Surface-based Functional Homogeneity in Human Connectomics

Xi-Nian Zuo
Chinese Academy of Sciences

Acknowledgements

Chinese Academy of Sciences

Lili Jiang, Zhi Yang, Hui-Jie Li, Gao-Xia Wei
Chao-Gan Yan, Ting Xu, Zhi-Xiong Yan,
Ning Yang, Yin-Shan Wang, Zhe Zhang,
Hao-Ming Dong, Lei Zhang, Quan Zhou,
JIn-Feng Wu, Ping Wang, Yi-Wen Zhang, …

Southwest University

Xu Chen, Jiang Qiu, Antao Chen

Hangzhou Normal University

Yu-Feng Zang, Xuchu Weng

Beijing Normal University

Yong He

New York University School of Medicine

F.Xavier Castellanos, Adriana Di Martino

Child Mind Institute

Michael Peter Milham, Ting Xu, R.Cameron Craddock

Indiana University

Olaf Sporn, Ye He

National University of Singapore

B.T. Thomas Yeo

University of Pennsylvania

Rickard Betzel

NSFC
National Natural Science
Foundation of China

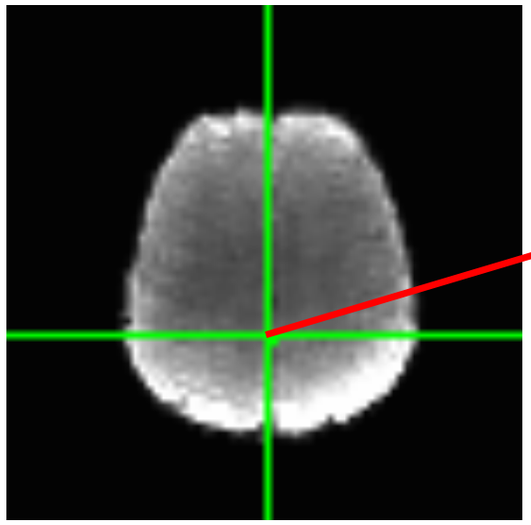
CHINESE ACADEMY OF SCIENCES

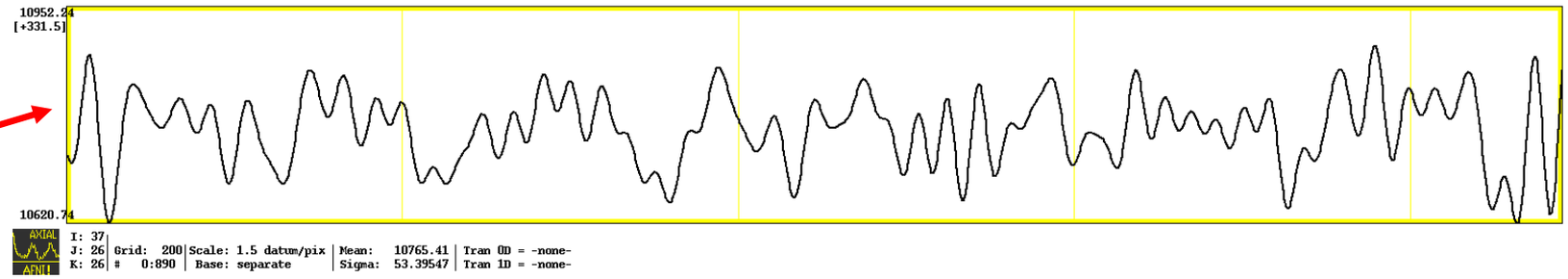
北京市科学技术委员会
Beijing Municipal Science & Technology Commission

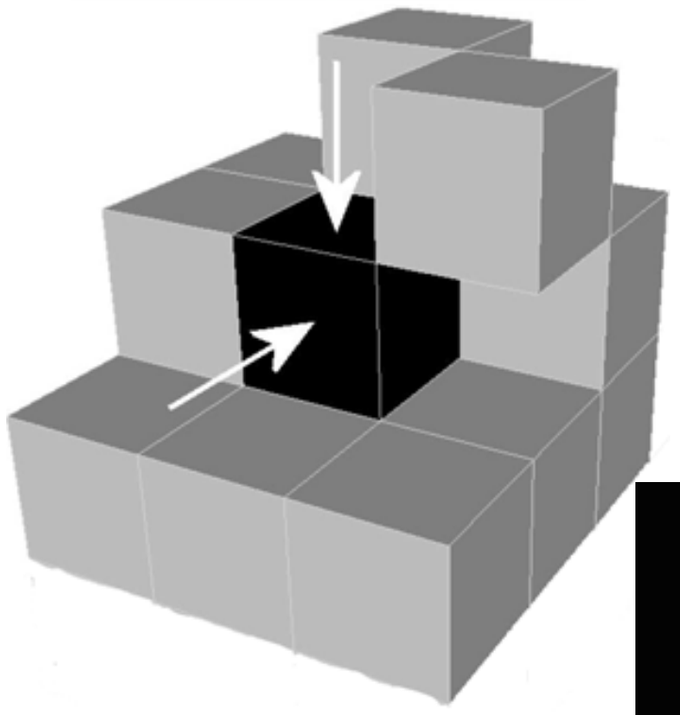
中国科学技术协会
China Association For Science and Technology

973
CHINA

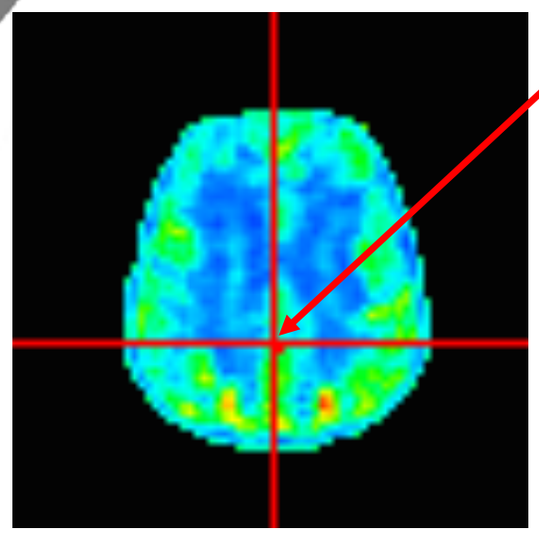
Local Functional Homogeneity: History







$$W = \frac{\sum_{i=1}^{n}\left(R_i\right)^2 - n\left(\bar{R}\right)^2}{\frac{1}{12}K^2\left(n^3 - n\right)} = 12\frac{\sum_{i=1}^{n}\left(\bar{R}_i\right)^2}{\left(n^3 - n\right)} - 3\frac{\left(n+1\right)}{\left(n-1\right)},$$



Advantages:

1. Locally relational measure
2. Robustness against noise
3. Non-parametric statistic
4. Temporal autocorrelation
5. Free of complicate settings
6. Fast implementation

Zang YF et al., 2004, Neuroimage

Kendall's Coefficient of Concordance (W): The Anatomy

Spatial Denoise (K=4)

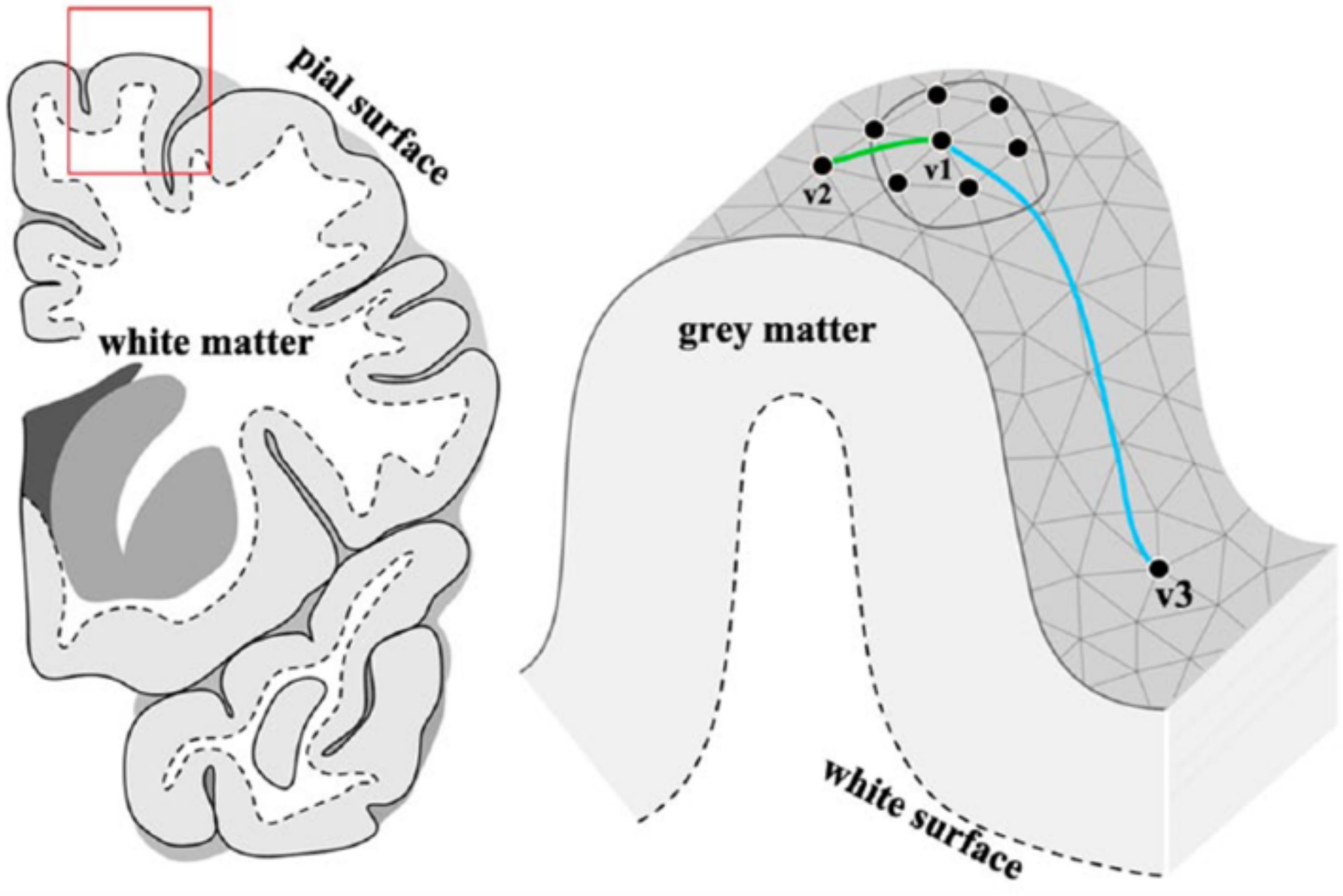
Temporal Denoise (n=10)

	Ranks (column-wise)				*Sum of Ranks*
	*neighbour*1	*neighbour*2	*neighbour*3	*neighbour*4	R_i
*tp*1	5	6	3	5	19.0
*tp*2	10	4	8	2	24.0
*tp*3	7	8	5	4	24.0
*tp*4	8	10	9	2	29.0
*tp*5	6	5	7	6	24.0
*tp*6	9	7	10	7	33.0
*tp*7	3	3	2	8	16.0
*tp*8	1.5	2	4	9	16.5
*tp*9	1.5	1	1	2	5.5
*tp*10	4	9	6	10	29.0

$$W = \frac{\sum_{i=1}^{n} (R_i)^2 - n(\bar{R})^2}{\frac{1}{12}K^2(n^3 - n)} = 12\frac{\sum_{i=1}^{n} (\bar{R}_i)^2}{(n^3 - n)} - 3\frac{(n+1)}{(n-1)}$$

