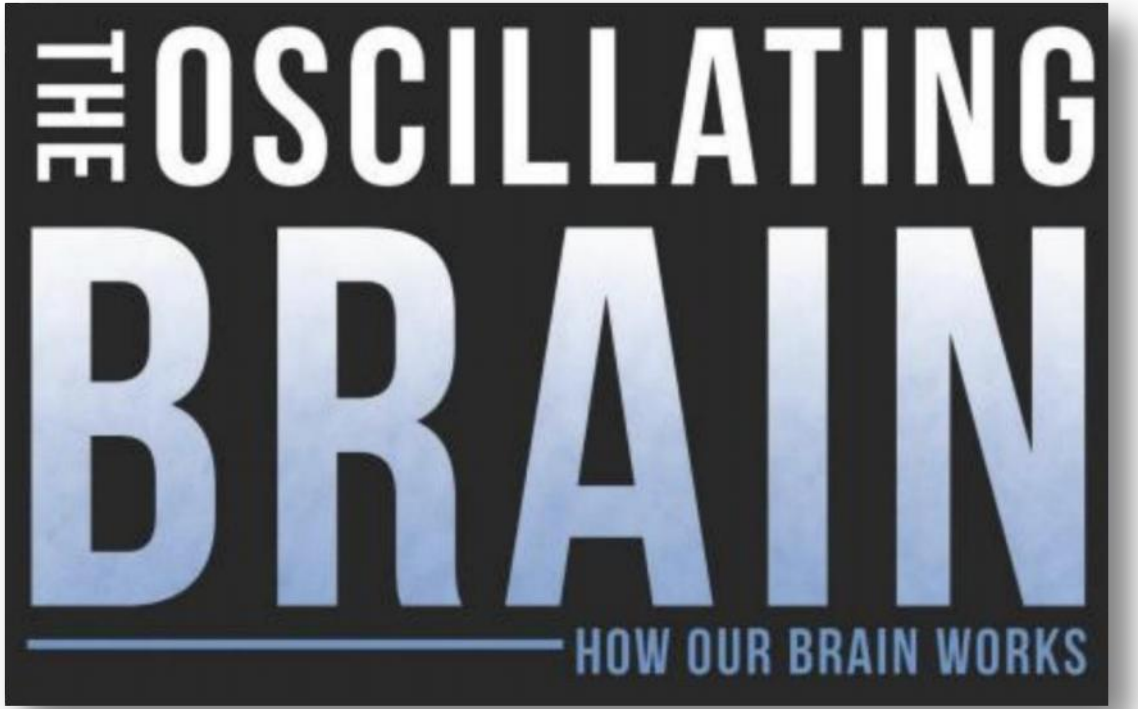


北京師範大學心理学部

Developmental Population Neuroscience

发展人口神经科学（我的脑功能研究观）

左西年 (Xi-Nian Zuo)

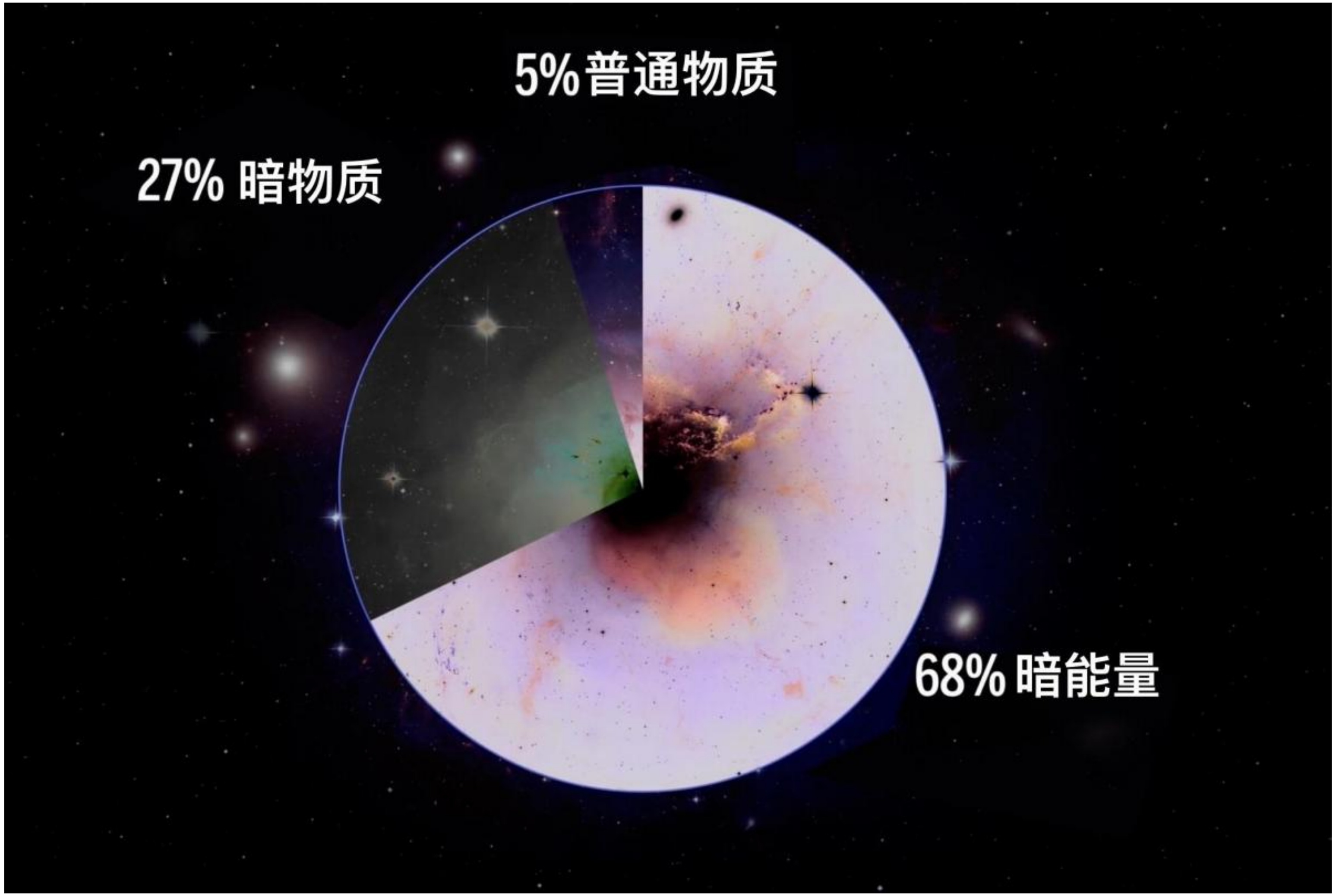
Beijing Normal University

State Key Lab of Cognitive Neuroscience & Learning

National Basic Science Data Center

Chinese Data-sharing Warehouse for In-vivo Imaging Brain

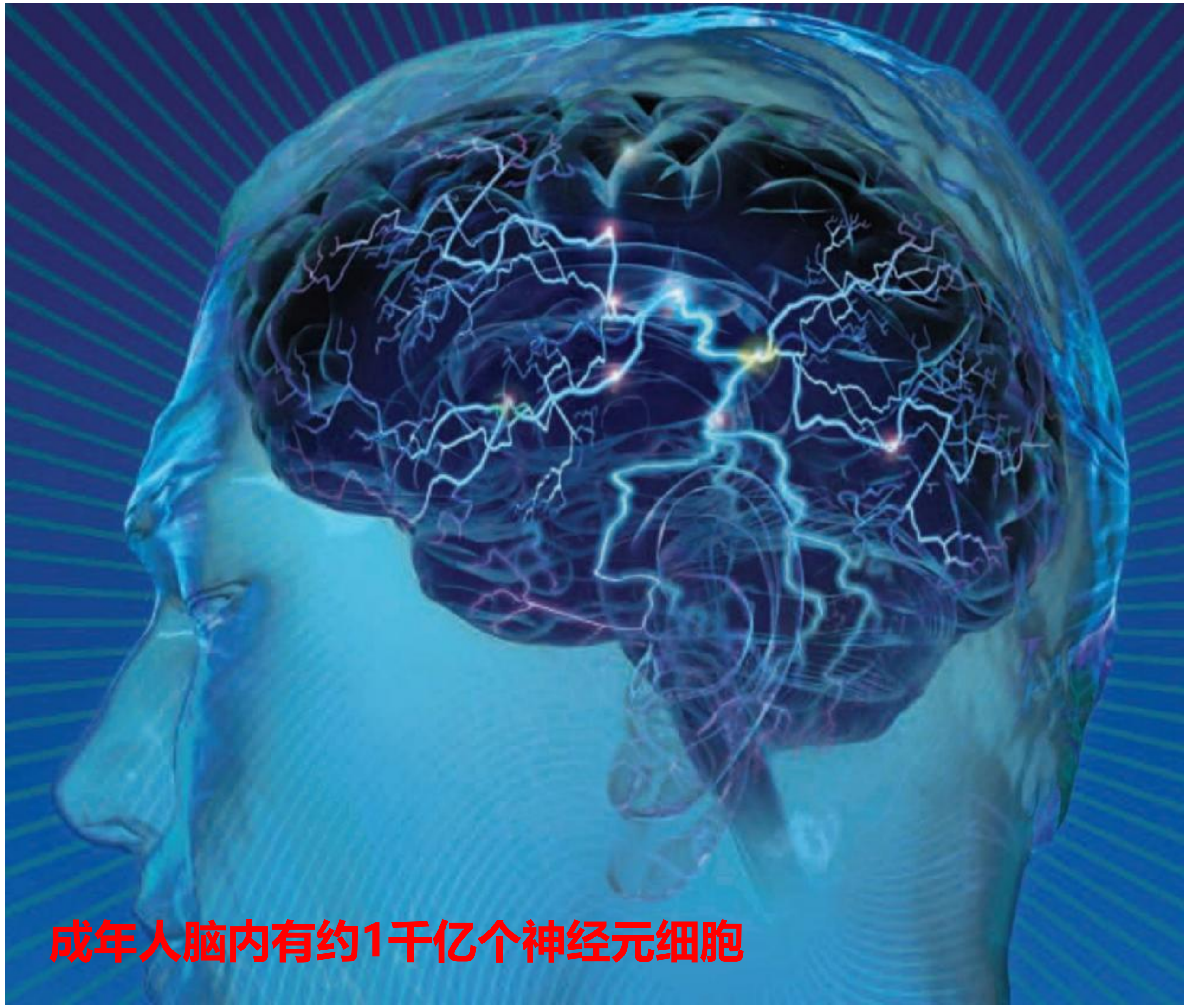
Universe and Dark Energy



Why is Brain Function So Important?

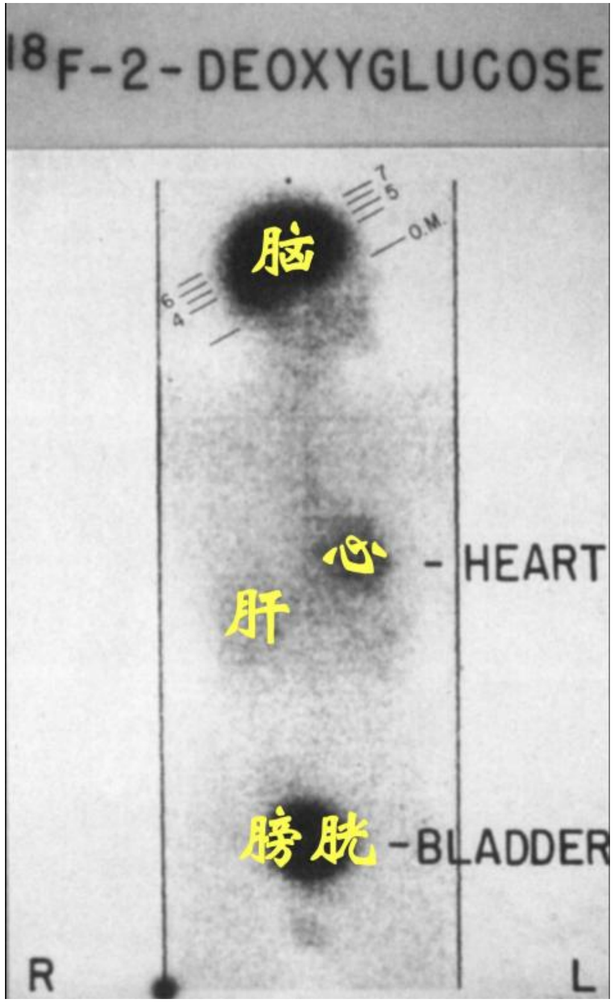
脑中暗能量

Dr. Marcus Raichle

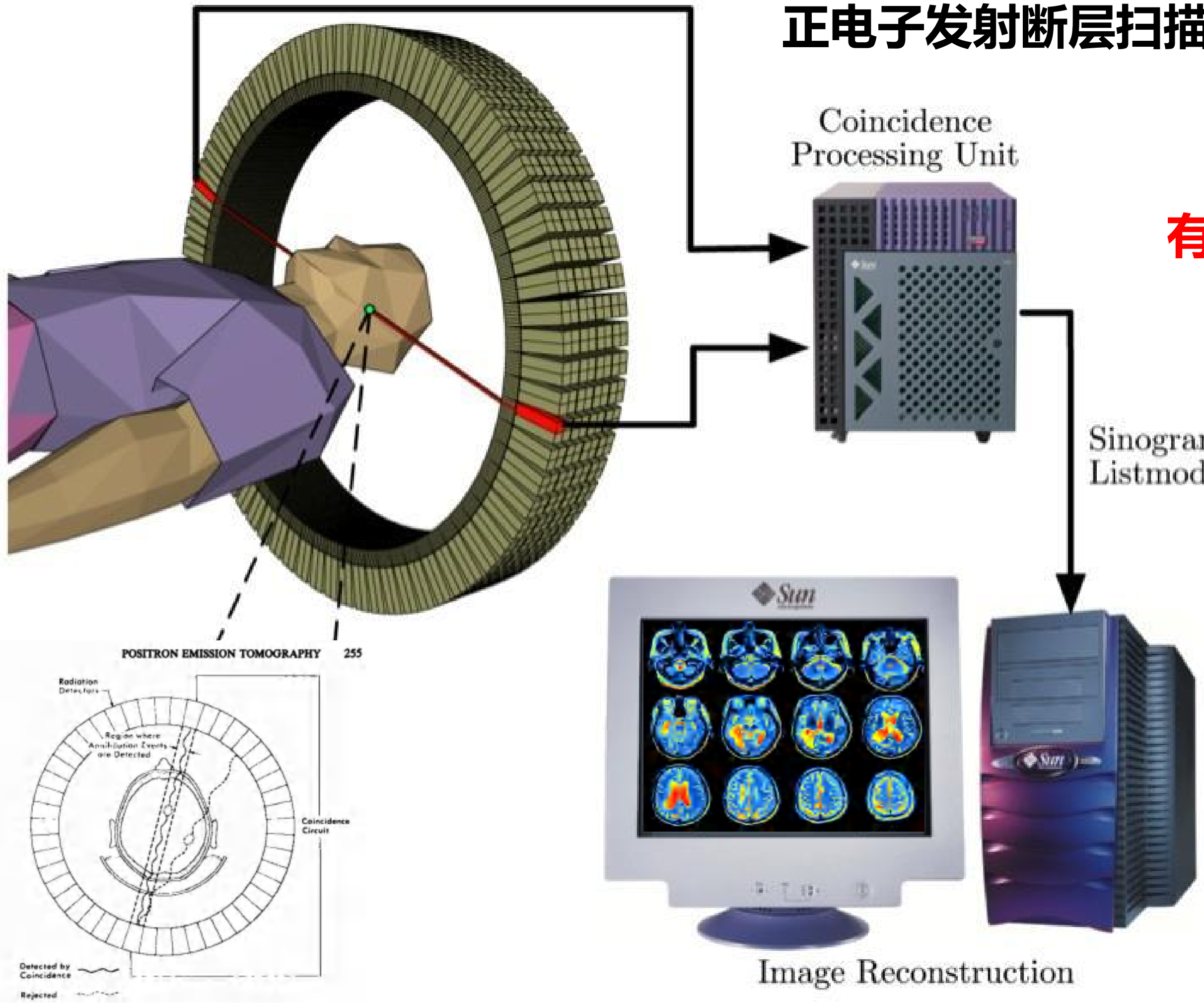


Marc’s Journey of Discovering Brain Function

Measuring The Human Brain Function via Energy Metabolism



正电子发射断层扫描-PET



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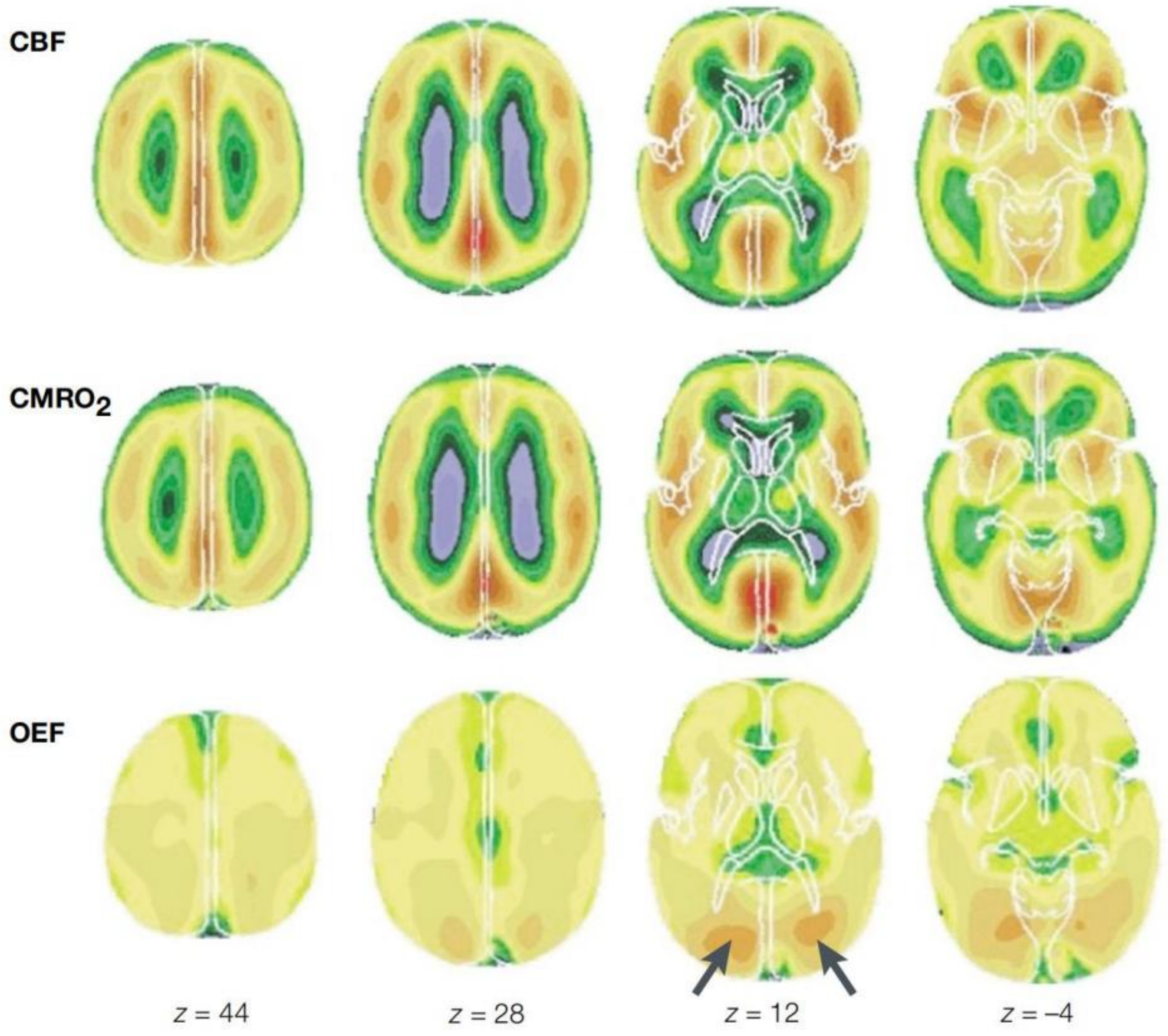
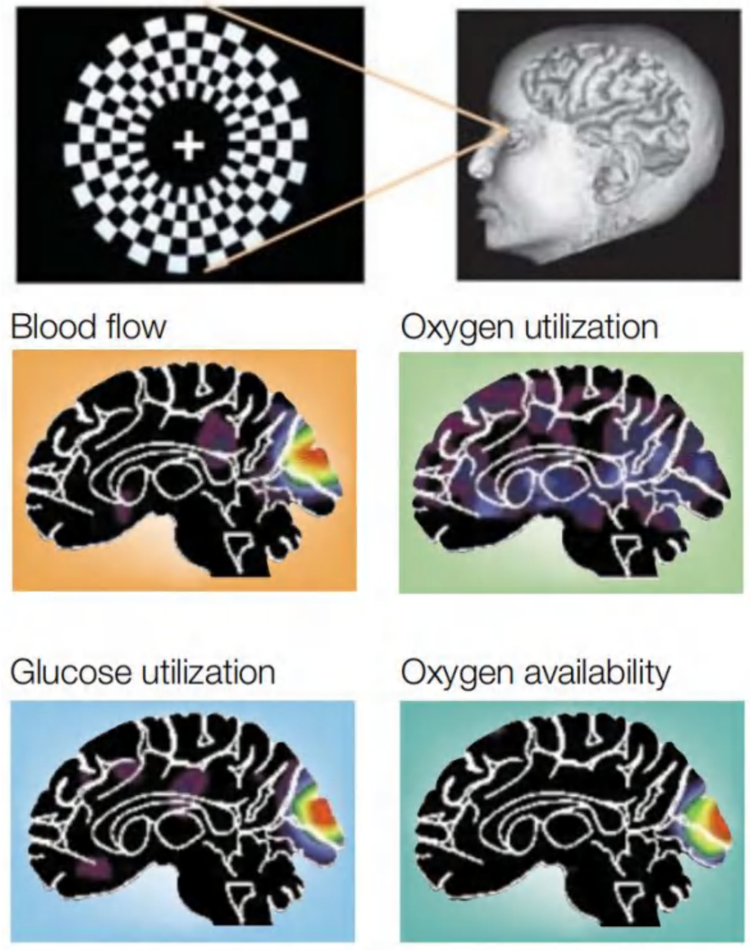
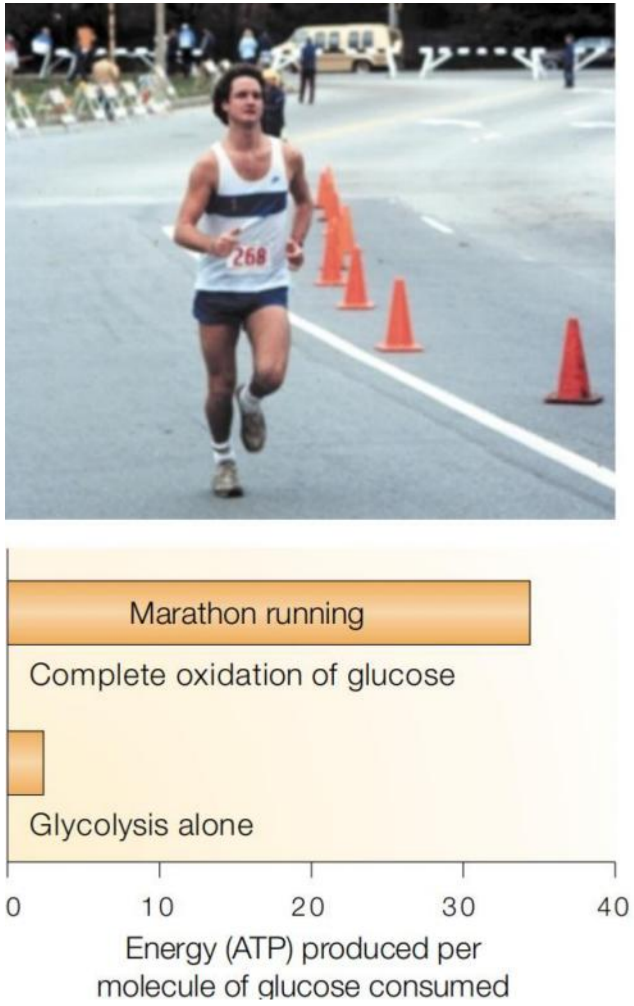
Measuring The Human Brain Function via Energy Metabolism



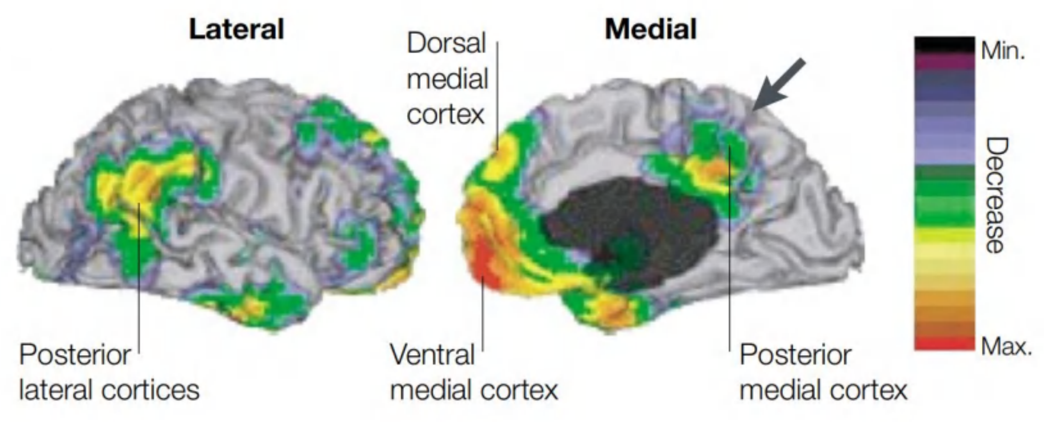


Measuring The Human Brain Function via Energy Metabolism



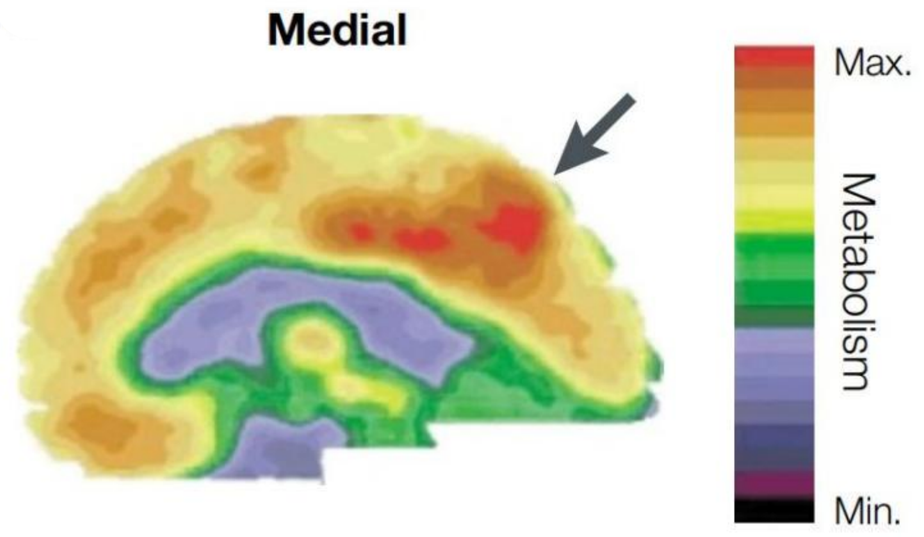
Measuring The Human Brain Function via Energy Metabolism

