

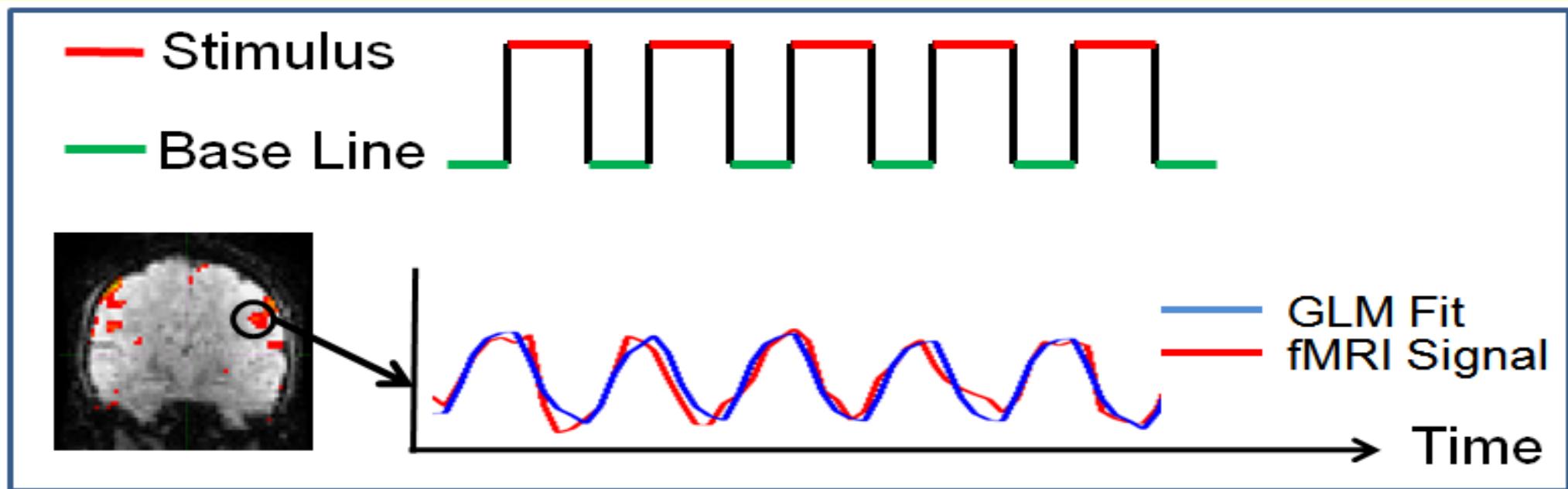
Holistic Atlases of Functional Networks and Interactions (HAFNI)

Tianming Liu

Department of Computer Science and Bioimaging Research Center
The University of Georgia

December 4, 2014

GLM



ICA

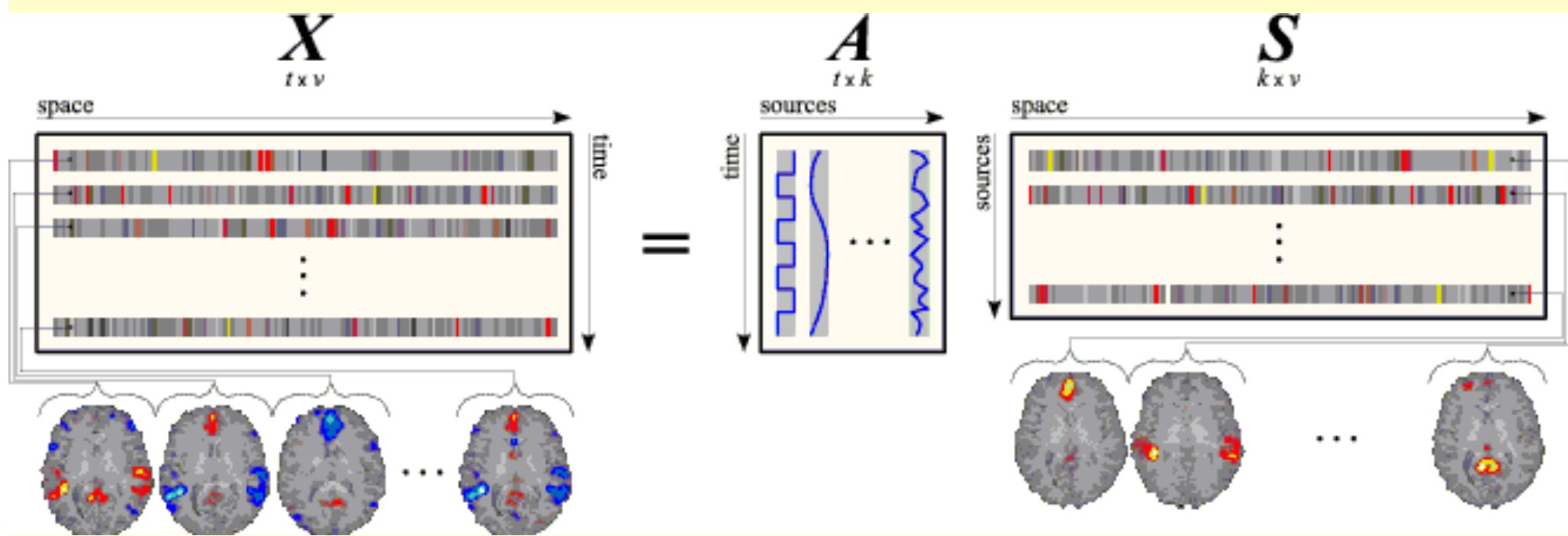
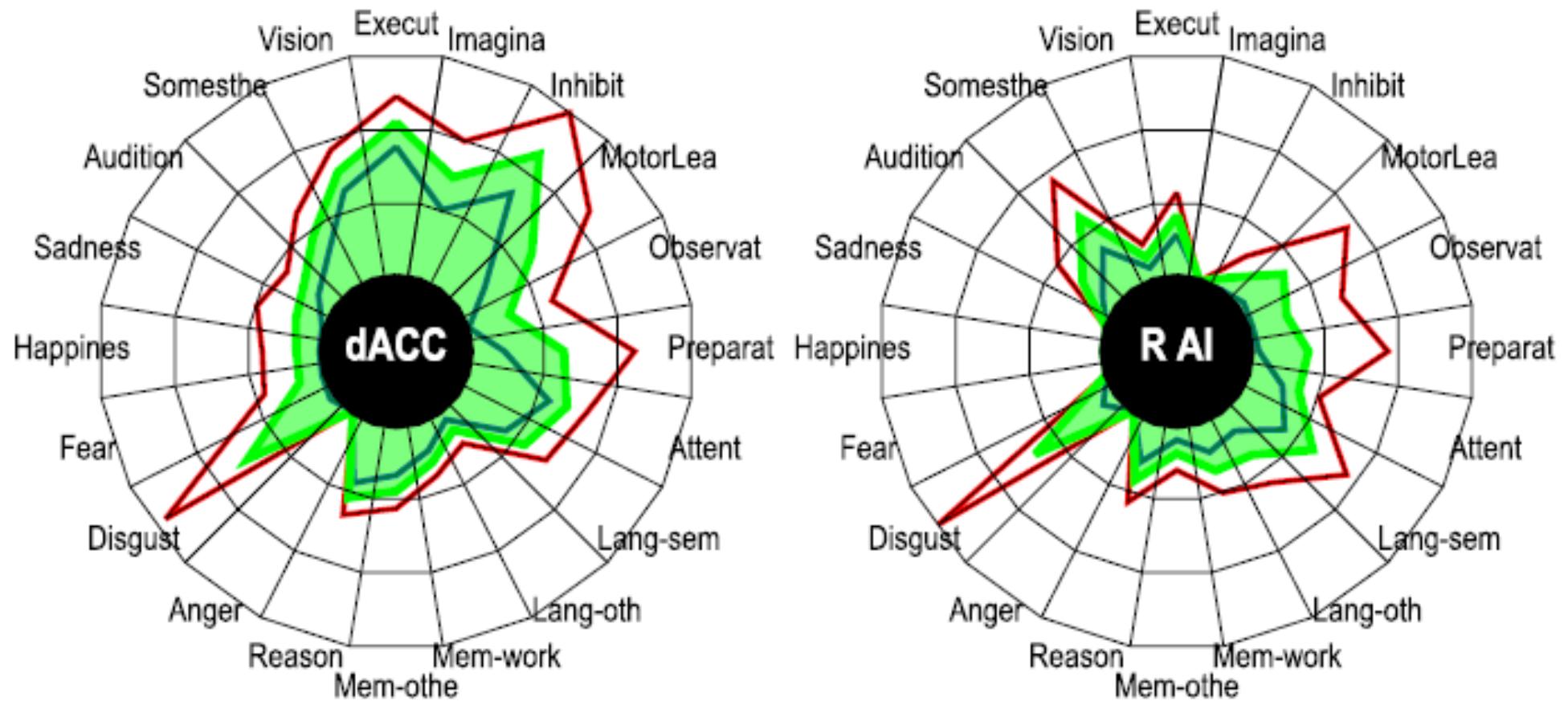


Figure courtesy: J Ylipaavalniemi

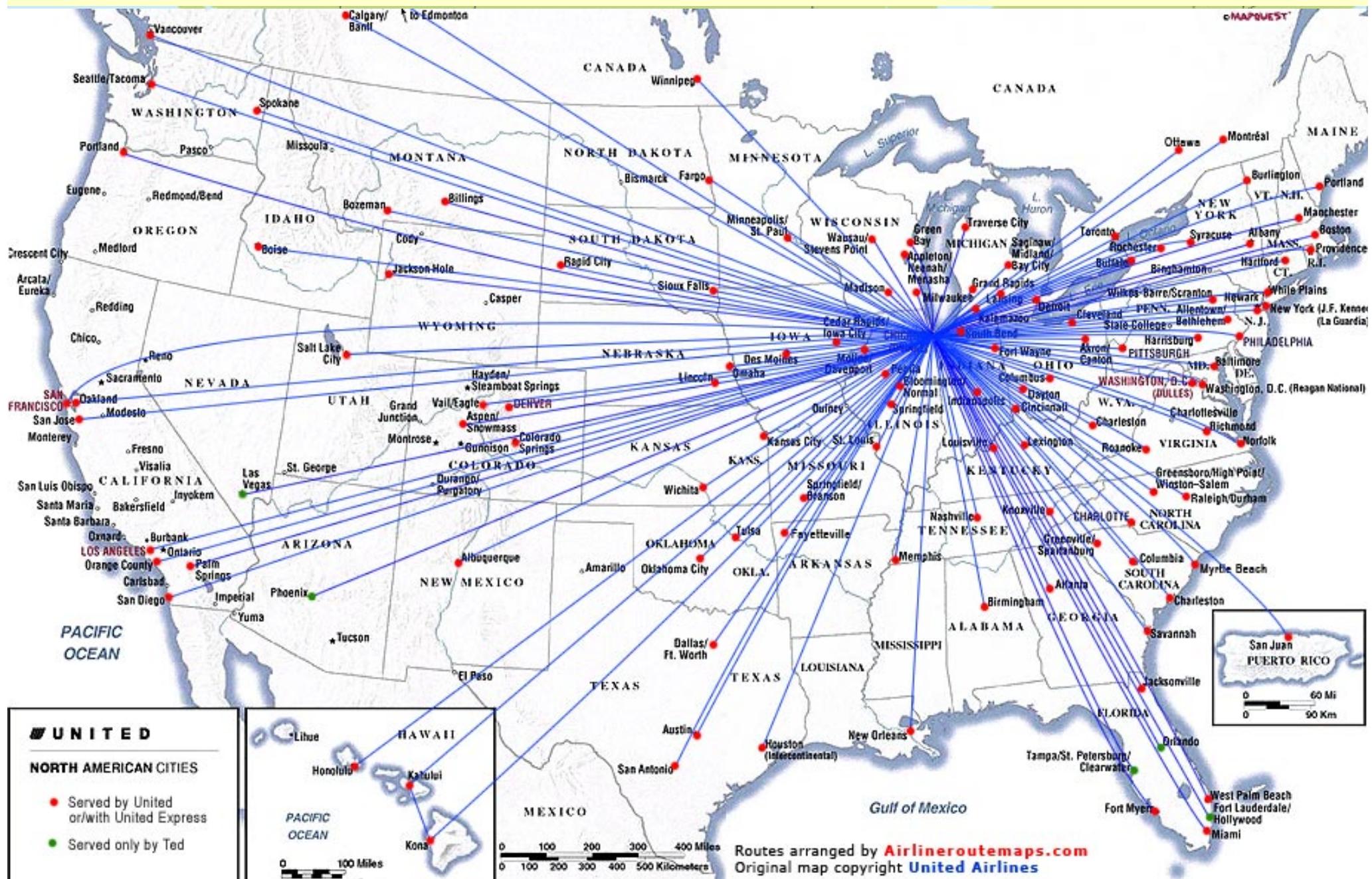
Functional Diversity Profiles



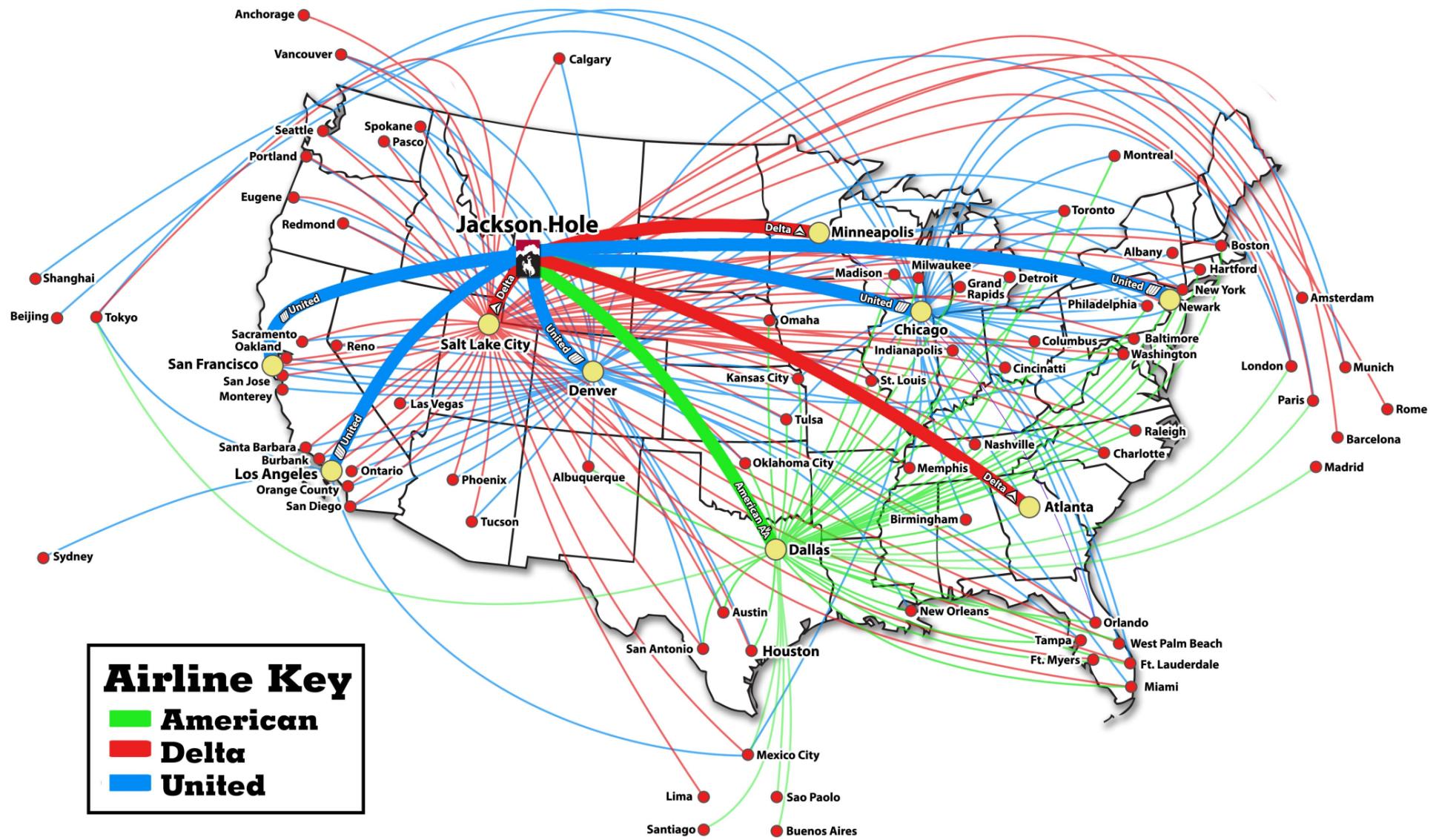
The polar plots illustrate the diversity profile of two brain regions, the dorsal anterior cingulate cortex (ACC) and the right anterior insula (AI).