Zuo XN et al., 2013, Neuroimage; Legendre P et al., 2010, E Res Design

Local Functional Homogeneity: Revisit after 10 Years



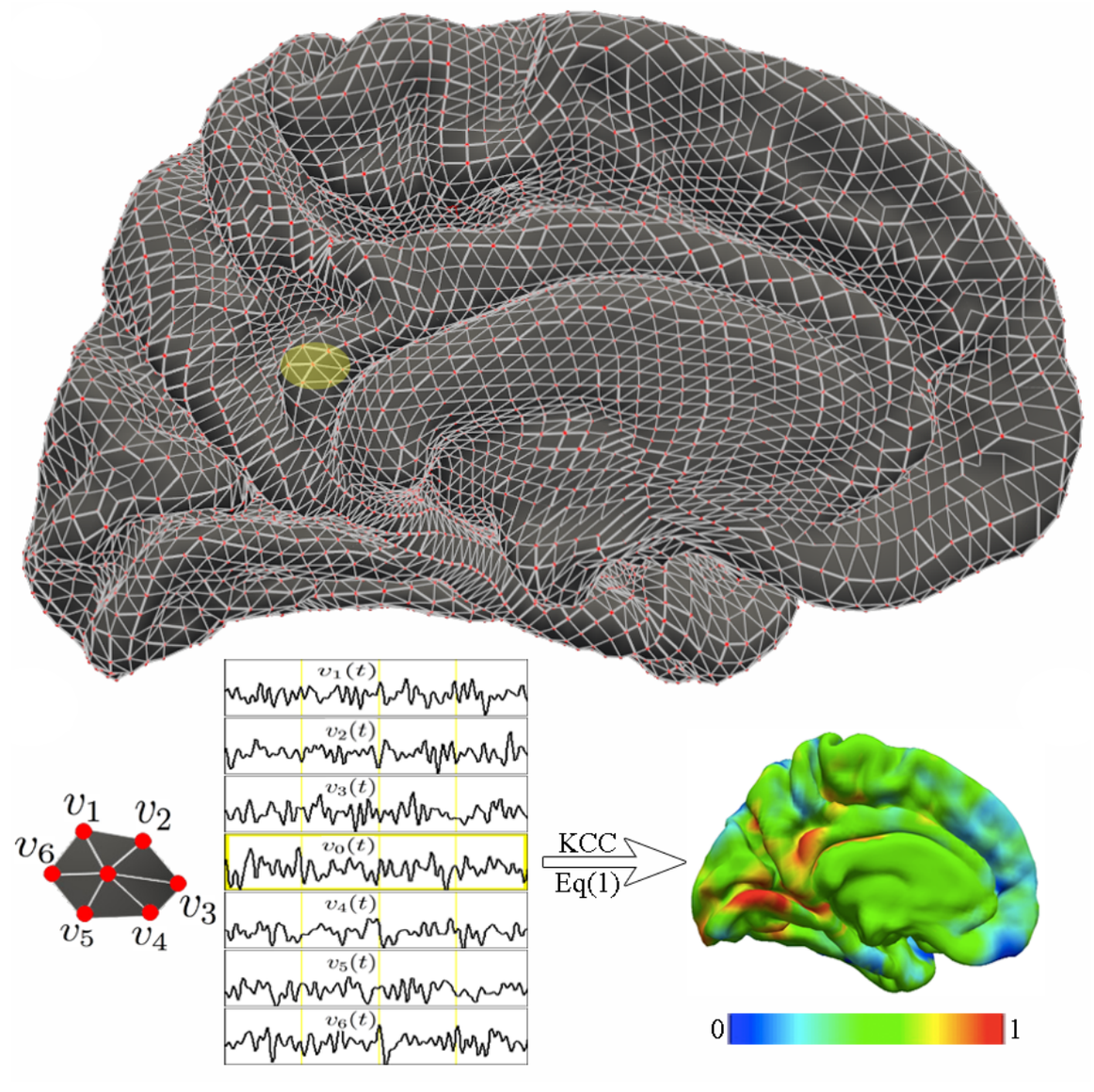
VolumeReHo:

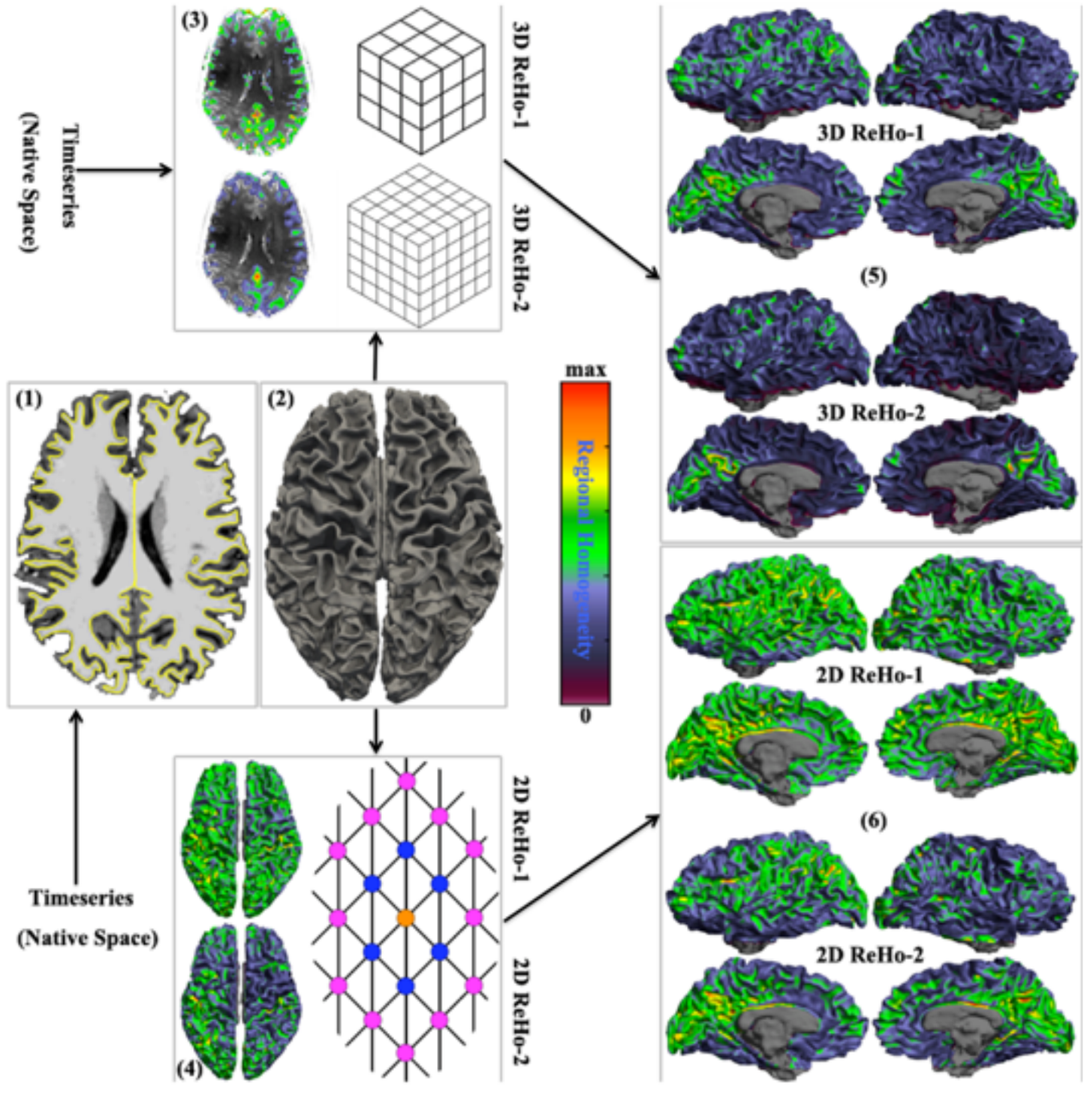
1. mixes signals of multiple tissues;
2. neglects the intrinsic geometry of the highly folded human cortex;
3. ignores 2d sheet-like functional organisation.

SurfaceReHo:

1. takes grey matter signals;
2. integrates the intrinsic folded geometry of the human cortex;
3. reflects functional organisation of the cerebral cortex.

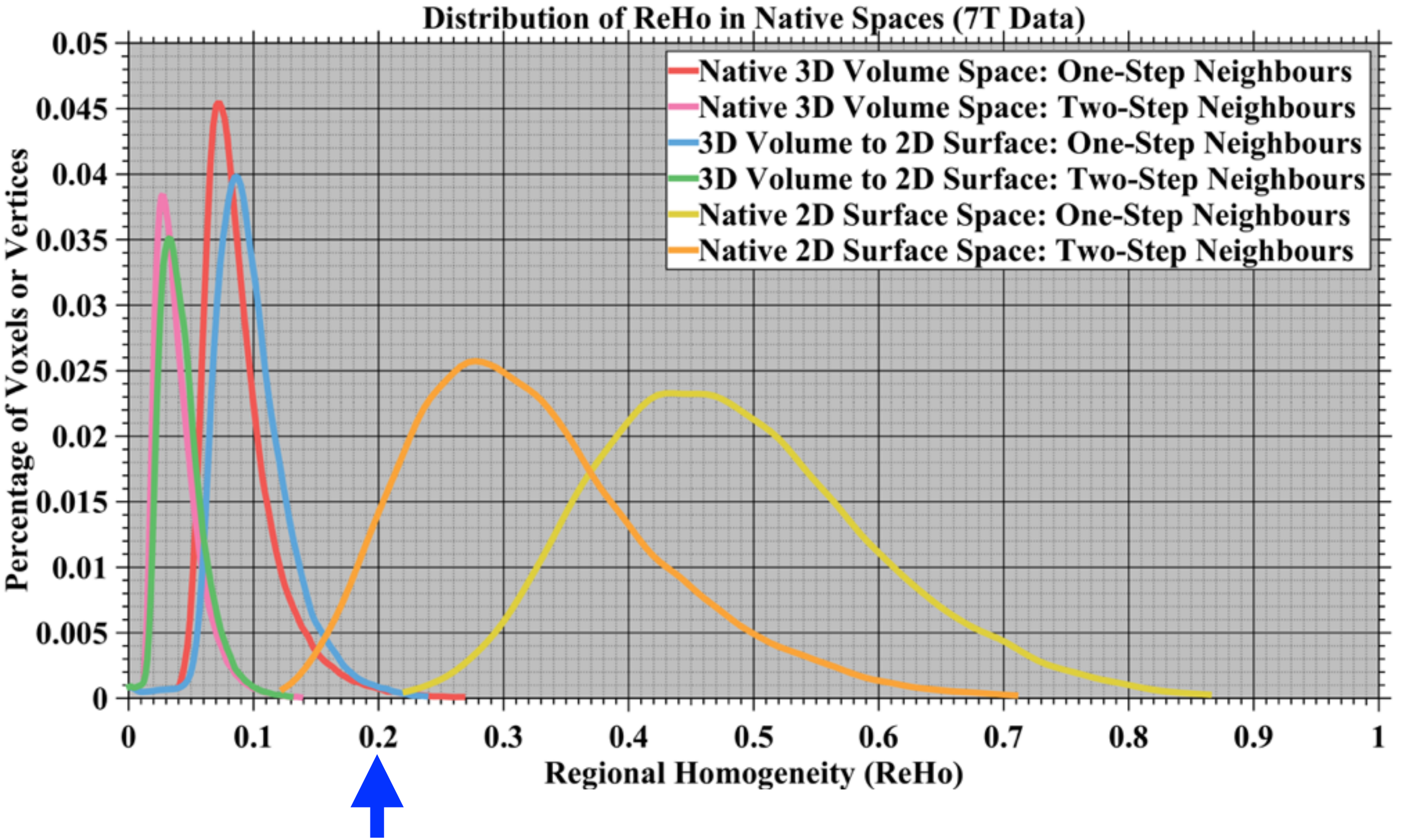
Local Functional Homogeneity: Revisit after 10 Years





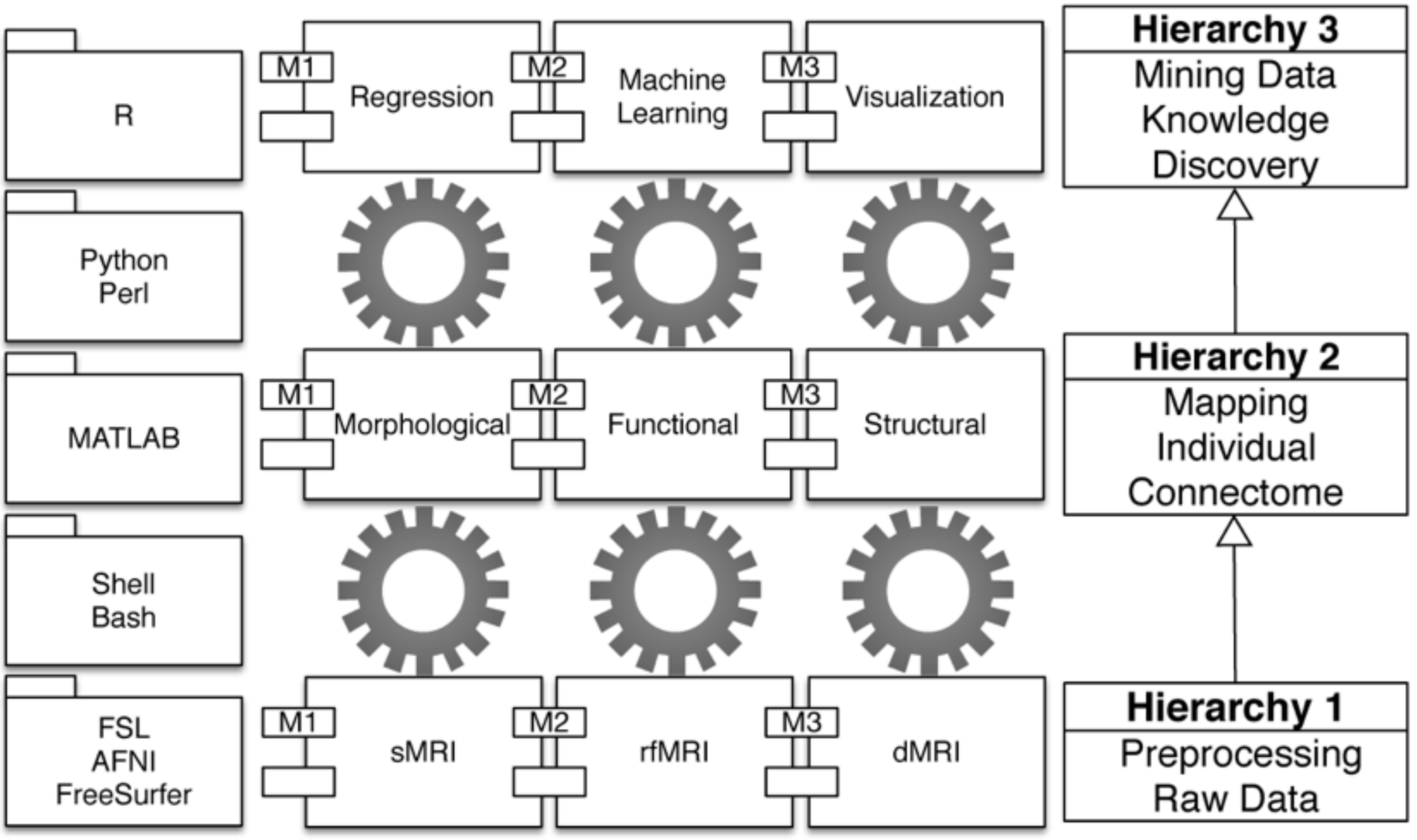
Zuo XN et al., 2013, Neuroimage; Jiang L and Zuo XN, 2016, Neuroscientist