奋斗

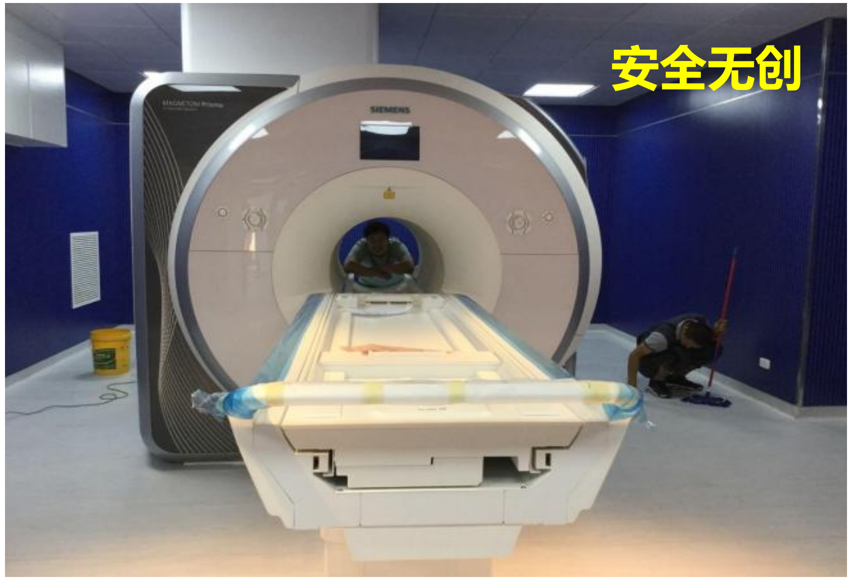


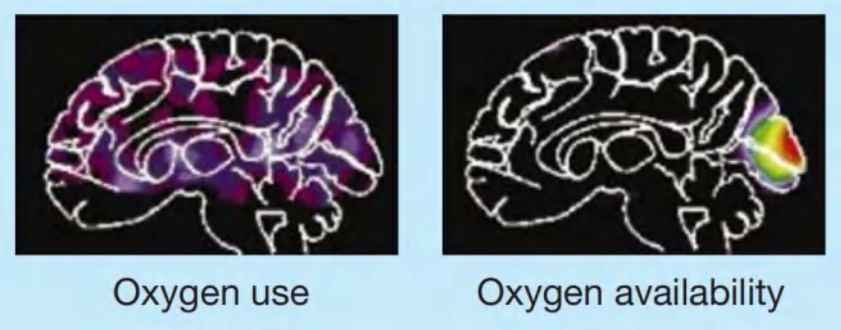
高代谢脑区

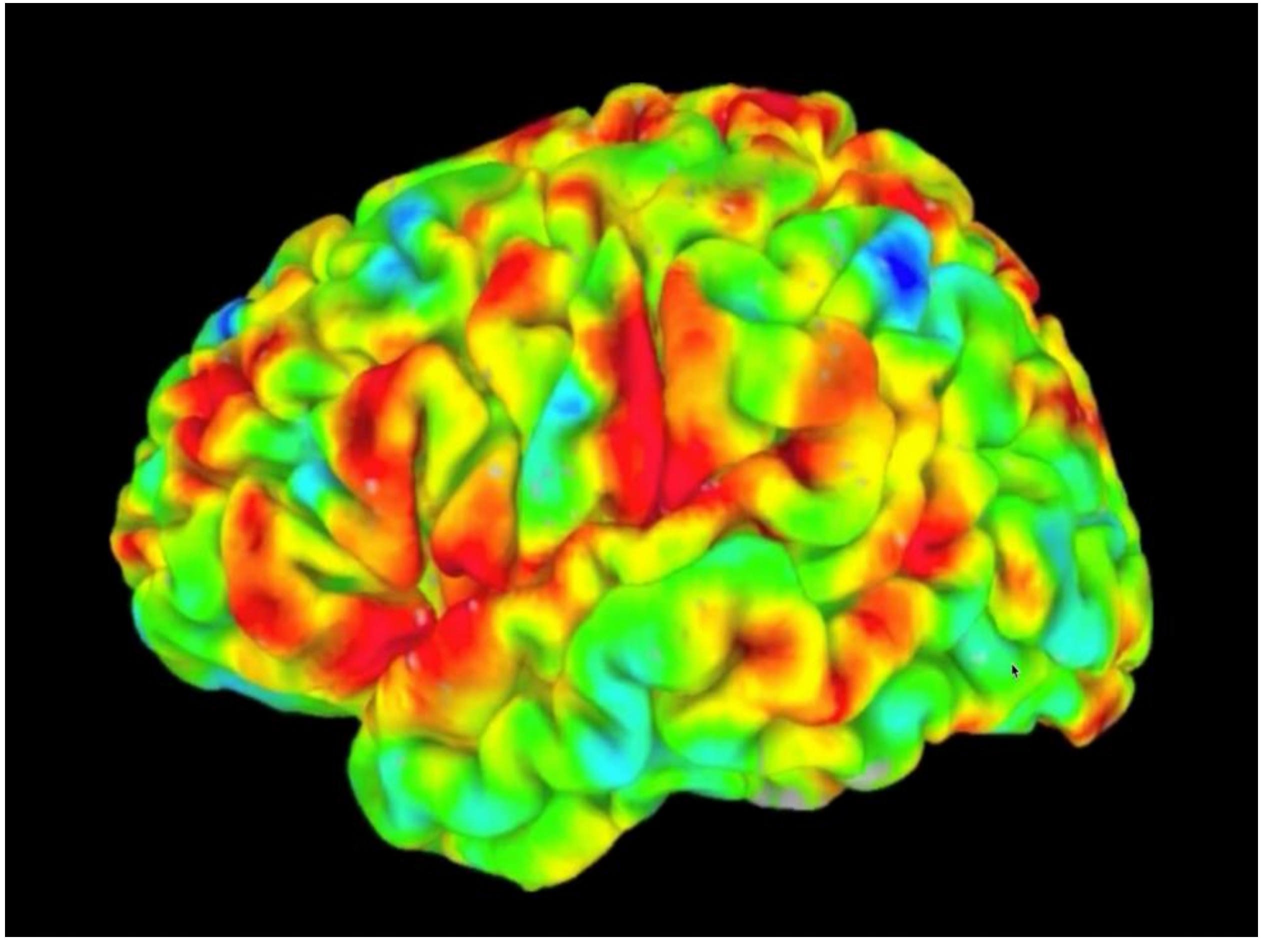
躺平



Measuring Brain Function via Spontaneous Activity

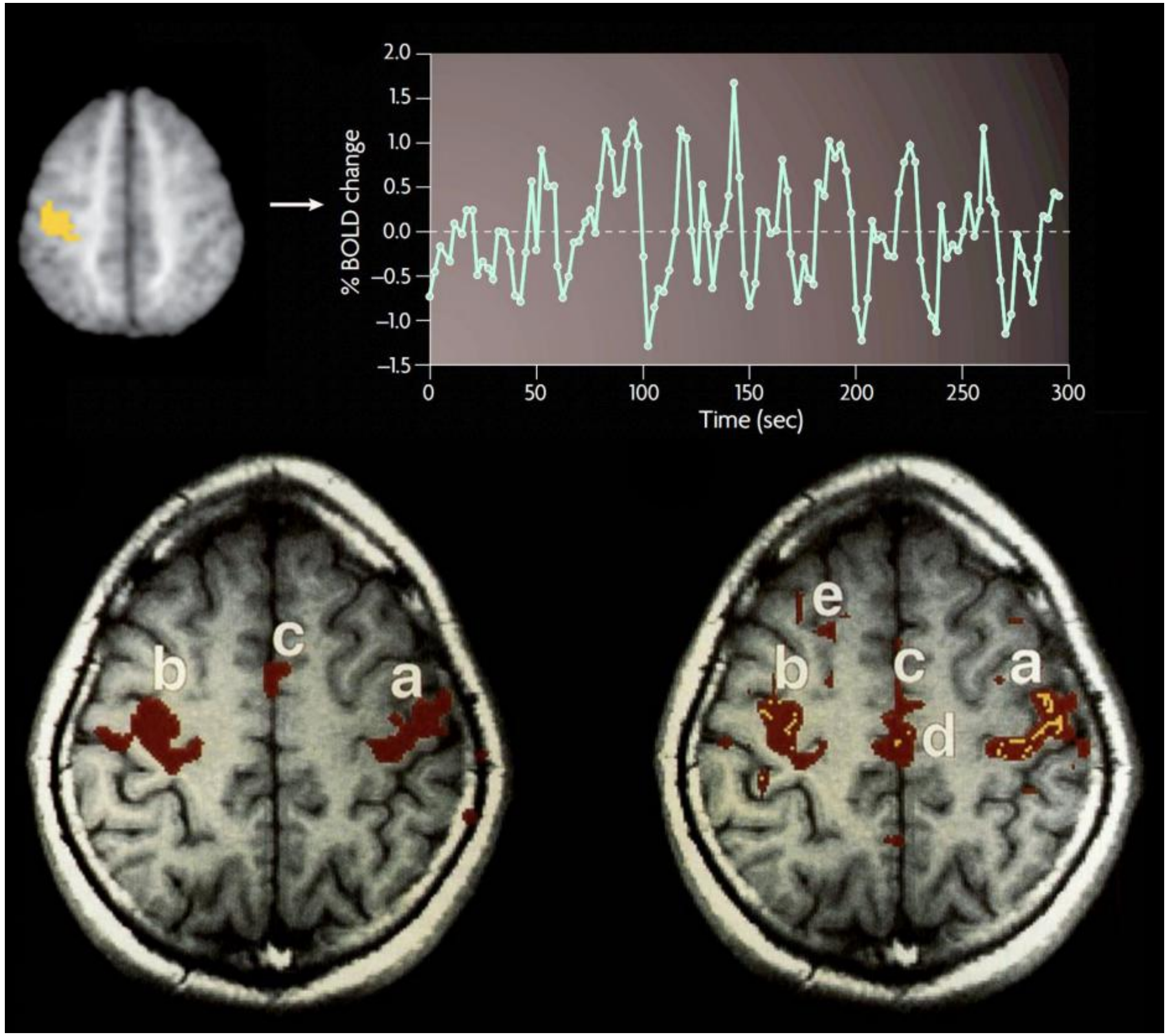




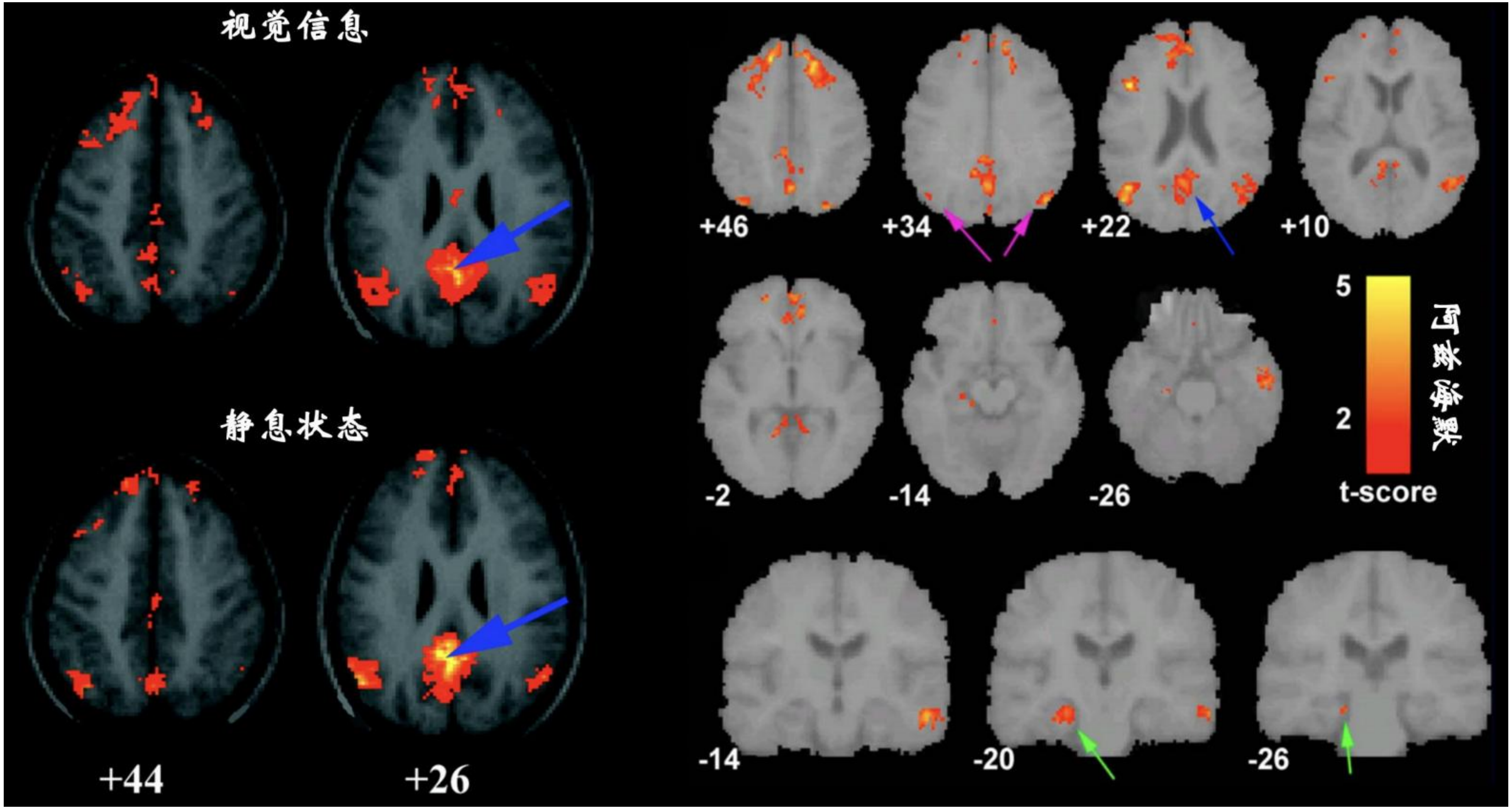


Measuring Brain Function via Spontaneous Activity

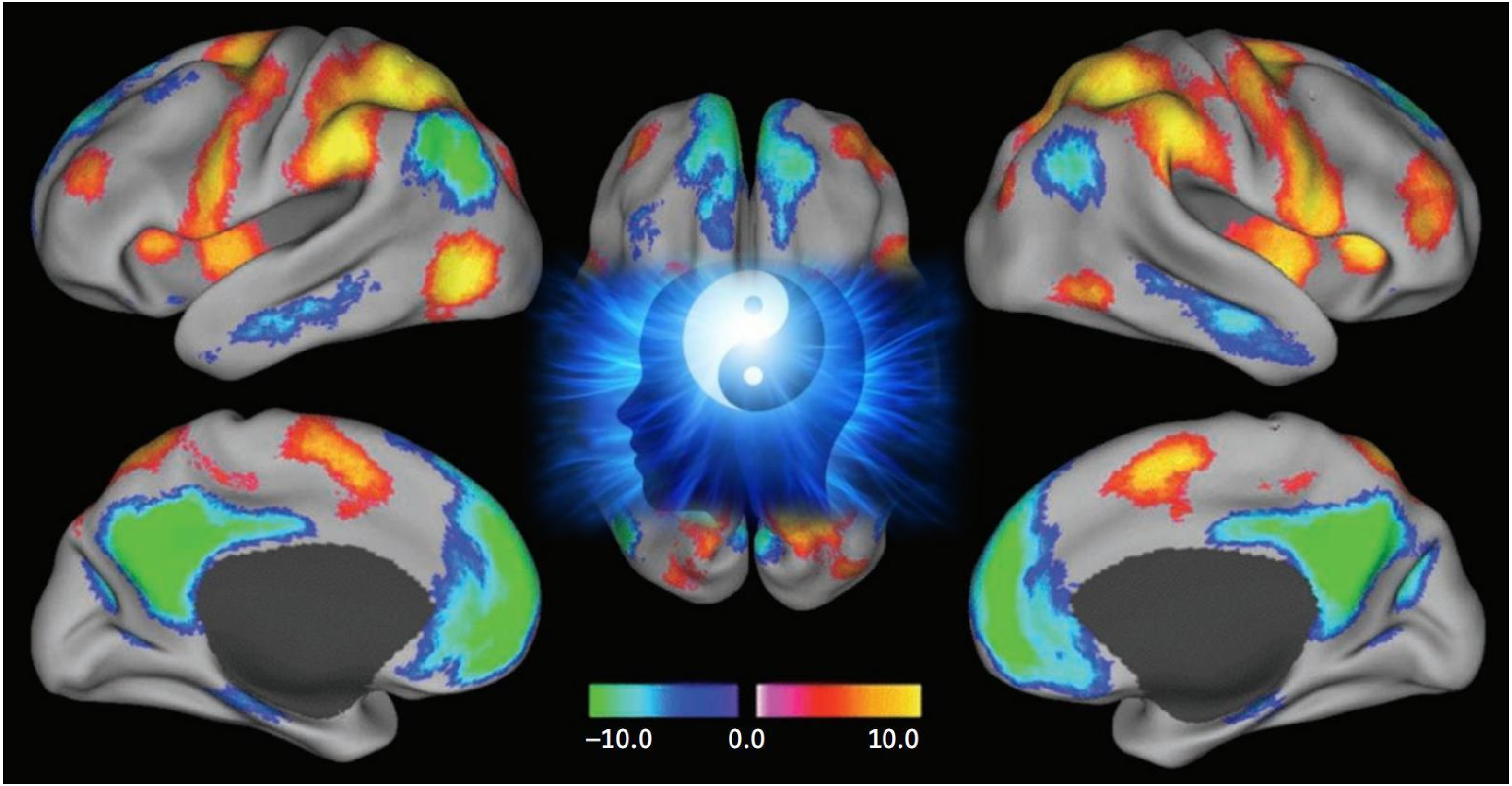
Dr. Bharat Biswal



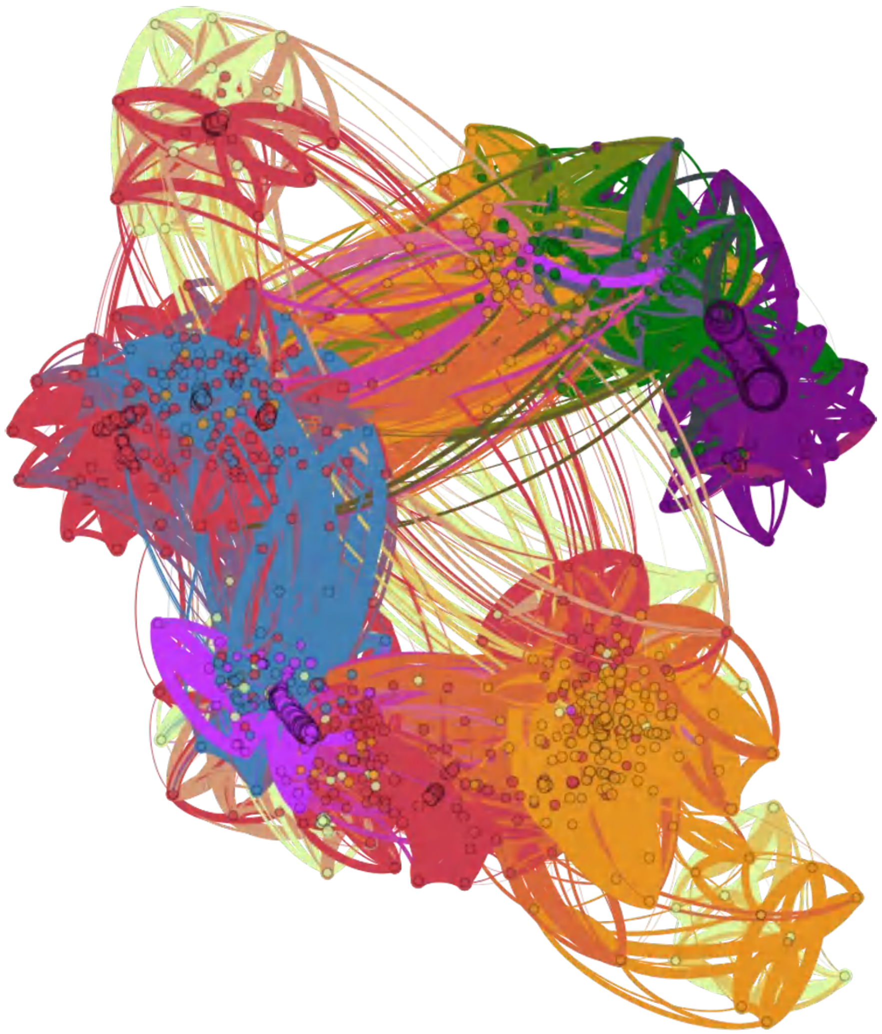
Define Default Mode Network

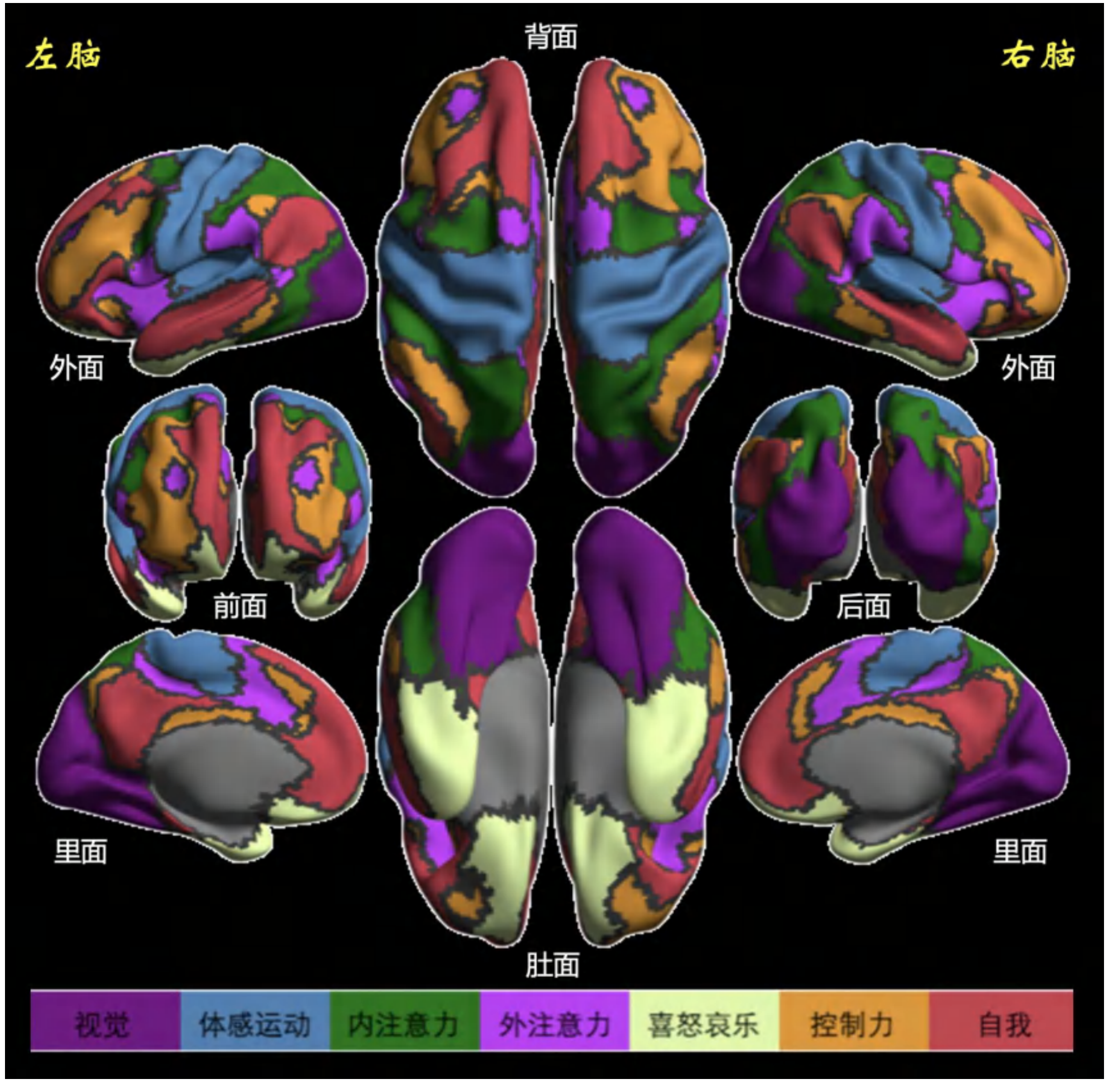


Intrinsic Activity versus Extrinsic Activity

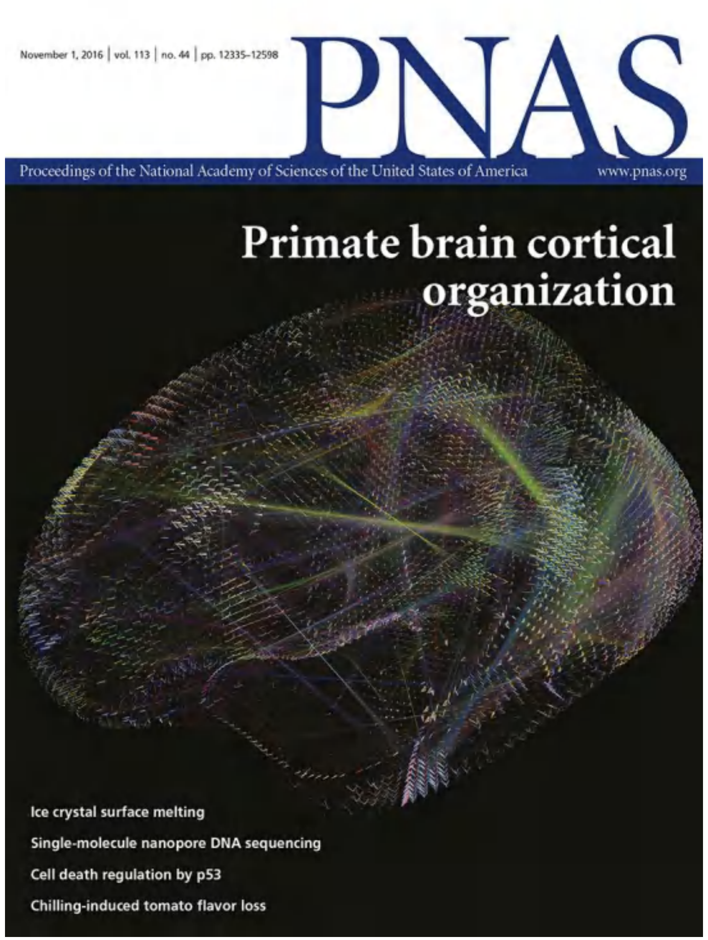


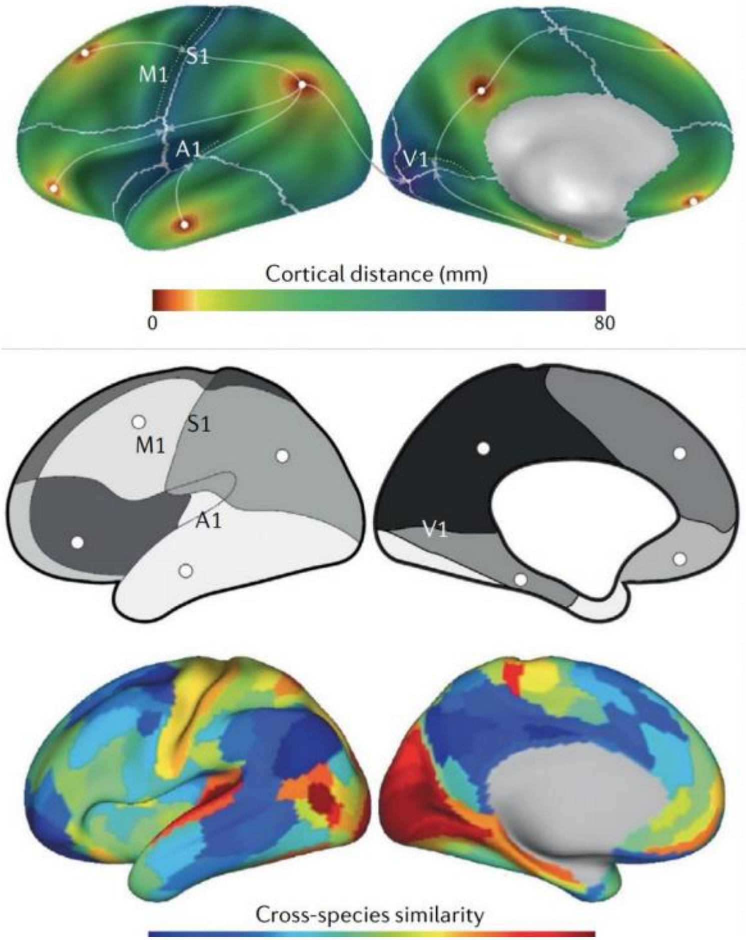
Living with Human Connectomes

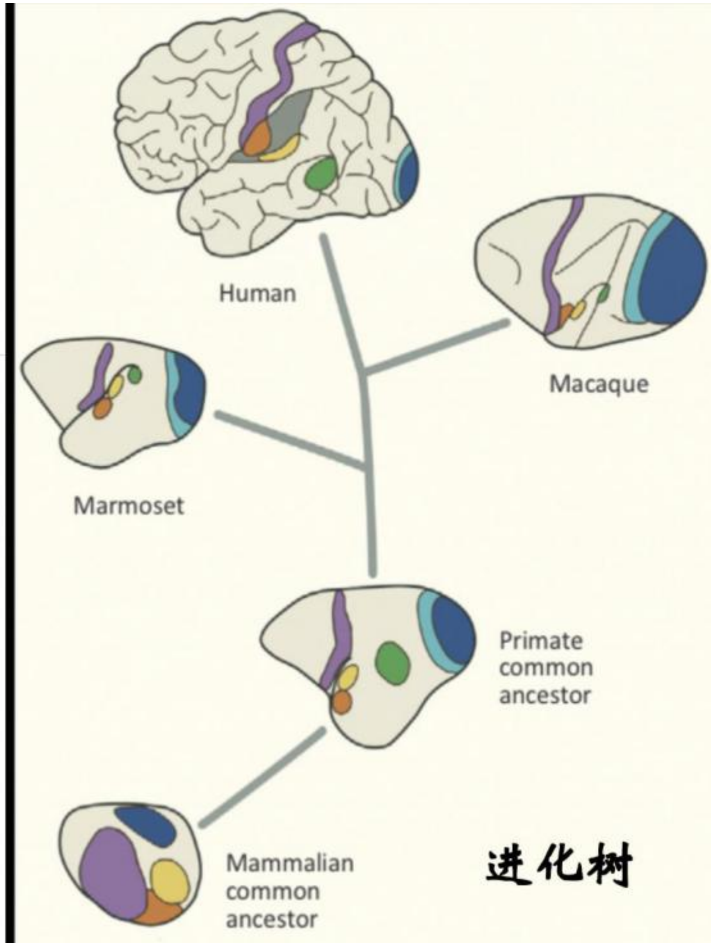




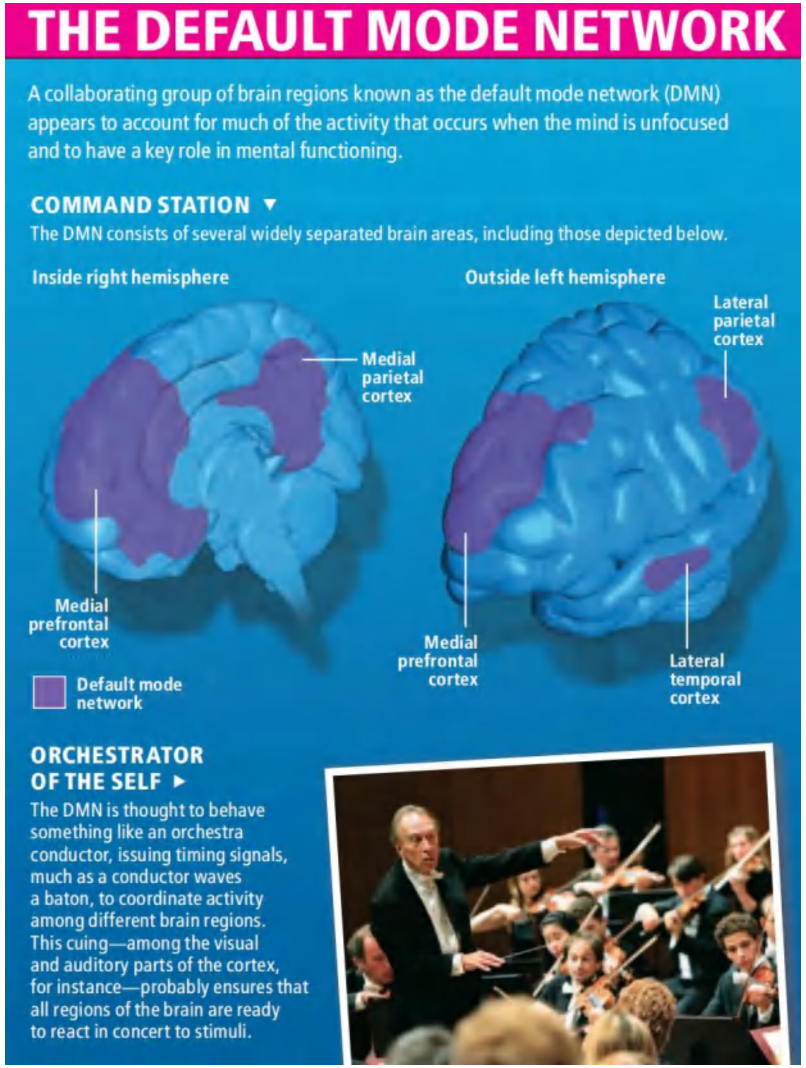
Organizing Human Connectomes via Evolutionary

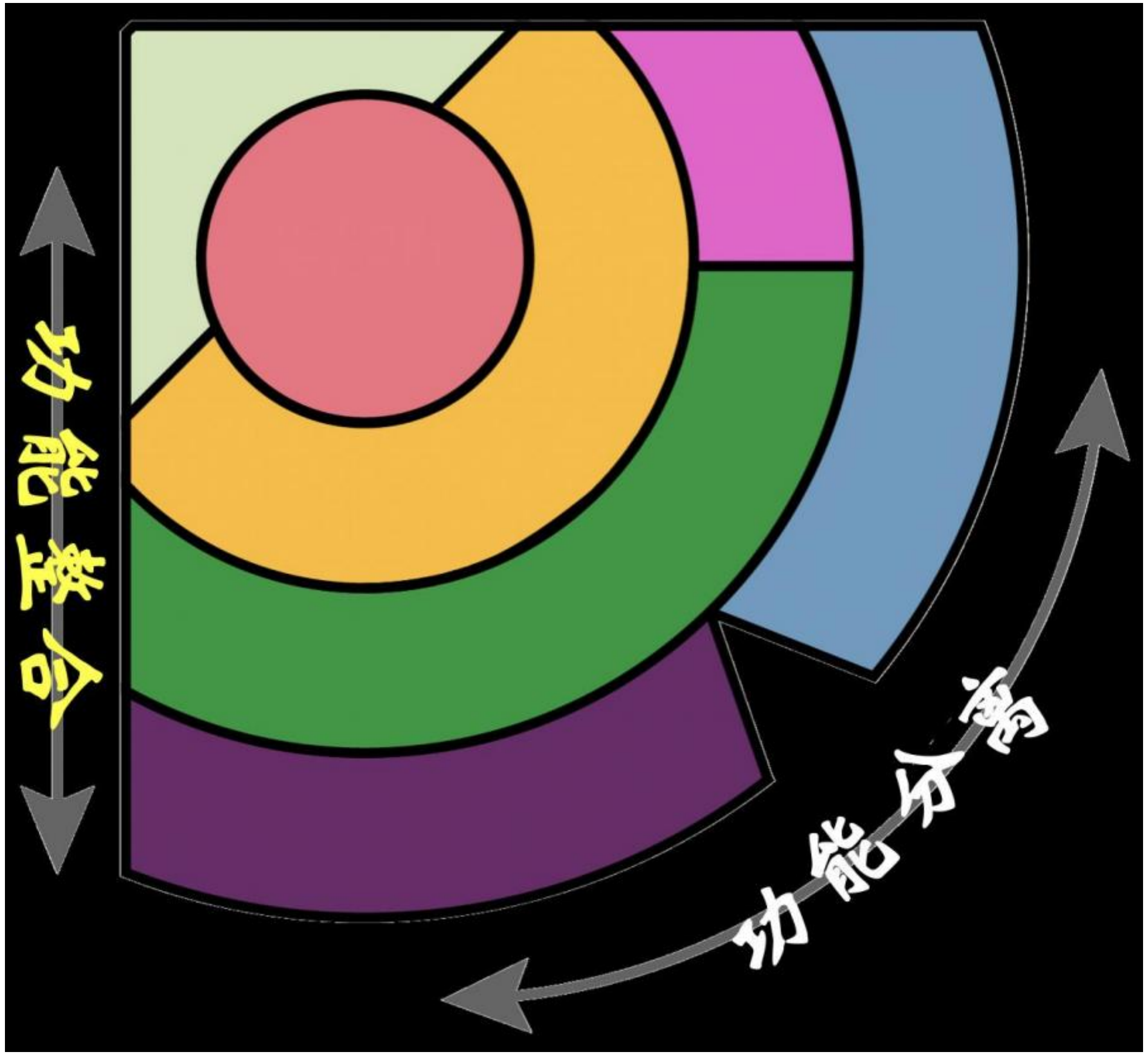




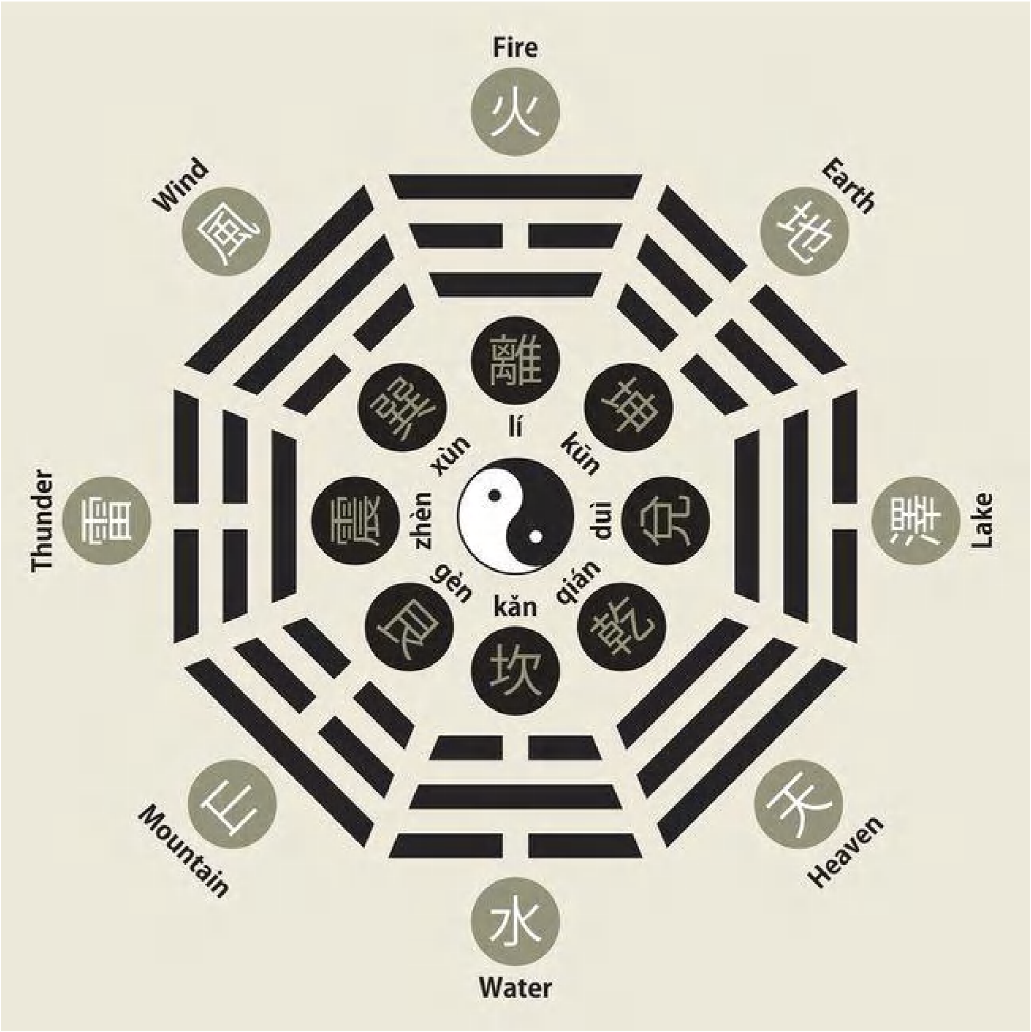


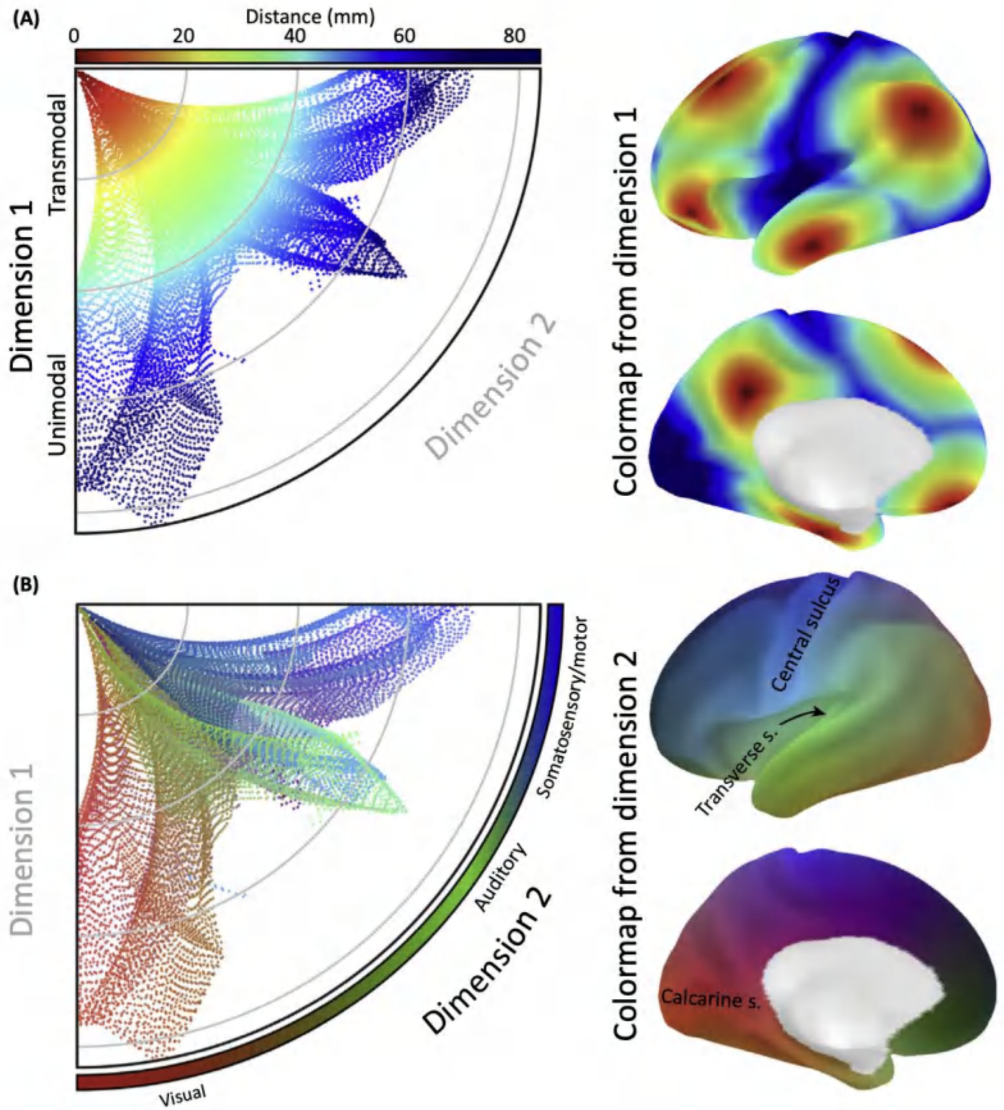
Playing Your Symphony with Connectome



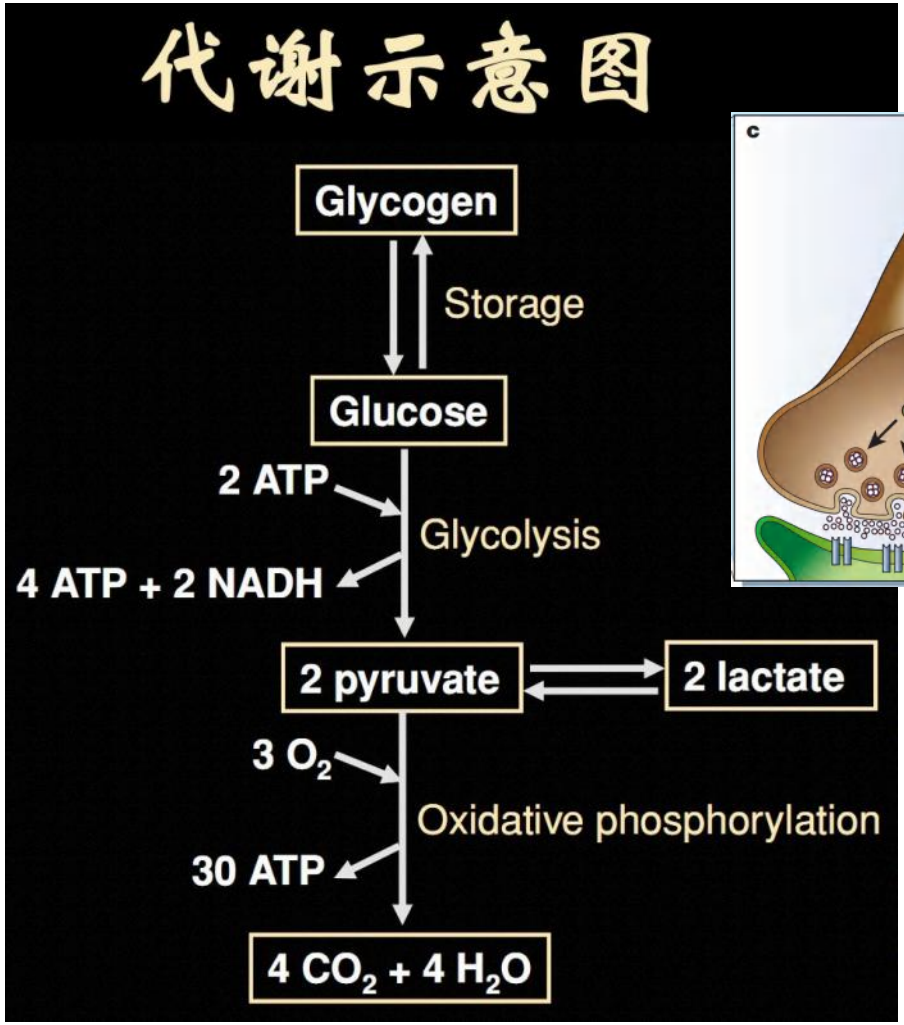


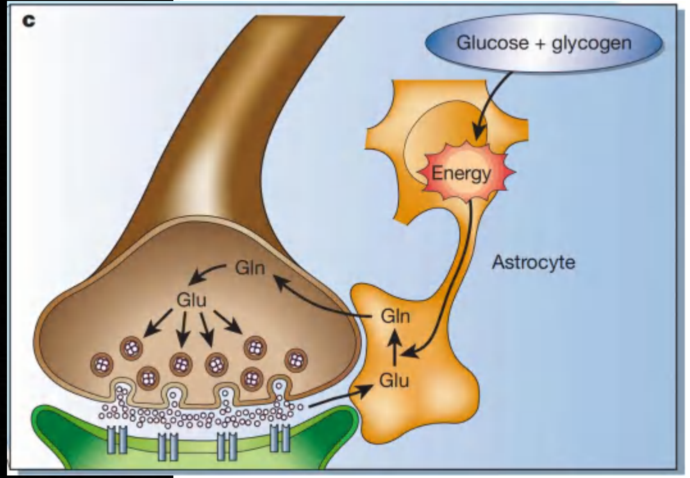
A Coordination and Navigation System of Brain and Mind

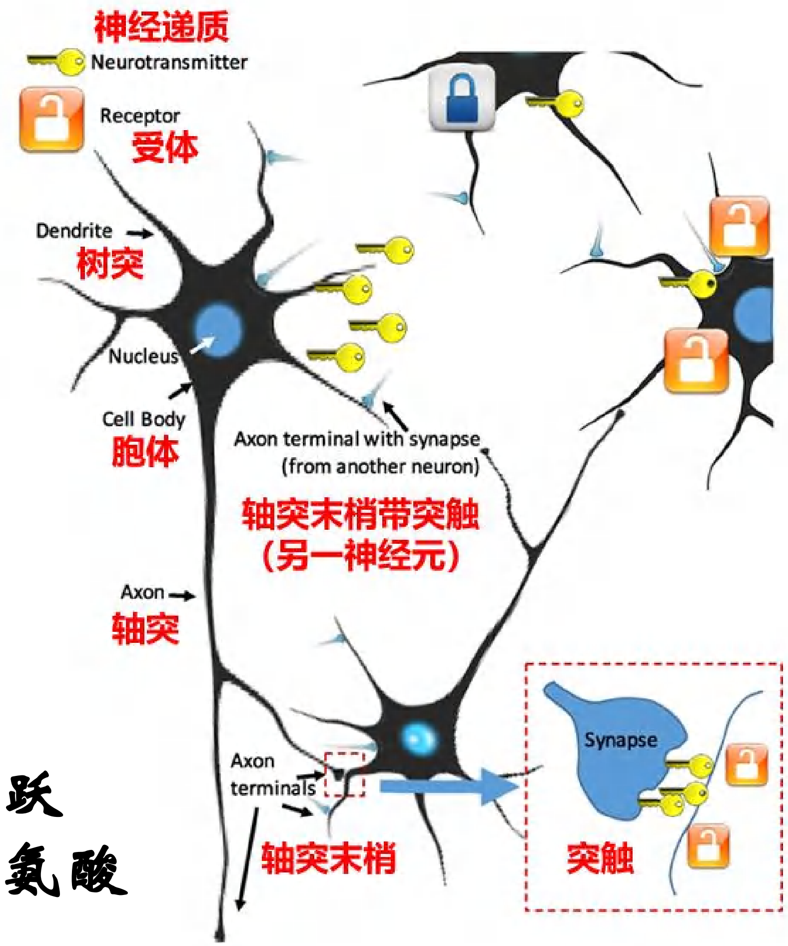




Getting Brain Energy From Dark to Luminosity



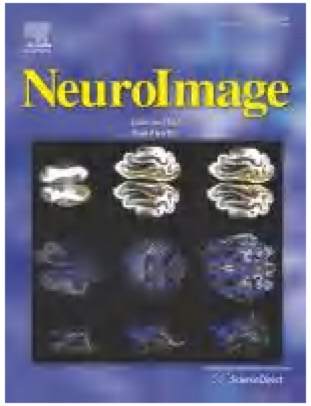


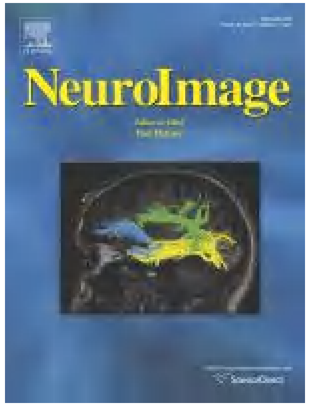


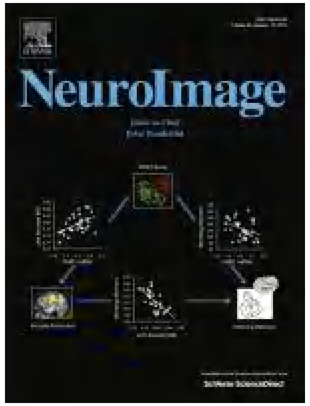
80%神经元活跃
90%突触释放谷氨酸

FMRI信号
反映神经元信息处理

My Personal Journey: The First Five Ideas Published







My Personal Journey: The First Story

NeuroImage 49 (2010) 1432–1445

Contents lists available at ScienceDirect

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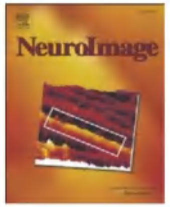

The oscillating brain: Complex and reliable