Anderson et al., NeuroImage, 2013

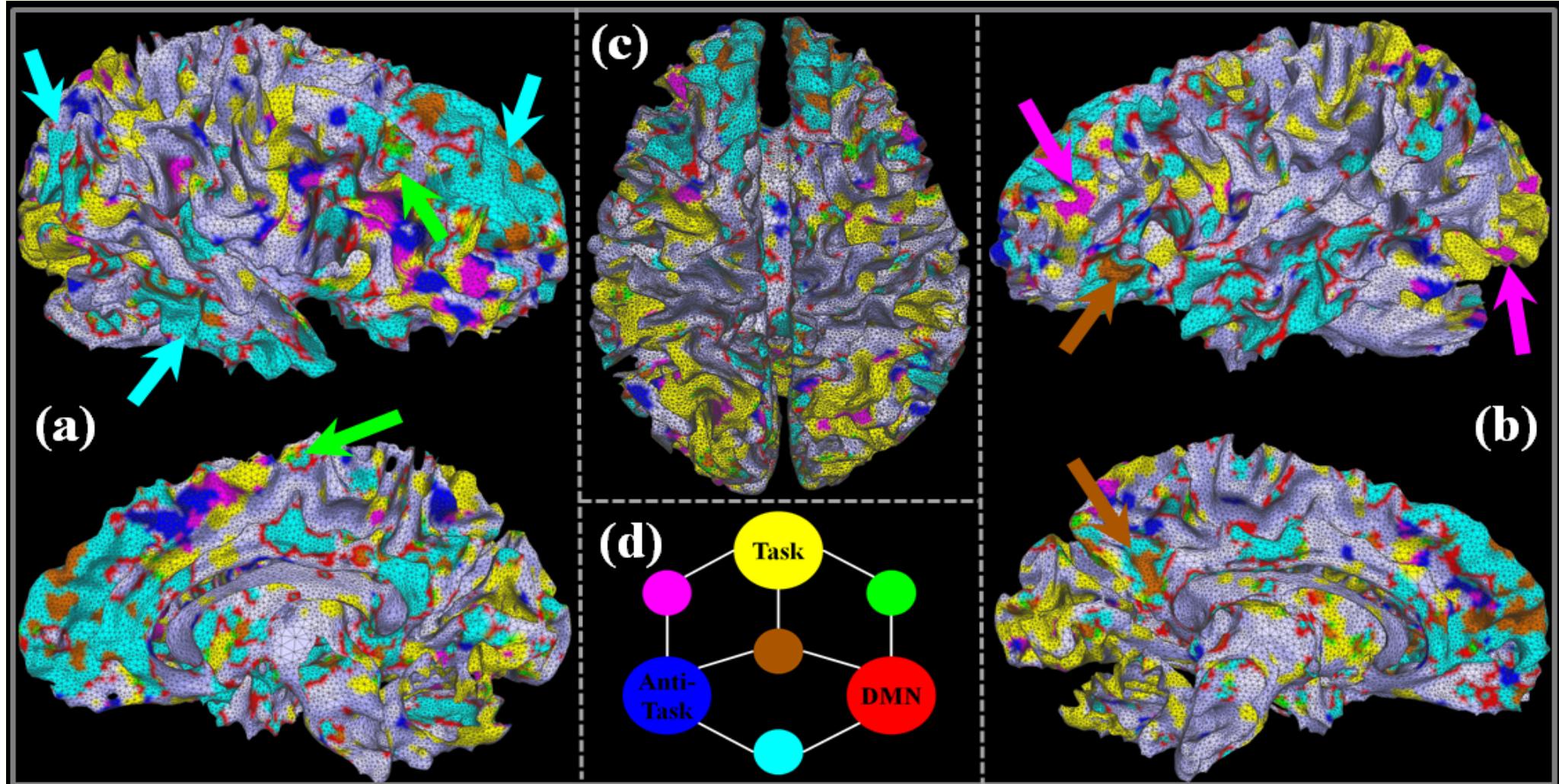
Network Activity Compositions



Network Activity Compositions

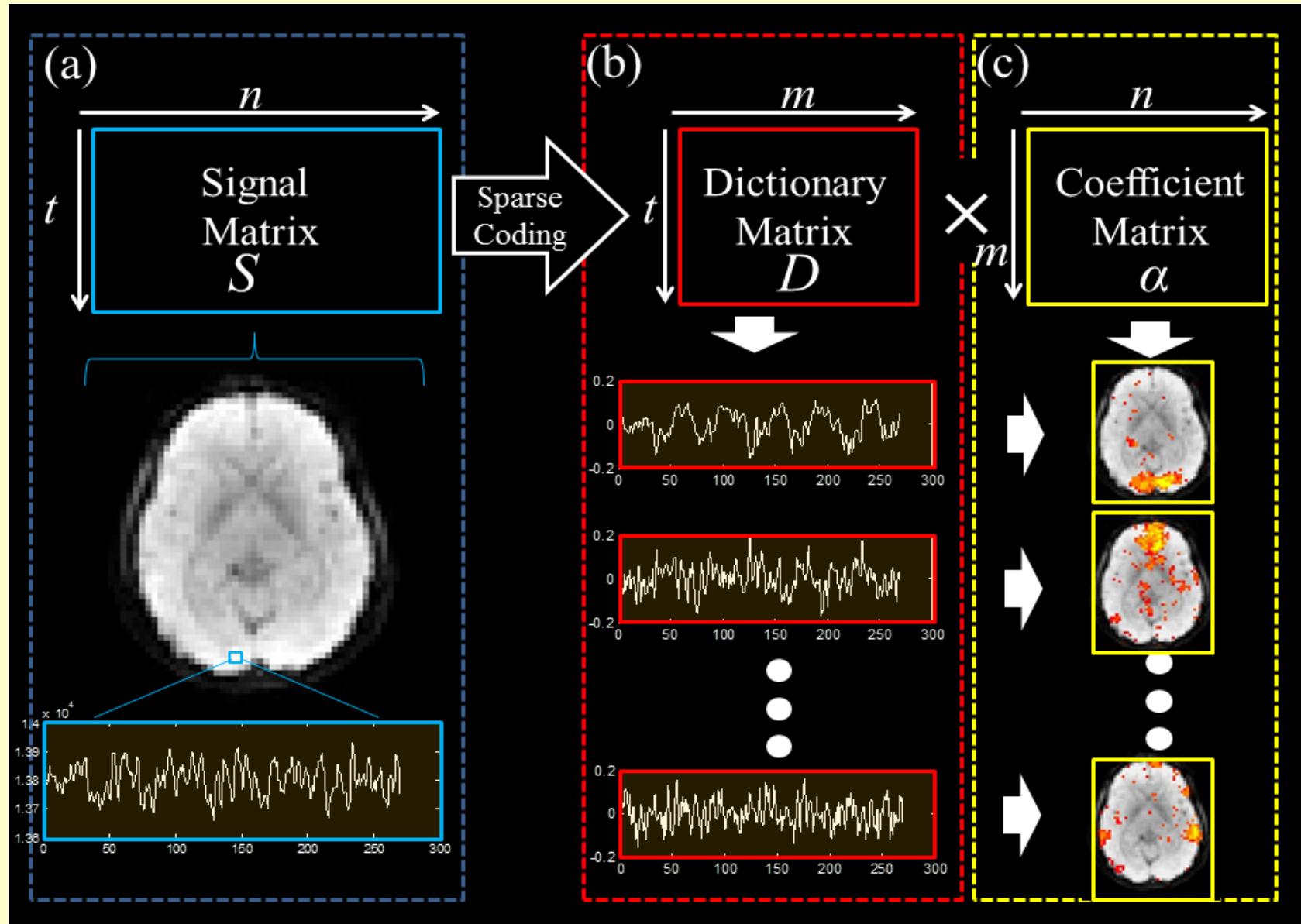


Infer Network Compositions



*Lv et al., IEEE TBME in press, 2014
Lv et al., MedIA, in press, 2014*

Sparse Representation



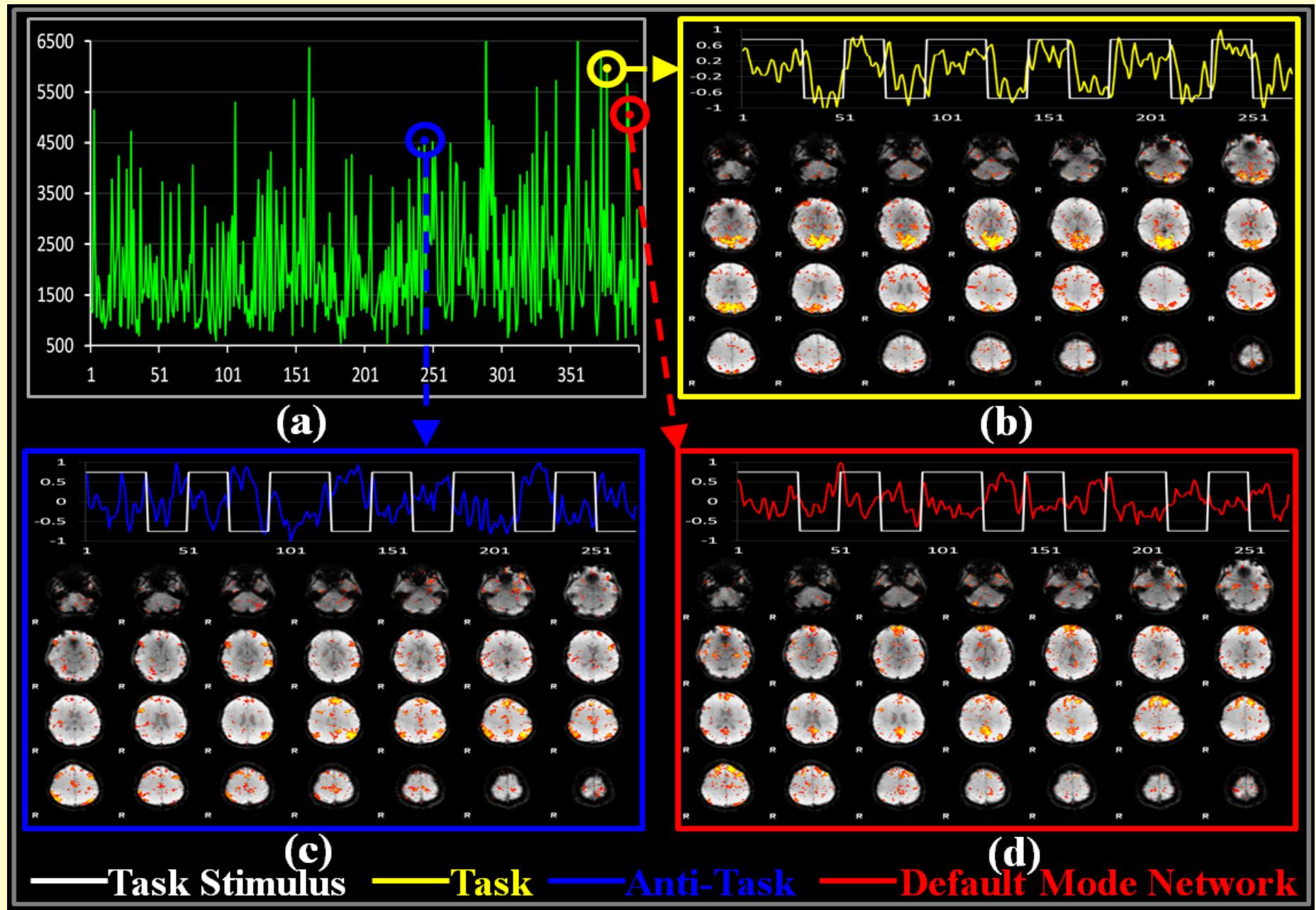
*Lv et al., IEEE TBME in press, 2014
Lv et al., MedIA, in press, 2014*