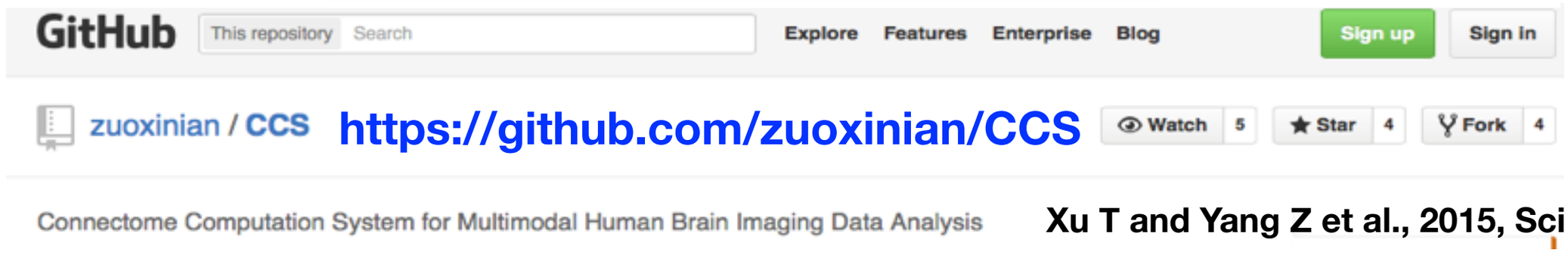
Local Functional Homogeneity: Voxel vs Vertex



