.25 mm, however, there is no information loss by resizing the images because the data were not downsampled. This is a common procedure of VBM analysis for rat/mouse brain to facilitate coregistration (Biedermann et al., 2012; Suzuki et al., 2013, 2015; Sumiyoshi et al., 2014). The images were then realigned to adjust for head motion, and coregistered to the standard rat brain template (Valdes-Hernandez and Sumiyoshi, 2011). Every image was then segmented into gray matter (GM), white matter (WM) and cerebrospinal fluid (CSF) by the unified segmentation method (Ashburner and Friston, 2005). In this step, the bias correction images were generated and used for the segmentation process. The probabilistic GM, WM, and CSF maps of the rat template brain were selected as the tissue priors. In order to accurately register the individual GM, WM, and CSF maps to the corresponding template, the non-linear DARTEL algorithm was used for normalization, which included the following steps: (i) the group-specific (test/retest group) GM, WM, and CSF templates were respectively created by the DARTEL algorithm after 6 iterative computations; (ii) the individual GM, WM, and CSF images were spatially normalized to the group-specific templates, which used the Jacobian determinant to account for the expansion or contraction of brain regions; (iii) the group-specific templates were rigid-body aligned to the standard rat brain template, and the obtained affine transformation matrix was used to coregister the individual modulated GM, WM, and CSF images to the template space. Finally, a 2-mm FWHM Gaussian kernel, which is corresponding to a width of 0.2 mm in the original rat brain, was used to smooth all normalized GM, WM, and CSF images. To investigate how spatial smoothing may affect test-retest reliability, different Gaussian smooth kernels (4 mm, 6 mm, 8 mm, 10 mm) were used to smooth the normalized images.

2.5. Cortical volume calculation based on the standard atlas

The standard rat brain template provides a 96-subregion parcellation atlas (Fig. 1, see Supplemental Table 1 for detailed descriptions), and every subregion in the atlas was used as a mask. Only the GM images were used for the calculation of cortical volume. The cortical volume of each subregion was then calculated from the masked individual normalized GM

images using a publicly available MATLAB program (http://www.cs.ucl.ac.uk/staff/G.Ridgway/vbm/get_totals.m). In addition, the volume of the GM, WM, CSF, the left brain, the right brain and the whole brain (GM +WM +CSF) were also calculated for subsequent test-retest evaluation. Here, the left and right brain were the unpartitioned regions in the respective part of rat atlas.

2.6. Test-retest reliability

The test-retest reliability of cortical volume was evaluated using three different methods: the intraclass coefficient (ICC), the percent volume change (PVC), and the Pearson correlation coefficient (PCC).

The ICCs of all 96 cortical subregions were computed utilizing a two-way mixed model (i.e. ICC (3,1)) (Frassle et al., 2015) with the following equation:

$$ICC(3,1) = \frac{\sigma_{Between}^2 - \sigma_{within}^2}{\sigma_{Between}^2 + \sigma_{within}^2}$$

For each subregion, the PVC value was computed from the group mean of individual PVC, which was derived according to the following equation:

$$PVC = \frac{|Volume_{retest} - Volume_{test}|}{Volume_{test}}$$

The PCC is a conventional measure to reflect the similarity of two variables; therefore, the volumes of all 96 cortical subregions in the test and retest group were used to compute the PCC according to the following formula:

$$PCC = \frac{Cov(Volume_{test}, Volume_{retest})}{\sqrt{Var(Volume_{test})} \sqrt{Var(Volume_{retest})}}$$

3. Results

3.1. Test-retest reliability of atlas-based cortical volume measurement with VBM

No difference in data quality was observed between the test and retest groups. The SNR of the test and retest groups were both 28 ± 4 (mean $\pm$ standard deviation, $p = 0.104$; Paired t-test).

Atlas-based cortical volume measurements obtained using the VBMDARTEL analysis method showed high test-retest reliability in most regions. The mean ICC, PVC, and PCC across the 96 subregions were 0.937 ± 0.059 , $0.45\% \pm 0.53\%$, and 0.941 ± 0.054 (mean $\pm$ standard deviation). The test-retest reliability values of all subregions as measured by the ICC, PVC, and PCC (all P values were less than 0.001) are summarized in Table 1.