Sparse Representation

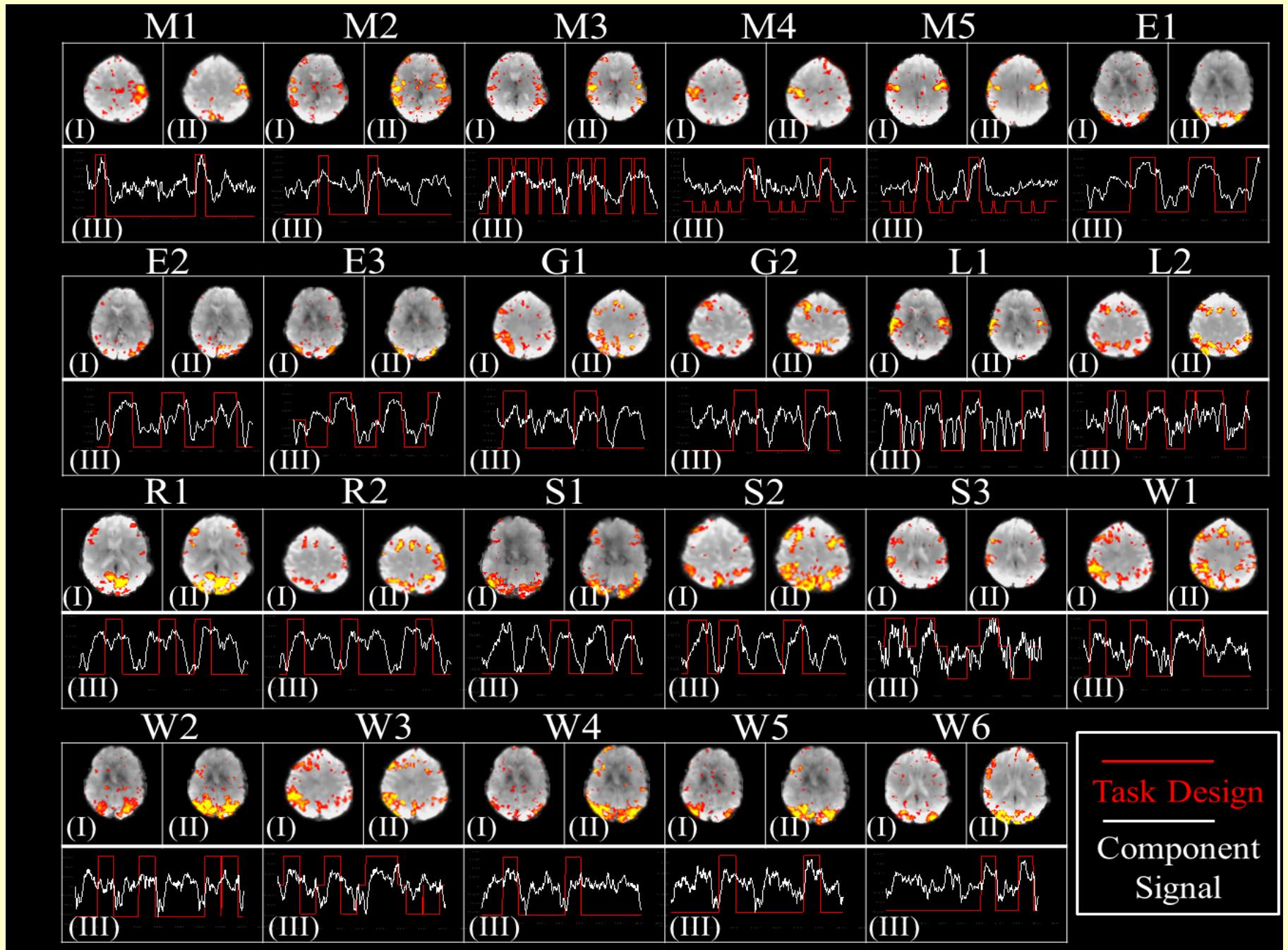
$$\min_{D \in C, \alpha \in \mathbb{R}^{m \times n}} \frac{1}{2} \|S - D\alpha\|_F^2 + \lambda \|\alpha\|_{1,1}$$

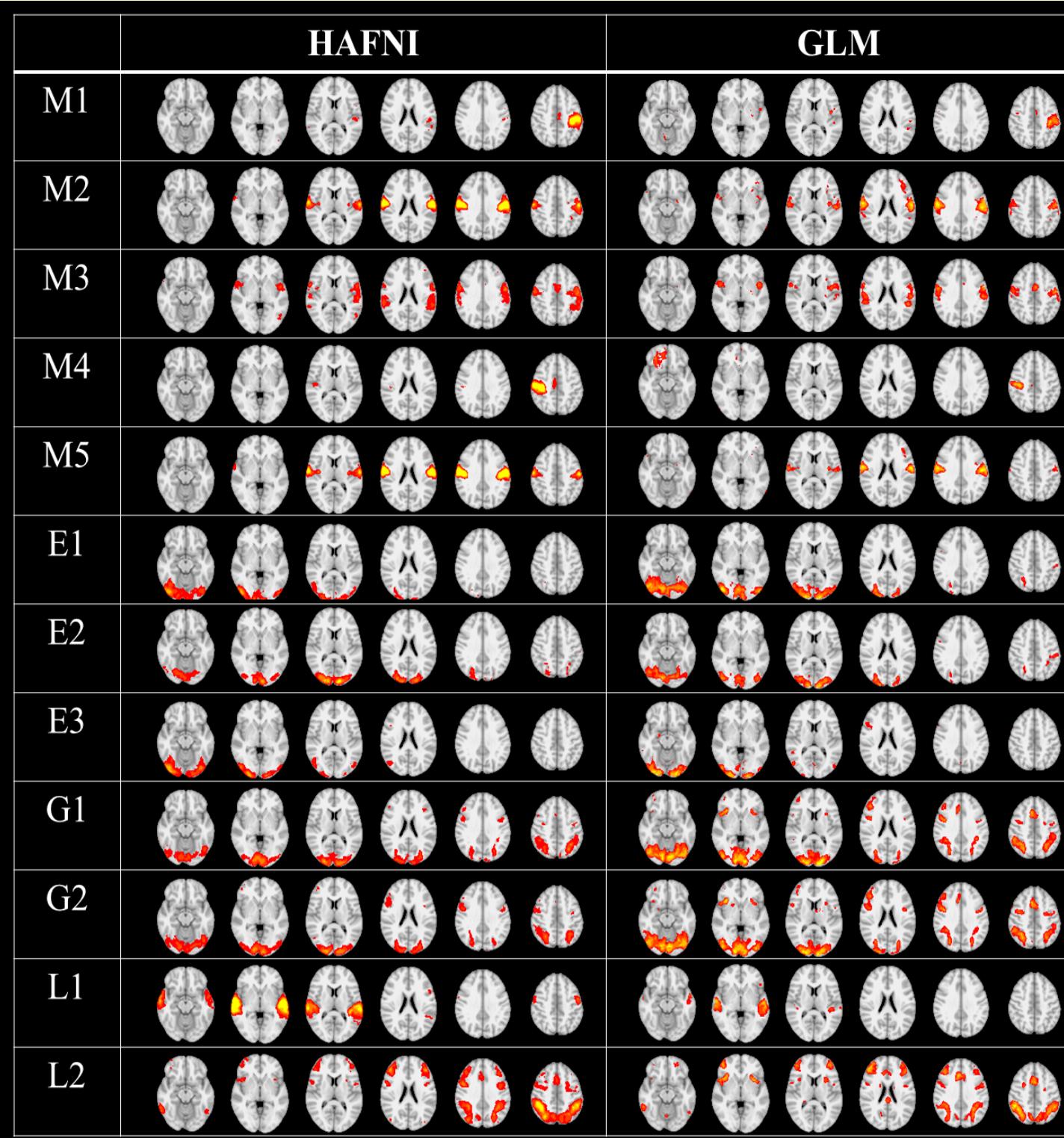
Lv et al., IEEE TBME in press, 2014
Lv et al., MedIA, in press, 2014