Jiang L and Zuo XN, 2016, Neuroscientist

ReHo Computation

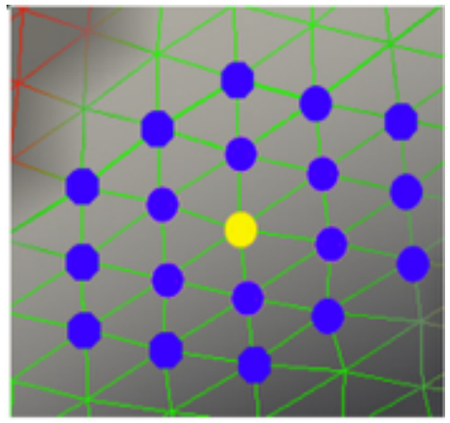




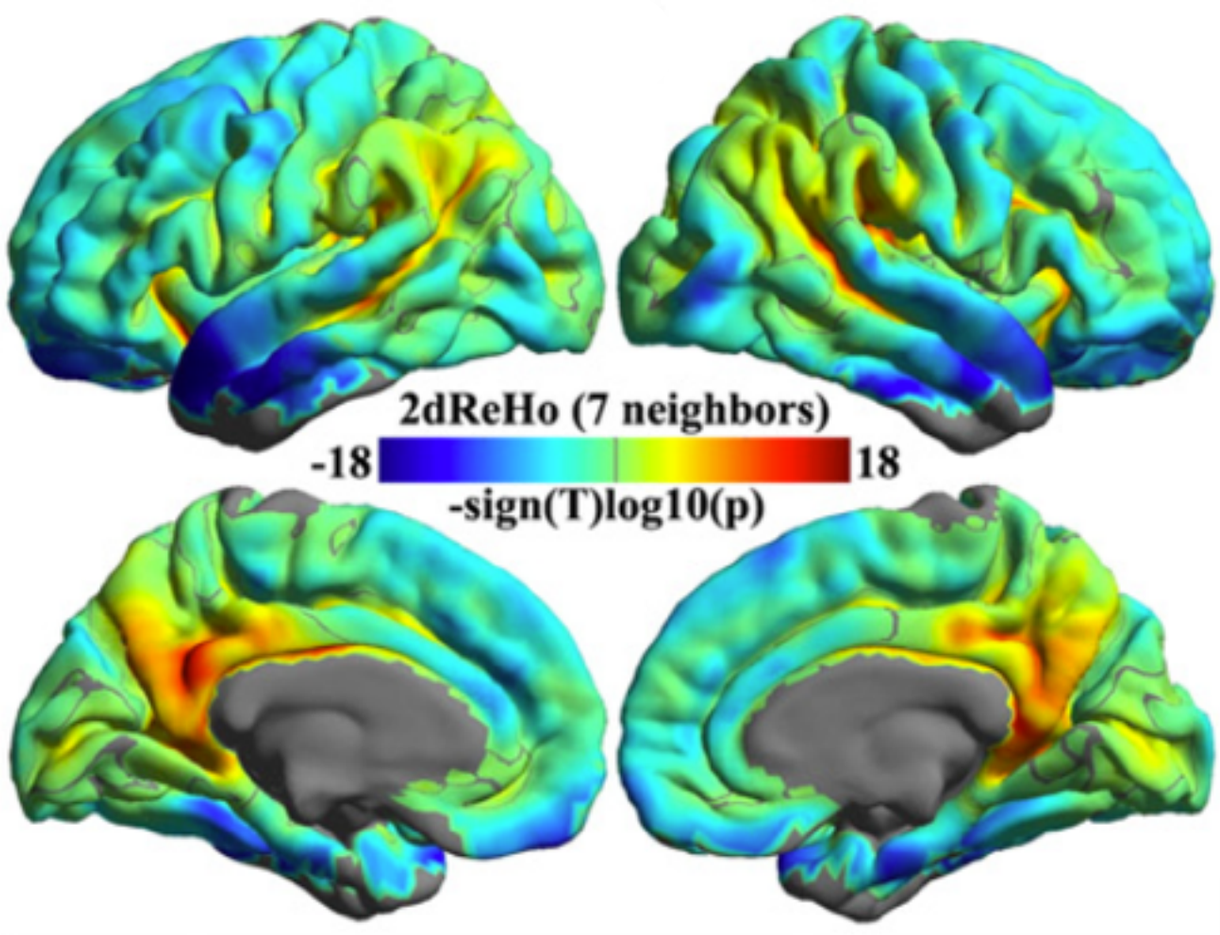
Xu T and Yang Z et al., 2015, Sci Bull

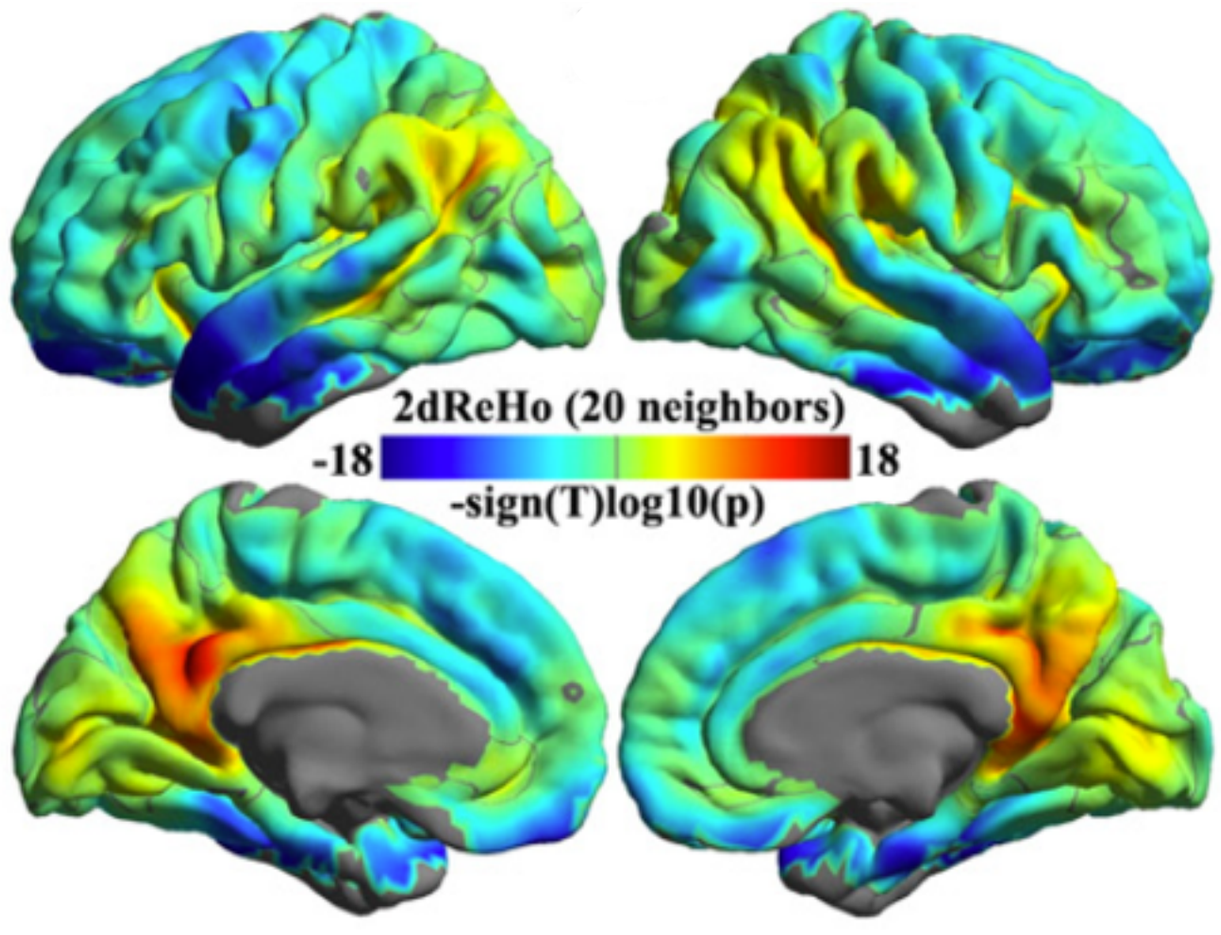
2dReHo Spatial Maps

Six Vertices



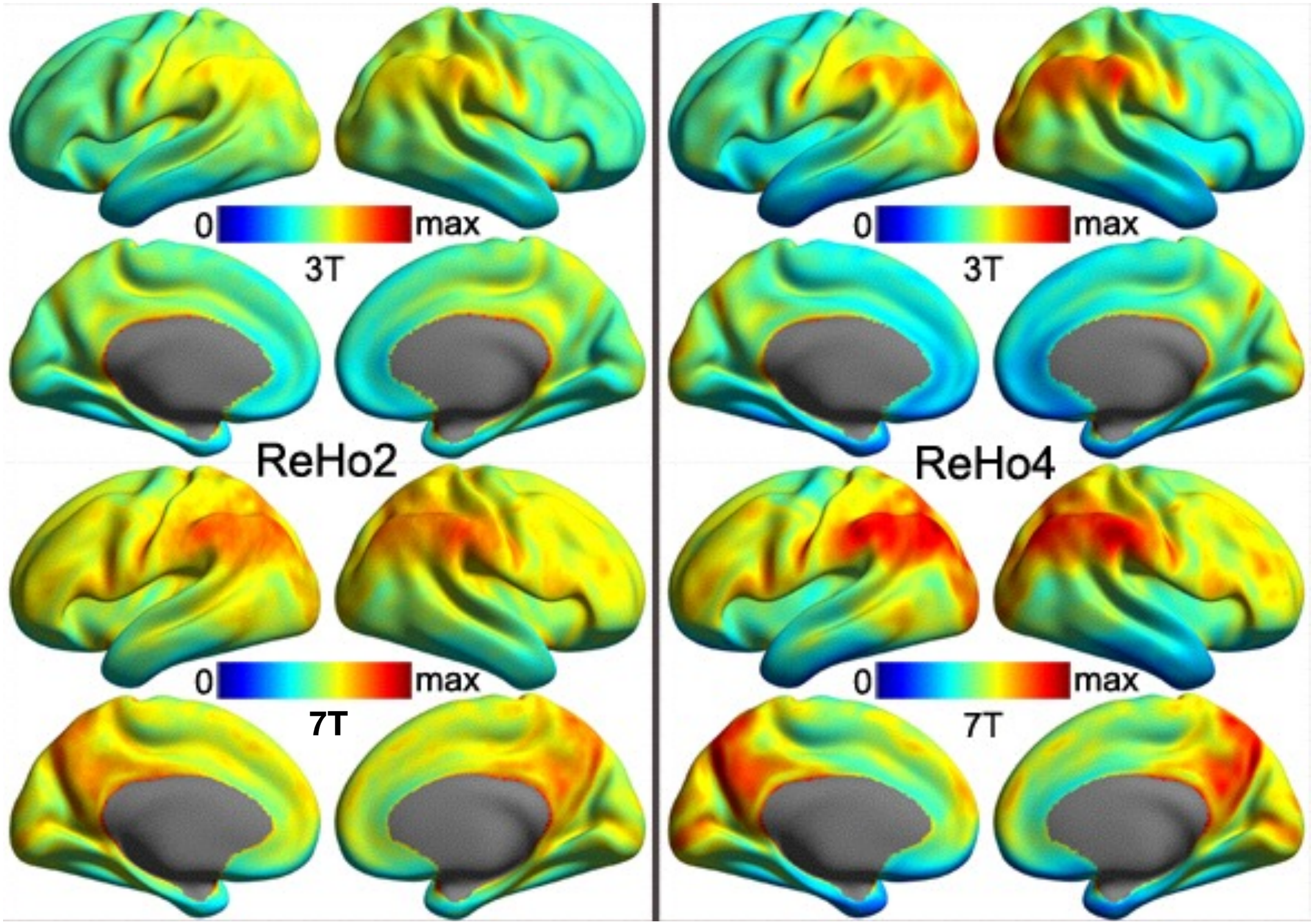
Twenty Vertices





Zuo XN et al., 2013, Neuroimage

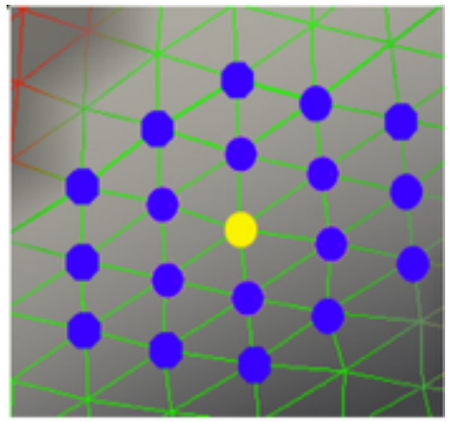
2dReHo Spatial Maps: HCP 3T vs 7T



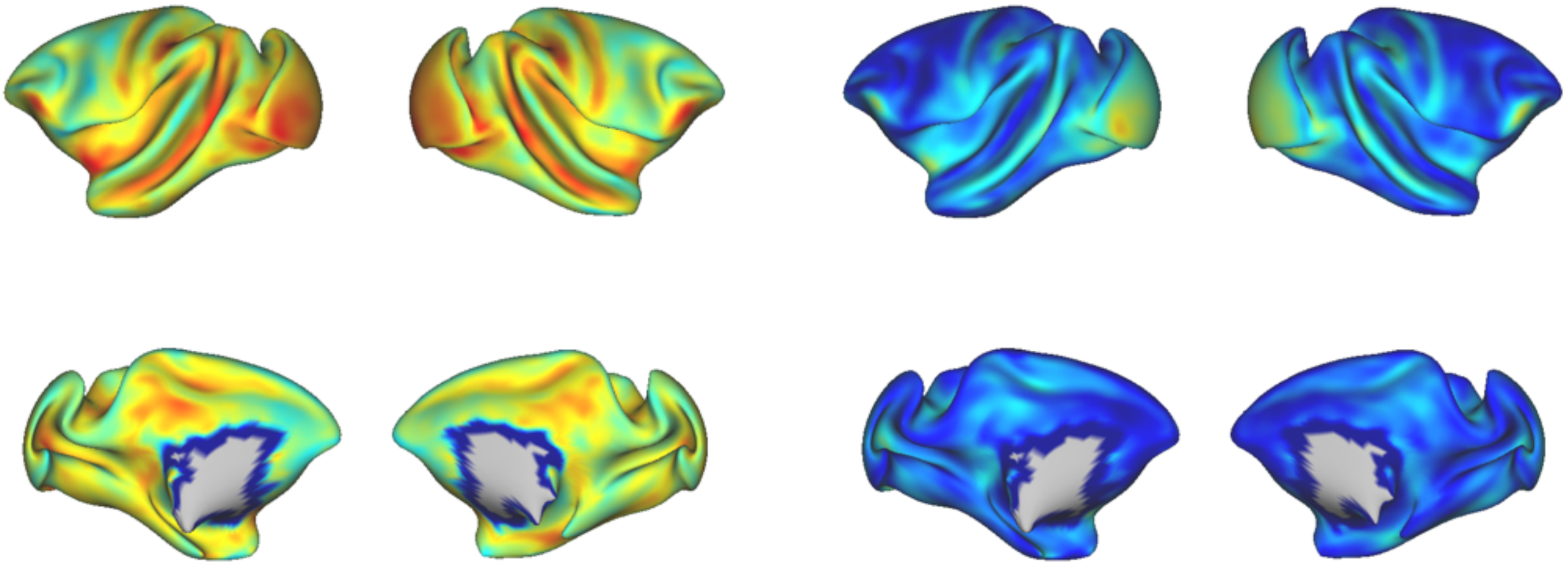
Xing XX et al., In Preparation

2dReHo Spatial Maps: Monkey

Six Vertices



Twenty Vertices

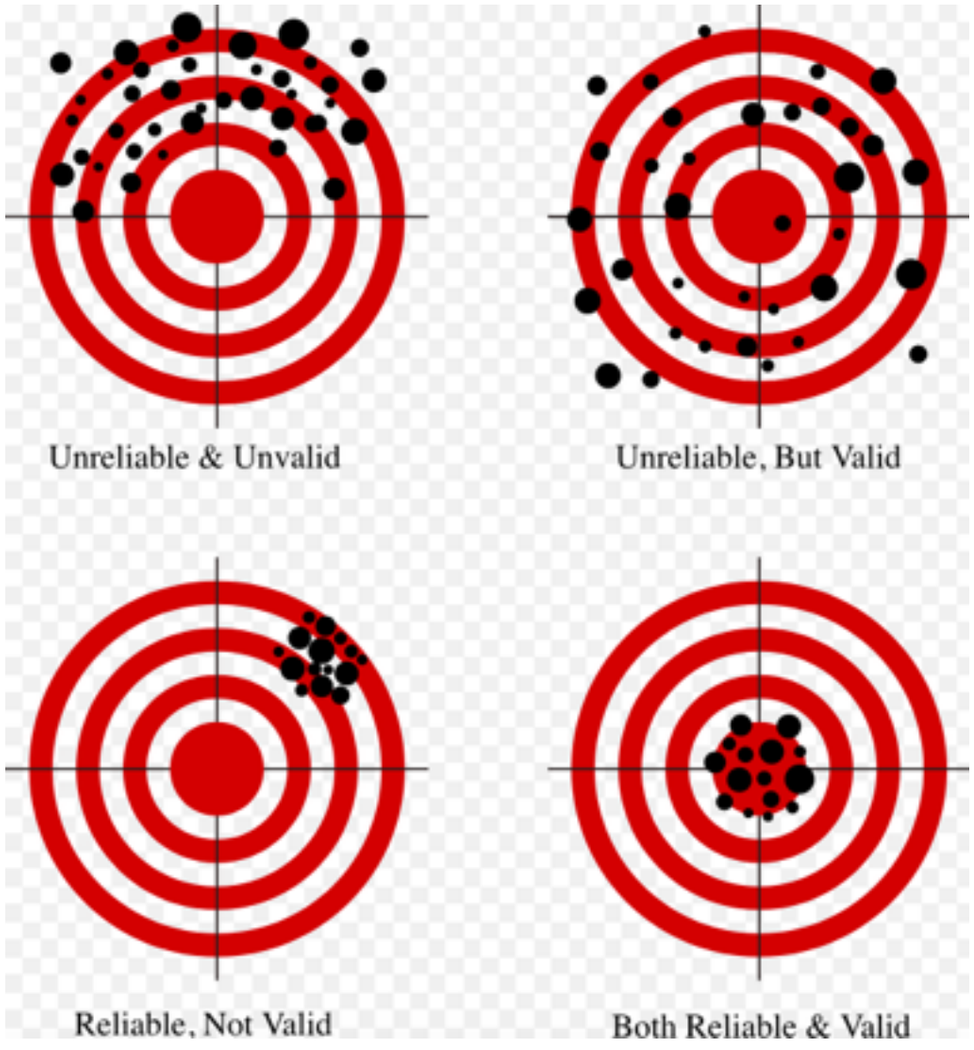


Xu T et al., In Preparation

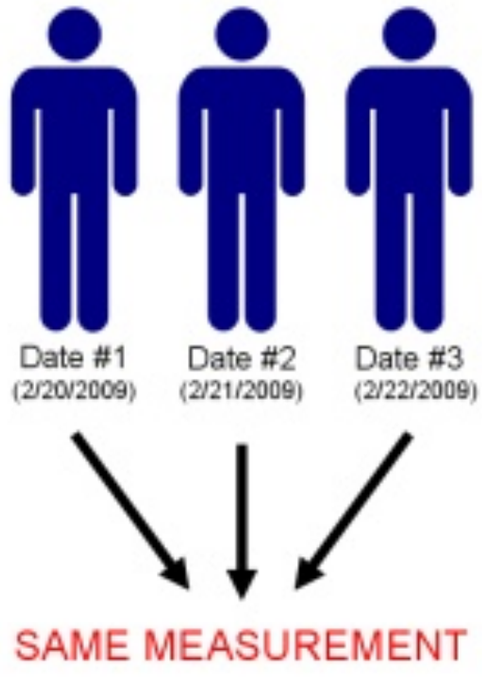
The Reliability of Clinical Diagnoses: State of the Art

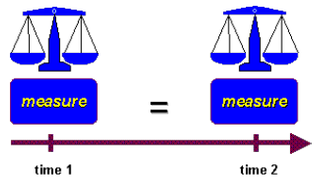
Helena Chmura Kraemer

Department of Psychiatry and Behavioral Sciences, Stanford University (Emerita), Palo Alto, California 94301; and Department of Psychiatry, University of Pittsburgh, Pittsburgh, Pennsylvania 15213; email: hckhome@pacbell.net