Similar to the test-retest measures in the human MRI studies (Zuo and Xing, 2014; Andellini et al., 2015), reliability could be categorized into five levels according to the ICC values: excellent ($ICC \geq 0.8$); good ($0.8 > ICC \geq 0.6$); moderate ($0.6 > ICC \geq 0.4$); low ($0.4 > ICC \geq 0.2$); and poor ($0.2 > ICC > 0$). Based on this categorization scheme, most subregions of the rat brain showed 'excellent' reliability, with only four subregions showing 'good' reliability: the left/right RSGb (No. 55 & 56, Table 1) and the left/right RSGc (No. 57 & 58, Table 1). These regions with lower reliability are shown in Fig. 2.

The PVC results were consistent with the ICC results. Eight regions displayed PVC values higher than 1.51% ($PVC_{mean} + 2 \times PVC_{SD}$), including the right amygdalopiriform transition area (APir, No. 8, Table 1), left medial entorhinal cortex (MEnt, No. 41, Table 1), the left/right RSGb (No. 55 & 56, Table 1), the left/right RSGc (No. 57 & 58, Table 1), and the left/right ventral intermediate entorhinal cortex (VIEnt, No. 95 & 96, Table 1). Only four regions showed PCC values lower than 0.83 ($PCC_{mean} - 2 \times PCC_{SD}$), including the left/right RSGb (No. 55 & 56, Table 1) and the left/right RSGc (No. 57, 58, Table 1).

The global measures of cortical volume also showed high test-retest reliability. The volume measurements of the GM, WM, CSF, the left brain, the right brain, and the whole brain all displayed excellent ICC values and high PCC values (Table 1). However, the CSF showed lower test-retest reliability than the GM and WM. The left and right brain volume were found to have lower test-retest reliabilities than the whole brain volume.

Finally, we found that the ICC, PCC and PVC values were highly correlated (ICC vs. PCC, $r = 0.990$; ICC vs. PVC, $r = -0.768$; PCC vs. PVC, $r = -0.683$, all $p < 0.001$), indicated consistent findings with different methods of reliability assessment.

3.2. The smoothing effect on test-retest reliability of VBM measures

Previous VBM studies in rat models have used smoothing kernels as large as 10 mm (Sumiyoshi et al., 2014). To investigate how reliability of VBM measures is dependent on smoothing, we applied different Gaussian smoothing kernels (4 mm, 6 mm, 8 mm, 10 mm) and reassessed test-retest reliability. We observed that a larger smoothing kernel could slightly reduce the volume estimation. Estimates of the whole brain volume based on different smoothing kernels were illustrated in Fig. 3. However, we found that different smoothing kernels did not significantly influence ICC and PCC (See Supplemental Table 2), although ICC and PCC were slightly enlarged with larger smoothing kernel (only a trend but not statistically significant).

4. Discussion

In the present study, we rigorously evaluated the test-retest reliability of the cortical volume of the rat brain as estimated by VBM-DARTEL analysis. Our results indicated excellent test-retest reliability in most cortical regions, suggesting that atlas-based cortical volume data derived from VBM-DARTEL analysis are robust and can be used as a quantitative measure of the rat brain anatomy for neurobiological studies. At the same time, some regions demonstrated relatively lower reliability, indicating the volumetric changes in these regions

must be interpreted with caution. We also found that moderate smoothing has little effect on test-retest reliability.

High test-retest reliability of the VBM-DARTEL method may be partially due to its improved registration. Compared to the Deformation Based Morphometry method, which does not use a *priori* structural knowledge during registration (van Eede et al., 2013), the VBM method first segments the brain with the help of a *priori* probability template to parcellate the whole brain into GM, WM and CSF. The subsequent registration is performed with the segmented tissues and thus is less dependent on the high image contrast among various regions. However, it should be noted that the high test-retest reliability measured at a 6-h interval only reflects the reliability of the imaging data and processing method. Reliability is likely to be lower in longitudinal studies due to other sources of variation, including the status of the MRI equipment, factors related to the operator, and true biological changes over time.

The smoothing kernel was the only arbitrary variable in the preprocessing procedure. Here, we investigated the impact of smoothing on test-retest reliability. We observed that a larger smoothing kernel can slightly increase test-retest reliability and may lead to lower volume estimation. Nevertheless, test-retest reliability was minimally affected by smoothing when the kernel is within 10 mm. We also found that test-retest reliability of the left and right brain regions was lower than that of the whole brain, suggesting that the volume of left and right brain regions may fluctuate more obviously than the average of the whole brain. Future studies are needed to further explore the possible causes.