Xi-Nian Zuo [a], Adriana Di Martino [a], Clare Kelly [a], Zarrar E. Shehzad [a], Dylan G. Gee [a], Donald F. Klein [a,b,d], F. Xavier Castellanos [a,b], Bharat B. Biswal [b,c,*], Michael P. Milham [a,*]

[a] *Phyllis Green and Randolph Cōwen Institute for Pediatric Neuroscience at the New York University Child Study Center, New York, NY, USA*
[b] *Nathan Kline Institute for Psychiatric Research, Orangeburg, NY, USA*
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A R T I C L E I N F O

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A B S T R A C T

The human brain is a complex dynamic system capable of generating a multitude of oscillatory waves in support of brain function. Using fMRI, we examined the amplitude of spontaneous low-frequency oscillations (LFO) observed in the human resting brain and the test–retest reliability of relevant amplitude measures. We confirmed prior reports that gray matter exhibits higher LFO amplitude than white matter. Within gray matter, the largest amplitudes appeared along mid-brain structures associated with the "default-mode" network. Additionally, we found that high-amplitude LFO activity in specific brain regions was reliable across time. Furthermore, parcellation-based results revealed significant and highly reliable ranking orders of LFO amplitudes among anatomical parcellation units. Detailed examination of individual low frequency bands showed distinct spatial profiles. Intriguingly, LFO amplitudes in the slow-4 (0.027–0.073 Hz) band, as defined by Buzsáki et al., were most robust in the basal ganglia, as has been found in spontaneous electrophysiological recordings in the awake rat. These results suggest that amplitude measures of LFO can contribute to further between-group characterization of existing and future "resting-state" fMRI datasets.