Concept: Reliability and Validity





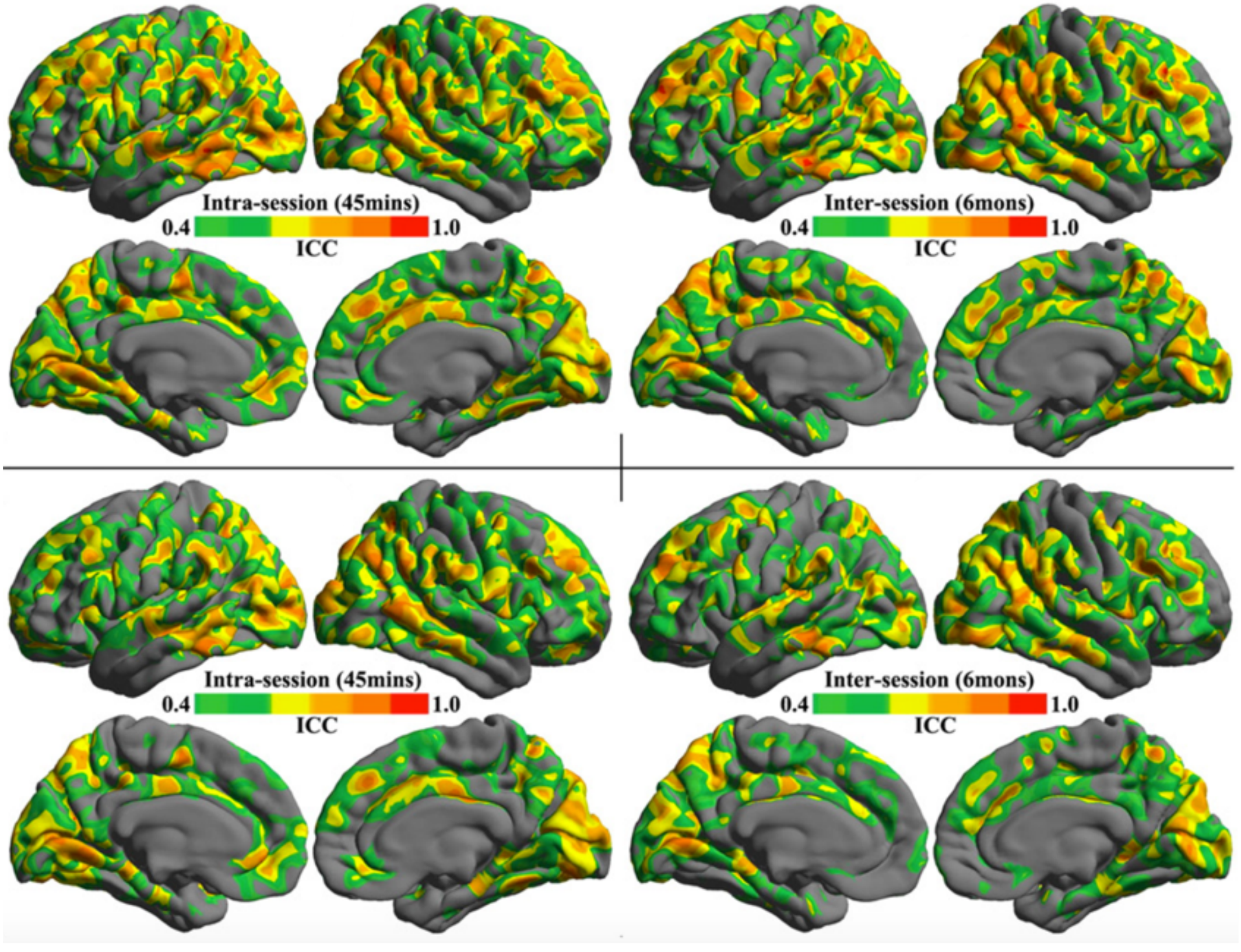
$$ICC = \frac{MSb - MSw}{MSb + MSw}$$

$$A' = A + n(A)$$

$$B' = B + n(B)$$

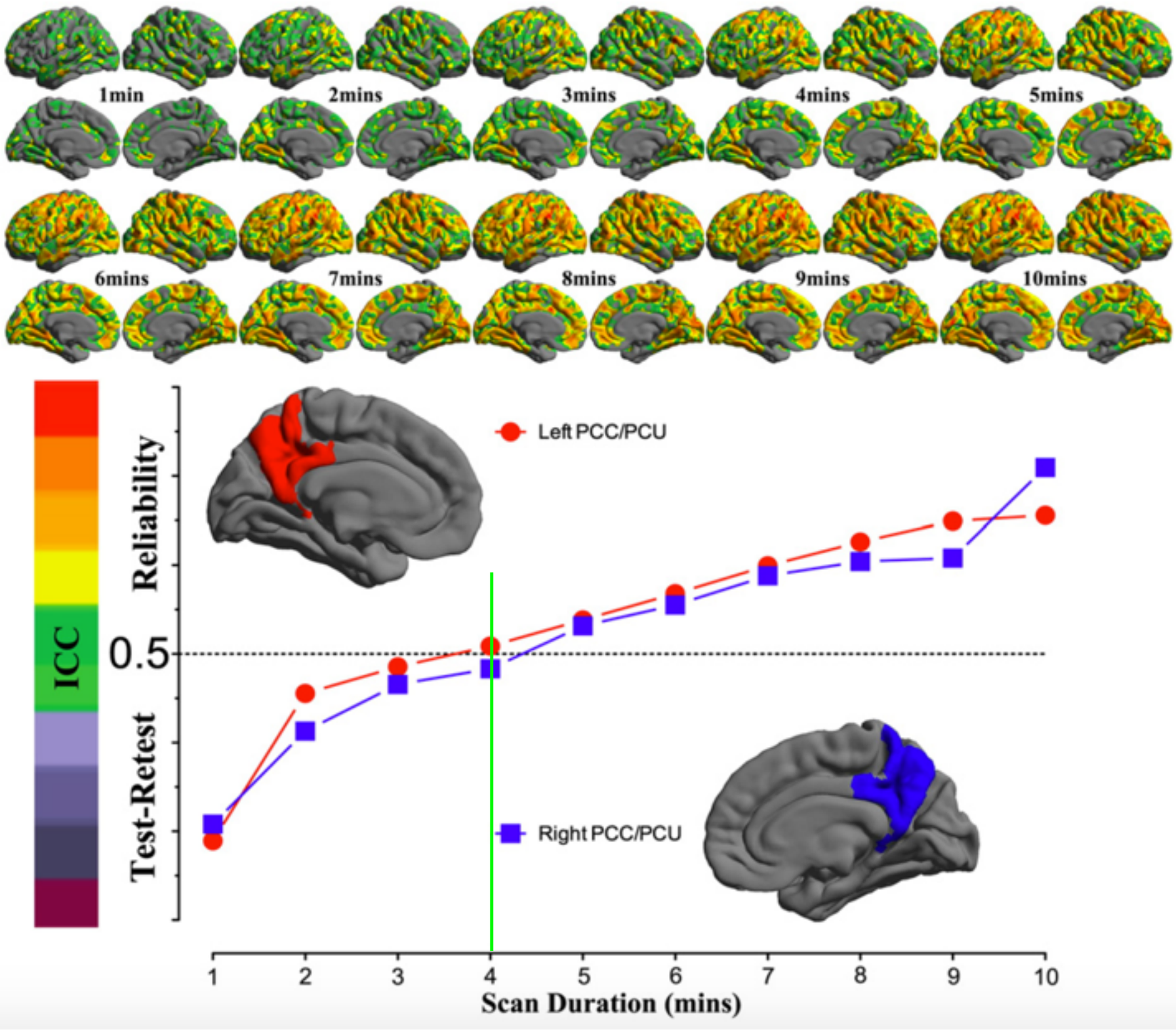
$$r(A',B') = r(A,B)\sqrt{ICC(A)ICC(B)}$$

2dReHo: Test-Retest Reliability



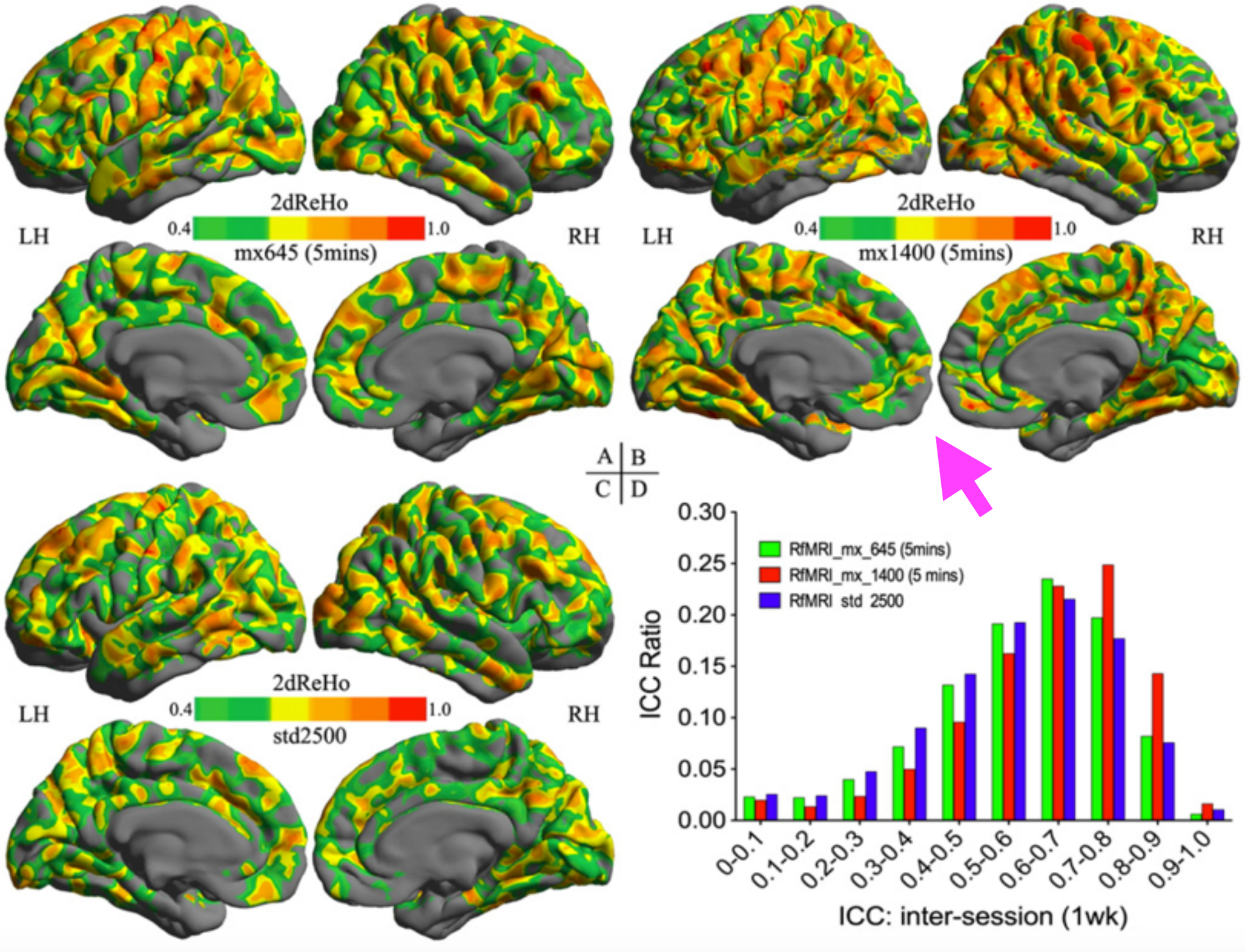
Zuo XN et al., 2013, Neuroimage

2dReHo Reliability: How Long Scan We Need?