Dictionary Learning and Characterization



Application on HCP Data

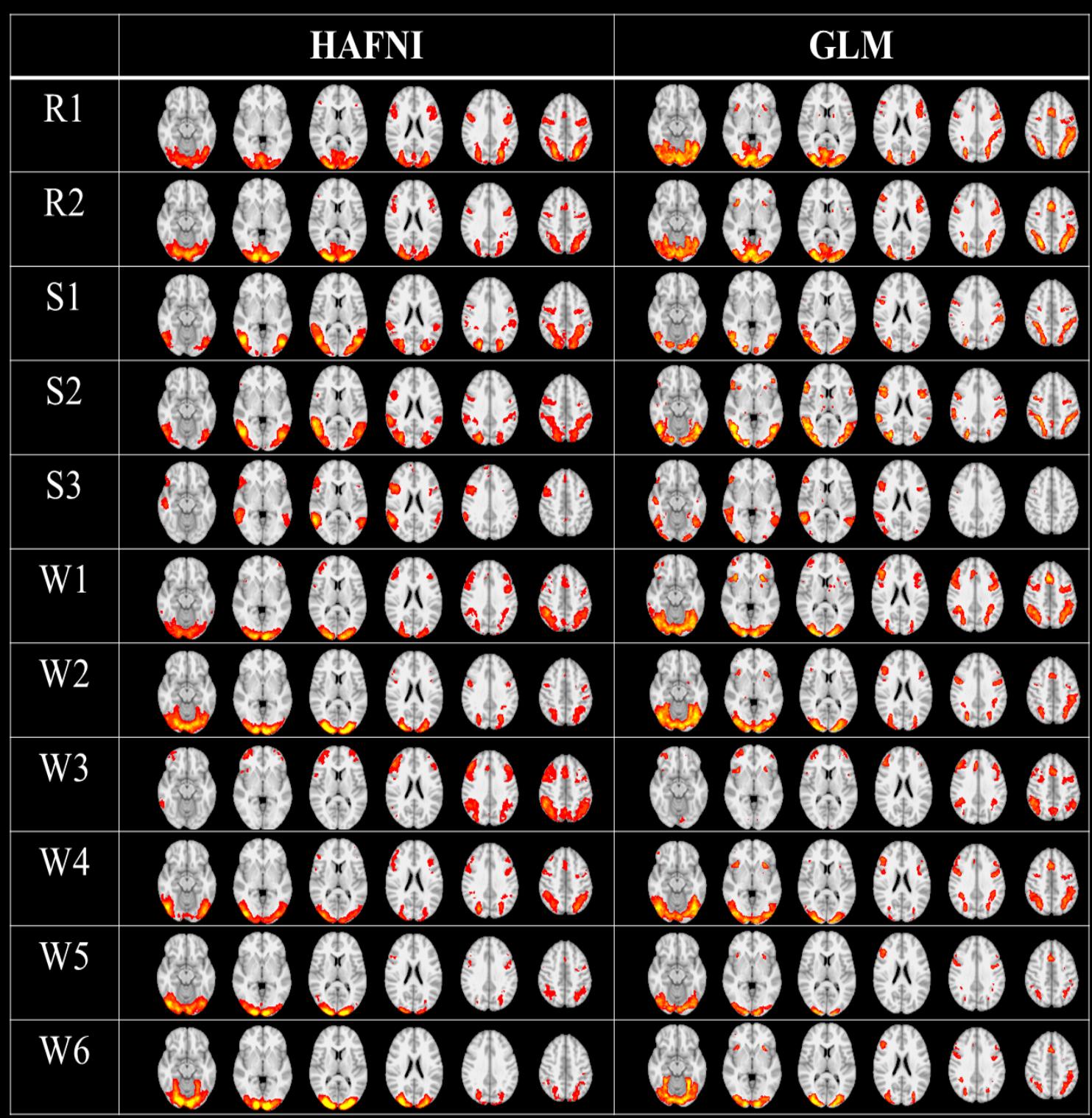




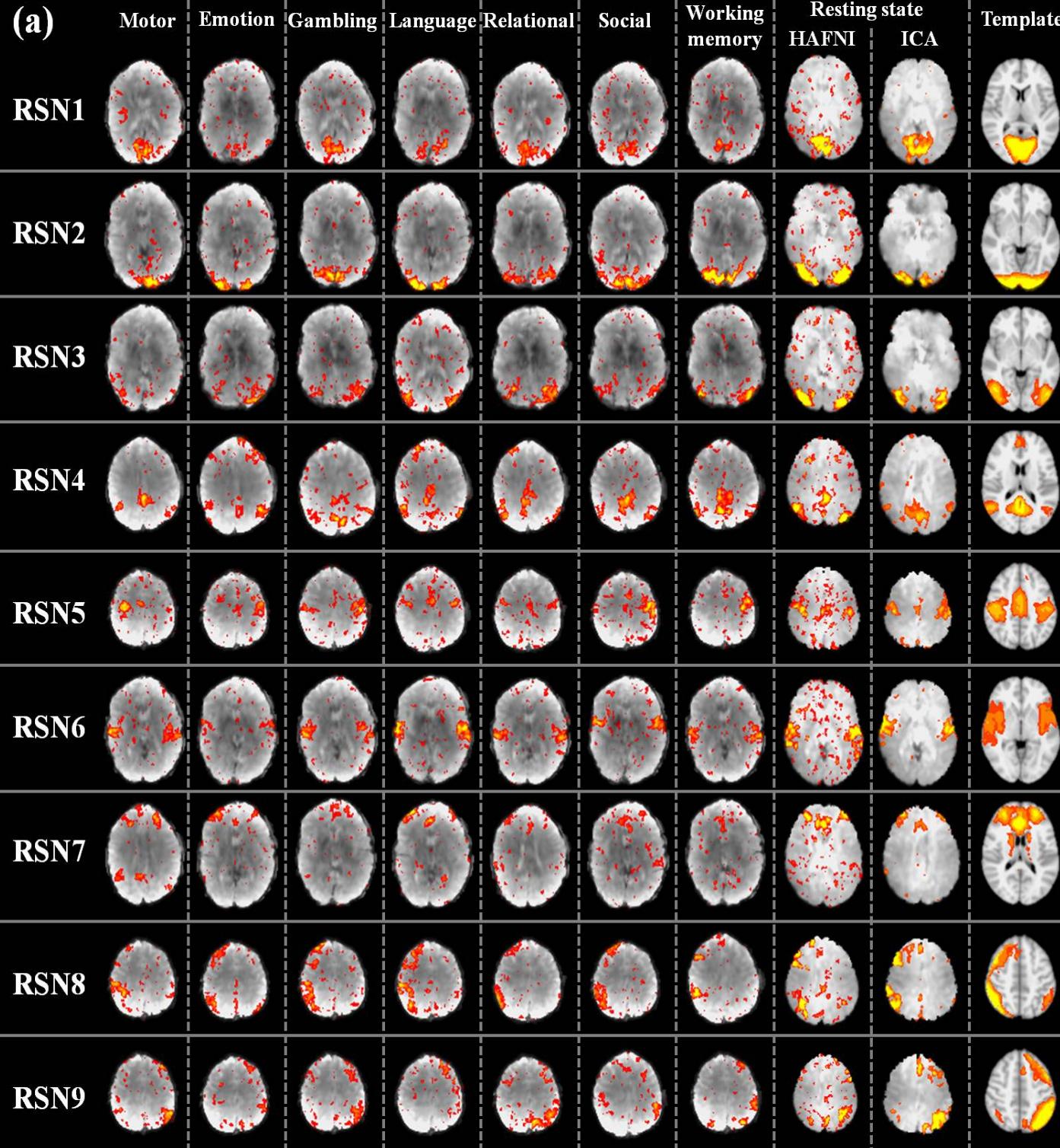
Application on HCP Data: Tasks

*Lv et al., IEEE TBME
in press, 2014*

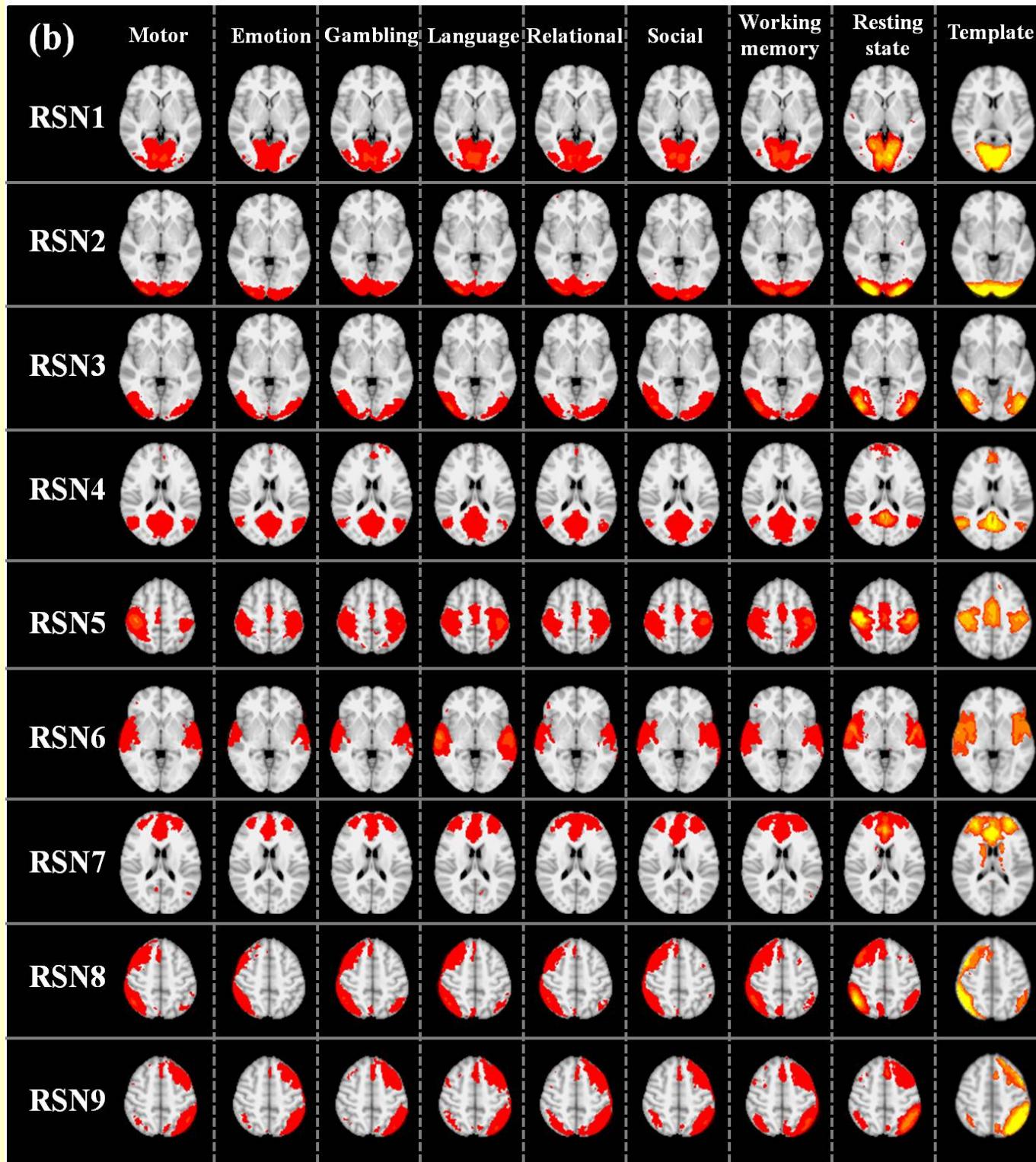
*Lv et al., MedIA, in
press, 2014*



Application on HCP Data: Tasks

(a)

Application on HCP Data: Resting State



Application on HCP Data: Resting State

Holistic Atlases of Functional Networks and Interactions (HAFNI)

hafni.cs.uga.edu

Google

Holistic Atlases of Functional Networks and Interactomes (HAFNI)

Welcome to the home page of Holistic Atlases of Functional Networks and Interactomes (HAFNI), an ongoing project of the Cortical Architecture Imaging and Discovery (CAID) lab at the University of Georgia. Currently we have 23 stabilized functional components identified by the group-wise HAFNI results from Human Connectome Project (HCP) task dataset, and 9 stabilized resting-state functional components from HCP resting dataset.

In the links below you could find the spatial and temporal patterns of the functional brain networks by HAFNI in HCP datasets.

[Cross-examination of HAFNI vs. GLM results on HCP task-related dataset with multiple threshold applied \(HCP dataset, 68 subjects, 7 tasks, 400 components\)](#)

[List of finalized task-related networks in HCP-Task dataset](#)

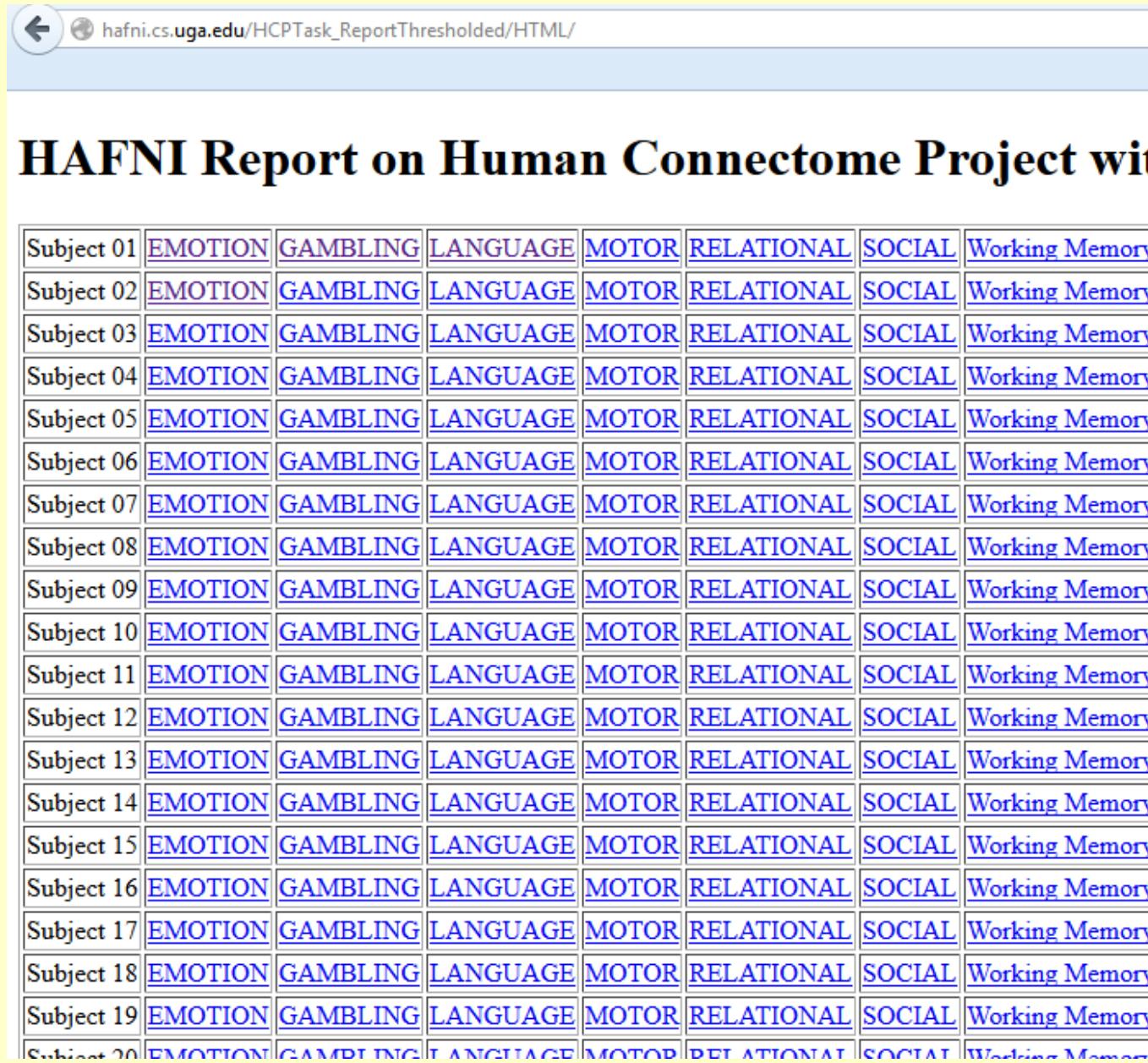
[List of finalized resting-state networks in task and resting state dataset](#)

Contact

Tianming Liu, Associate Professor, Department of Computer Science / Bioimaging Research Center, The University of Georgia, Athens, GA 30602. Email: tliu(at)cs.uga.edu



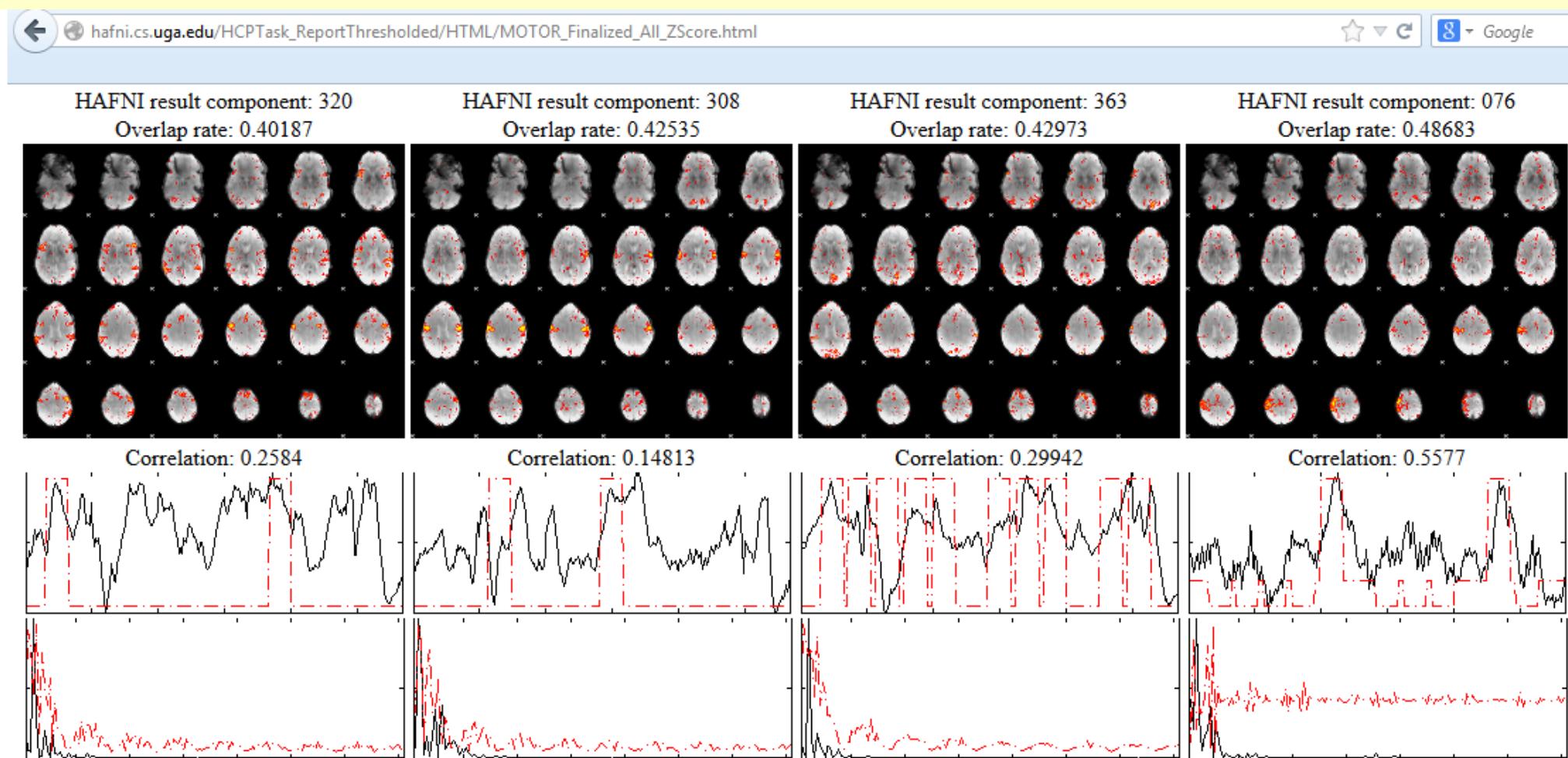
Holistic Atlases of Functional Networks and Interactions (HAFNI)



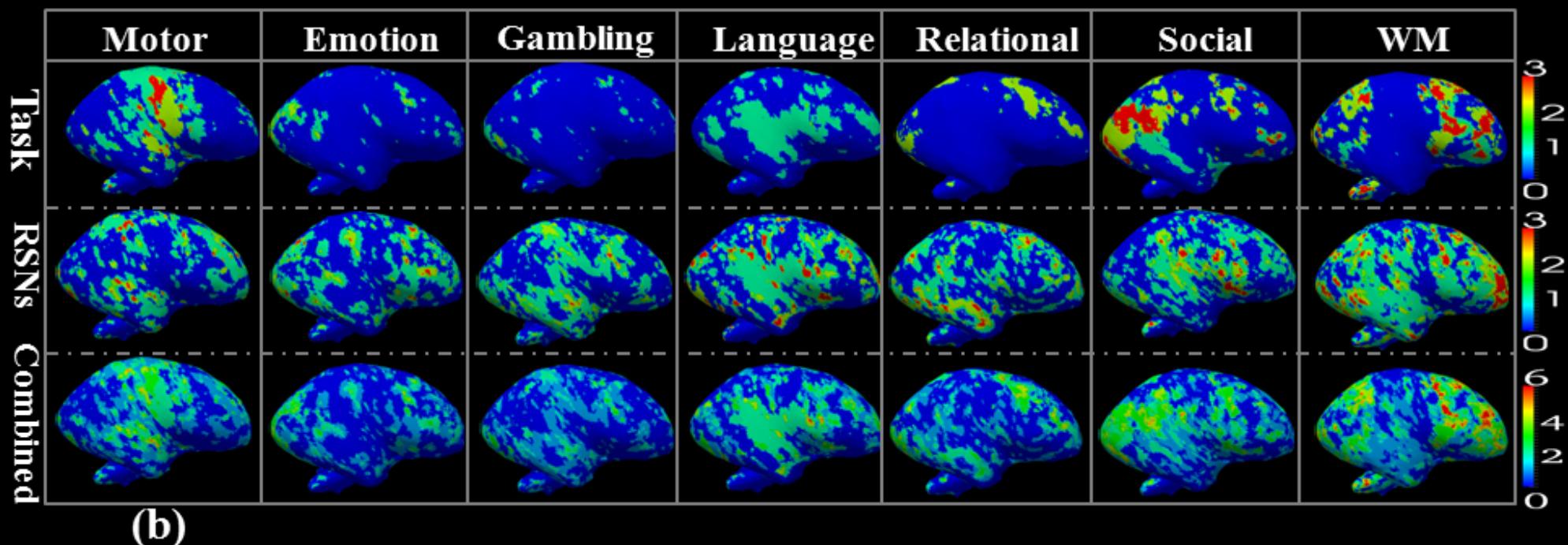
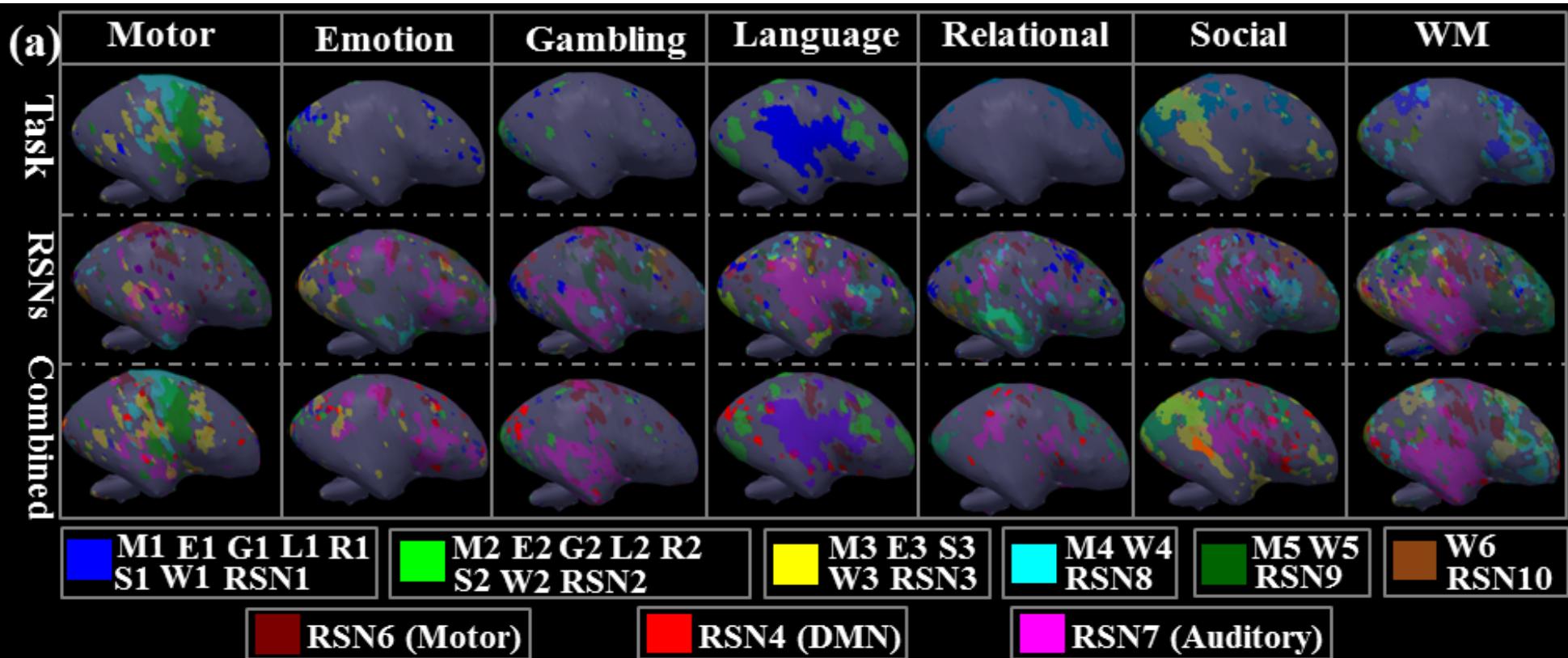
The screenshot shows a web browser window with the URL hafni.cs.uga.edu/HCPTask_ReportThresholded/HTML/. The page title is "HAFNI Report on Human Connectome Project with". Below the title is a table with 20 rows, each representing a subject (Subject 01 to Subject 20) and listing functional networks: EMOTION, GAMBLING, LANGUAGE, MOTOR, RELATIONAL, SOCIAL, and Working Memory.