My Personal Journey: The First Story

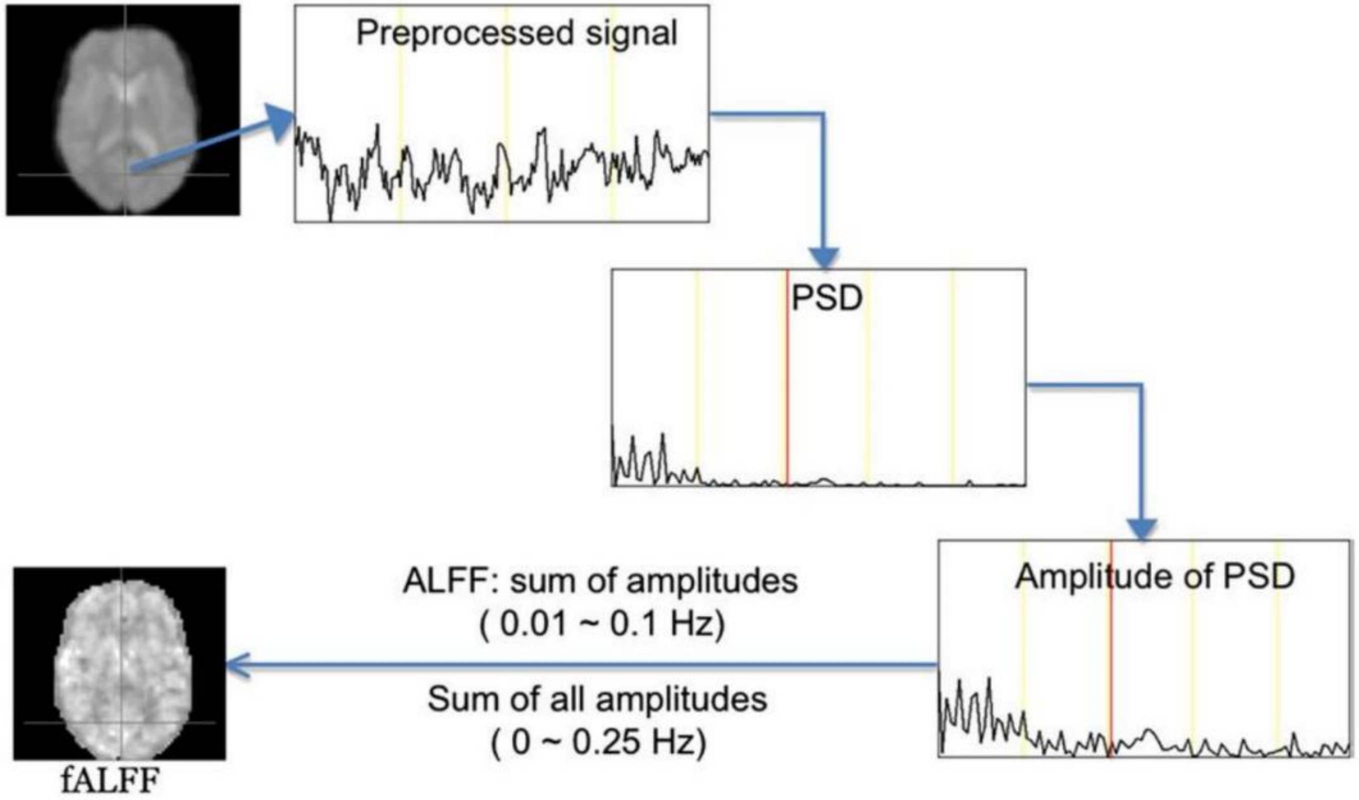

Fig. 1. Computational diagram for individual amplitude of low frequency fluctuations (ALFF) and fractional ALFF (fALFF) maps. This sketch summarizes the main steps taken to conduct power spectral density (PSD) analyses of the resting state fMRI signal and to compute the amplitude measures of low frequency oscillations implemented here: the amplitude of low frequency fluctuations (ALFF), and the fractional ALFF (fALFF). All calculations are done in a participant's native space. The red line is at 0.1 Hz. For group-level statistical analysis, these ALFF and fALFF maps are converted into *Z*-score maps by subtracting mean and dividing standard deviation within a whole brain mask for the participant.

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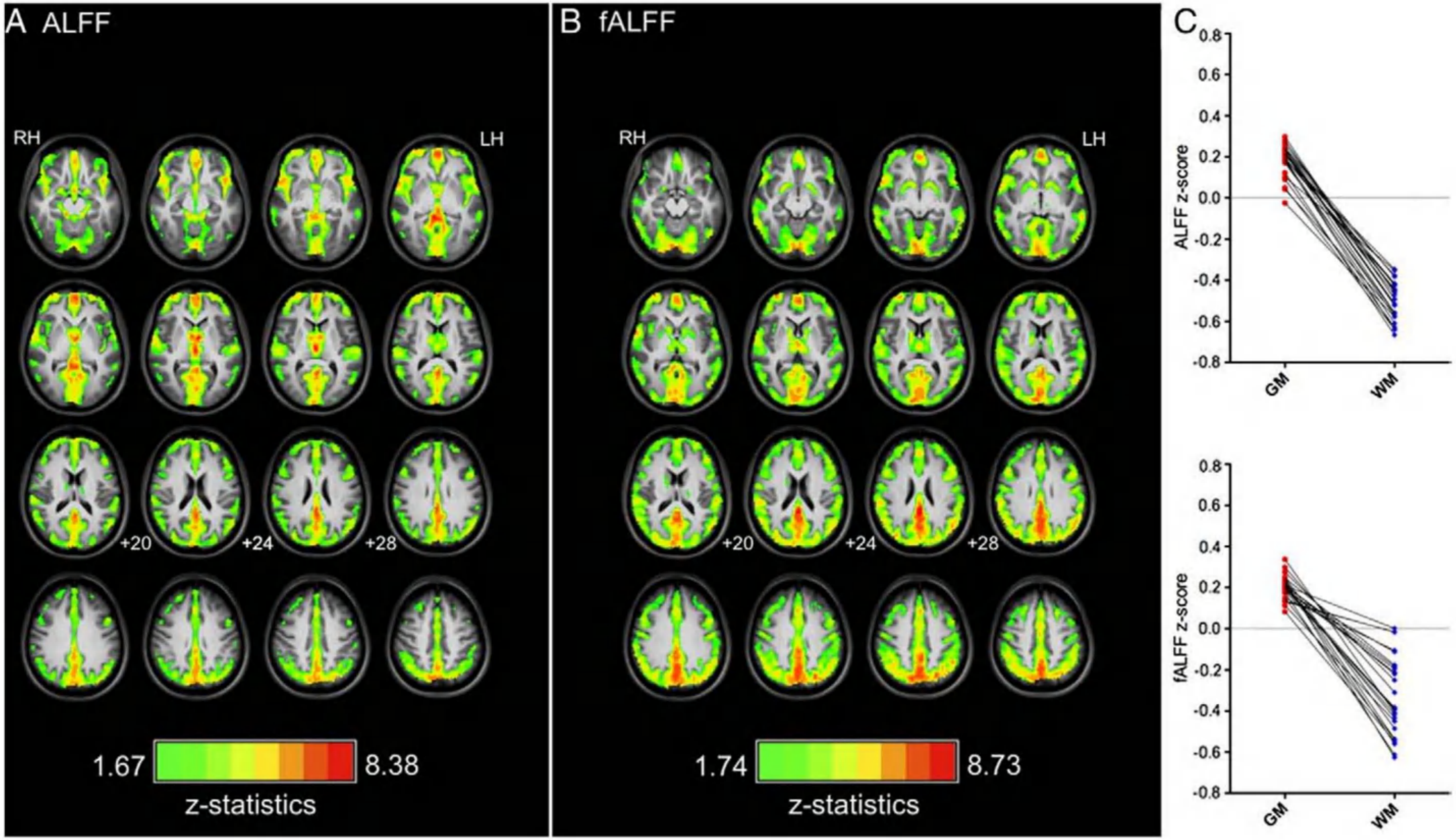

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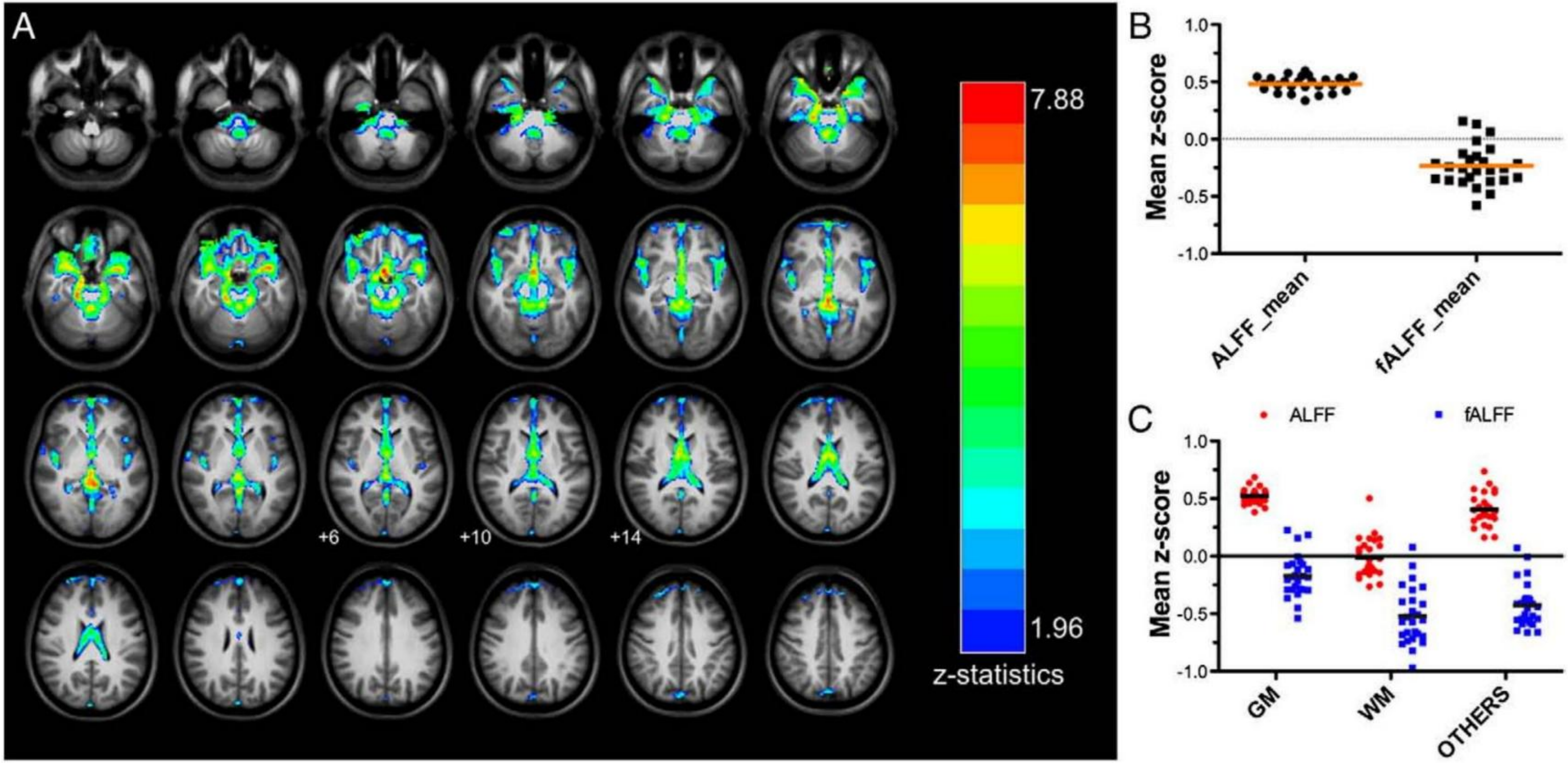

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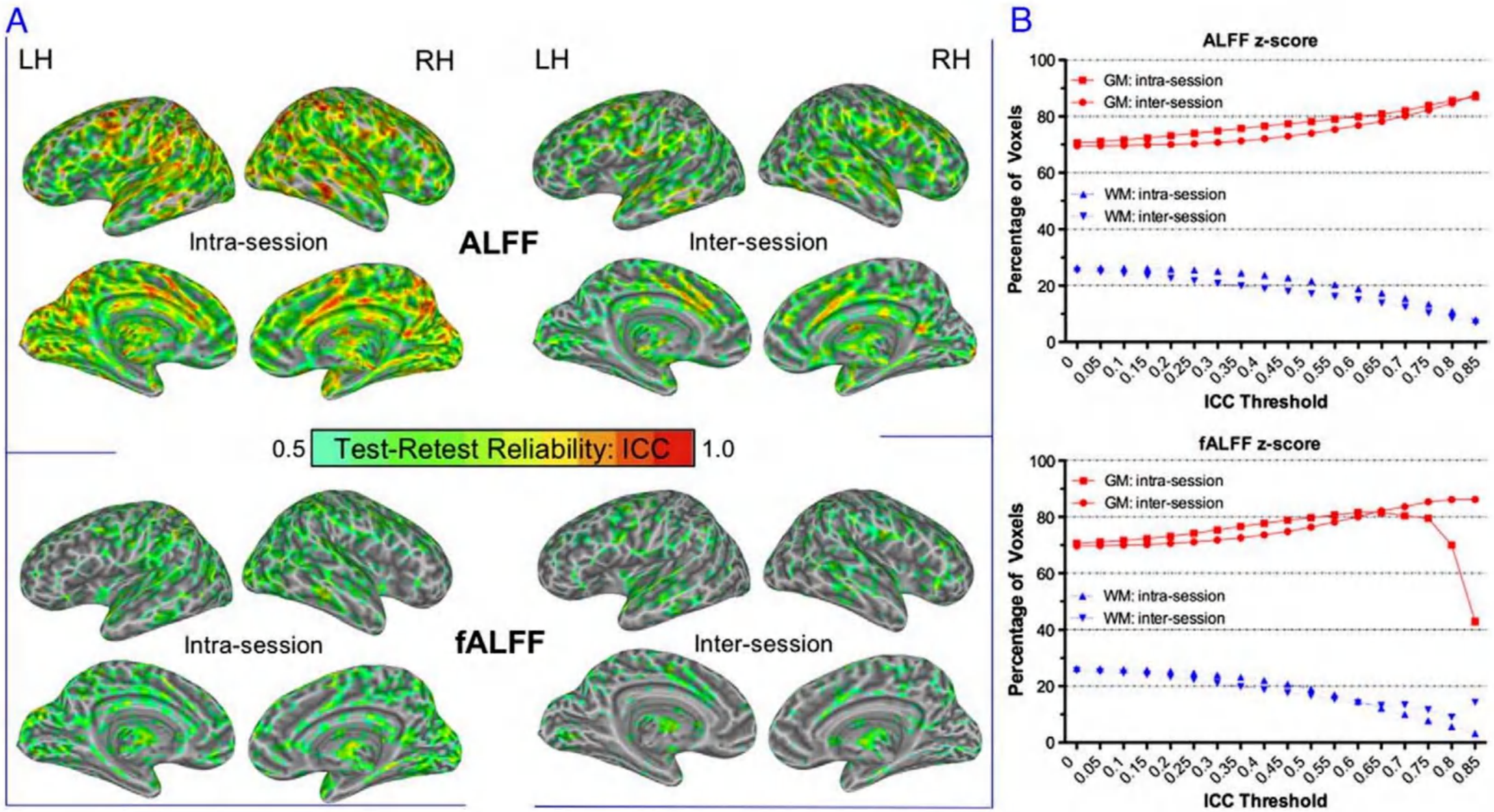

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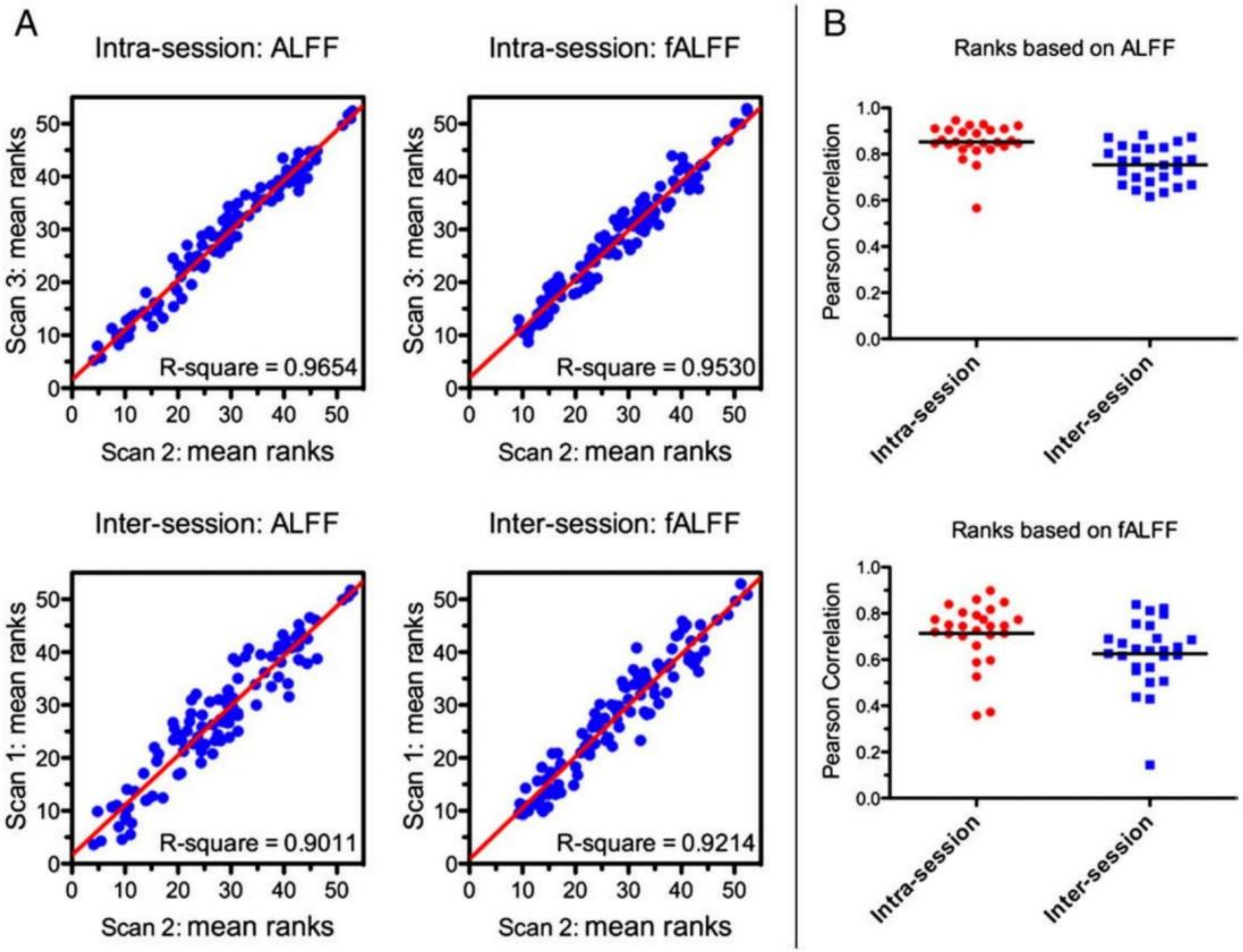

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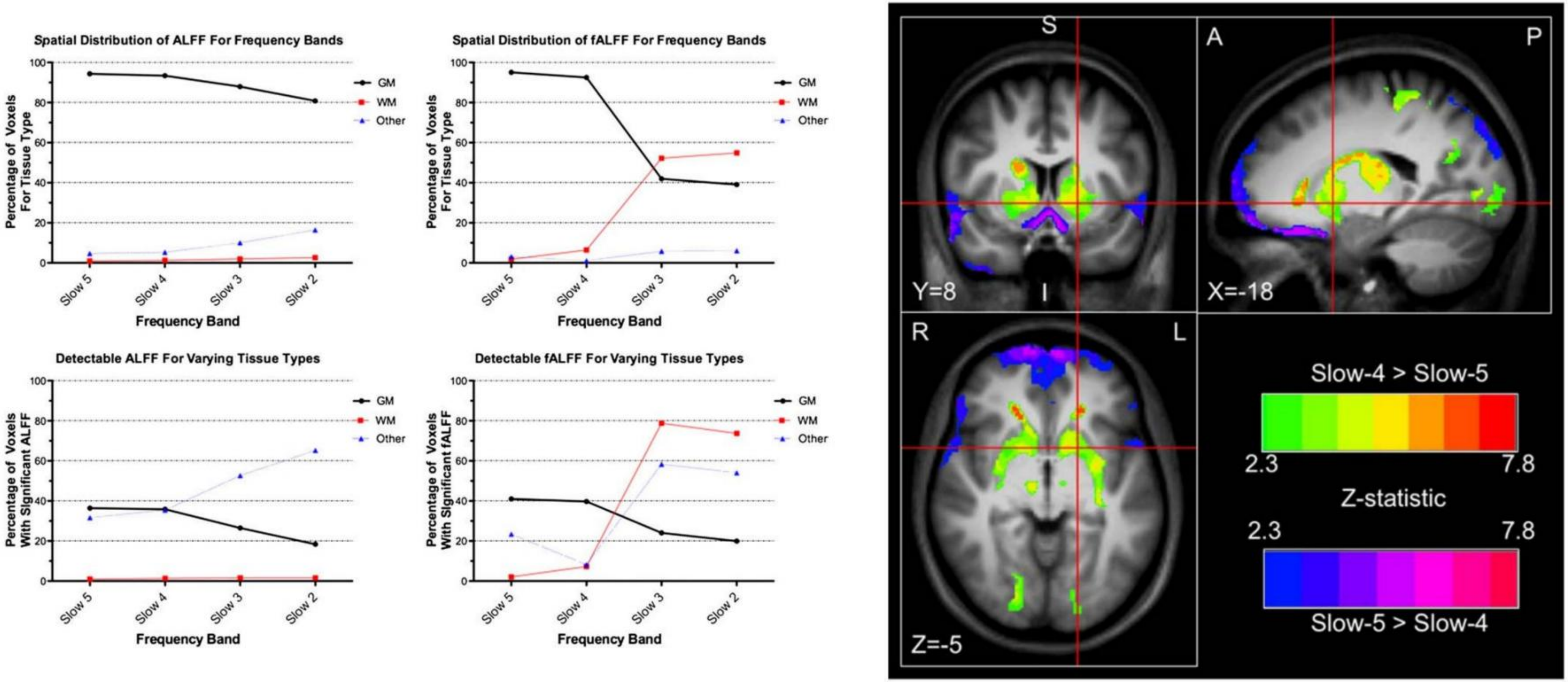

My Personal Journey: The Second Story

NeuroImage 49 (2010) 2163–2177

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Reliable intrinsic connectivity networks: Test–retest evaluation using ICA and dual regression approach

Xi-Nian Zuo [a], Clare Kelly [a], Jonathan S. Adelstein [a], Donald F. Klein [a,b,c], F. Xavier Castellanos [a,b], Michael P. Milham [a,*]

[a] Phyllis Green and Randolph Cōwen Institute for Pediatric Neuroscience, New York University Child Study Center, New York, NY, USA
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ABSTRACT

Functional connectivity analyses of resting-state fMRI data are rapidly emerging as highly efficient and powerful tools for in vivo mapping of functional networks in the brain, referred to as intrinsic connectivity networks (ICNs). Despite a burgeoning literature, researchers continue to struggle with the challenge of defining computationally efficient and reliable approaches for identifying and characterizing ICNs. Independent component analysis (ICA) has emerged as a powerful tool for exploring ICNs in both healthy and clinical populations. In particular, temporal concatenation group ICA (TC-GICA) coupled with a back-reconstruction step produces participant-level resting state functional connectivity maps for each group-level component. The present work systematically evaluated the test–retest reliability of TC-GICA derived RSFC measures over the short-term (<45 min) and long-term (5–16 months). Additionally, to investigate the degree to which the components revealed by TC-GICA are detectable via single-session ICA, we investigated the reproducibility of TC-GICA findings. First, we found moderate-to-high short- and long-term test–retest reliability for ICNs derived by combining TC-GICA and dual regression. Exceptions to this finding were limited to physiological- and imaging-related artifacts. Second, our reproducibility analyses revealed notable limitations for template matching procedures to accurately detect TC-GICA based components at the individual scan level. Third, we found that TC-GICA component's reliability and reproducibility ranks are highly consistent. In summary, TC-GICA combined with dual regression is an effective and reliable approach to exploratory analyses of resting state fMRI data.