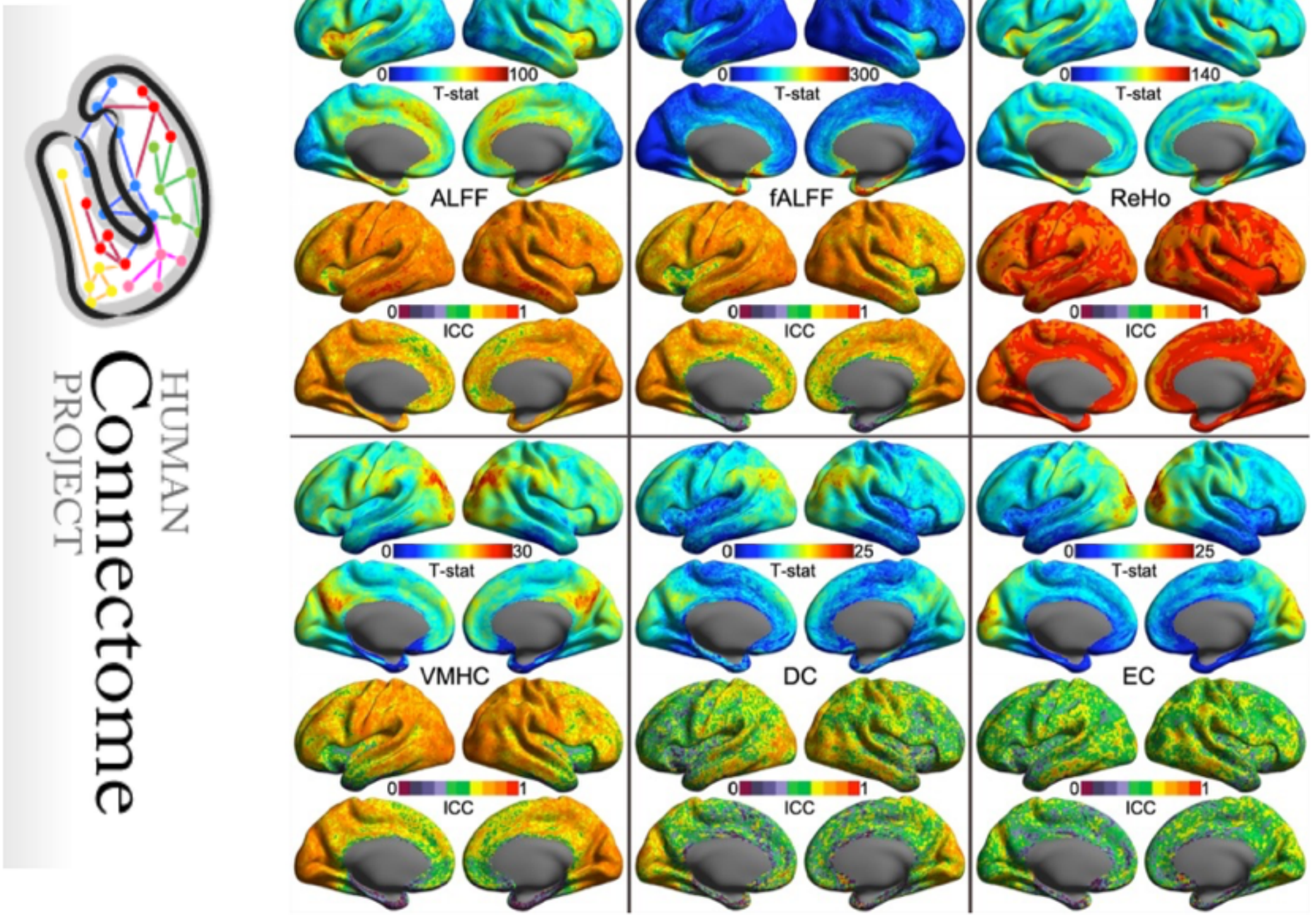
Zuo XN et al., 2013, Neuroimage

2dReHo Reliability: Imaging Resolution



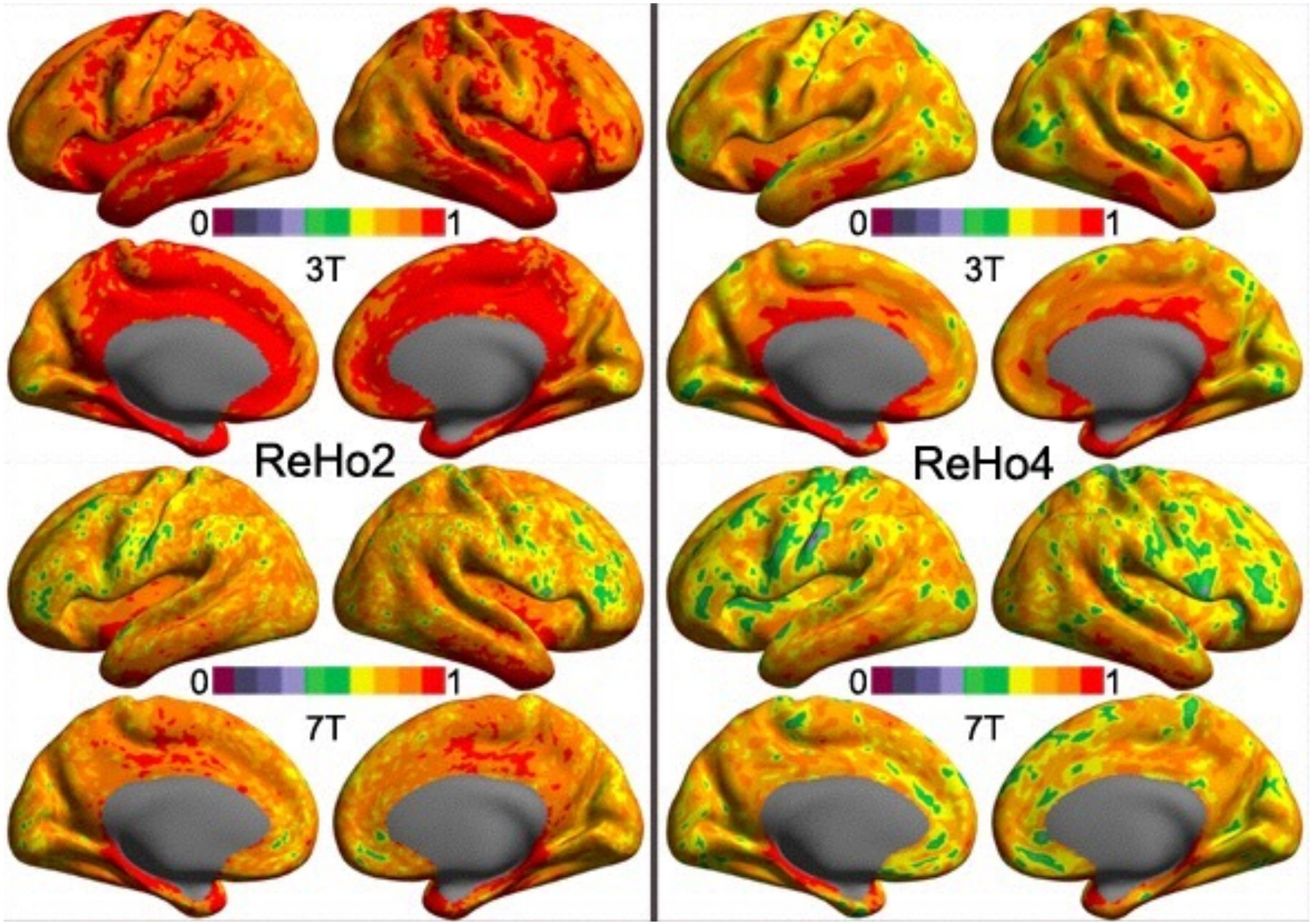
Zuo XN et al., 2013, Neuroimage

2dReHo Reliability: HCP



Zuo XN and Xing XX, 2014, Neurosci Biobehav Rev

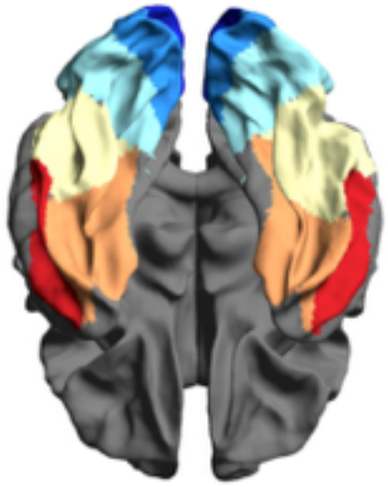
2dReHo Reliability: HCP 3T vs 7T

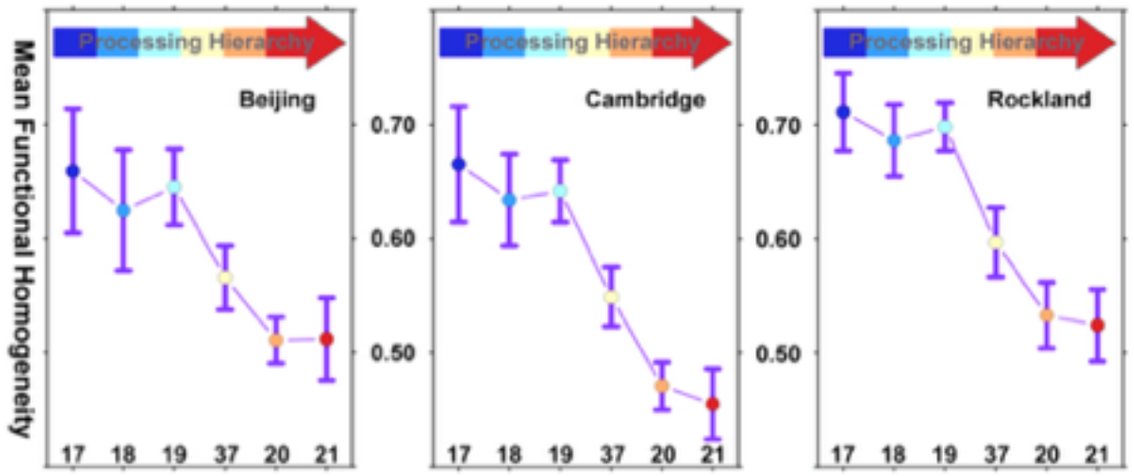


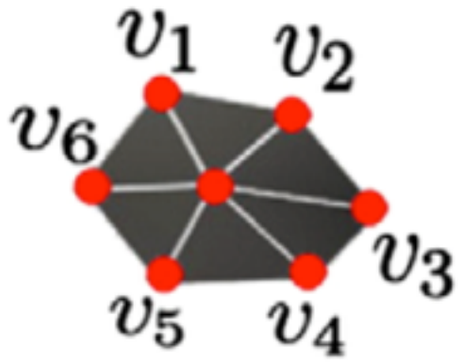
Xing XX et al., In Prep

2dReHo Validity: Functional Architecture

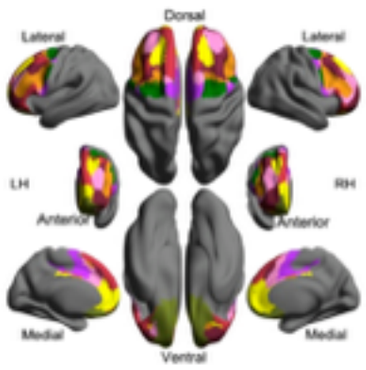
VVS

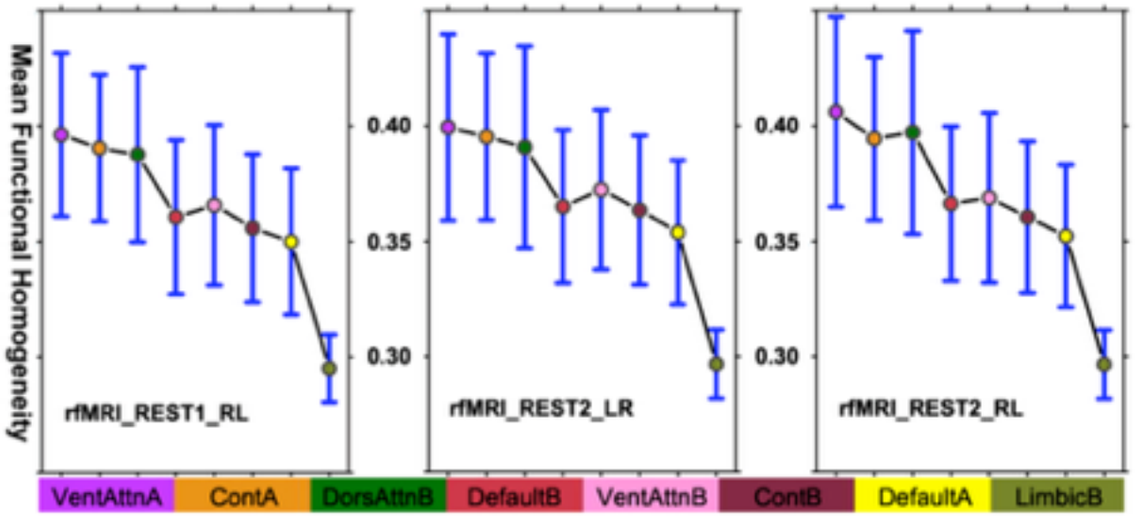






PFC

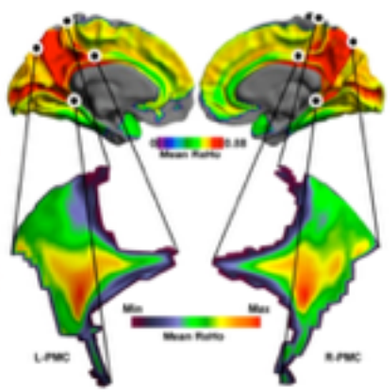


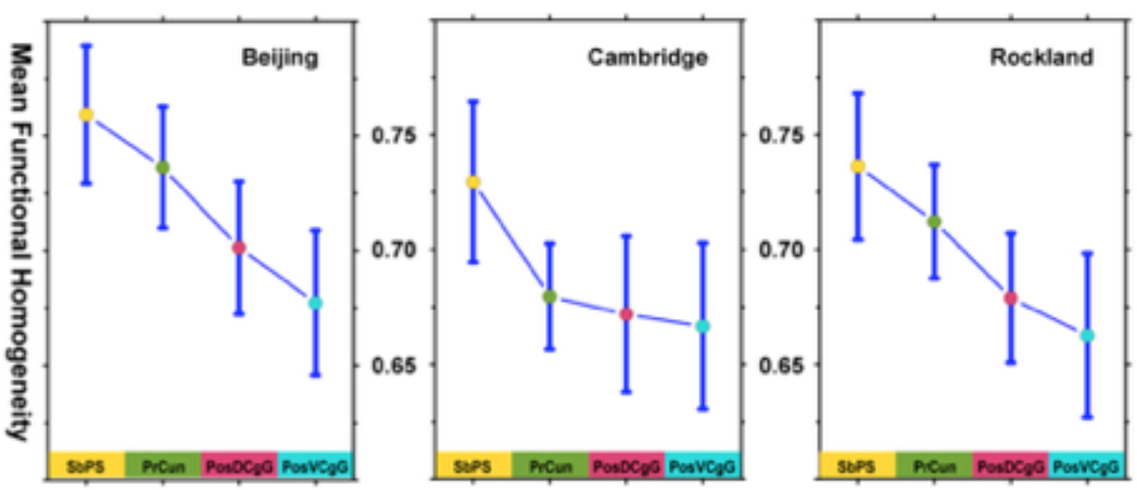