The present study used three different methods to assess the test-retest reliability of cortical volume, including the ICC, PVC, and PCC. ICC is one of the most widely used indices of test-retest reliability in the literature. However, PCC and PVC can offer supplementary information about reliability. Good test-retest reliability is reflected by high ICC, low PVC and high PCC values. Although the three indices represent different aspects of test-retest reliability, the three methods yielded compatible conclusions for most subregions. However, results from these methods may slightly differ from one another. For example, the left MEnt (No. 41, Table 1) and VIENT (No.96, Table 1) demonstrated excellent ICC and PCC values, but relatively poor PVC measures. Although future studies are needed to confirm the significance of differences among these three indices, the PVC and PCC measures may provide extra quantitative information about the test-retest reliability alongside ICC. Finally, it is also worth to mention that the criteria for grading the test-retest reliability based on PVC and PCC are not yet established.

While 92 of the 96 subregions demonstrated excellent ICC values, the left/right RSGb and left/right RSGc showed lower reliability than other regions. Compared to other regions, these four regions did not show a significant difference in the SNR, thus the lower test-retest reliability was not due to poor signal. A potential explanation of these differences could be the physical positions of RSGb/RSGc, as they are located on the edge of brain surface, which may be more strongly influenced by registration errors than other regions. While technical reasons may be the main cause of the low reliability values in these regions, we could not completely rule out the possibility of some physiological changes such as

fluctuations in blood flow. It has been reported that, similar to the entorhinal cortex, the RSGb/RSGc is a main node for the exchange of information between the hippocampus and other limbic areas of the brain (Van Groen and Wyss, 2003) and is provided with enough blood supply by local blood vessel (Tan et al., 2015). Future studies are warranted to understand the exact cause of the low reliability in these regions. Given that volumetric measures in these regions are less reliable, volumetric differences observed in longitudinal and cross-sectional studies, as well as in case-control comparisons, must be interpreted with caution.

A limitation of the present study is that the rat atlas used here only partitions the whole rat brain into 96 subregions; some cortical and subcortical regions are not included in the atlas. However, the atlas used in this study represents the state-of-the-art rat brain atlas, which is digitized based on the latest version of the Paxinos&Watson atlas (Sixth edition) and is the only template in Paxinos space to have been generated by a 7.0 T MRI scanner so far. A follow-up study can be conducted once a finer digitized atlas is established. Additionally, regional volume obtained from the atlas-based VBM method may differ from the biological reality, because image contrast in structural MRI may not be high enough to identify the borders between different compartments. Finally, while test-retest reliability is a prerequisite for the validity of the VBM measurement, reliability does not necessarily mean accuracy of the measurement, because noise distribution or systematic error of the registration algorithm can also be ‘robust’ in a given subject.

5. Conclusion

The VBM-DARTEL method can measure the atlas-based cortical volume of the rat brain with very high test-retest reliability in most brain regions, and could serve as a robust, in vivo and non-invasive tool to study cortical volume changes associated with brain diseases in rat models.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Fig. 1.
96 subregions in the rat brain atlas. The subregions are color coded.

Fig. 2.
The RSGb (yellow) and RSGc (orange) of the rat brain. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 3.

Estimates of the whole brain volume based on different smoothing kernels. Note that the label ‘_r’ stands for the retest group, and the blue horizontal lines represent the mean values and the green error bars mark 1 SD (standard deviation). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1

The test-retest reliability of the volume measurements in all ROIs of the rat brain.

No.	Brain region	ICC	PVC	PCC
1	AID_right	0.969	0.26%	0.970
2	AIP_left	0.943	0.23%	0.943
3	AIP_right	0.920	0.59%	0.927
4	AIV_left	0.954	0.09%	0.954
5	AIV_right	0.958	0.08%	0.958
6	AI_left	0.970	0.37%	0.973
7	APir_left	0.952	1.14%	0.965
8	APir_right	0.844	1.52%	0.886
9	AUD_left	0.958	0.26%	0.958
10	AUD_right	0.952	0.26%	0.953
11	Au1_left	0.957	0.31%	0.957
12	Au1_right	0.956	0.45%	0.958
13	AuV_left	0.938	0.49%	0.940
14	AuV_right	0.930	0.31%	0.932
15	Cg1_left	0.968	0.23%	0.969
16	Cg1_right	0.970	0.21%	0.972
17	Cg2_left	0.969	0.61%	0.974
18	Cg2_right	0.977	0.72%	0.985
19	DIEnt_left	0.948	0.86%	0.953
20	DIEnt_right	0.890	1.37%	0.904
21	DI_left	0.965	0.32%	0.967
22	DI_right	0.941	0.37%	0.943
23	DLEnt_left	0.956	0.25%	0.957
24	DLEnt_right	0.921	1.05%	0.938
25	DLO_left	0.975	0.17%	0.975
26	DLO_right	0.965	0.10%	0.967
27	Ect_left	0.928	0.47%	0.933
28	Ect_right	0.934	1.03%	0.953
29	Fr3_left	0.980	0.30%	0.983
30	Fr3_right	0.966	0.40%	0.969
31	GIDI_left	0.914	0.29%	0.915
32	GIDI_right	0.863	0.78%	0.872
33	GI_left	0.963	0.35%	0.966
34	GI_right	0.937	0.27%	0.938
35	LPtA_left	0.964	0.45%	0.966
36	LPtA_right	0.937	0.34%	0.939
37	M1_left	0.976	0.46%	0.979
38	M1_right	0.974	0.25%	0.976
39	M2_left	0.984	0.29%	0.985