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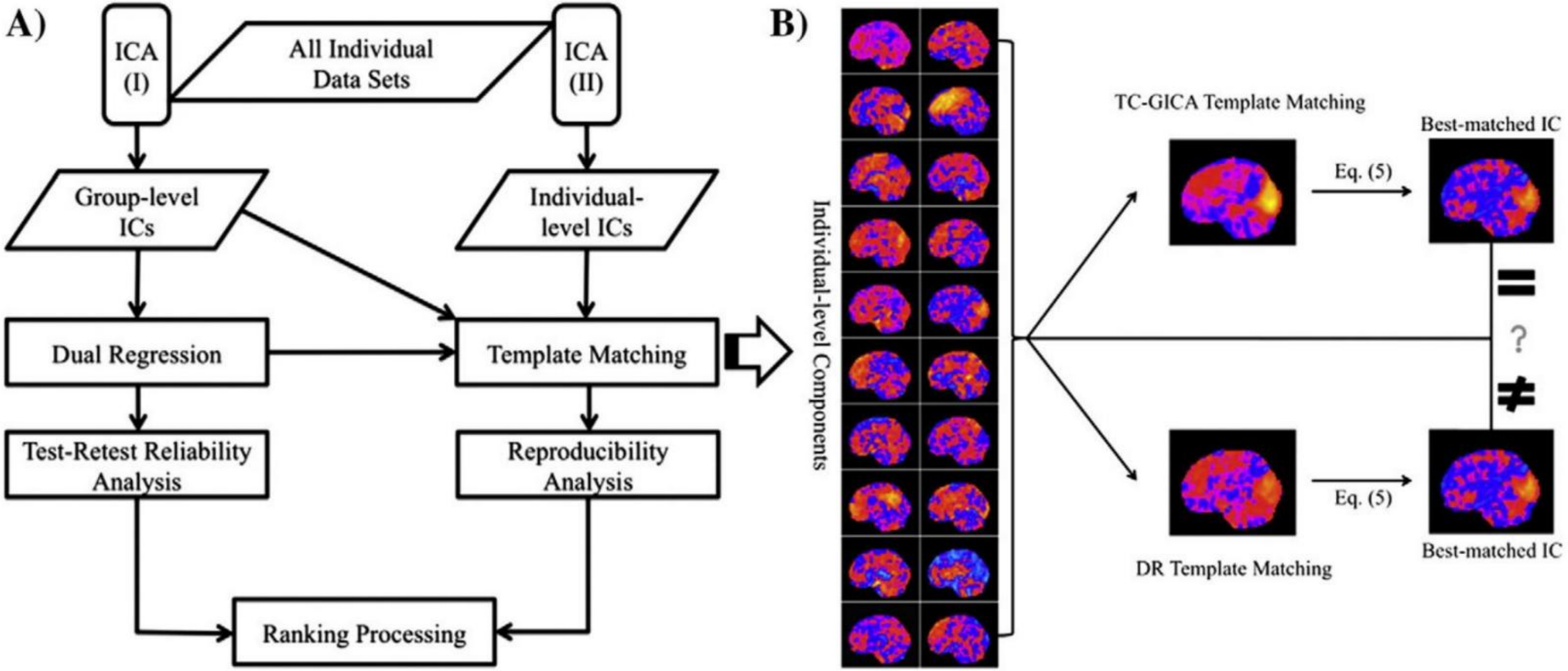

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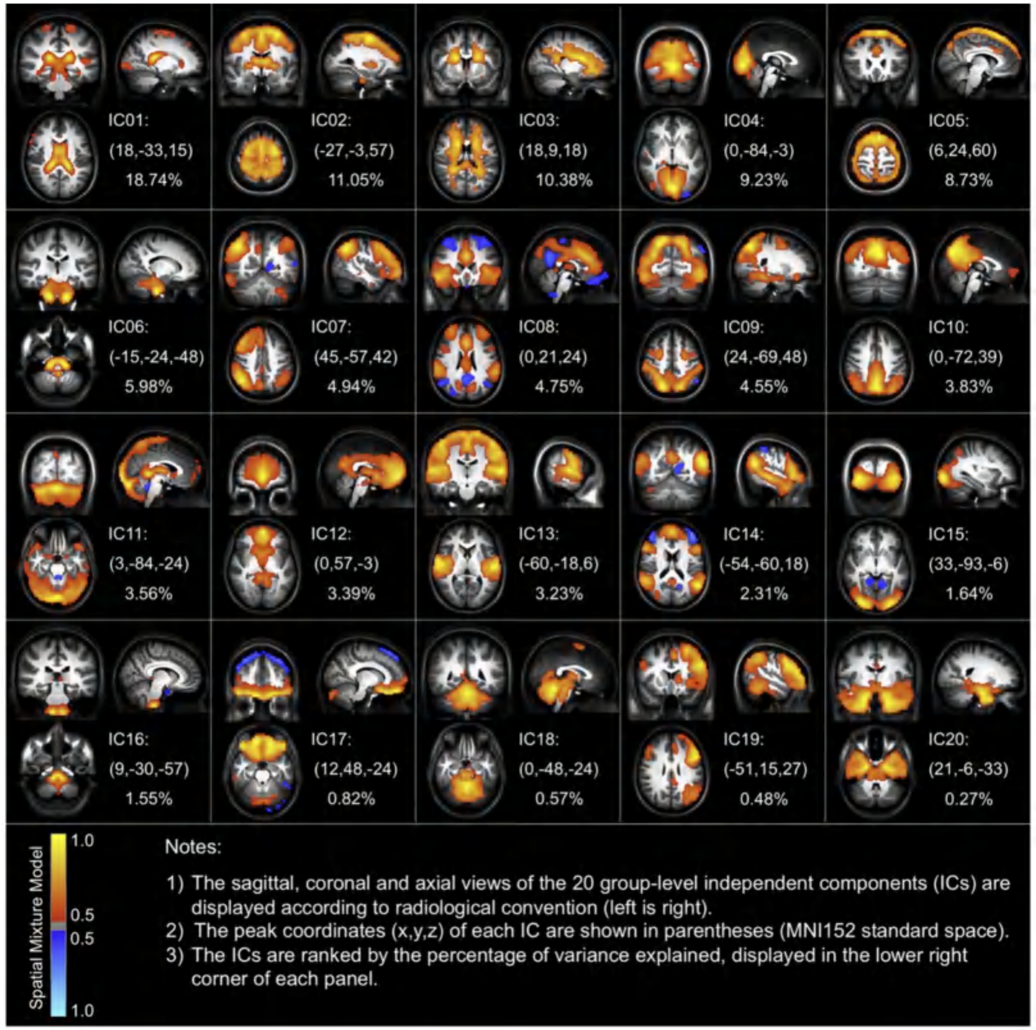

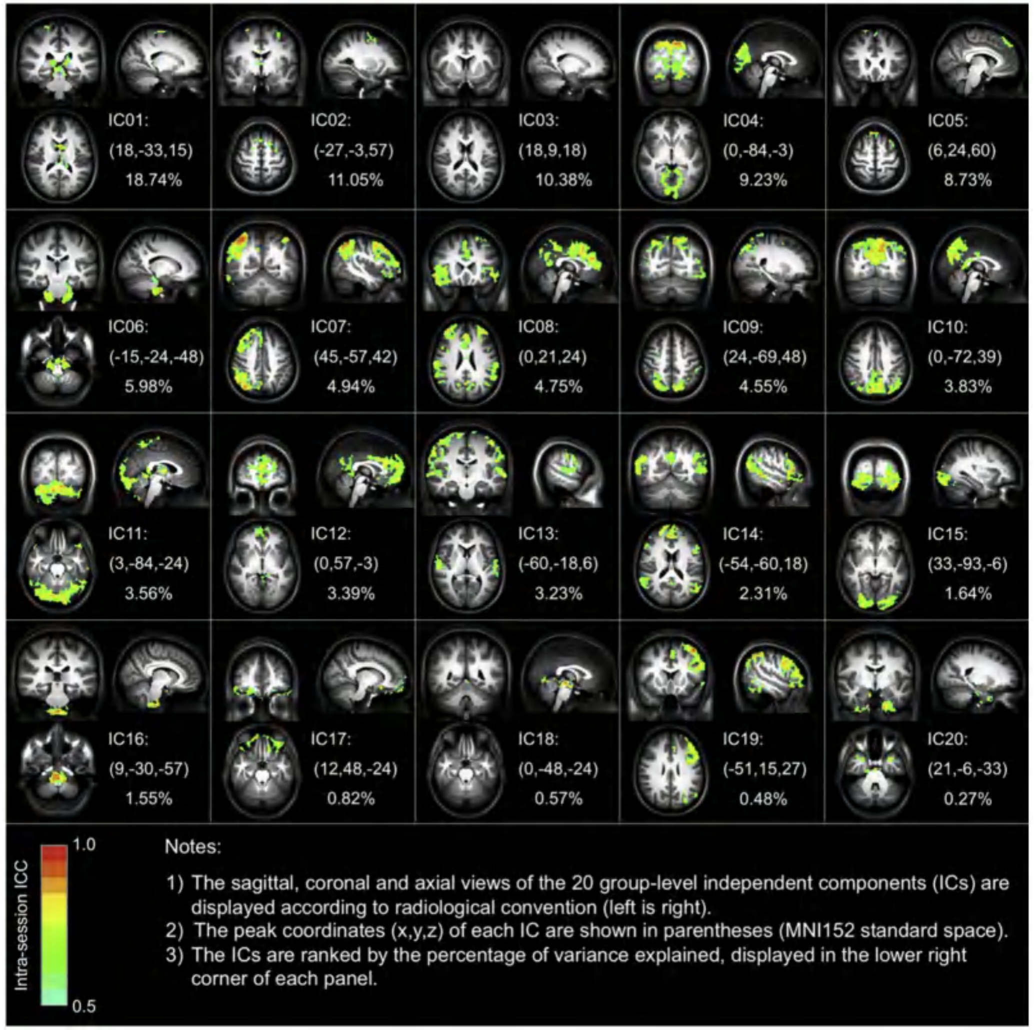

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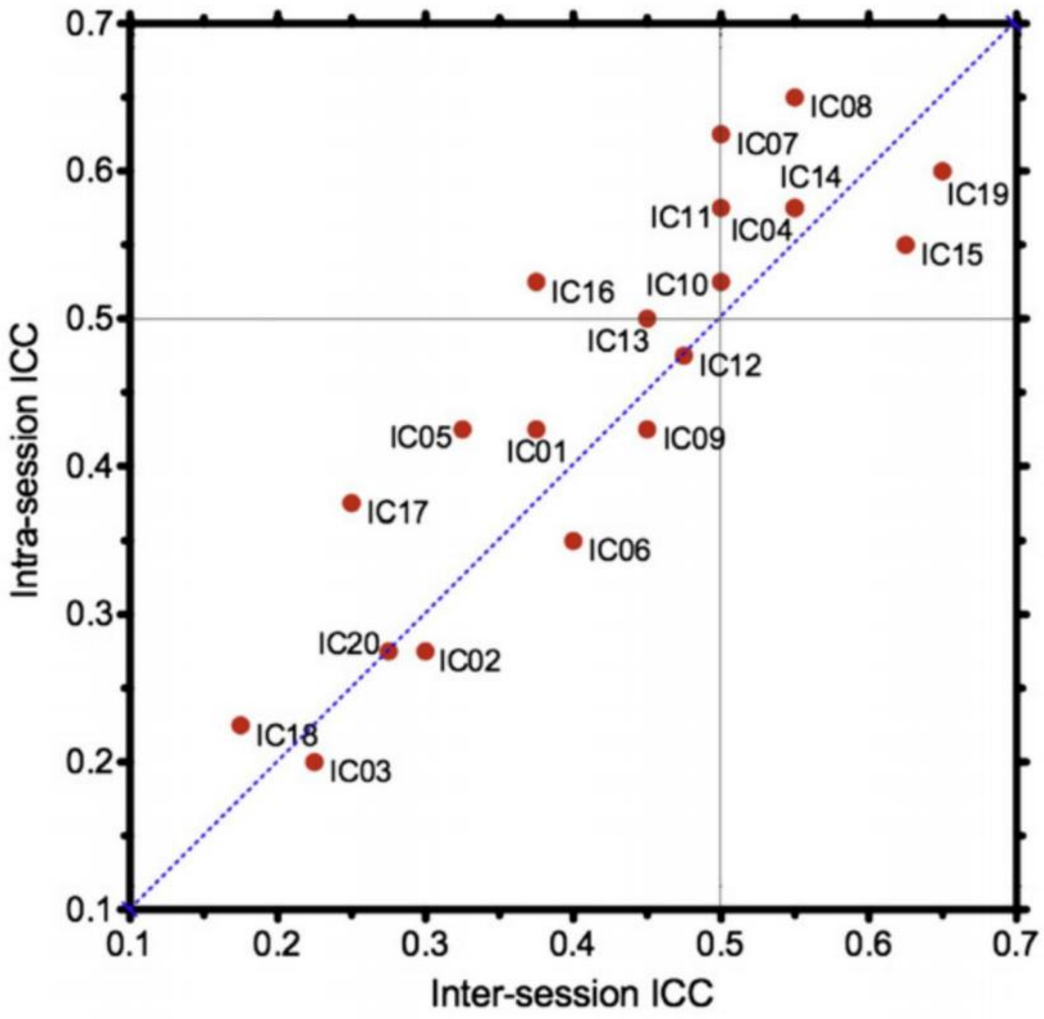

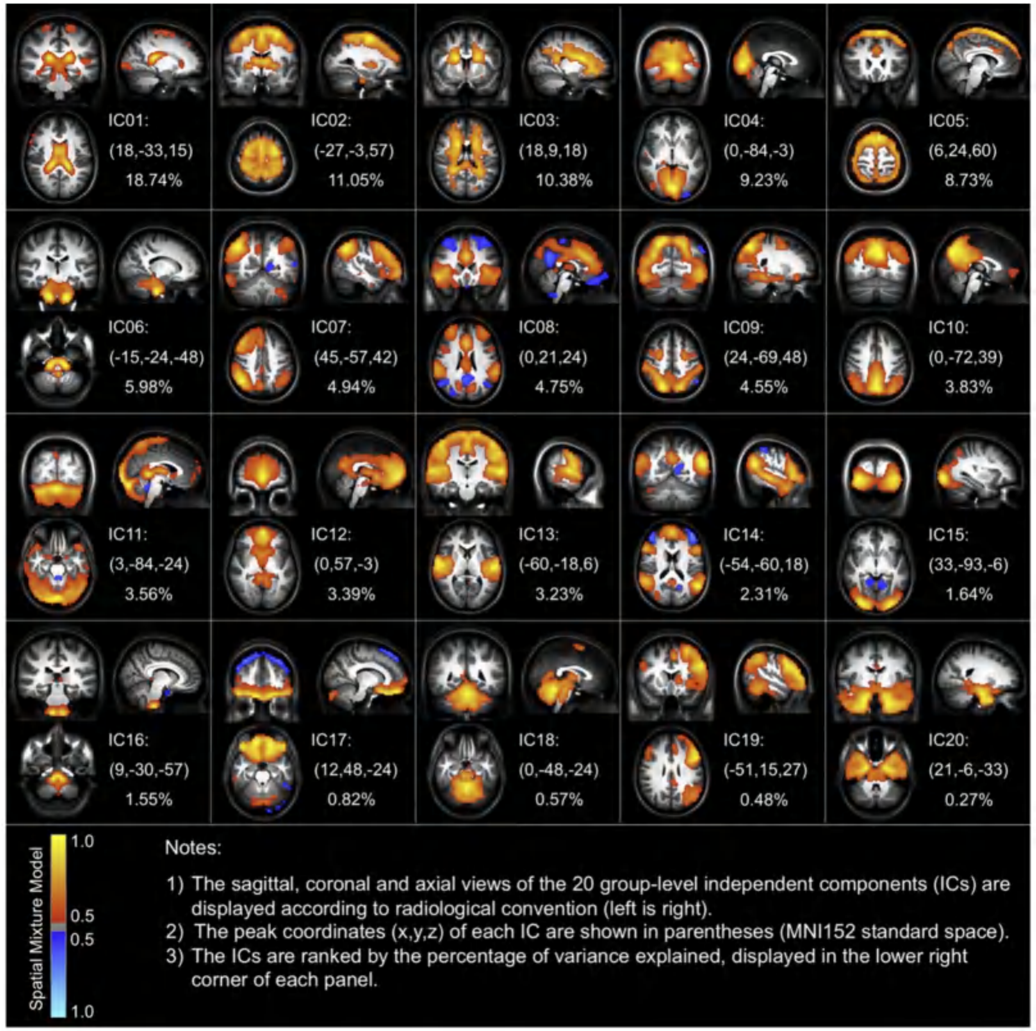

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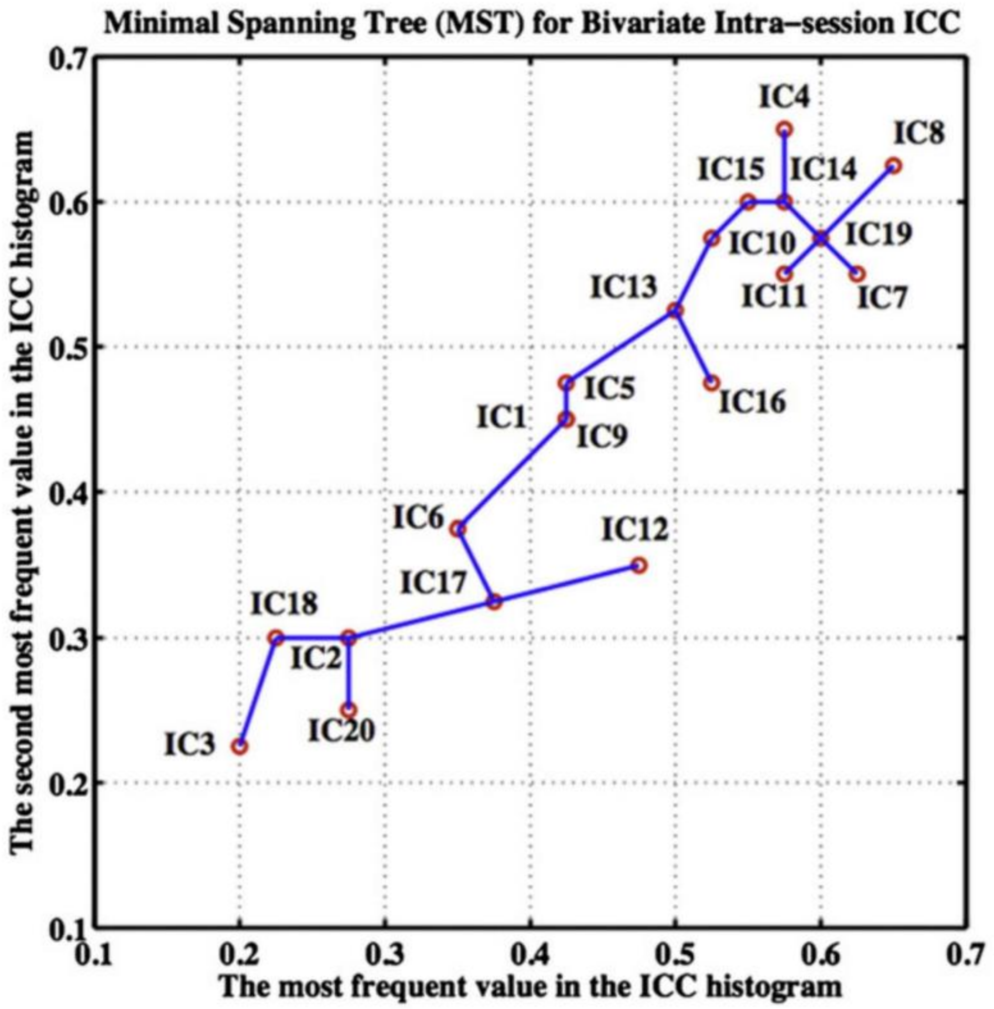

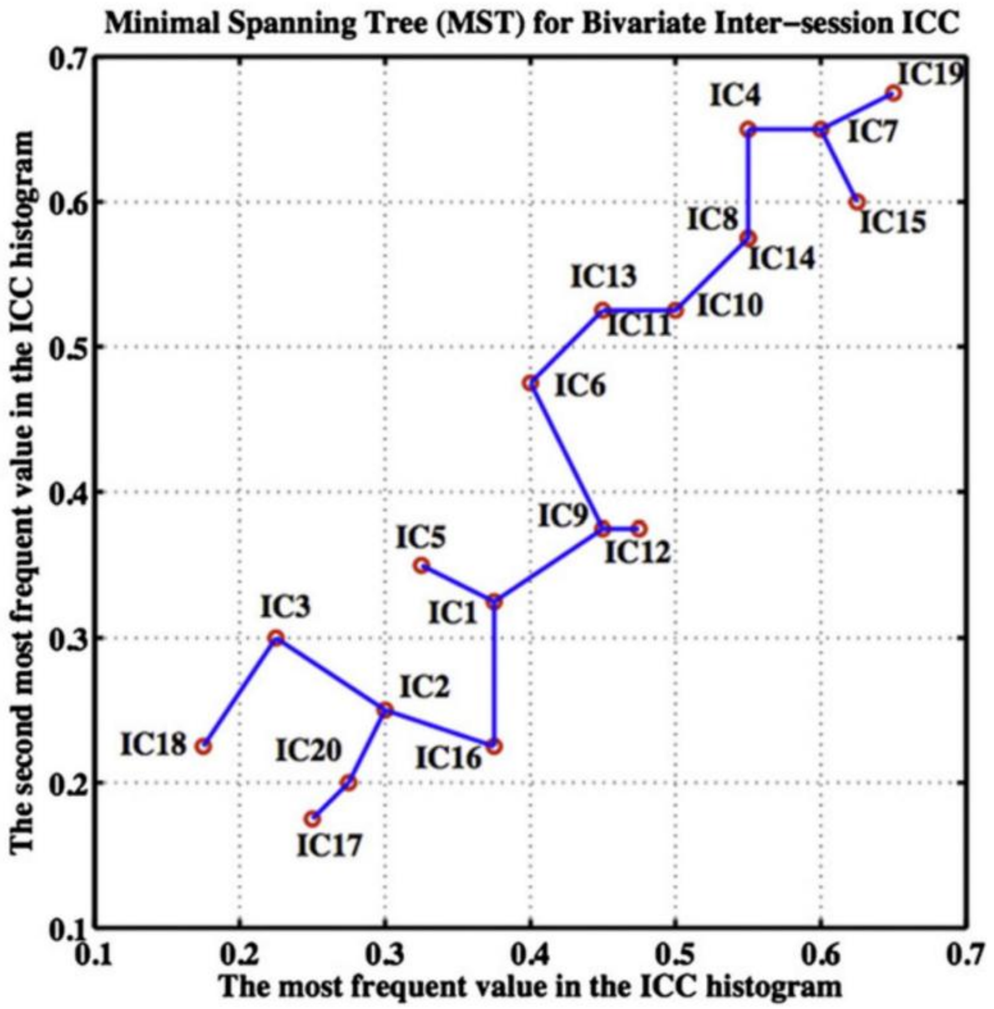

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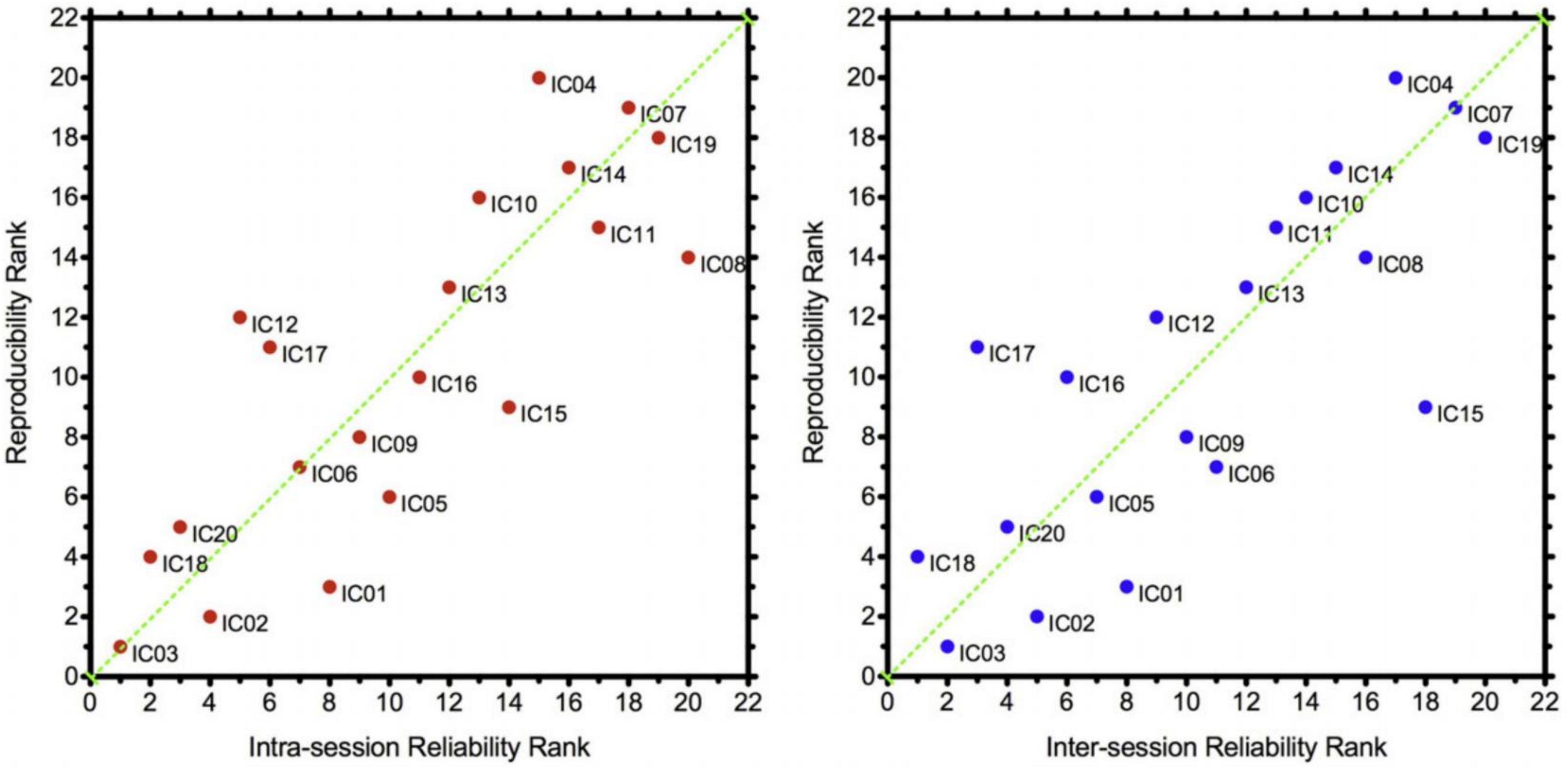