$$W = \frac{\sum_{i=1}^{n}(R_i)^2 - n(\bar{R})^2}{\frac{1}{12}K^2(n^3-n)}$$

$$= 12\frac{\sum_{i=1}^{n}(\bar{R}_i)^2}{(n^3-n)} - 3\frac{(n+1)}{(n-1)}$$

PMC



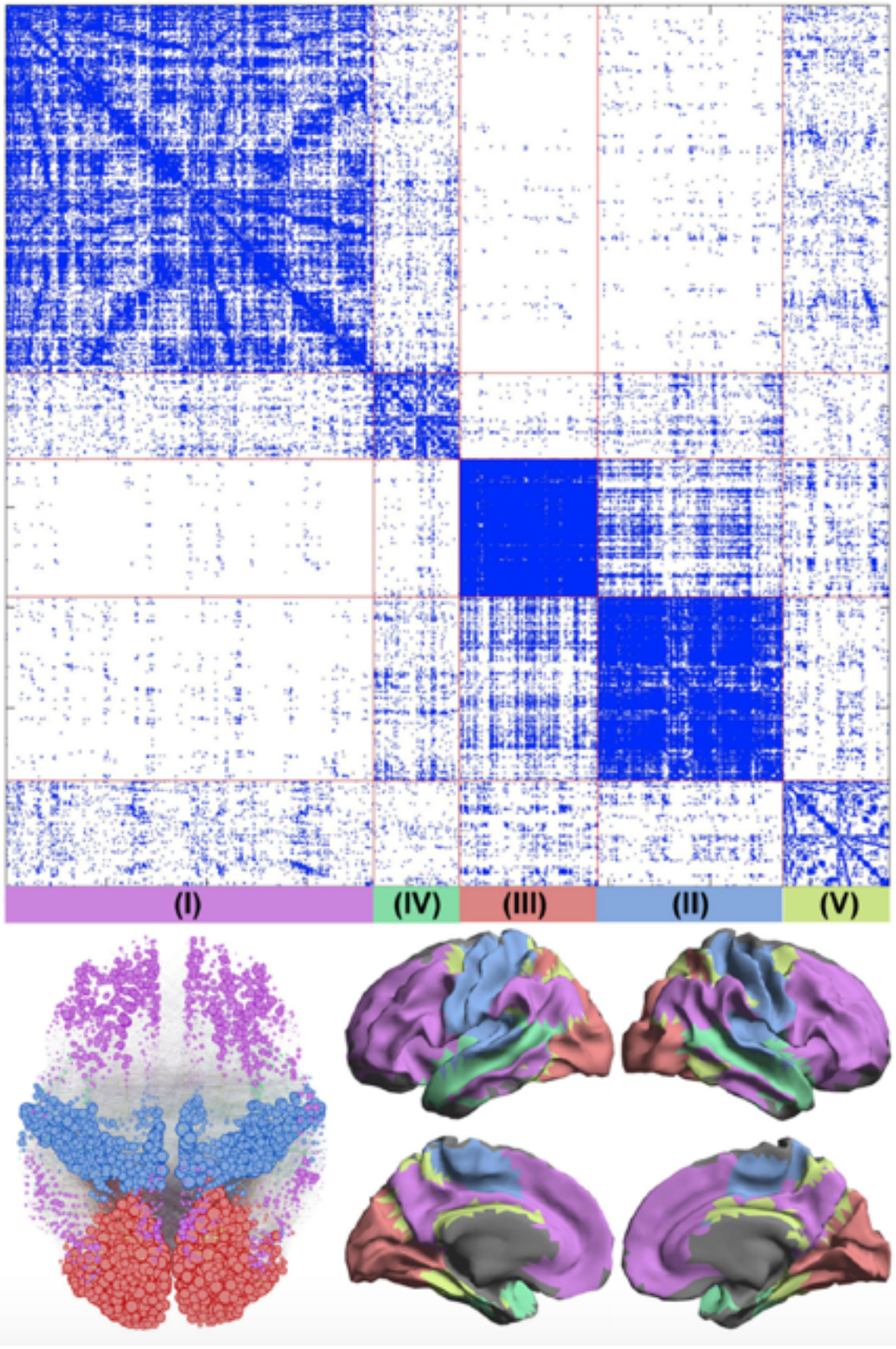


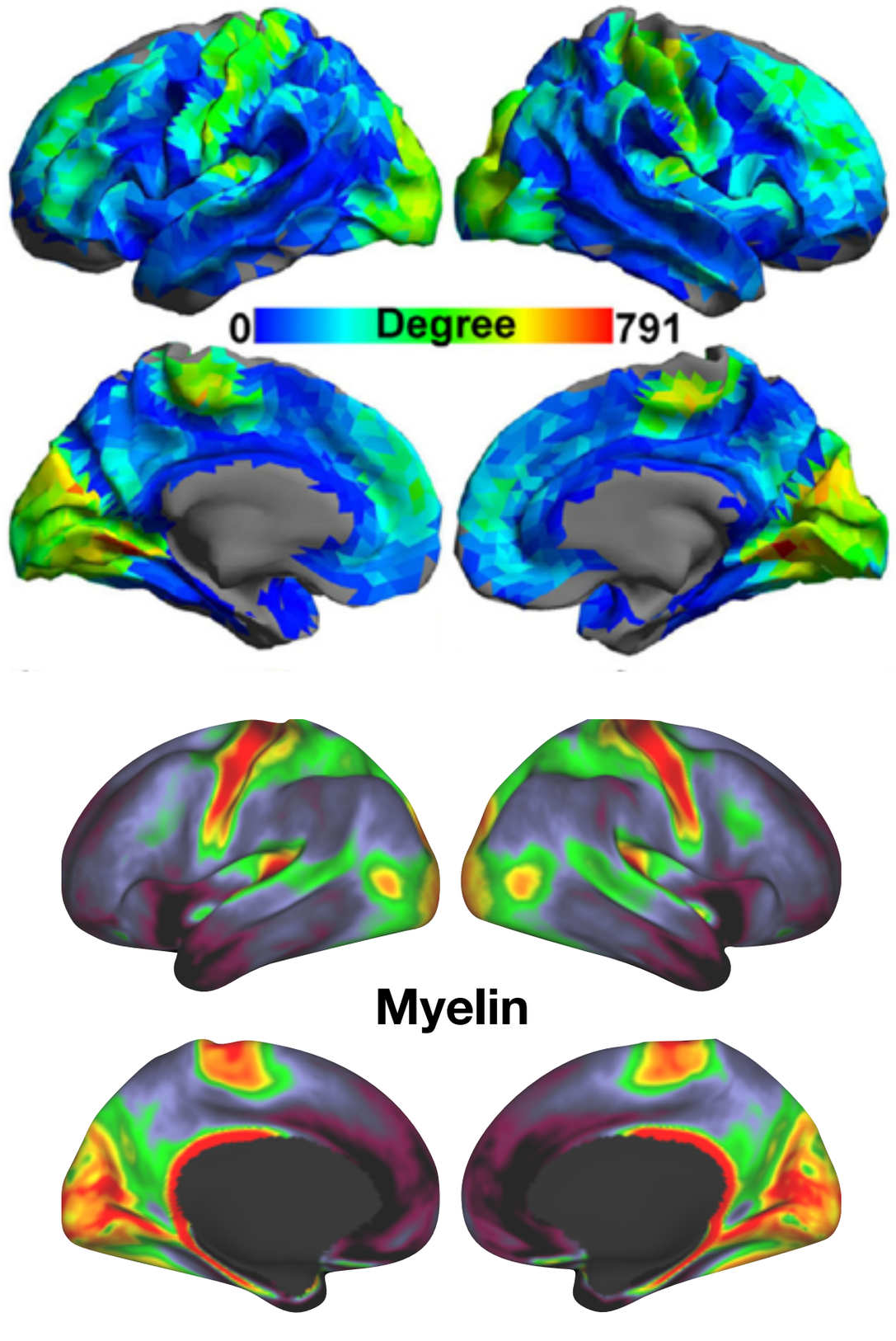
nki

1000 FUNCTIONAL CONNECTOMES PROJECT

Jiang L et al., 2015, Brain Struct Func

2dReHo Validity: Functional Covariance



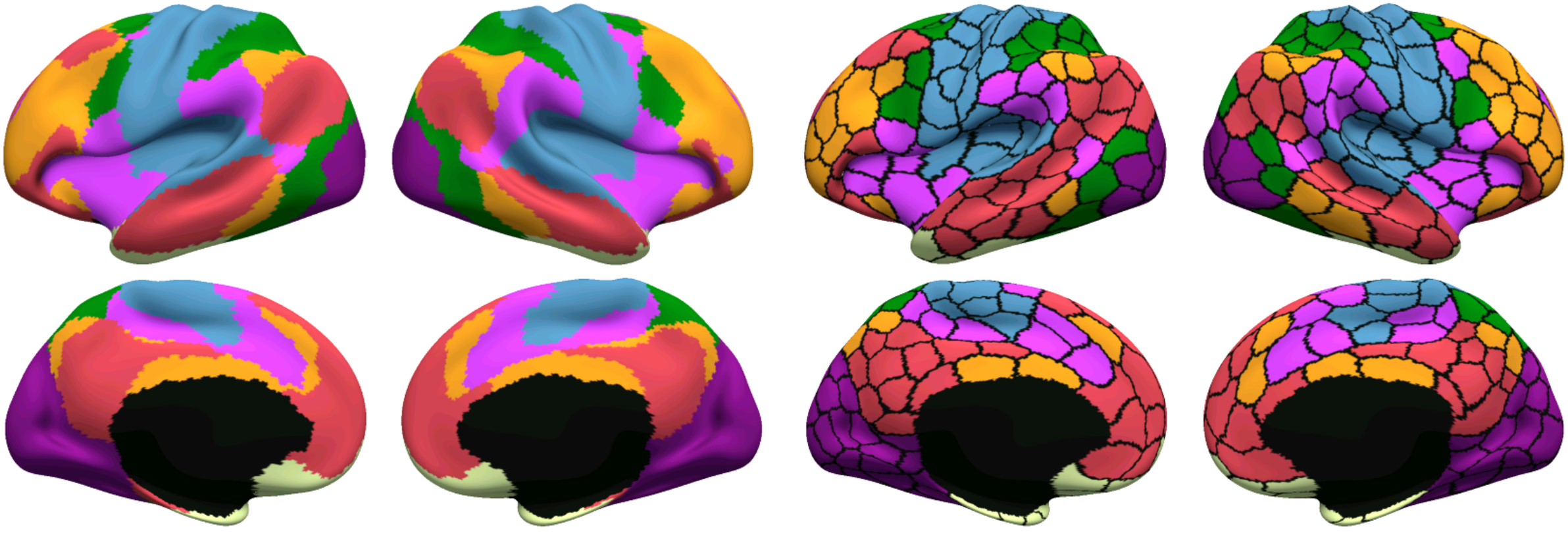


Jiang L et al., 2015, Brain Struct Func; Glasser M et al., 2011, J Neurosci; Glasser M et al., 2016, Nature

Human Resting Brain Atlas: Functional Homogeneity Driven

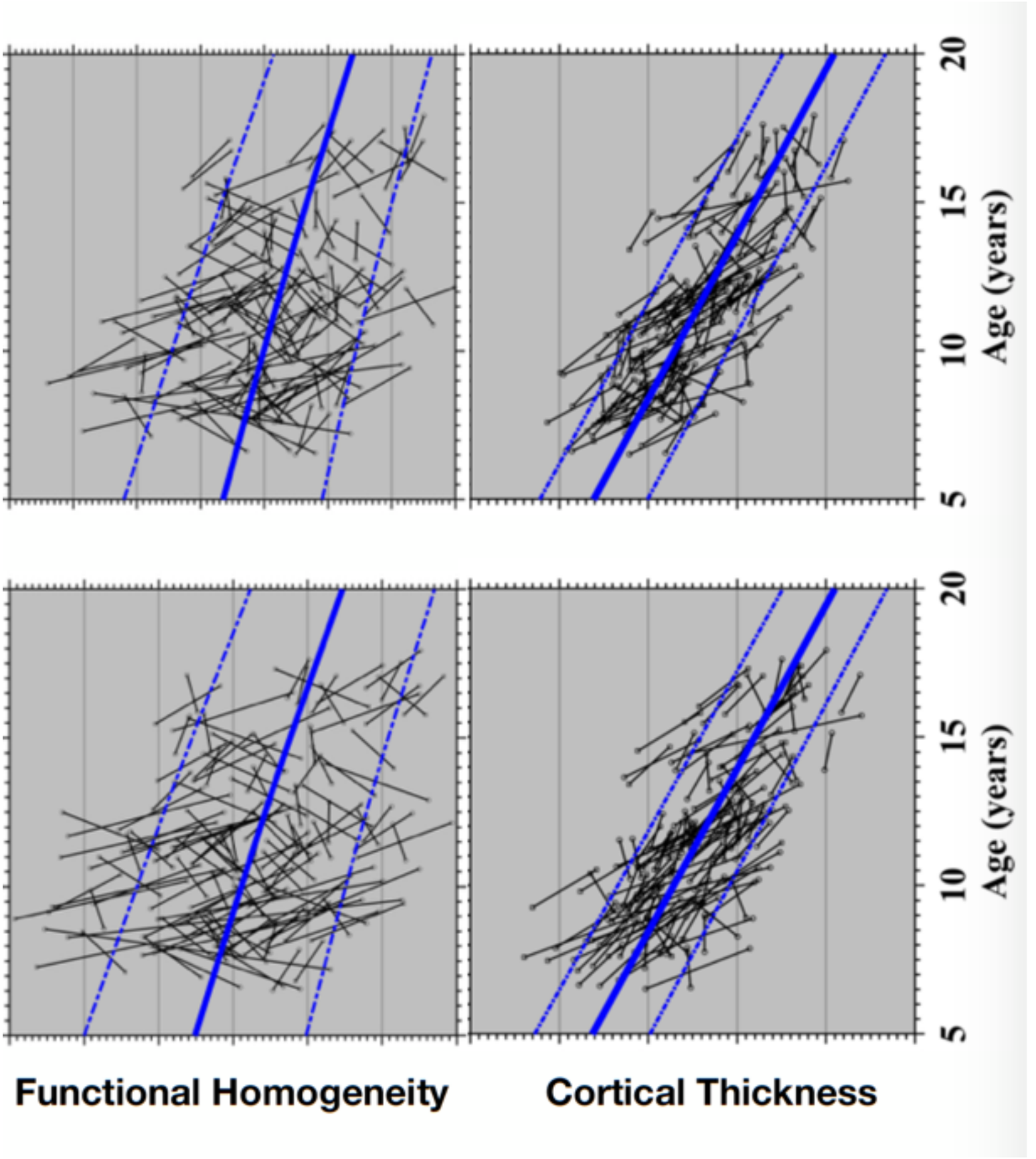
Yeo2011 7Networks

Yeo2011 Refined



Schaefer et al., 2016, Under Review

Longitudinal Design
(1.2yrs follow up)