Subject 01	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 02	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 03	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 04	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 05	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 06	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 07	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 08	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 09	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 10	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 11	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 12	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 13	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 14	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 15	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 16	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 17	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 18	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 19	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory
Subject 20	EMOTION	GAMBLING	LANGUAGE	MOTOR	RELATIONAL	SOCIAL	Working Memory

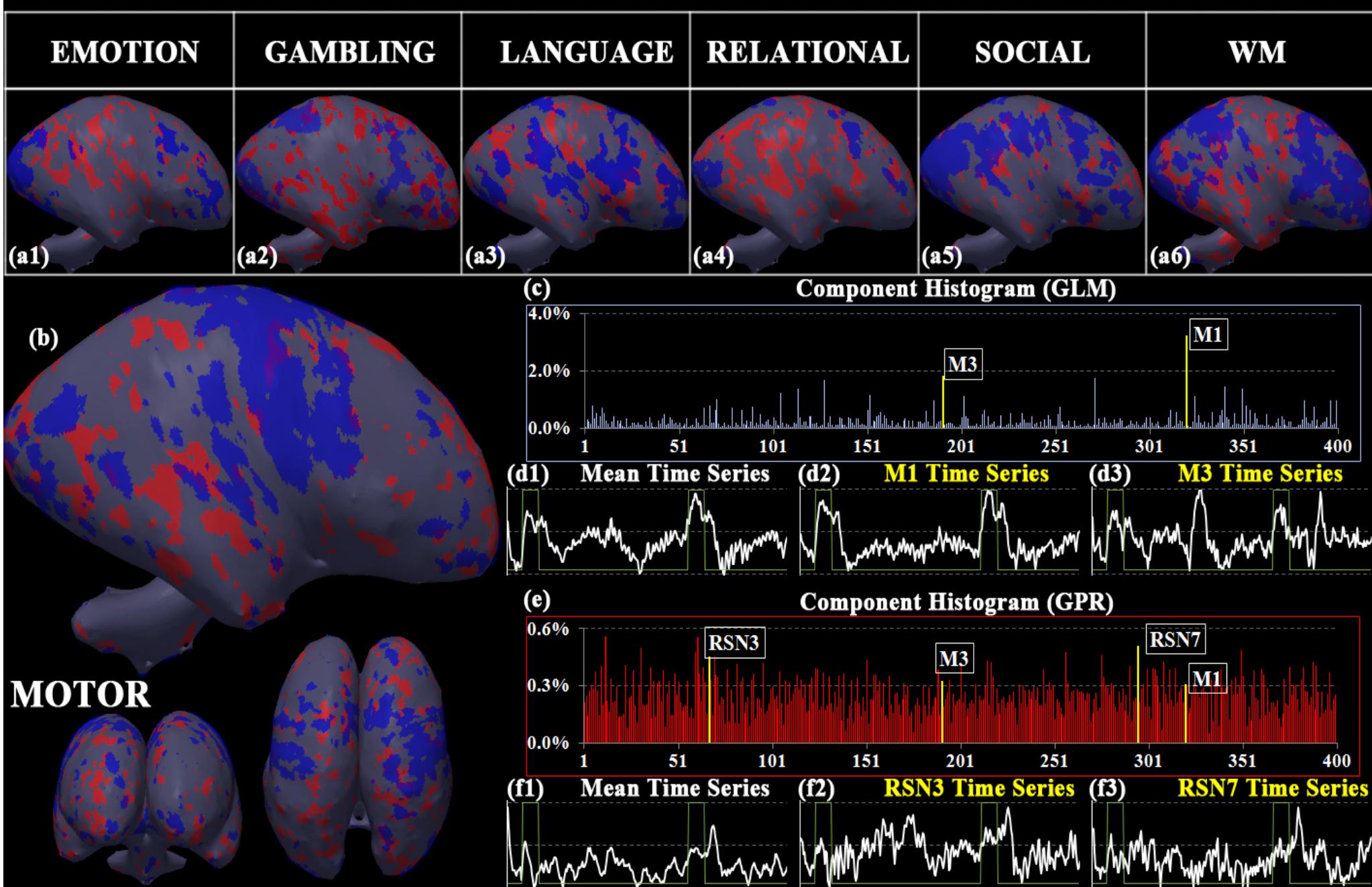
Holistic Atlases of Functional Networks and Interactions (HAFNI)



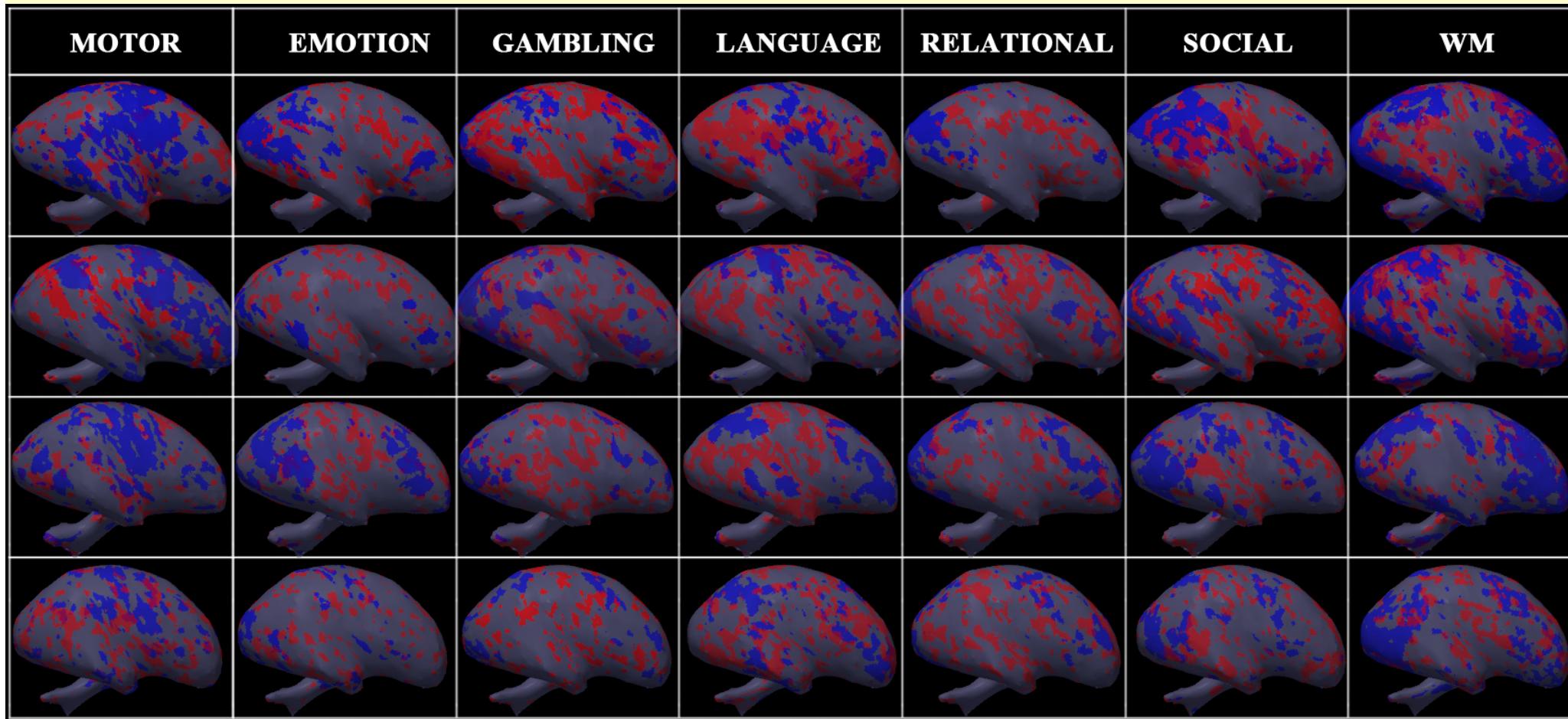
Lv et al., IEEE TBME in press, 2014
Lv et al., MedIA, in press, 2014