No.	Brain region	ICC	PVC	PCC
40	M2_right	0.979	0.07%	0.979
41	MEnt_left	0.878	2.18%	0.934
42	MEnt_right	0.899	0.57%	0.901
43	MPtA_left	0.932	0.01%	0.931
44	MPtA_right	0.936	0.31%	0.944
45	PRh_left	0.938	0.37%	0.940
46	PRh_right	0.948	0.20%	0.948
47	PtPC_left	0.936	0.03%	0.934
48	PtPC_right	0.949	0.17%	0.951
49	PtPD_left	0.968	0.20%	0.968
50	PtPD_right	0.958	0.15%	0.958
51	PtPR_left	0.930	0.13%	0.930
52	PtPR_right	0.951	0.16%	0.951
53	RSD_left	0.937	0.05%	0.937
54	RSD_right	0.878	0.47%	0.880
55	RSGb_left	0.683	1.83%	0.693
56	RSGb_right	0.650	1.67%	0.666
57	RSGc_left	0.732	1.53%	0.739
58	RSGc_right	0.706	2.95%	0.740
59	S1BF_left	0.968	0.37%	0.970
60	S1BF_right	0.971	0.25%	0.972
61	S1DZ0_left	0.967	0.57%	0.972
62	S1DZ0_right	0.976	0.10%	0.977
63	S1DZ_left	0.974	0.16%	0.974
64	S1DZ_right	0.972	0.06%	0.972
65	S1FL_left	0.966	0.13%	0.966
66	S1FL_right	0.967	0.24%	0.969
67	S1HL_left	0.963	0.10%	0.963
68	S1HL_right	0.955	0.02%	0.957
69	S1J_left	0.977	0.24%	0.977
70	S1J_right	0.968	0.01%	0.969
71	S1Sh_left	0.967	0.09%	0.969
72	S1Sh_right	0.953	0.12%	0.953
73	S1Tr_left	0.952	0.28%	0.952
74	S1Tr_right	0.941	0.25%	0.943
75	S1ULp_left	0.979	0.25%	0.980
76	S1ULp_right	0.971	0.19%	0.972
77	S1_left	0.929	0.02%	0.928
78	S1_right	0.943	0.01%	0.942
79	S2_left	0.974	0.10%	0.974
80	S2_right	0.939	0.48%	0.942
81	TeA_left	0.938	0.16%	0.937

No.	Brain region	ICC	PVC	PCC
82	TeA_right	0.953	0.21%	0.953
83	V1B_left	0.967	0.24%	0.967
84	V1B_right	0.972	0.33%	0.973
85	V1M_left	0.942	0.14%	0.942
86	V1M_right	0.935	0.23%	0.934
87	V1_left	0.964	0.30%	0.967
88	V1_right	0.938	0.12%	0.937
89	V2L_left	0.958	0.44%	0.961
90	V2L_right	0.964	0.07%	0.963
91	V2ML_left	0.940	0.24%	0.939
91	V2ML_right	0.915	0.57%	0.922
93	V2MM_left	0.937	0.39%	0.936
94	V2MM_right	0.913	0.91%	0.928
95	VIEntD_left	0.882	1.60%	0.905
96	VIEnt_right	0.867	2.17%	0.897
97	GM	0.918	0.91%	0.940
98	WM	0.918	0.35%	0.921
99	CSF	0.865	0.26%	0.864
100	Left brain	0.811	1.47%	0.856
101	Right brain	0.837	1.29%	0.874
102	Whole brain	0.946	0.50%	0.955

Abbreviation: PCC, Pearson correlation coefficient; ICC, intraclass coefficient; PVC, percent volume change.