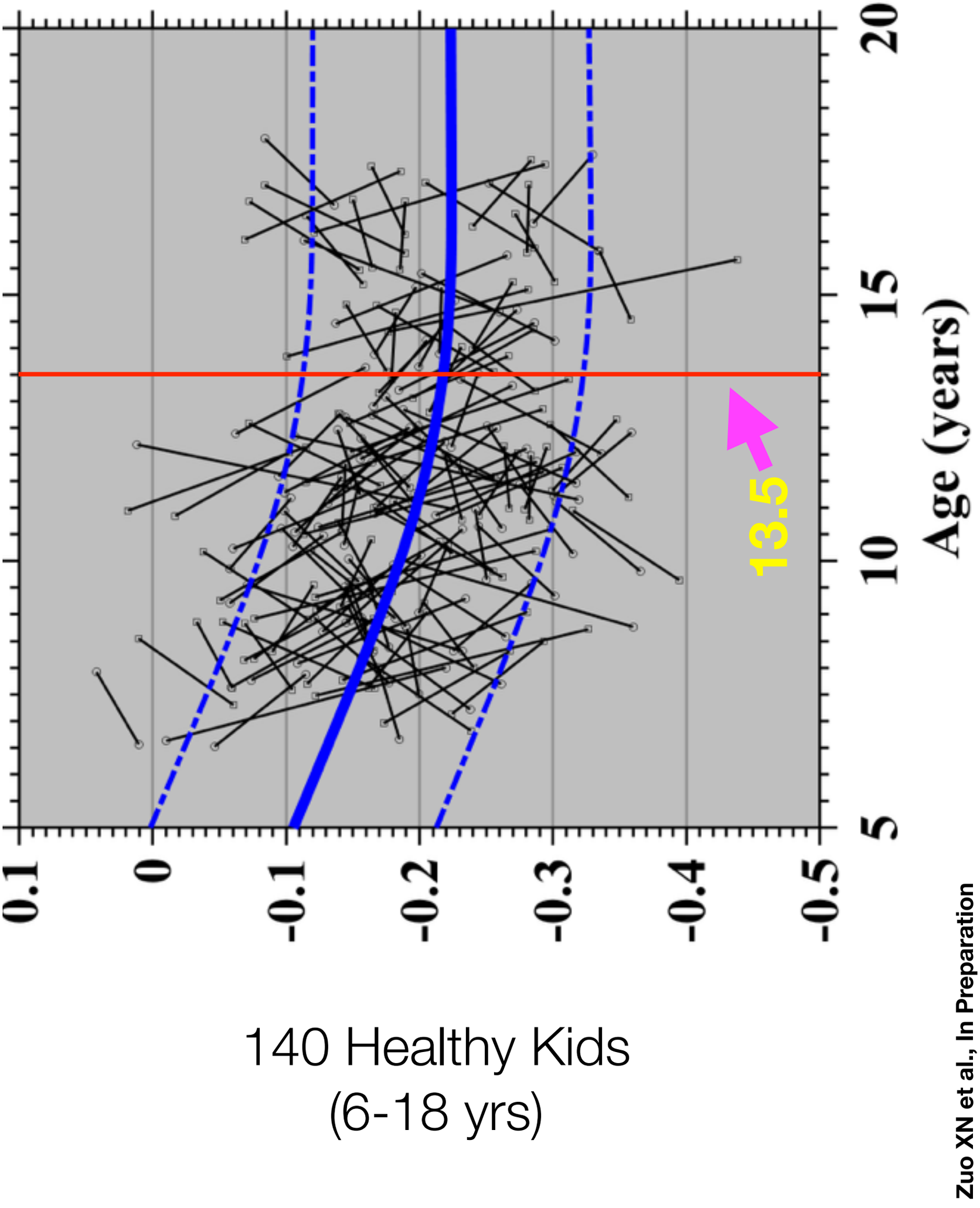


2dReHo: Neuro development

Zuo XN et al., In Prep

140 Healthy Kids
(6-18 yrs)

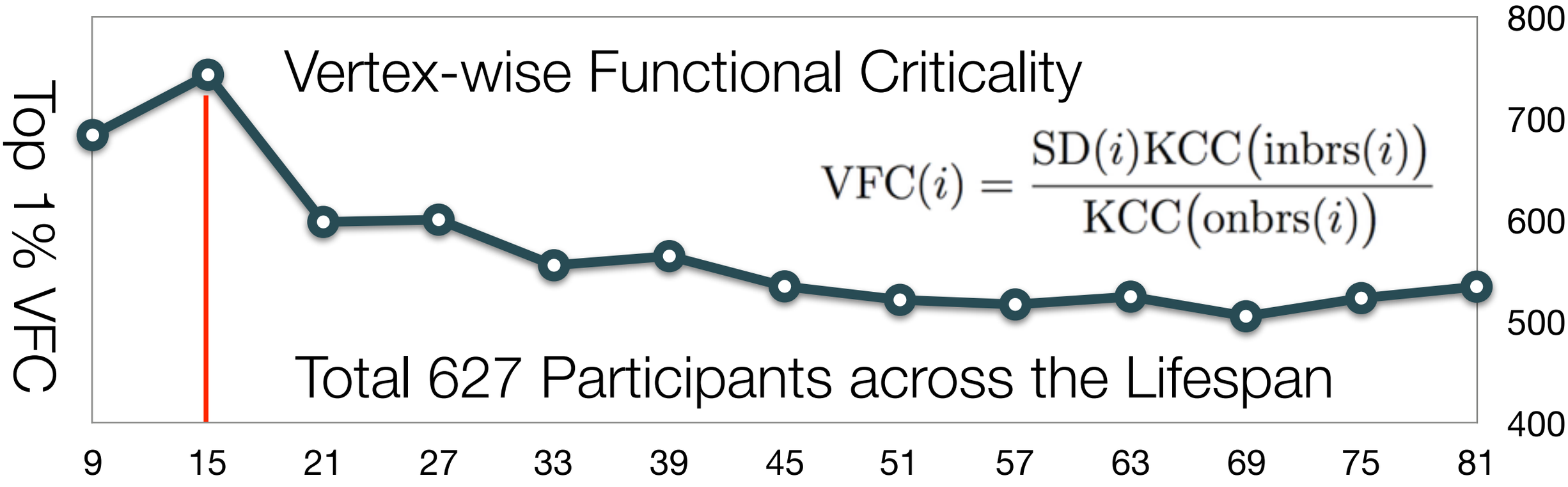
Longitudinal Design
(1.2yrs follow up)

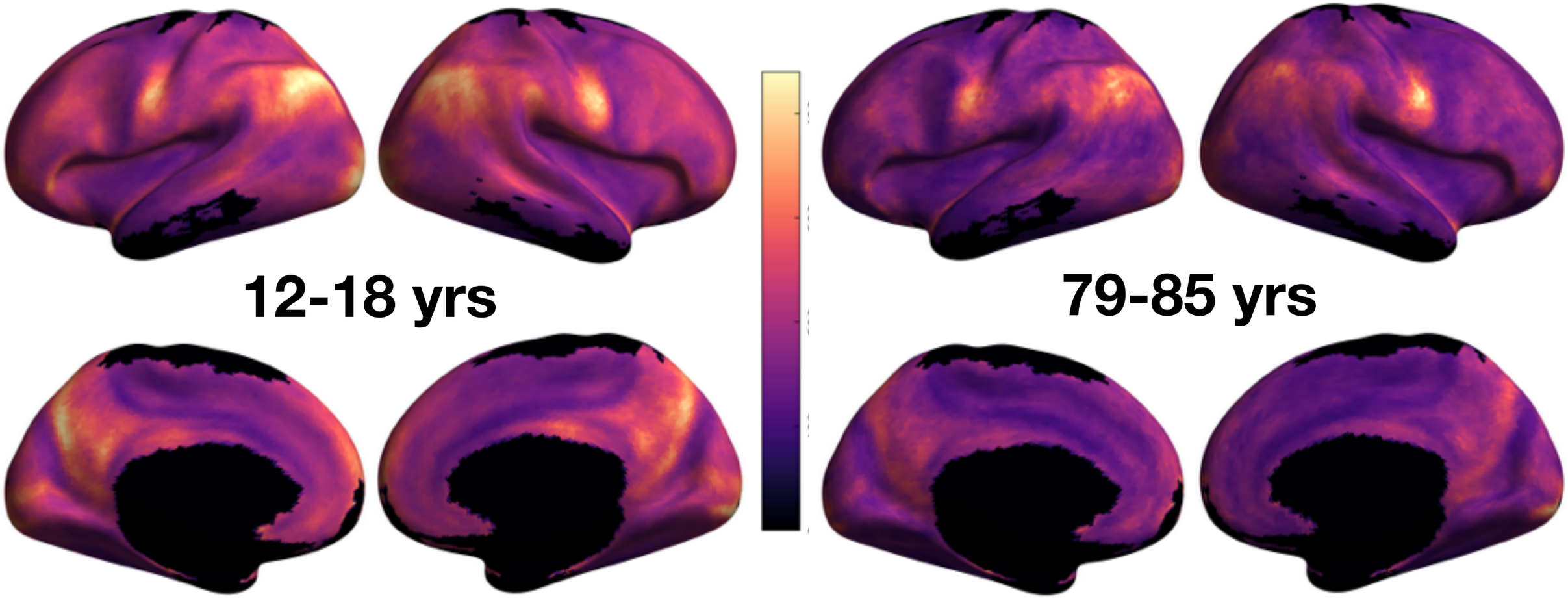


140 Healthy Kids
(6-18 yrs)

Zuo XN et al., In Preparation

More than Local: Lifespan Development





Jiang L et al., In Prep; Chen L et al., 2012, Sci Rep

Future: A Big Single-Site Lifespan Data Sharing

GEw750 3T
IPCAS
2 visits

SMS Prisma 3T
IBPCAS
2 visits

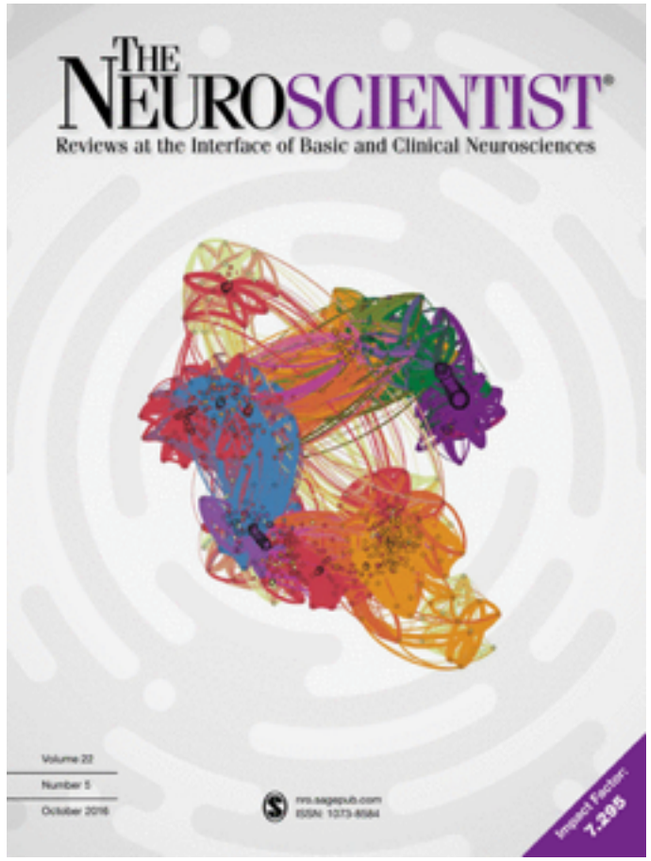
SMS 7T
IBPCAS
1 visit

Total 6,000 Visits, 1200 People (6-85 yrs)

Total 5 ReTests per Person

Regional Homogeneity: A Multimodal, Multiscale Neuroimaging Marker of the Human Connectome

Lili Jiang[1,2] and Xi-Nian Zuo[1,2,3,4]



Abstract

Much effort has been made to understand the organizational principles of human brain function using functional magnetic resonance imaging (fMRI) methods, among which resting-state fMRI (rfMRI) is an increasingly recognized technique for measuring the intrinsic dynamics of the human brain. Functional connectivity (FC) with rfMRI is the most widely used method to describe remote or long-distance relationships in studies of cerebral cortex parcellation, interindividual variability, and brain disorders. In contrast, local or short-distance functional interactions, especially at a scale of millimeters, have rarely been investigated or systematically reviewed like remote FC, although some local FC algorithms have been developed and applied to the discovery of brain-based changes under neuropsychiatric conditions. To fill this gap between remote and local FC studies, this review will (1) briefly survey the history of studies on organizational principles of human brain function; (2) propose local functional homogeneity as a network centrality to characterize multimodal local features of the brain connectome; (3) render a neurobiological perspective on local functional homogeneity by linking its temporal, spatial, and individual variability to information processing, anatomical morphology, and brain development; and (4) discuss its role in performing connectome-wide association studies and identify relevant challenges, and recommend its use in future brain connectomics studies.