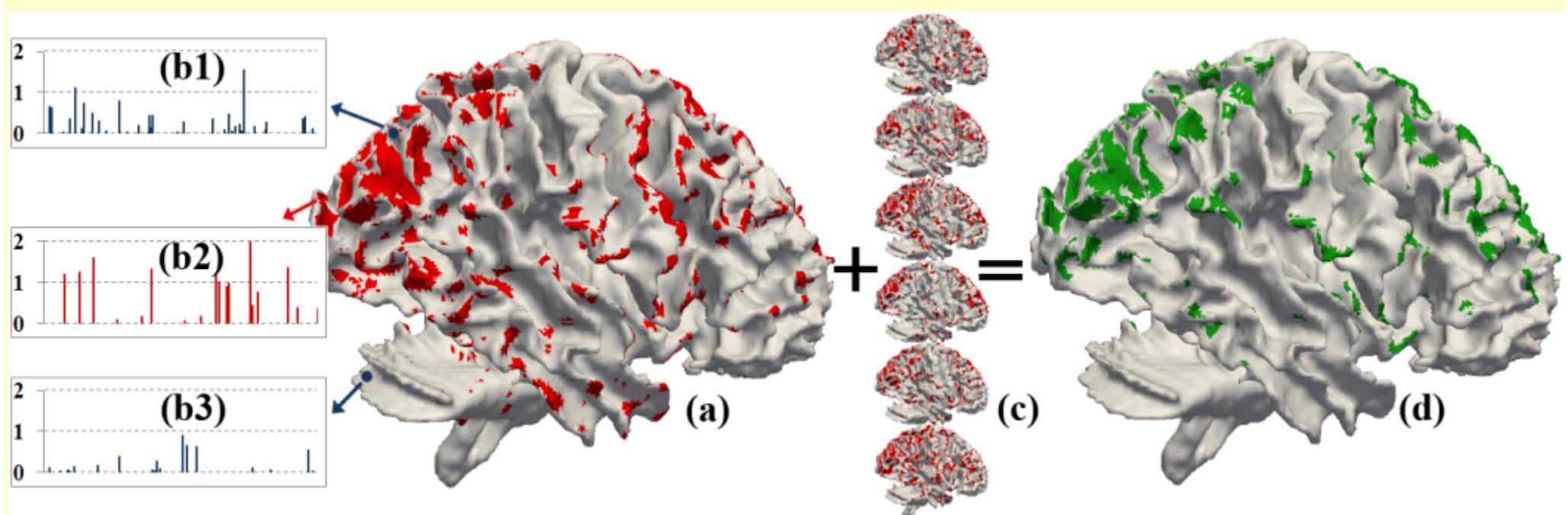
Reciprocal Organizational Architecture



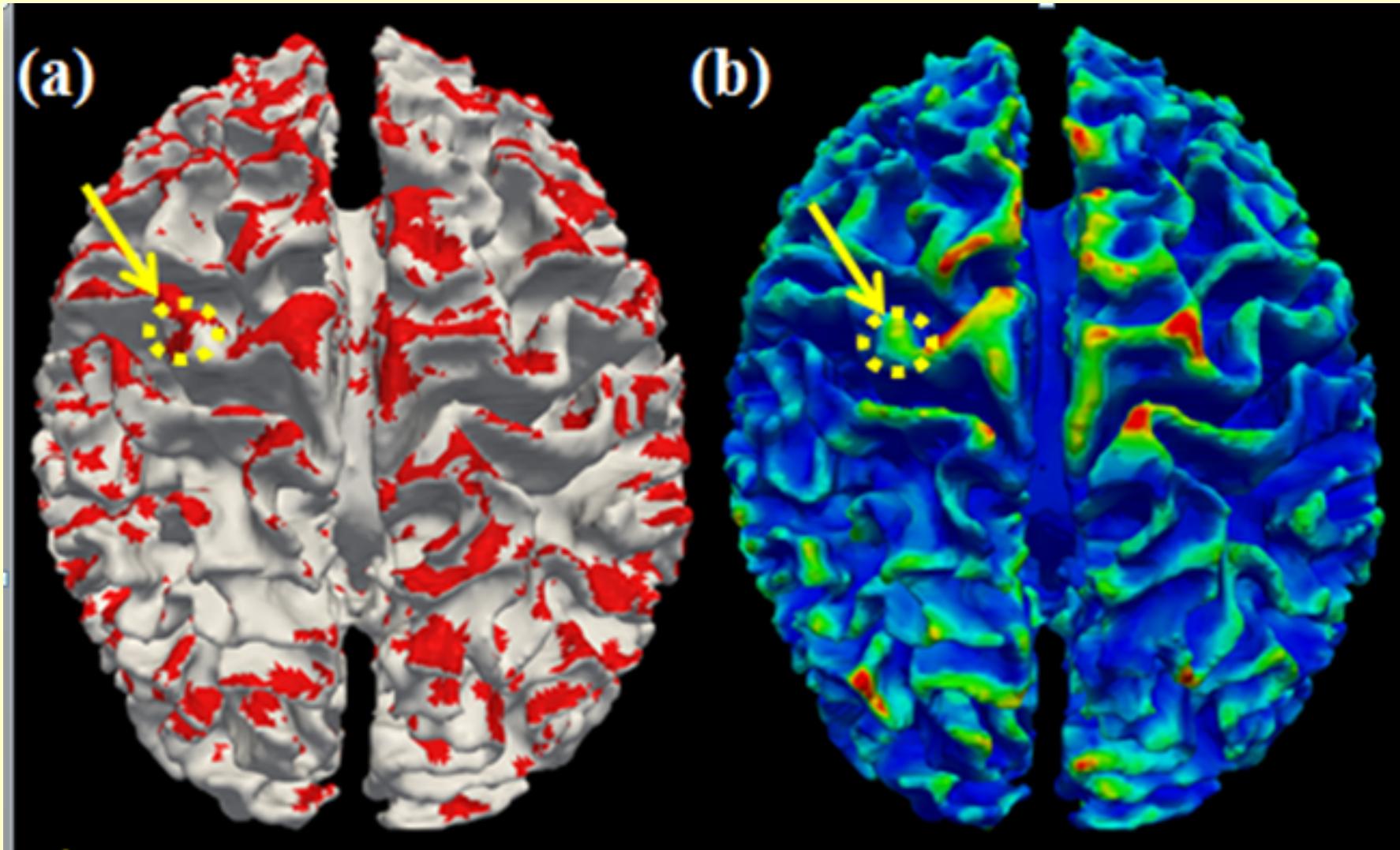
Reciprocal Organizational Architecture



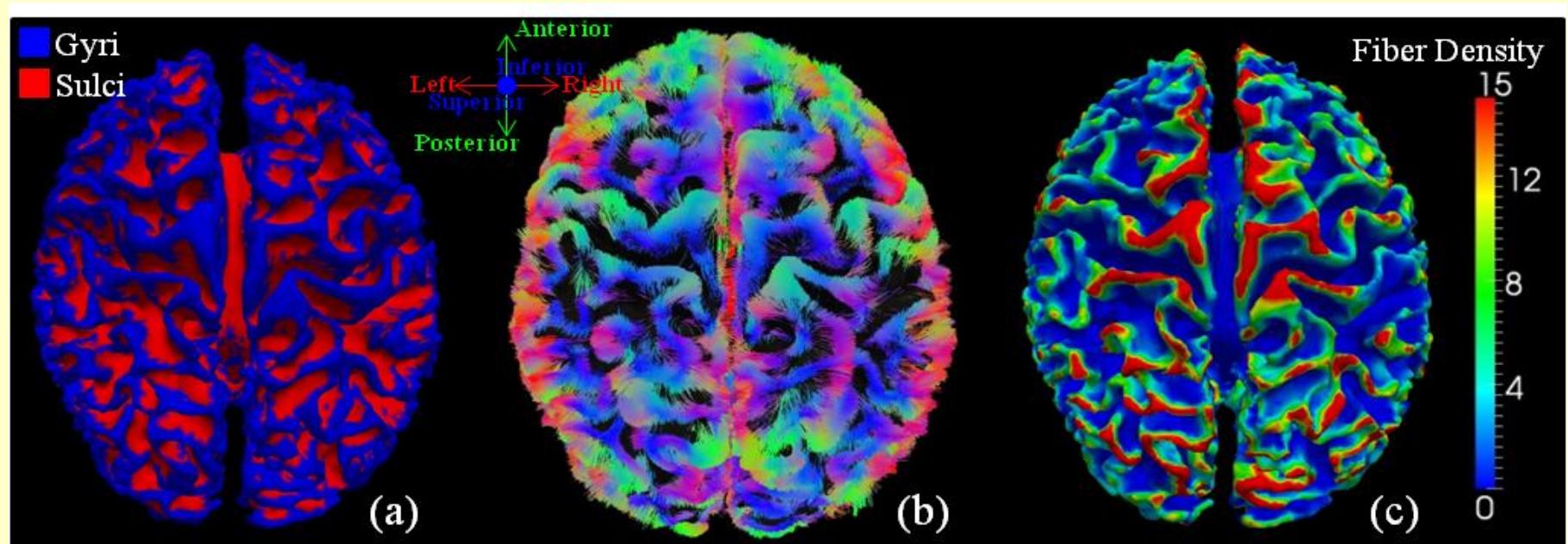
Highly Heterogeneous Regions (HHR)



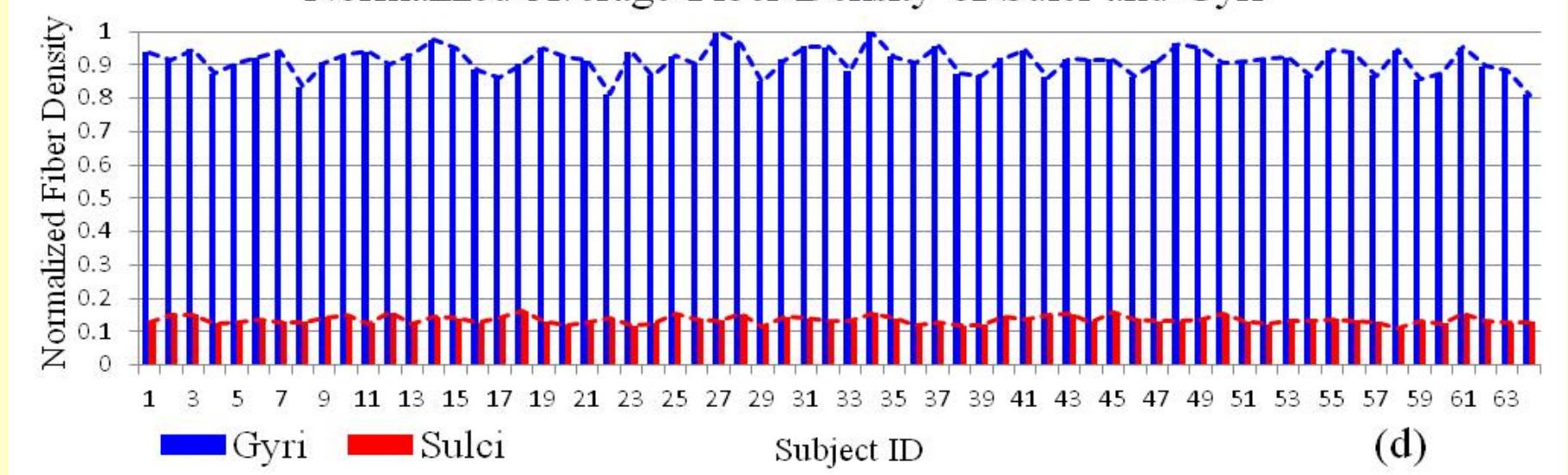
F-Highly Heterogeneous Regions (HHR)



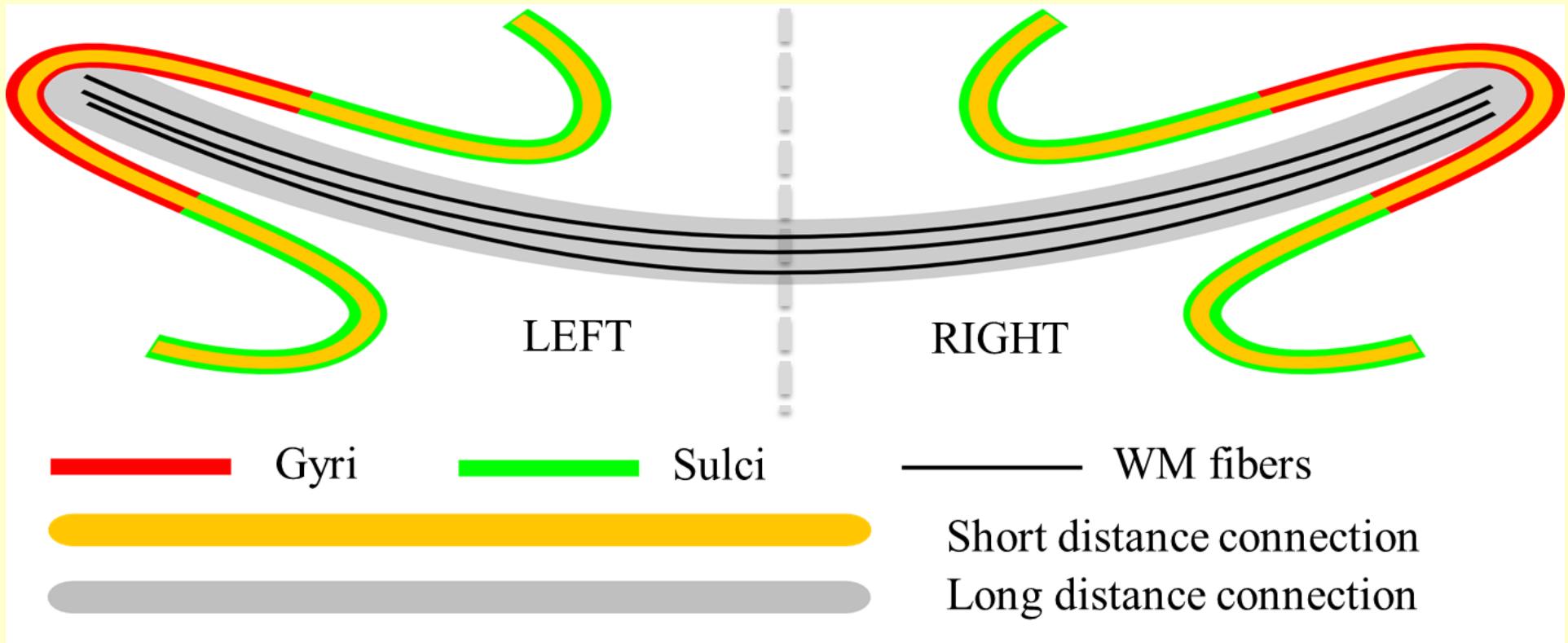
Gyri vs Sulci Connectivity Patterns



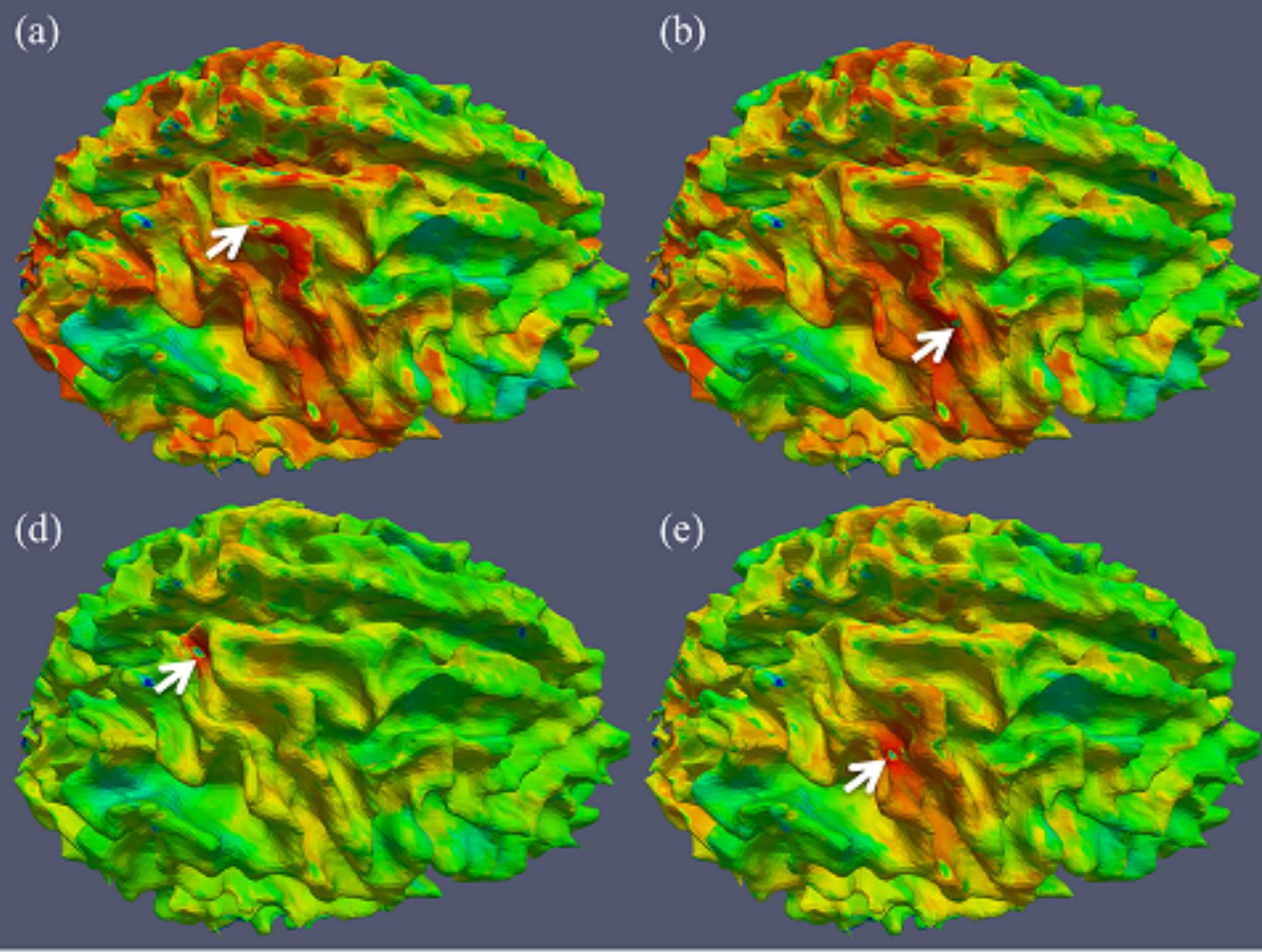
Normalized Average Fiber Density of Sulci and Gyri