My Personal Journey: The Third Story

15034 • The Journal of Neuroscience, November 10, 2010 • 30(45):15034–15043

Development/Plasticity/Repair

Growing Together and Growing Apart: Regional and Sex Differences in the Lifespan Developmental Trajectories of Functional Homotopy

Xi-Nian Zuo,[1,2] Clare Kelly,[1] Adriana Di Martino,[1,3] Maarten Mennes,[1] Daniel S. Margulies,[4] Saroja Bangaru,[1] Rebecca Grzadzinski,[1] Alan C. Evans,[5] Yu-Feng Zang,[2] F. Xavier Castellanos,[1,6] and Michael P. Milham[1,6]
[1]Phyllis Green and Randolph Cōwen Institute for Pediatric Neuroscience, New York University Langone Medical Center, New York, New York 10016, [2]State Key Laboratory of Cognitive Science and Learning, Beijing Normal University, Beijing 100875, China, [3]Division of Child and Adolescent Neuropsychiatry, Department of Neuroscience, University of Cagliari, 09126 Cagliari, Italy, [4]Max Planck Institute for Human Cognitive and Brain Sciences, D-04103 Leipzig, Germany, [5]McConnell Brain Imaging Center, Montreal Neurological Institute, McGill University, Montreal, Québec, Canada, H3A 2B4, and [6]Nathan Kline Institute for Psychiatric Research, Orangeburg, New York 10962

Functional homotopy, the high degree of synchrony in spontaneous activity between geometrically corresponding interhemispheric (i.e., homotopic) regions, is a fundamental characteristic of the intrinsic functional architecture of the brain. However, despite its prominence, the lifespan development of the homotopic resting-state functional connectivity (RSFC) of the human brain is rarely directly examined in functional magnetic resonance imaging studies. Here, we systematically investigated age-related changes in homotopic RSFC in 214 healthy individuals ranging in age from 7 to 85 years. We observed marked age-related changes in homotopic RSFC with regionally specific developmental trajectories of varying levels of complexity. Sensorimotor regions tended to show increasing homotopic RSFC, whereas higher-order processing regions showed decreasing connectivity (i.e., increasing segregation) with age. More complex maturational curves were also detected, with regions such as the insula and lingual gyrus exhibiting quadratic trajectories and the superior frontal gyrus and putamen exhibiting cubic trajectories. Sex-related differences in the developmental trajectory of functional homotopy were detected within dorsolateral prefrontal cortex (Brodmann areas 9 and 46) and amygdala. Evidence of robust developmental effects in homotopic RSFC across the lifespan should serve to motivate studies of the physiological mechanisms underlying functional homotopy in neurodegenerative and psychiatric disorders.

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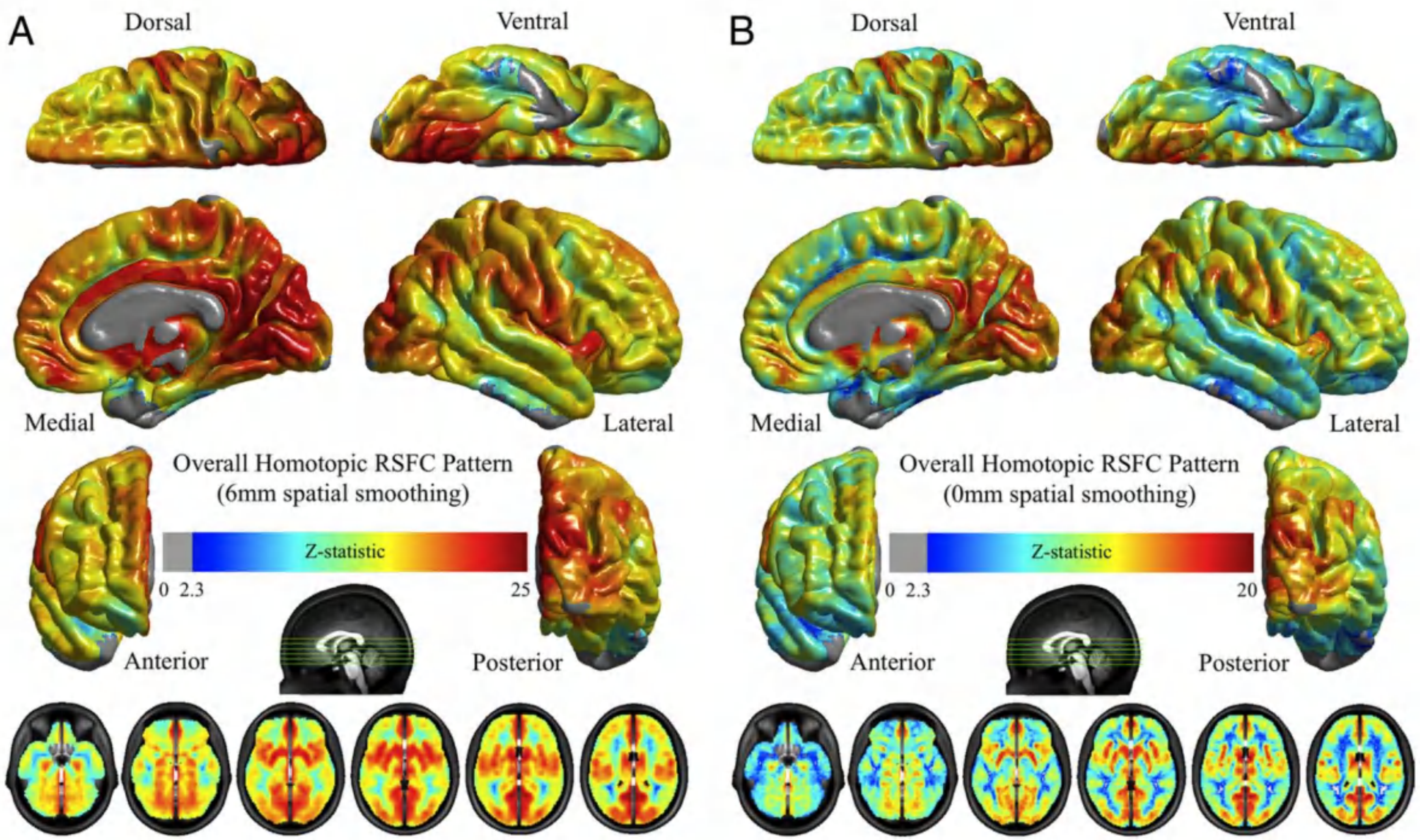

Figure 1. Whole-brain homotopic RSFC pattern. A multiple linear regression models the mean of VMHC at each voxel. One-sample tests on the individual VMHC values were performed. Correction for multiple comparisons was performed within one hemisphere (only one correlation for each pair of homotopic voxels) based on Gaussian random field theory (minimum $Z > 2.3$; cluster level, $p < 0.05$, corrected). The final statistical maps are visualized as six hemispheric surfaces (cortical regions) and six symmetric axial slices (subcortical regions) for both 6 mm FWHM (***A***) and 0 mm FWHM (***B***) spatial smoothing preprocessing strategies.

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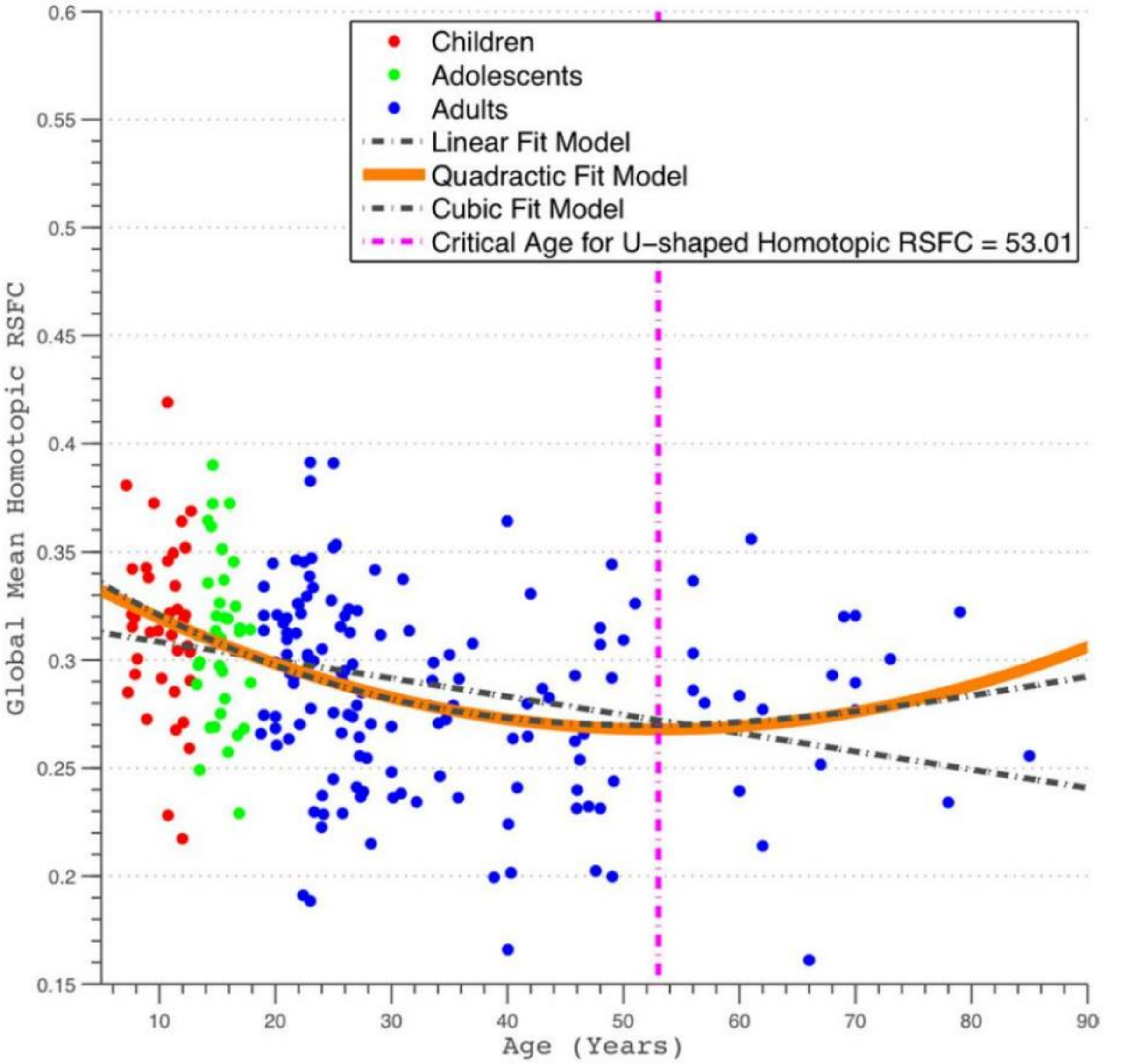

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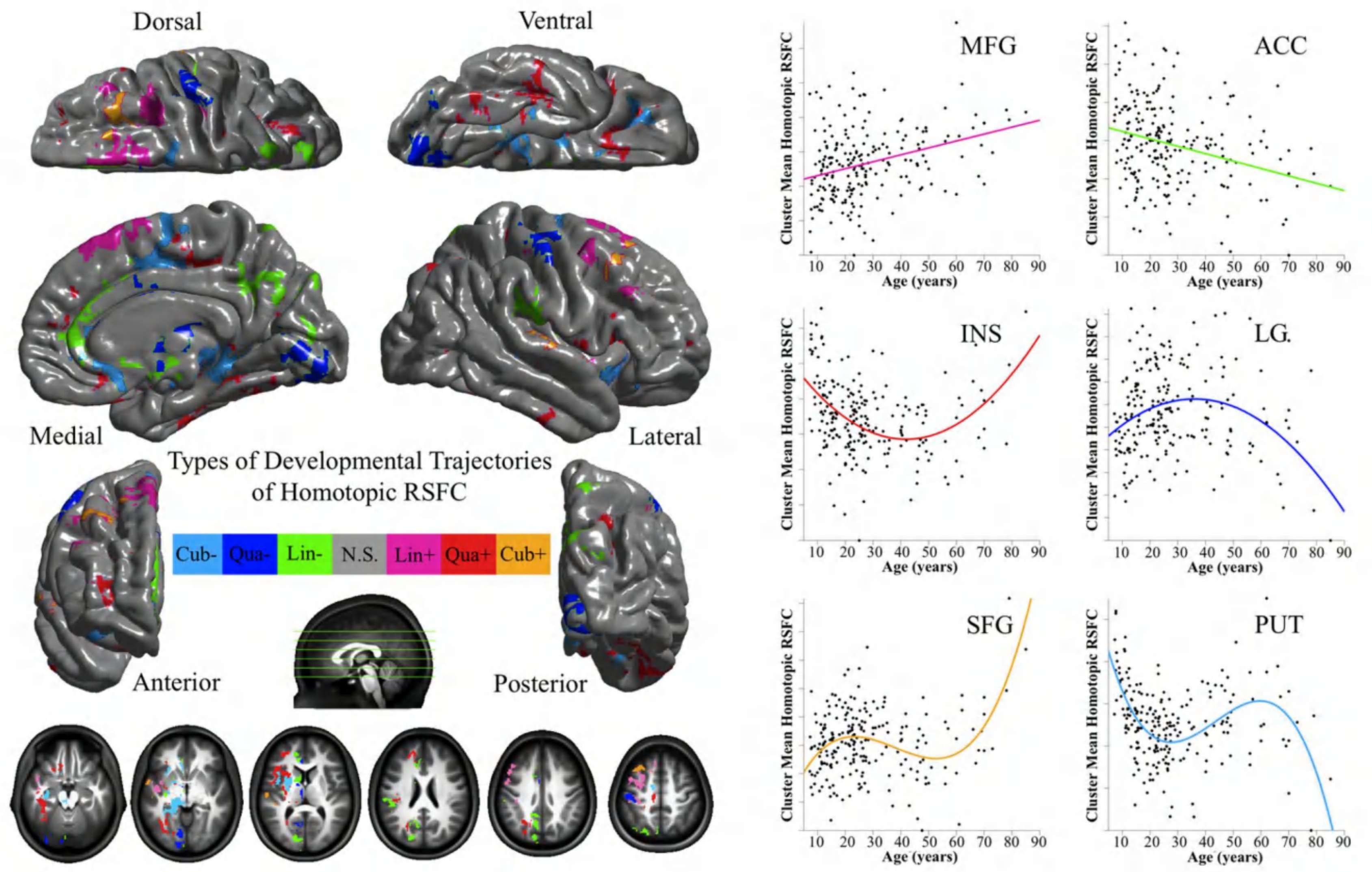

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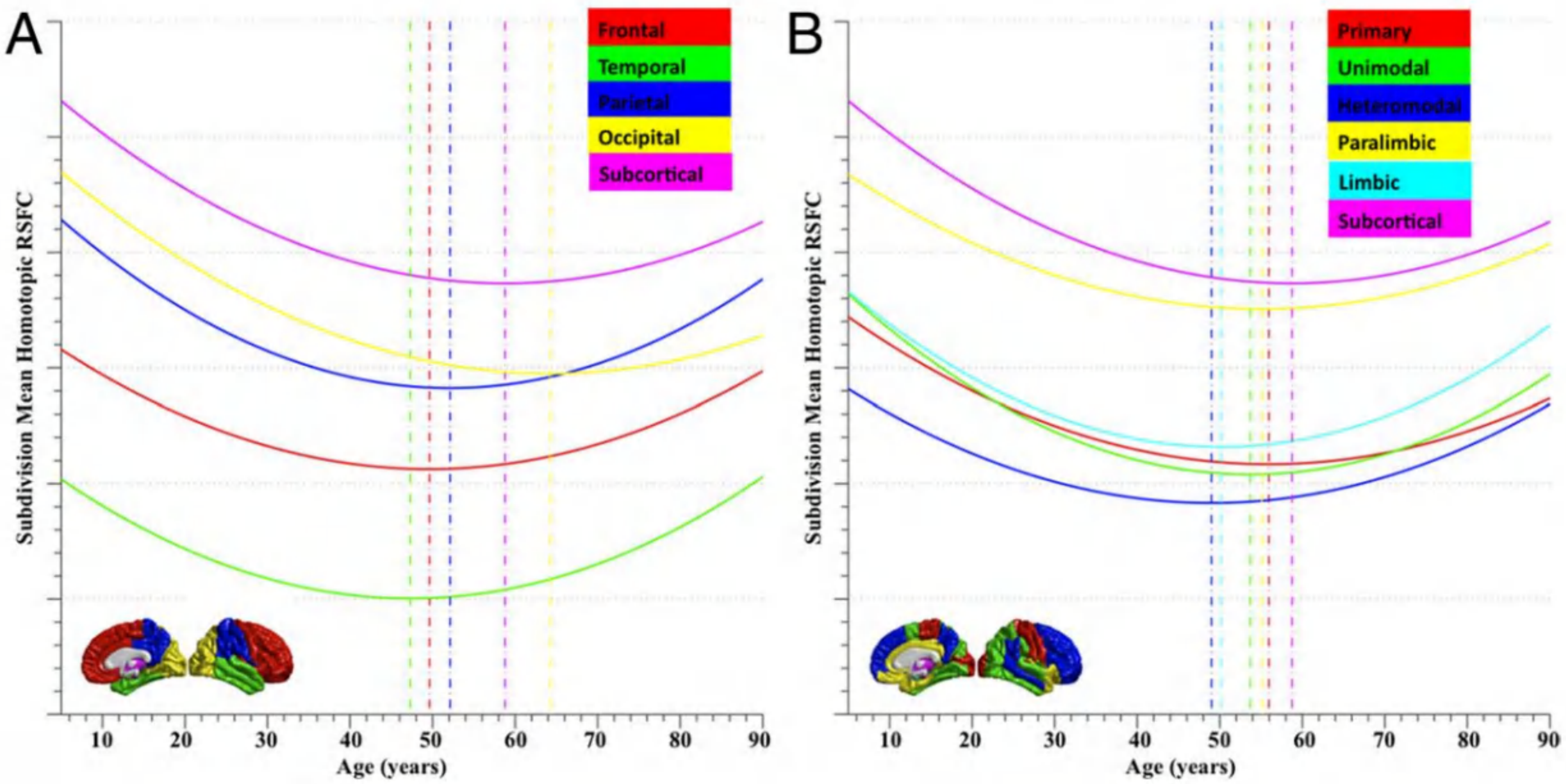

Figure 4. Trajectories of homotopic RSFC in large brain lobar/hierarchical subdivisions. Quadratic regression analyses selected by AIC on age and the mean VMHC of five brain structural subdivisions (***A***: frontal, temporal, parietal, and occipital lobes and subcortical region) or six hierarchical subdivisions (***B***: primary, unimodal, heteromodal, paralimbic, limbic, and subcortical) were conducted. These large brain units are visualized on the standard brain medial and lateral surfaces. The fit curves and their peak ages are plotted with the same color indicated on the surfaces. All the curve fits are shown significant after Bonferroni's correction.

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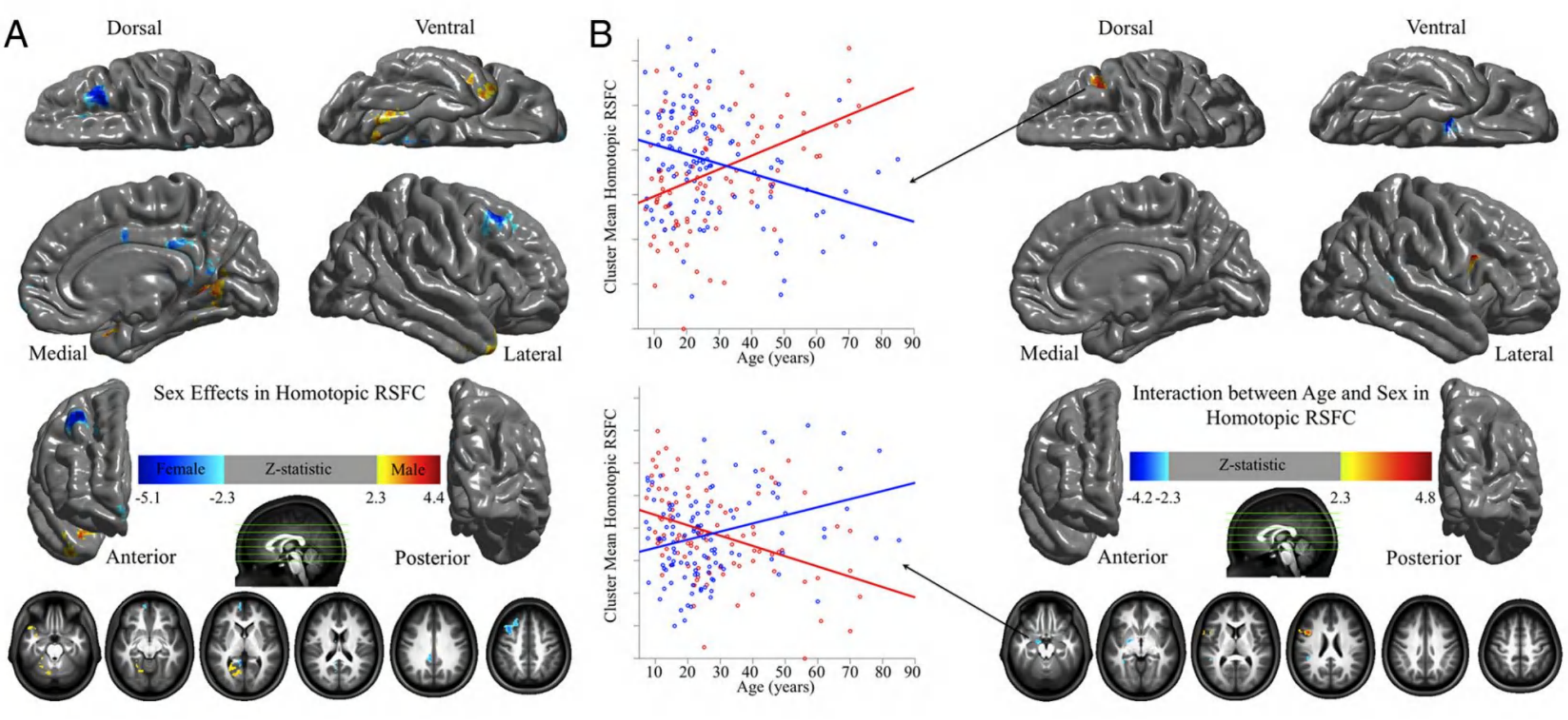

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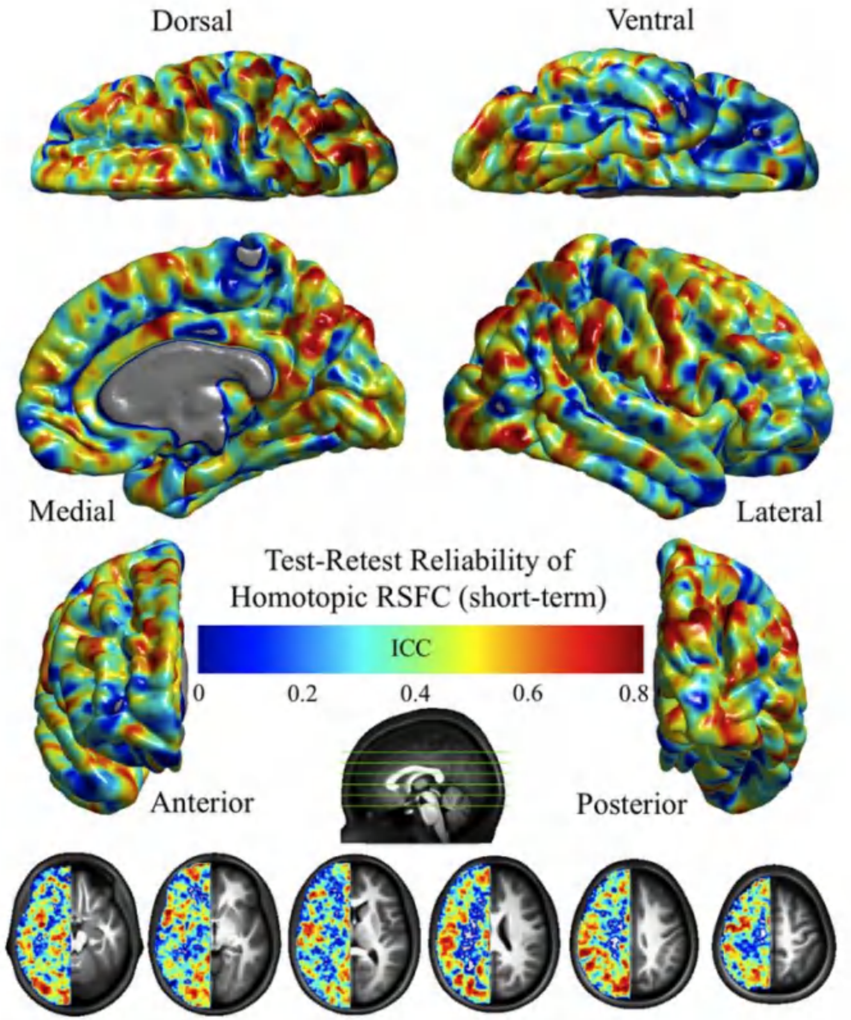

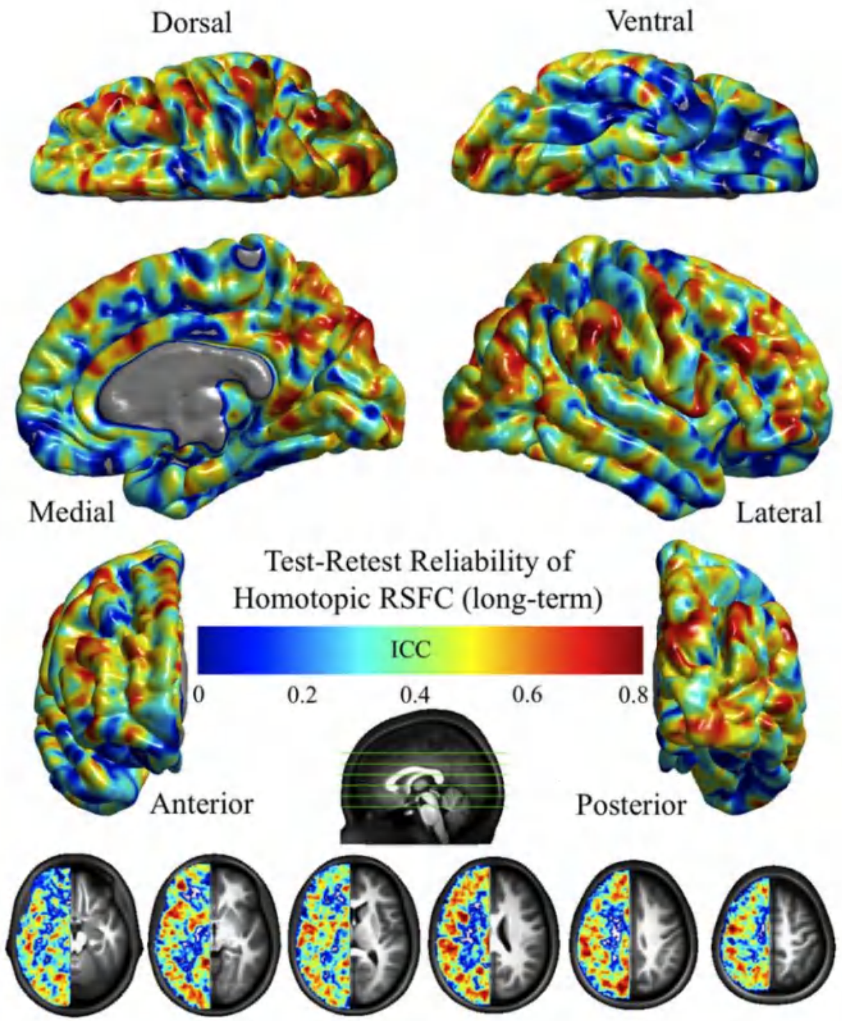

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Network Centrality in the Human Functional Connectome

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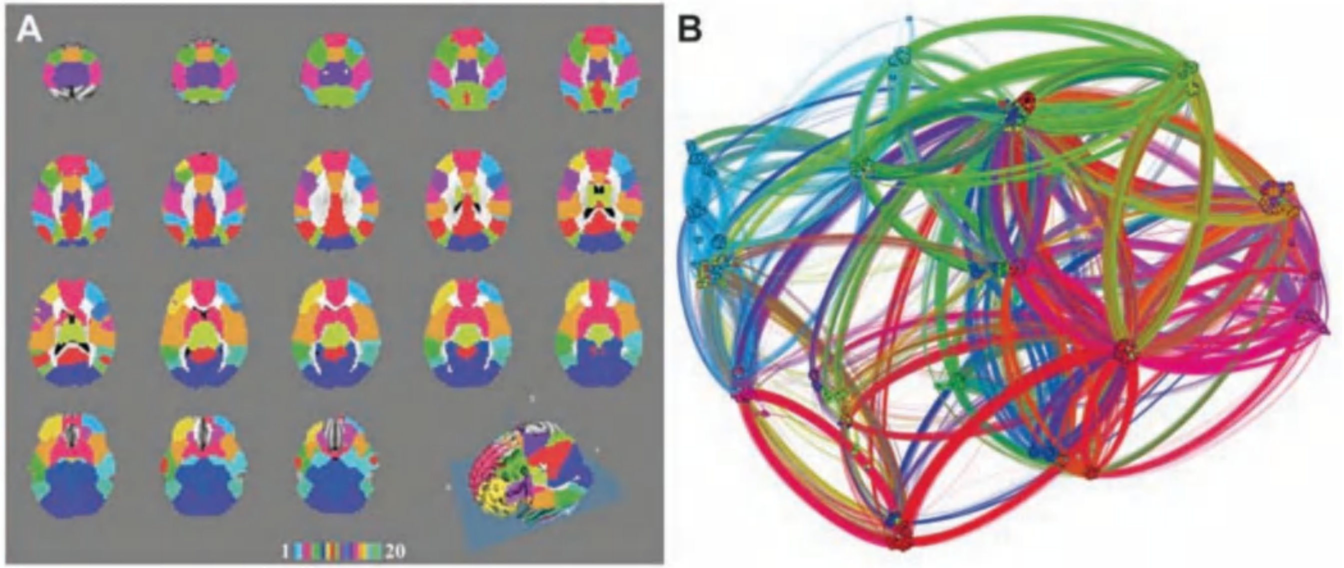

The network architecture of functional connectivity within the human brain connectome is poorly understood at the voxel level. Here, using resting state functional magnetic resonance imaging data from 1003 healthy adults, we investigate a broad array of network centrality measures to provide novel insights into connectivity within the whole-brain functional network (i.e., the functional connectome). We first assemble and visualize the voxel-wise (4 mm) functional connectome as a functional network. We then demonstrate that each centrality measure captures different aspects of connectivity, highlighting the importance of considering both global and local connectivity properties of the functional connectome. Beyond "detecting functional hubs," we treat centrality as measures of functional connectivity within the brain connectome and demonstrate their reliability and phenotypic correlates (i.e., age and sex). Specifically, our analyses reveal age-related decreases in degree centrality, but not eigenvector centrality, within precuneus and posterior cingulate regions. This implies that while local or (direct) connectivity decreases with age, connections with hub-like regions within the brain remain stable with age at a global level. In sum, these findings demonstrate the nonredundancy of various centrality measures and raise questions regarding their underlying physiological mechanisms that may be relevant to the study of neurodegenerative and psychiatric disorders.

Keywords: functional connectome, network centrality, resting-state fMRI, test–retest reliability, whole-brain connectivity

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Table 1
The "1000 Functional Connectomes" project data for current study

	Center	PI	*N*
1.	Baltimore, MD, USA	James J. Pekar/Stewart H. Mostofsky	23
2.	Bangor, UK	Stan Colcombe	20
3.	Berlin, Germany	Daniel Margulies	26
4.	Beijing, China	Yu-Feng Zang	192
5.	Cambridge, MA, USA	Randy L. Buckner	198
6.	Cleveland, OH, USA	Mark J. Lowe	31
7.	Dallas, TX, USA	Bart Rypma	24
8.	Leiden, Netherlands	Serge A R B. Rombouts	31
9.	Leipzig, Germany	Arno Villringer	37
10.	Milwaukee, WI, USA	Shi-Jiang Li	46
11.	Montreal, Canada	Alan C. Evans	51
12.	Munich, Germany	Christian Sorg/Valentin Riedl	15
13.	New York City, NY, USA	Michael Milham/F. Xavier Castellanos	59
14.	New York City, NY, USA	Michael Milham/F. Xavier Castellanos	20
15.	Newark, NJ, USA	Bharat B. Biswal	19
16.	Orangeburg, NY, USA	Matthew J. Hoptman	20
17.	Oulu, Finland	Vesa J. Kiviniemi/Juha Veijola	103
18.	Oxford, UK	Steve M. Smith/Clare Mackay	22
19.	Palo Alto, CA, USA	Michael Greicius	17
20.	Queensland, Australia	Katie McMahon	18
21.	Saint Louis, MO, USA	Bradley L. Schlaggar/Steven E. Petersen	31

Table 2
The functional parcellation including 20 functional communities

	Functional community
1.	Hippocampus (B)—Brain-stem (B)—Cerebellum Anterior Loble (B)
2.	Amygdala (B)—Parahippocampus (B)—Posterior Temporal Gyrus (R)
3.	Orbital Frontal Cortex (B)
4.	Striatum (B)—Medial Prefrontal Cortex (B)
5.	Anterior Temporal Gyrus (R)
6.	Temporal Gyrus (L)
7	Visual Cortex (B)
8.	Thalamus (B)
9.	Posterior Cingulate Cortex (B)—Precuneus (B)—Angular Cortex (B)—Superior Frontal Gyrus (B)—Parahippocampal Gyrus (B)—Medial Prefrontal Cortex (B)—Middle Temporal Gyrus (B)
10.	Dorsal Lateral Prefrontal Cortex (B-L)
11.	Middle Frontal Gyrus (R)—IFG (R)
12.	Middle Frontal Gyrus (L)—IFG (L)
13.	Supplementary Motor Cortex (B)—Middle Cingulate Gyrus (B)
14.	Precentral Gyrus (B)—Postcentral Gyrus (B)
15.	Anterior Cingulate Cortex (B)—Supramarginal Gyrus (B)—Inferior Parietal Lobule (B)—Superior Temporal Gyrus (B)—Insular Lobe (B)
16.	Superior Frontal Gyrus (L)—Middle Frontal Cortex (L)
17.	Middle Frontal Gyrus (R)—Inferior Parietal Lobule (B)
18.	Lateral Occipital Cortex (B)—Pecuneus (B)
19.	Superior Temporal Gyrus (L)—Middle Temporal Gyrus (R)
20.	Inferior Temporal Gyrus (B)

Note: B, Bilateral; L, Left; and R, Right.

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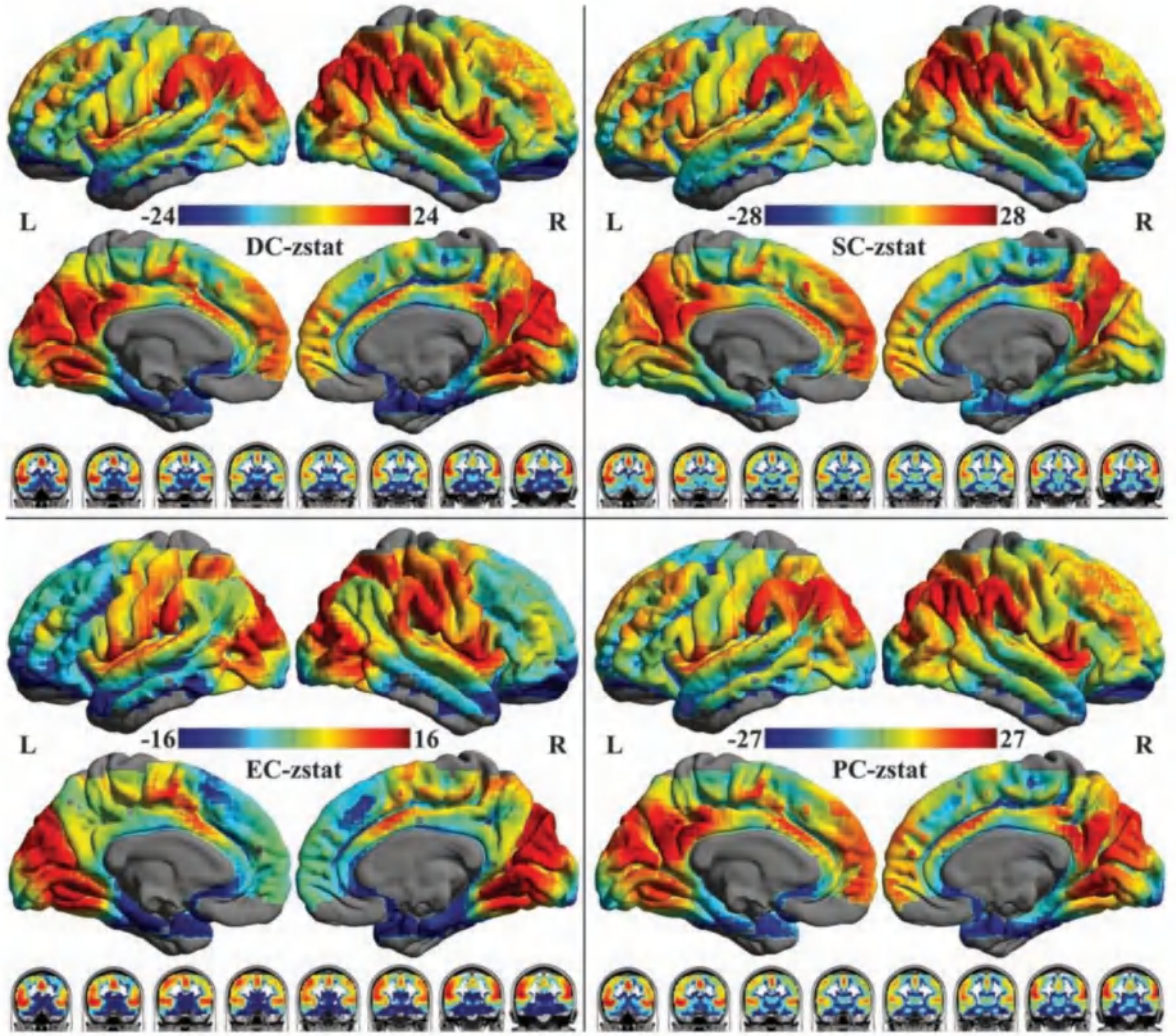

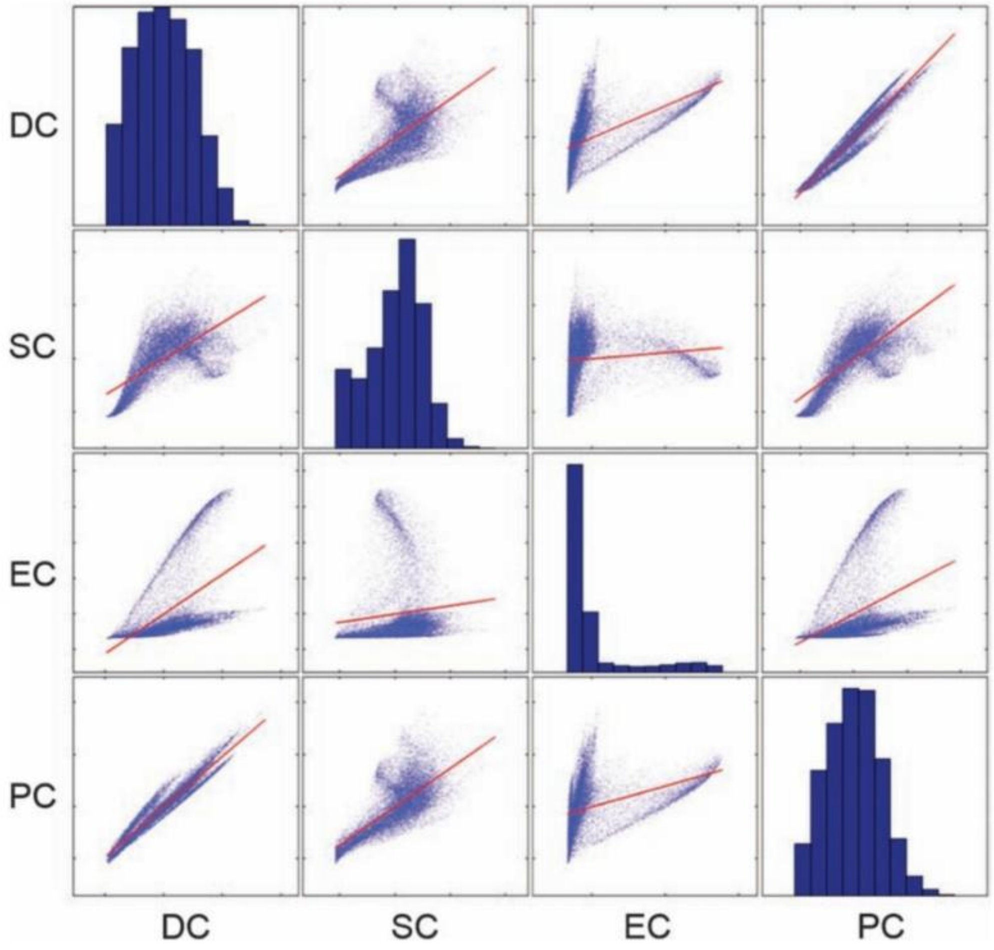

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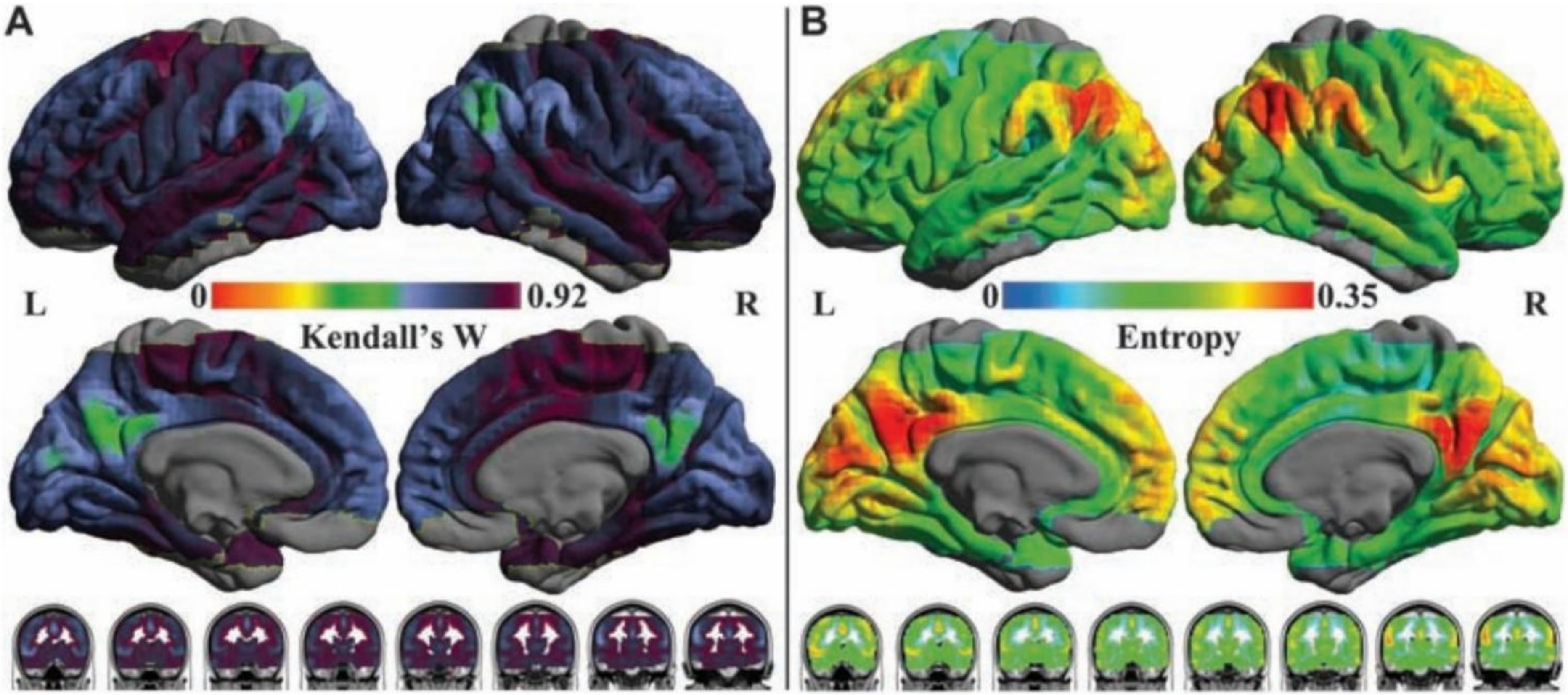

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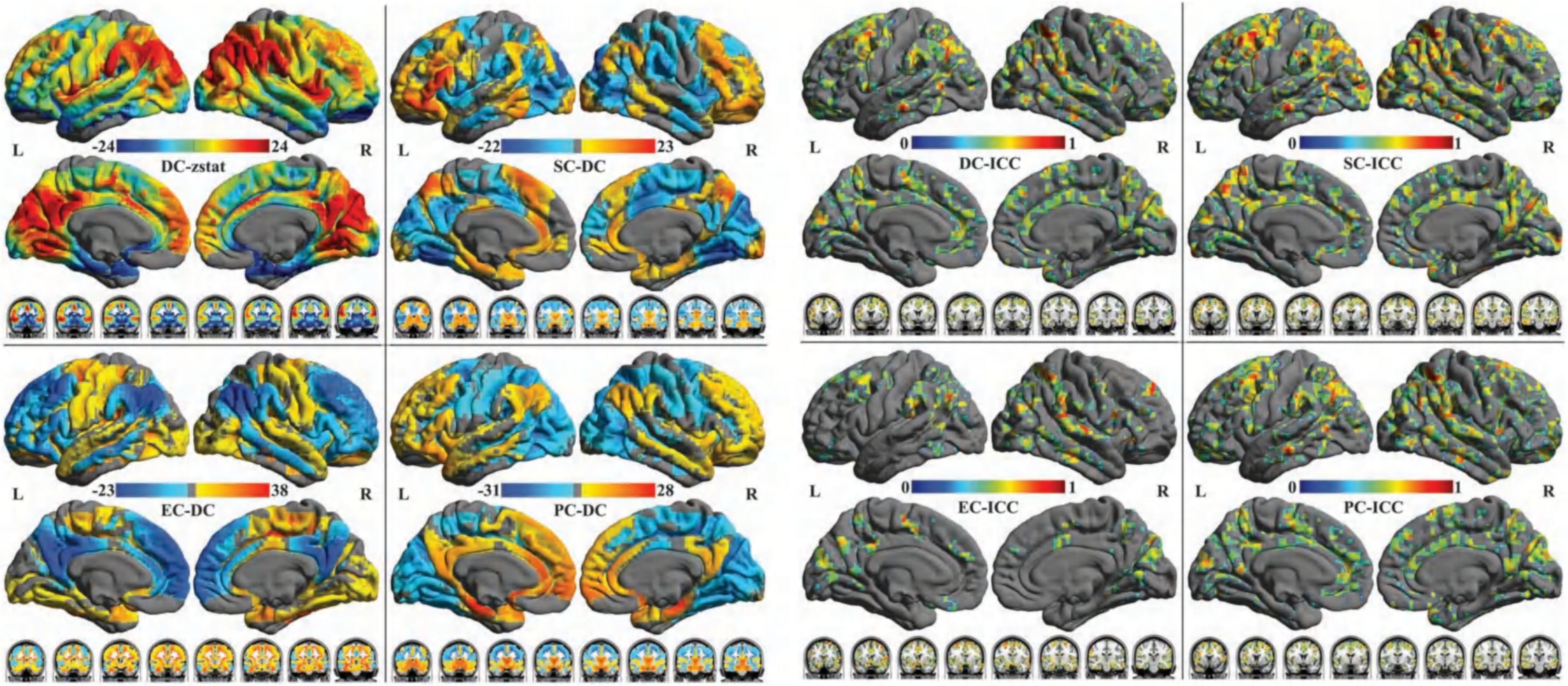