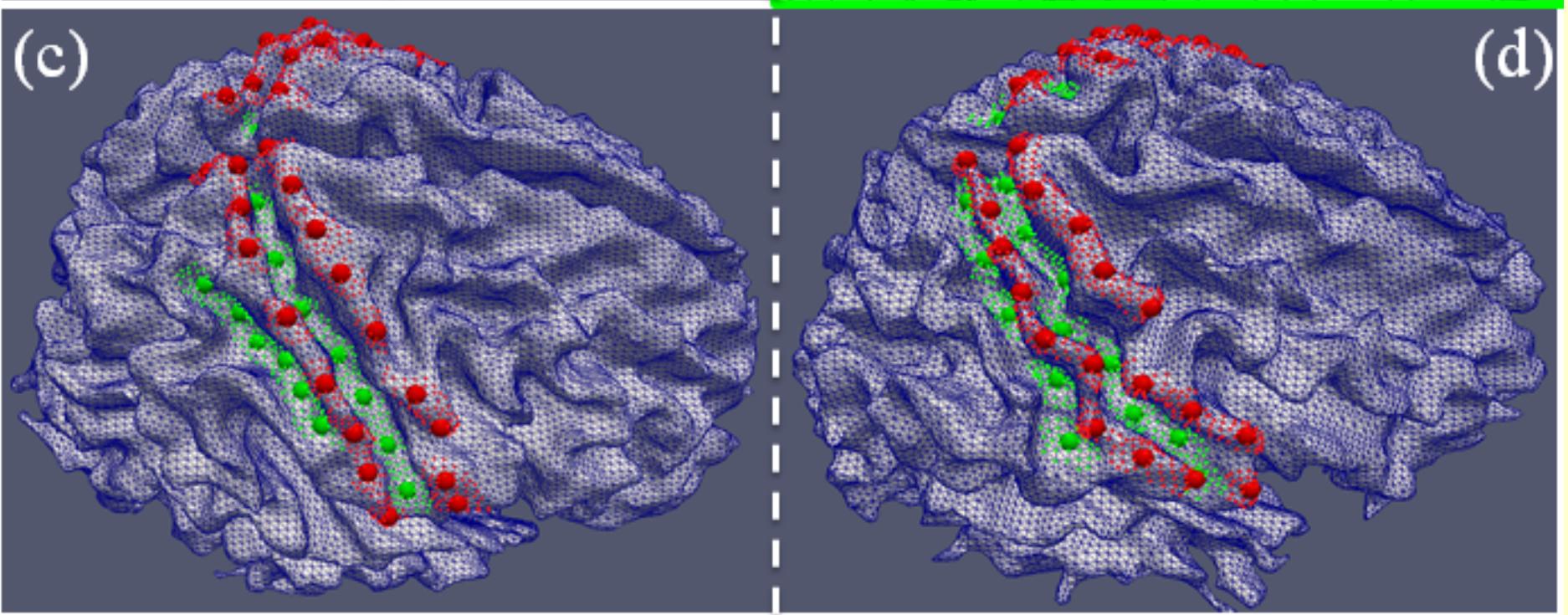
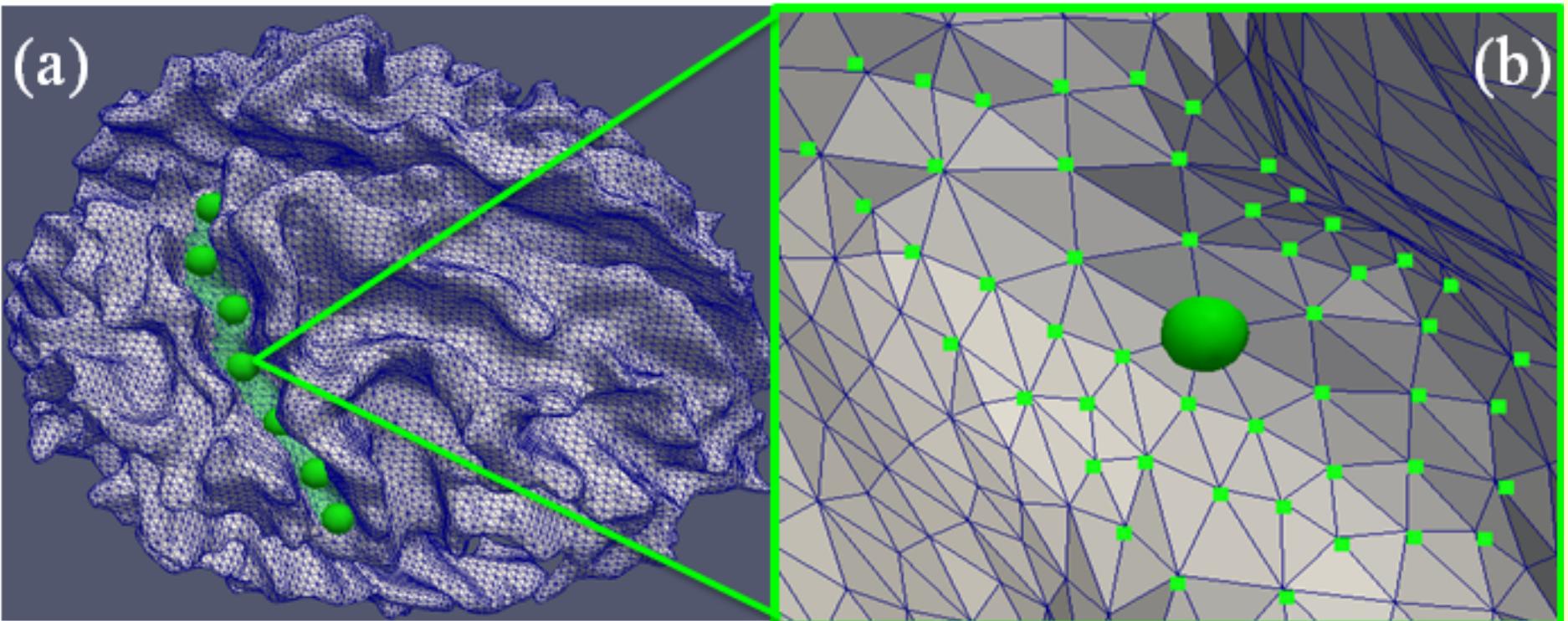


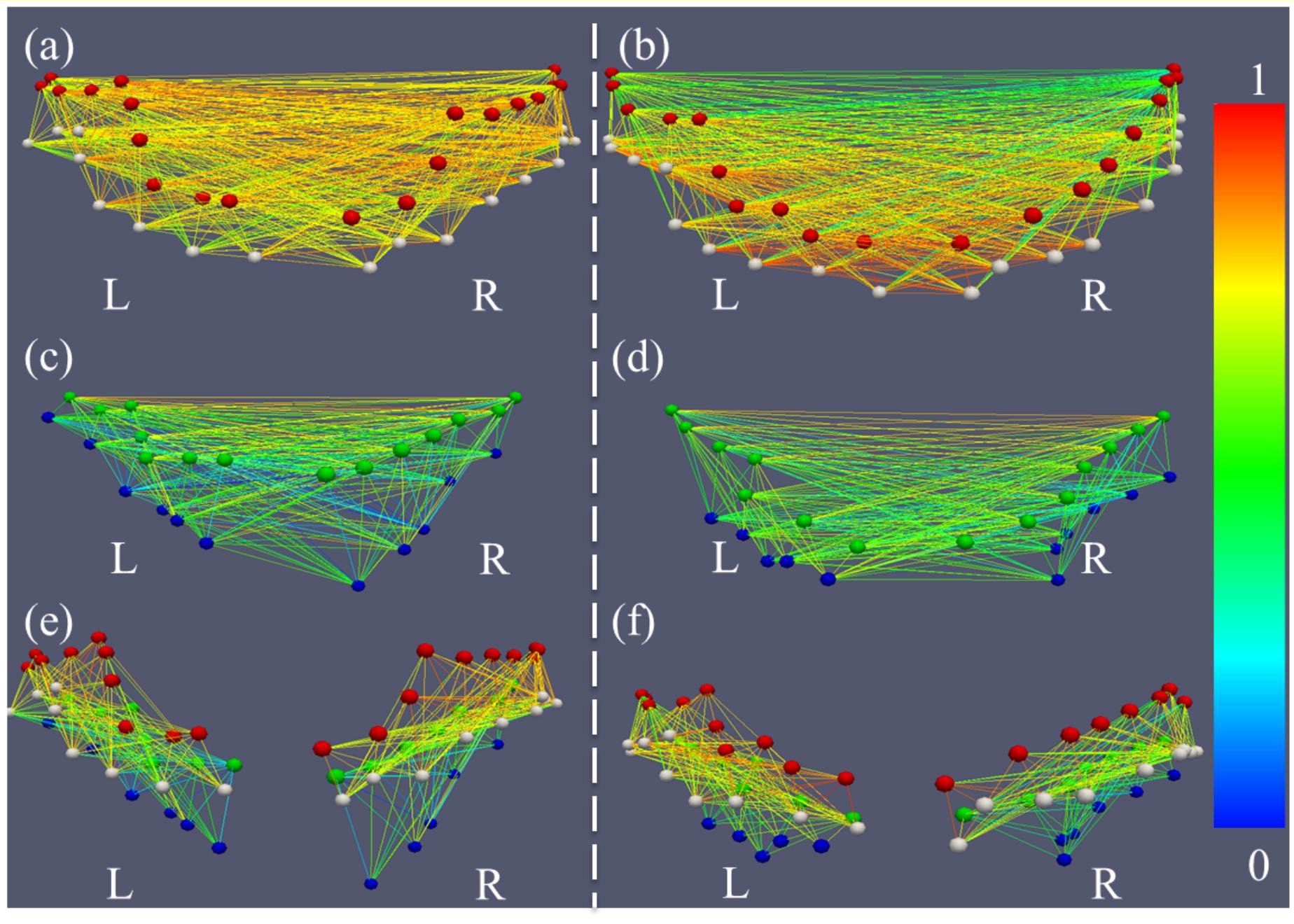
Gyri vs Sulci Functional Roles: A Hypothesis



Deng et al., BSF, 2013







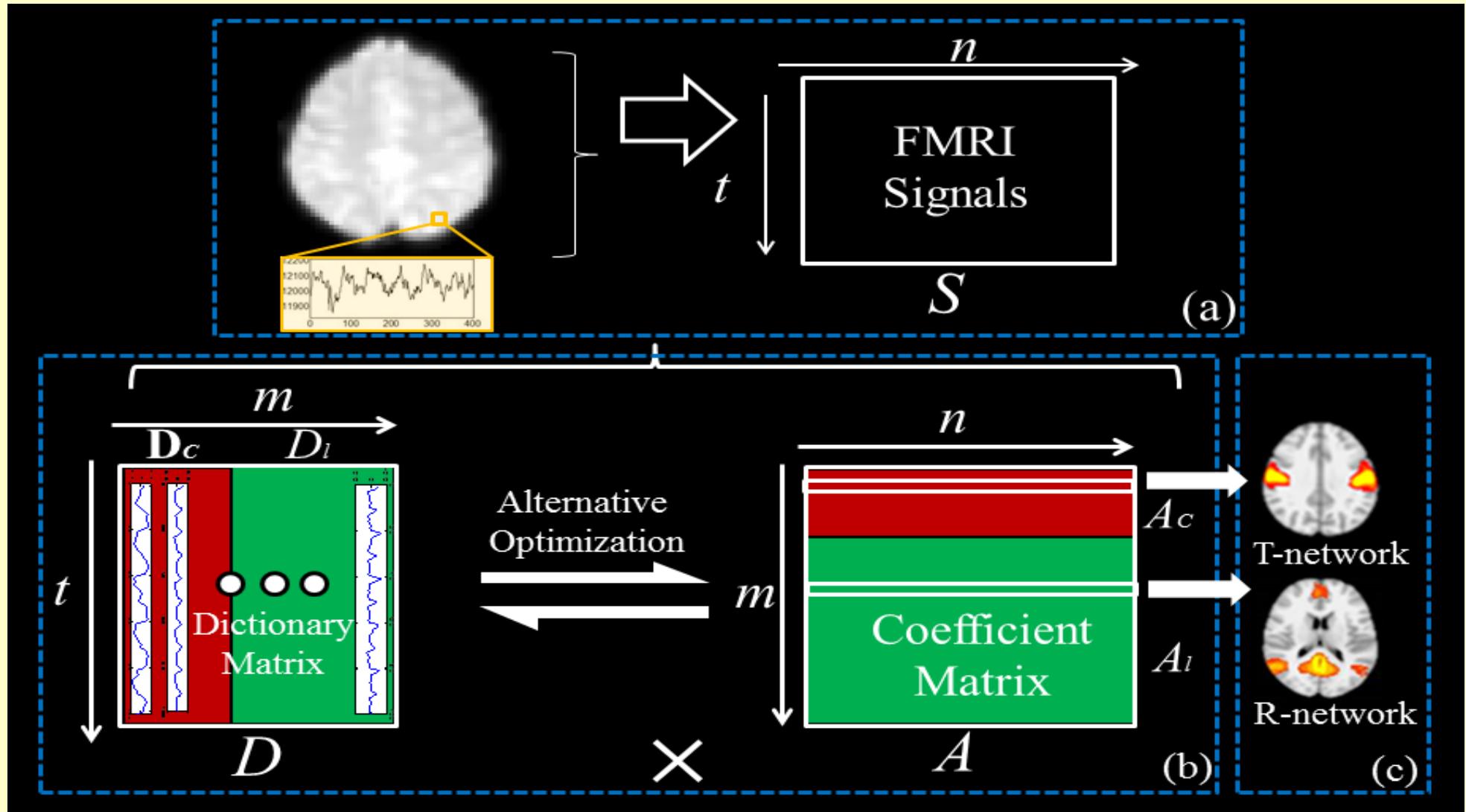


Axonal Pushing Theory of Cortical Folding

Representative Publications:

- Tao Zeng, Hanbo Chen, Ahmed Fakhry, Xiaoping Hu, Tianming Liu*, Shuiwang Ji*, Allen Mouse Brain Atlases Reveal Different Neural Connection and Gene Expression Patterns in Cerebellum Gyri and Sulci, **Brain Structure and Function**, 2014. *Joint-correspondence authors, in press. PDF
- Tuo Zhang, Hanbo Chen, Lei Guo, Kaiming Li, Longchuan Li, Shu Zhang, Dinggang Shen, Xiaoping Hu, Tianming Liu, Characterization of U-shape Streamline Fibers: Methods and Applications, **Medical Image Analysis**, 2014. in press. PDF
- Fan Deng, Xi Jiang, Dajiang Zhu, Tuo Zhang, Kaiming Li, Lei Guo, Tianming Liu, A functional model of cortical gyri and sulci, **Brain Structure and Function**, 2013. in press.PDF
- Hanbo Chen*, Tuo Zhang*, Lei Guo, Kaiming Li, Xiang Yu, Longchuan Li, Xintao Hu, Junwei Han, Xiaoping Hu**, Tianming Liu**, Coevolution of Gyral Folding and Structural Connection Patterns in Primate Brains, **Cerebral Cortex**, 2013. vol. 23(5), pp. 1208-1217. *Joint first authors, **Joint corresponding authors.PDF
- Jingxin Nie, Lei Guo, Kaiming Li, Yonghua Wang, Guojun Chen, Longchuan Li, Hanbo Chen, Fan Deng, Xi Jiang, Tuo Zhang, Ling Huang, Carlos Faraco, Degang Zhang, Cong Guo, Pew-Thian Yap, Xintao Hu, Gang Li, Jinglei Lv, Yixuan Yuan, Dajiang Zhu, Junwei Han, Dean Sabatinelli, Qun Zhao, L Stephen Miller, Bingqian Xu, Ping Shen, Simon Platt, Dinggang Shen, Xiaoping Hu, Tianming Liu, Axonal Fiber Terminations Concentrate on Gyri, **Cerebral Cortex**, 2012. vol. 22(12), pp. 2831-2839.PDF
- Kaiming Li, Lei Guo, Gang Li, Jingxin Nie, Carlos Faraco, Guangbin Cui, Qun Zhao, Stephen Miller, Tianming Liu, Gyral folding pattern analysis via surface profiling, **NeuroImage**, 52(4):1202–14, 2010.PDF