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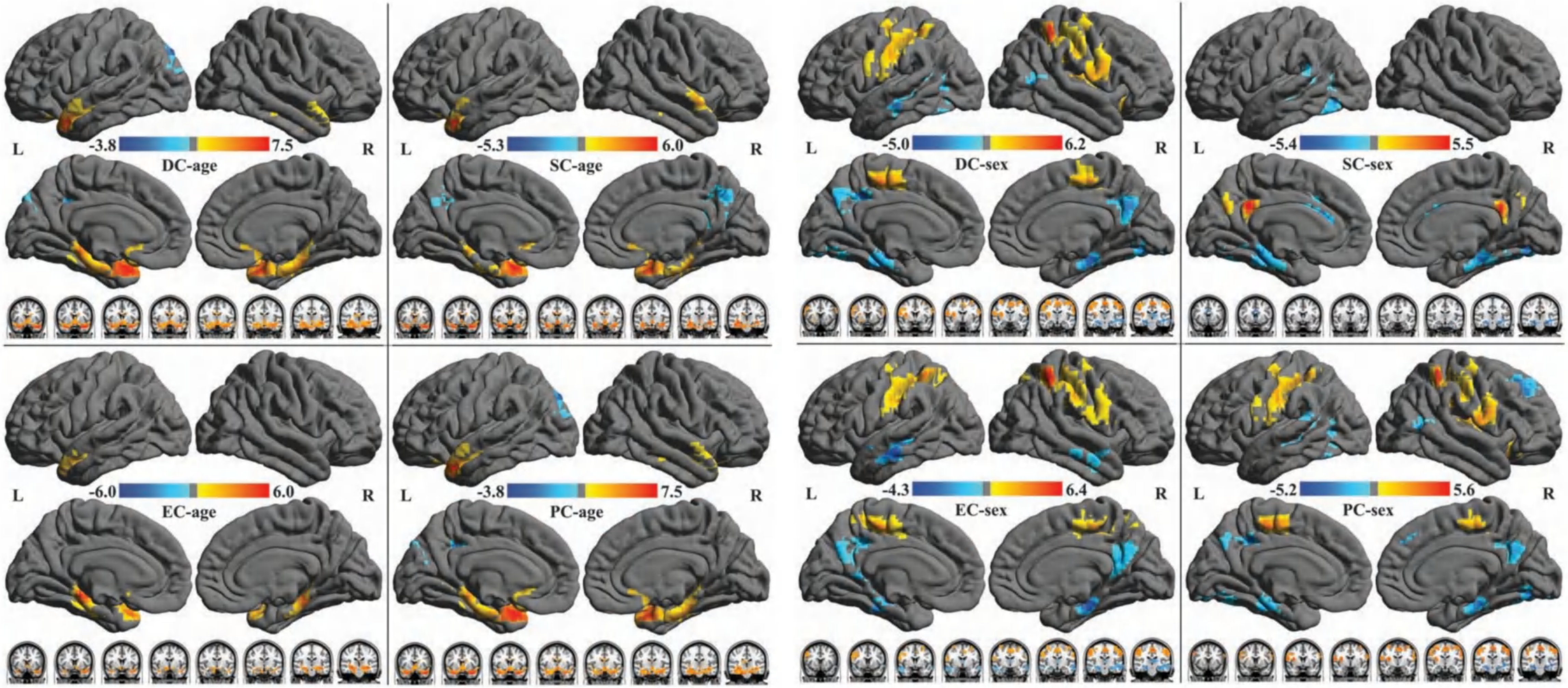

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Toward reliable characterization of functional homogeneity in the human brain: Preprocessing, scan duration, imaging resolution and computational space

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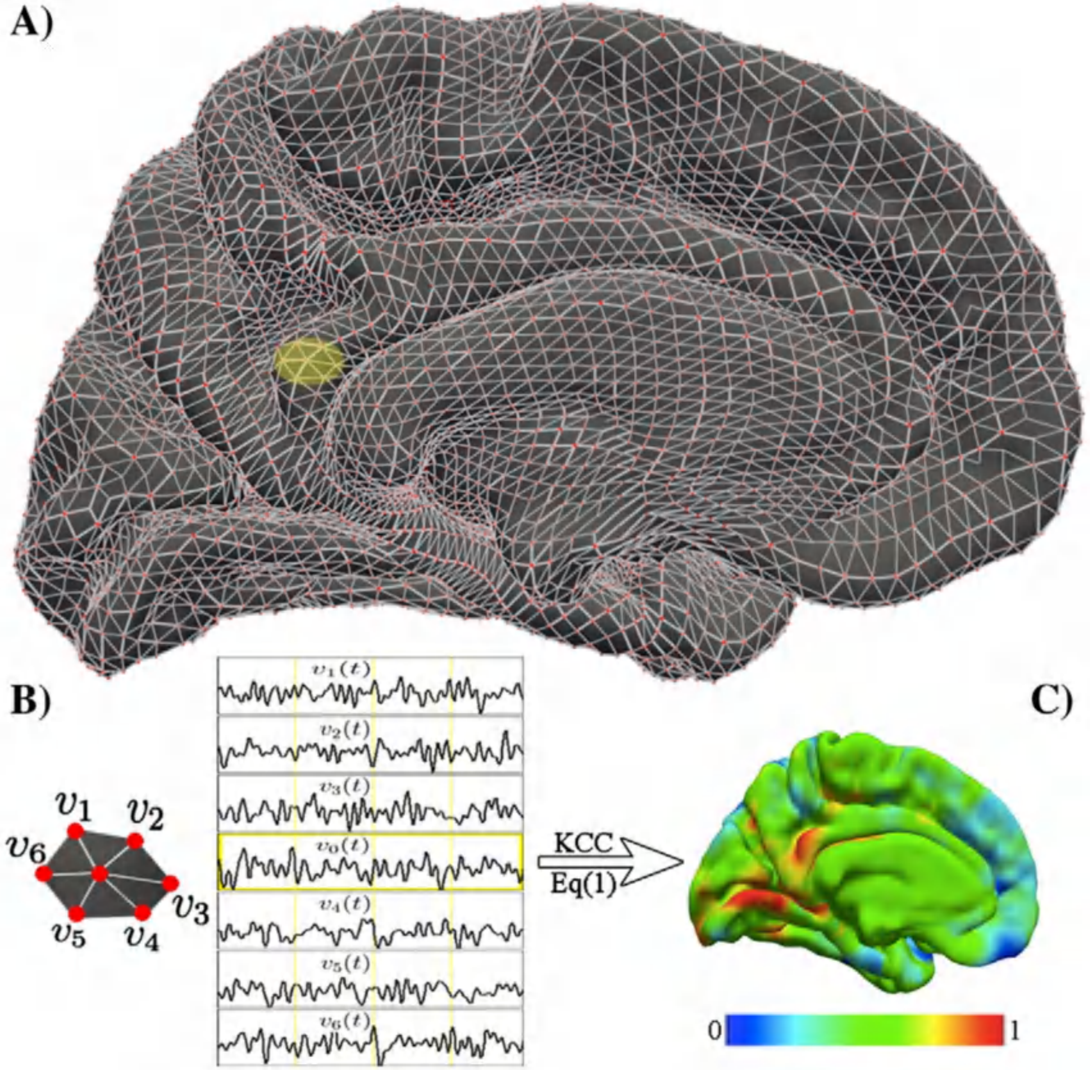
ABSTRACT

While researchers have extensively characterized functional connectivity between brain regions, the characterization of functional homogeneity within a region of the brain connectome is in early stages of development. Several functional homogeneity measures were proposed previously, among which regional homogeneity (ReHo) was most widely used as a measure to characterize functional homogeneity of resting state fMRI (R-fMRI) signals within a small region (Zang et al., 2004). Despite a burgeoning literature on ReHo in the field of neuroimaging brain disorders, its test–retest (TRT) reliability remains unestablished. Using two sets of public R-fMRI TRT data, we systematically evaluated the ReHo's TRT reliability and further investigated the various factors influencing its reliability and found: 1) nuisance (head motion, white matter, and cerebrospinal fluid) correction of R-fMRI time series can significantly improve the TRT reliability of ReHo while additional removal of global brain signal reduces its reliability, 2) spatial smoothing of R-fMRI time series artificially enhances ReHo intensity and influences its reliability, 3) surface-based R-fMRI computation largely improves the TRT reliability of ReHo, 4) a scan duration of 5 min can achieve reliable estimates of ReHo, and 5) fast sampling rates of R-fMRI dramatically increase the reliability of ReHo. Inspired by these findings and seeking a highly reliable approach to exploratory analysis of the human functional connectome, we established an R-fMRI pipeline to conduct ReHo computations in both 3-dimensions (volume) and 2-dimensions (surface).



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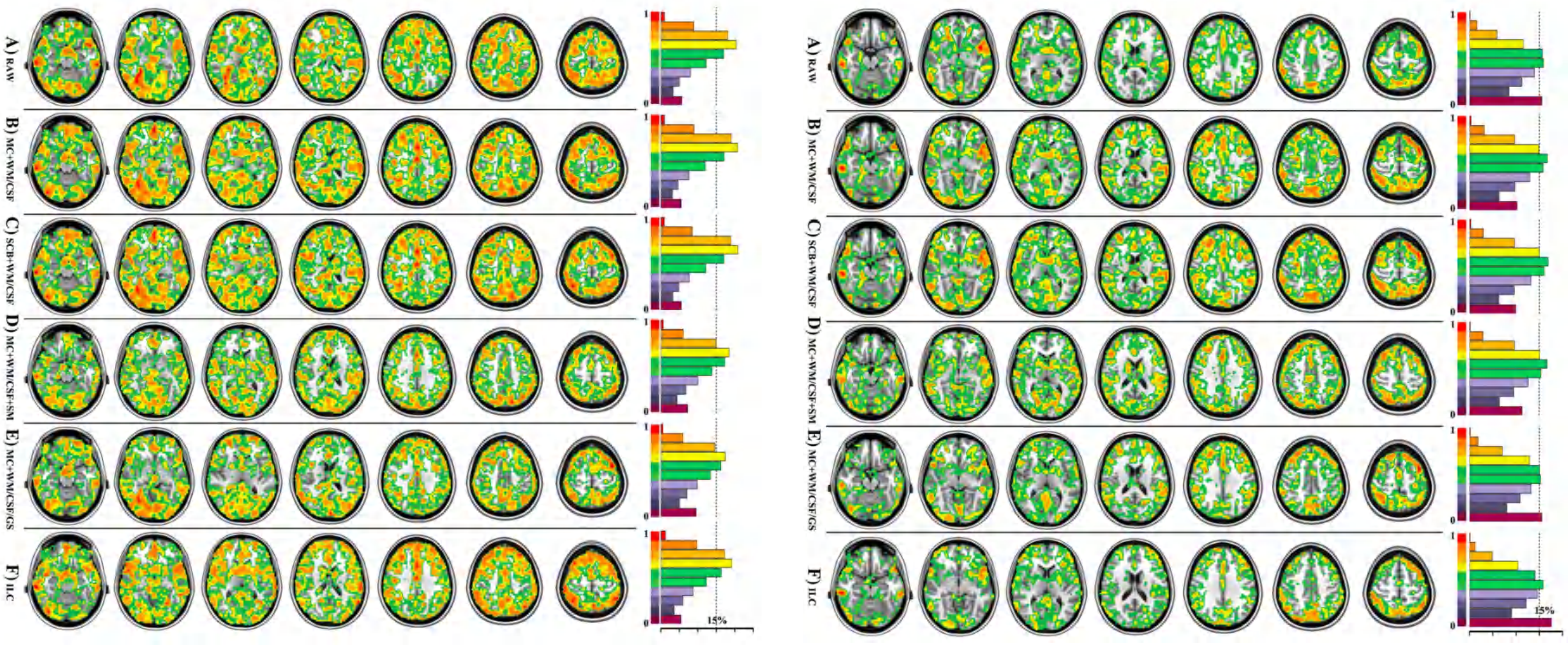

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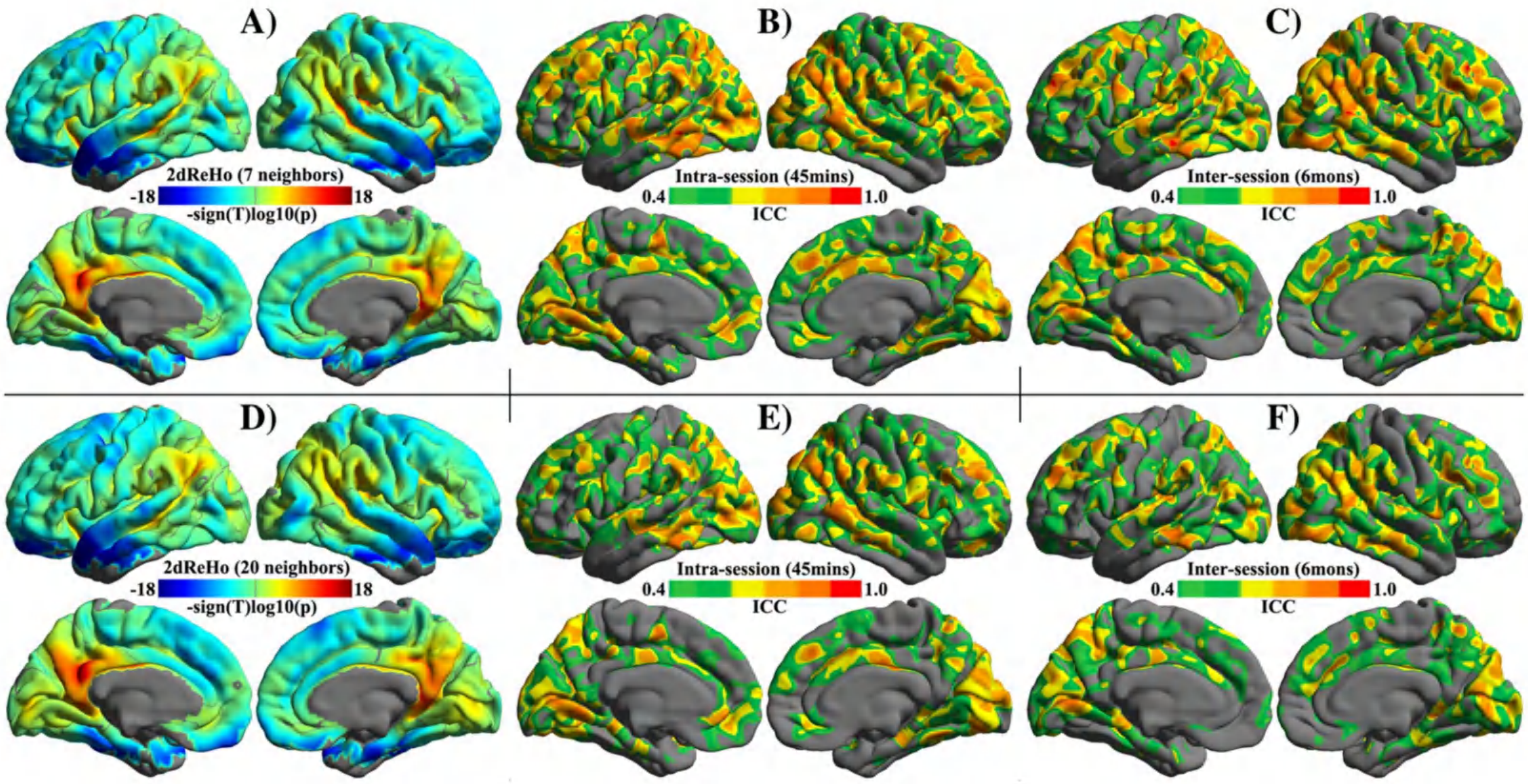

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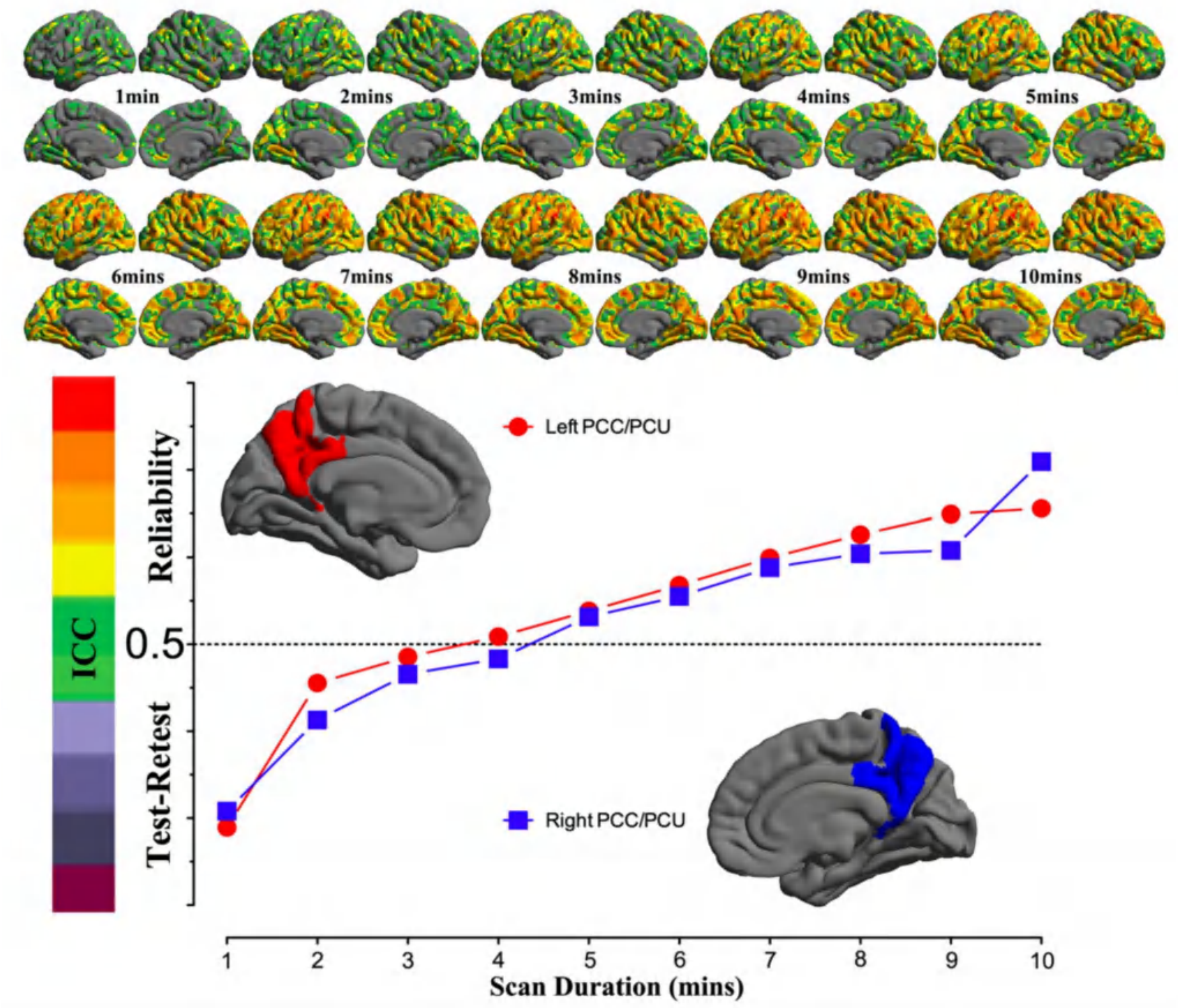

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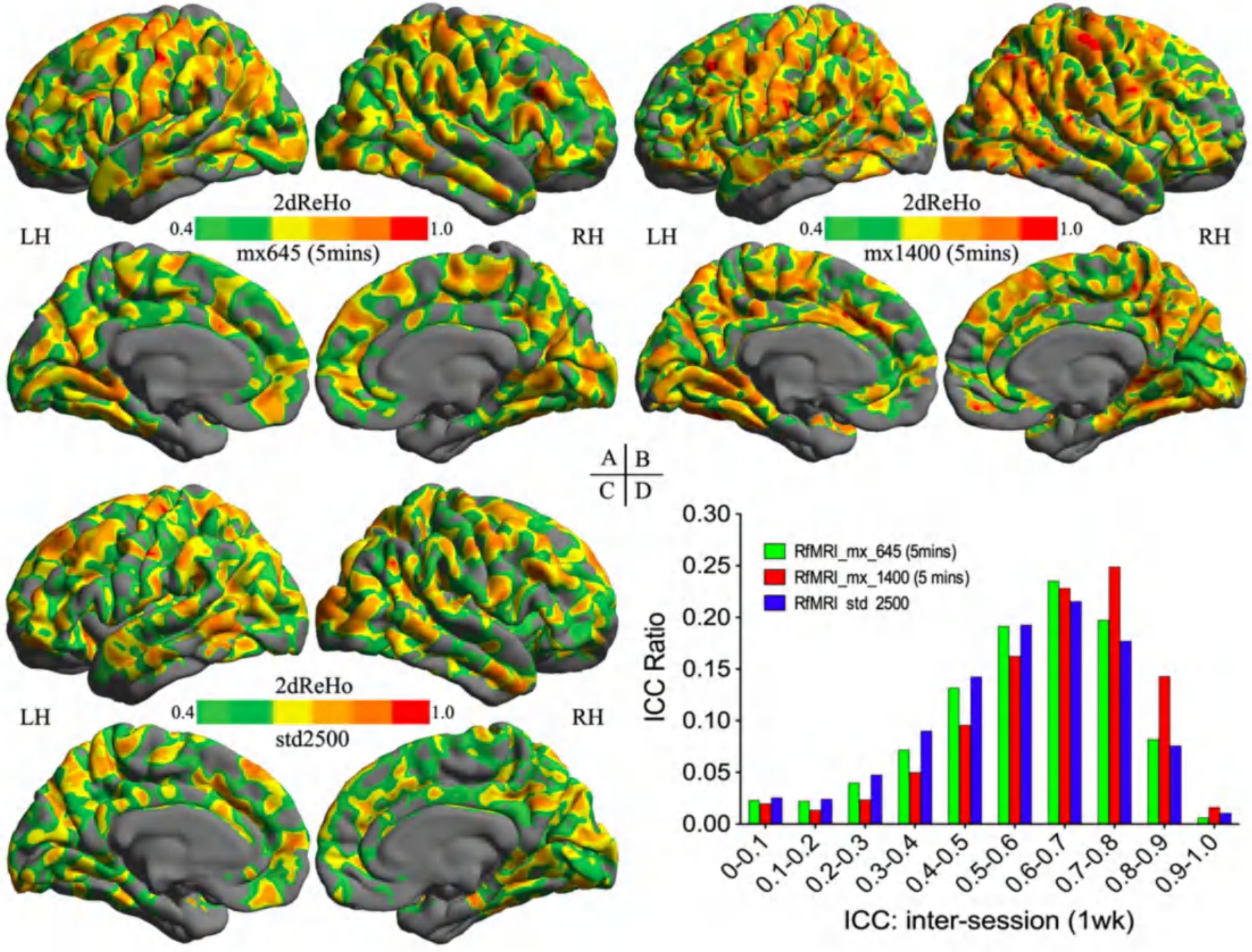

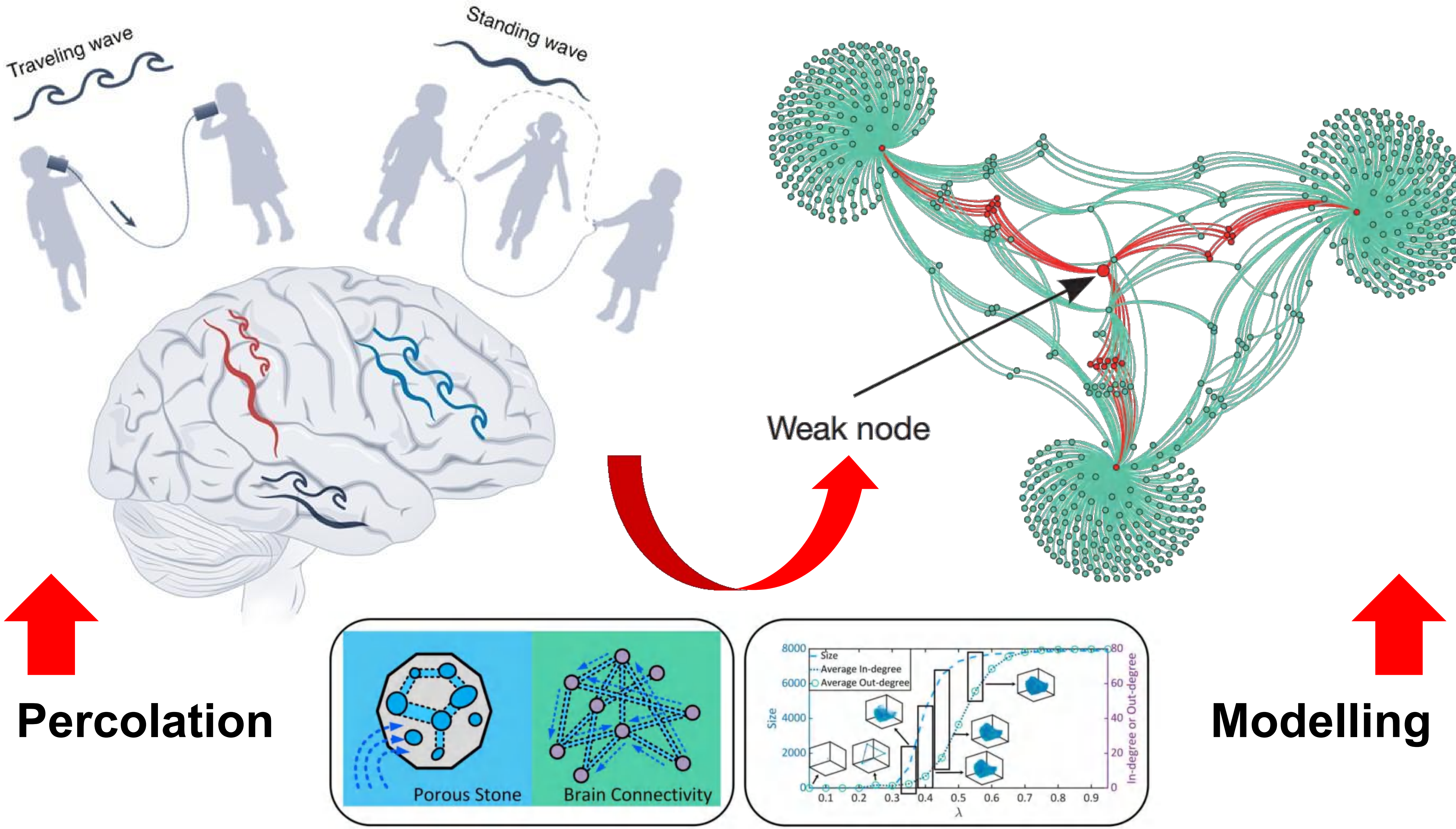
Traveling wave
Standing wave
Weak node
Percolation
Porous Stone
Brain Connectivity
Size
Average In-degree
Average Out-degree
8000
6000
4000
2000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
λ
80
60
40
20
0
In-degree or Out-degree
Modelling