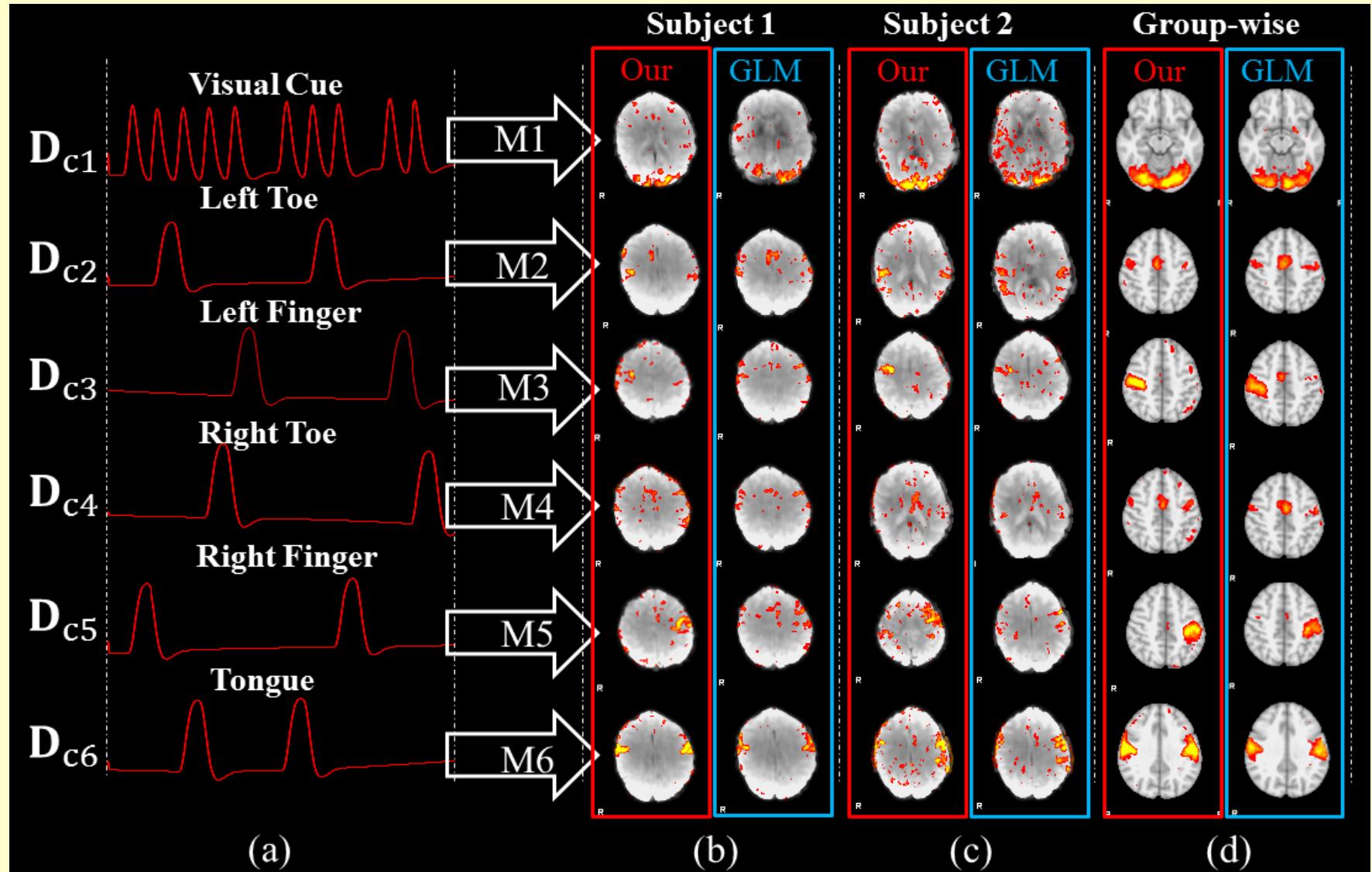
Supervised Dictionary Learning



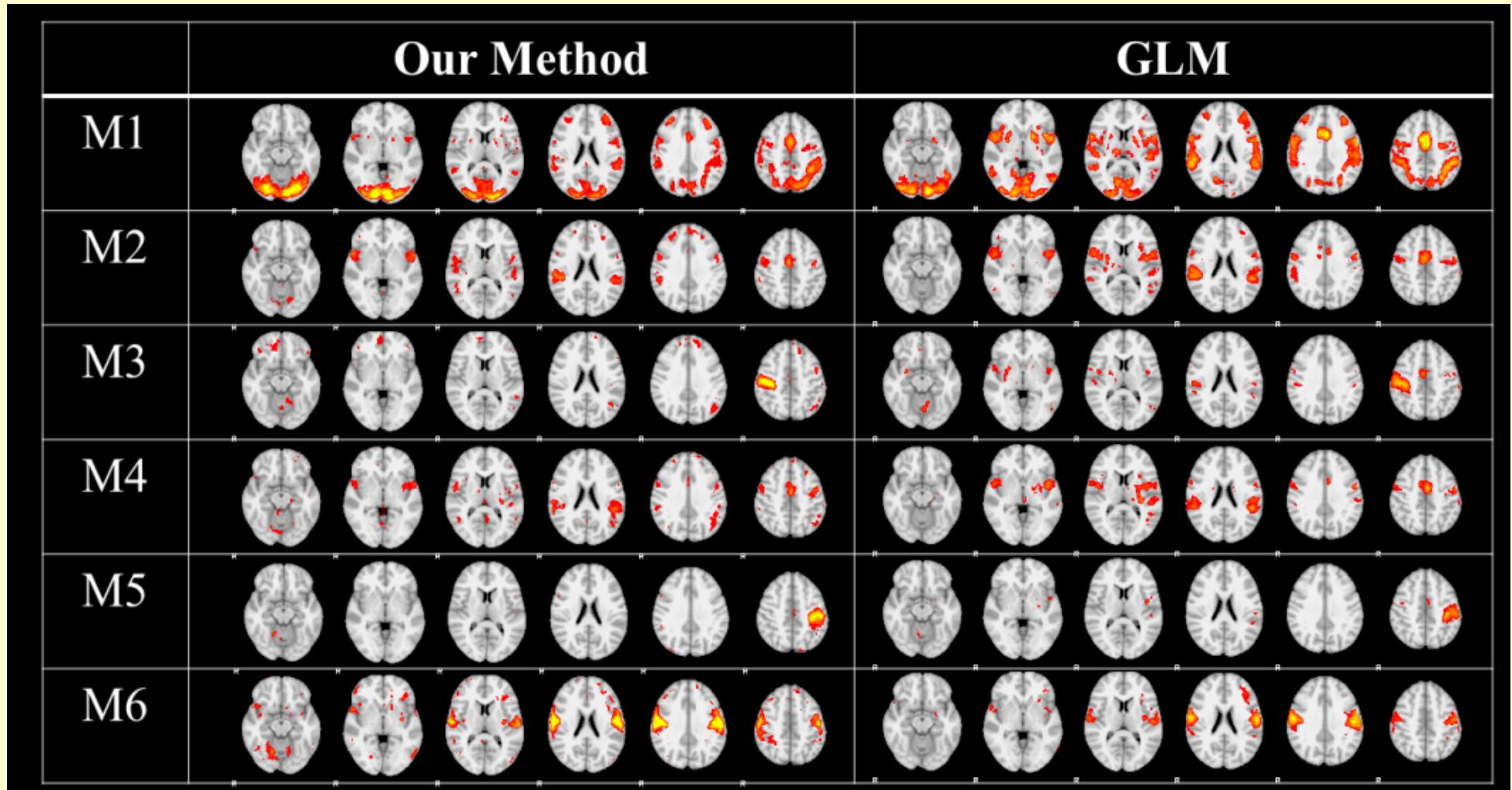
Supervised Dictionary Learning

$$\ell(s_i, D) \triangleq \min_{A_i \in \mathbb{R}^m} \frac{1}{2} \|s_i - [\mathbf{D}_c, D_l] A_i\|_2^2 + \lambda \|A_i\|_1$$

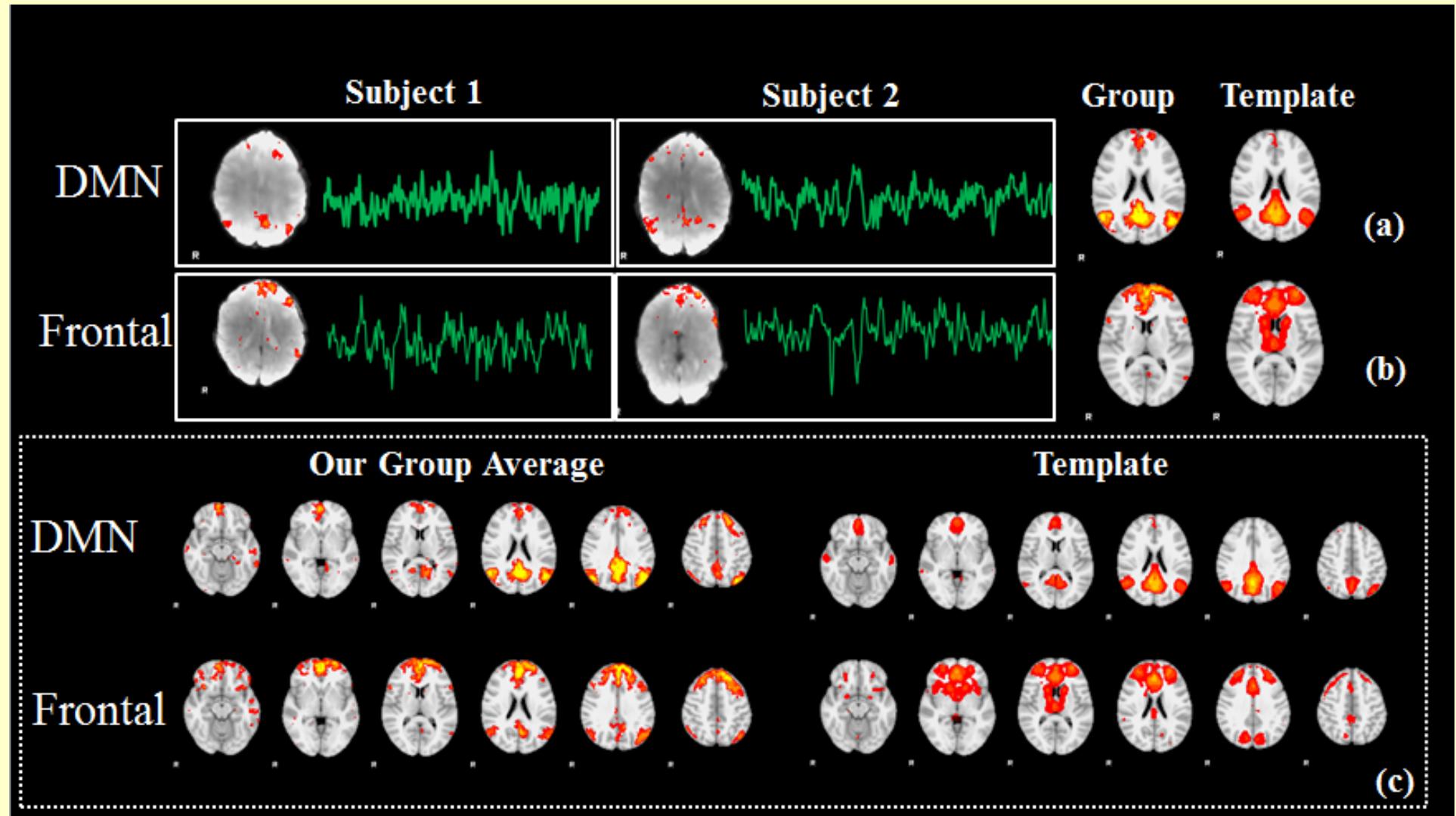
Supervised Dictionary Learning



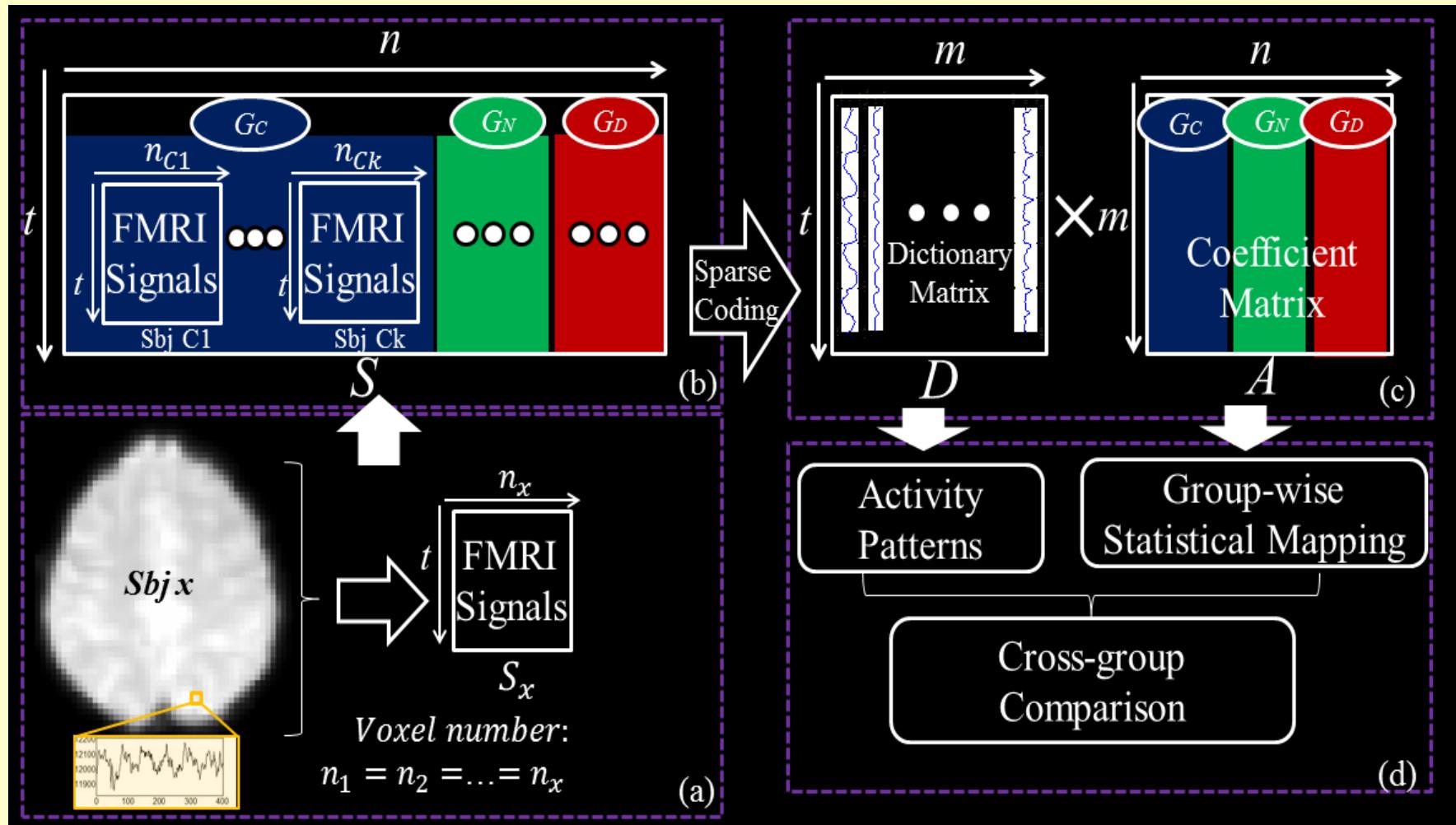
Supervised Dictionary Learning



Supervised Dictionary Learning

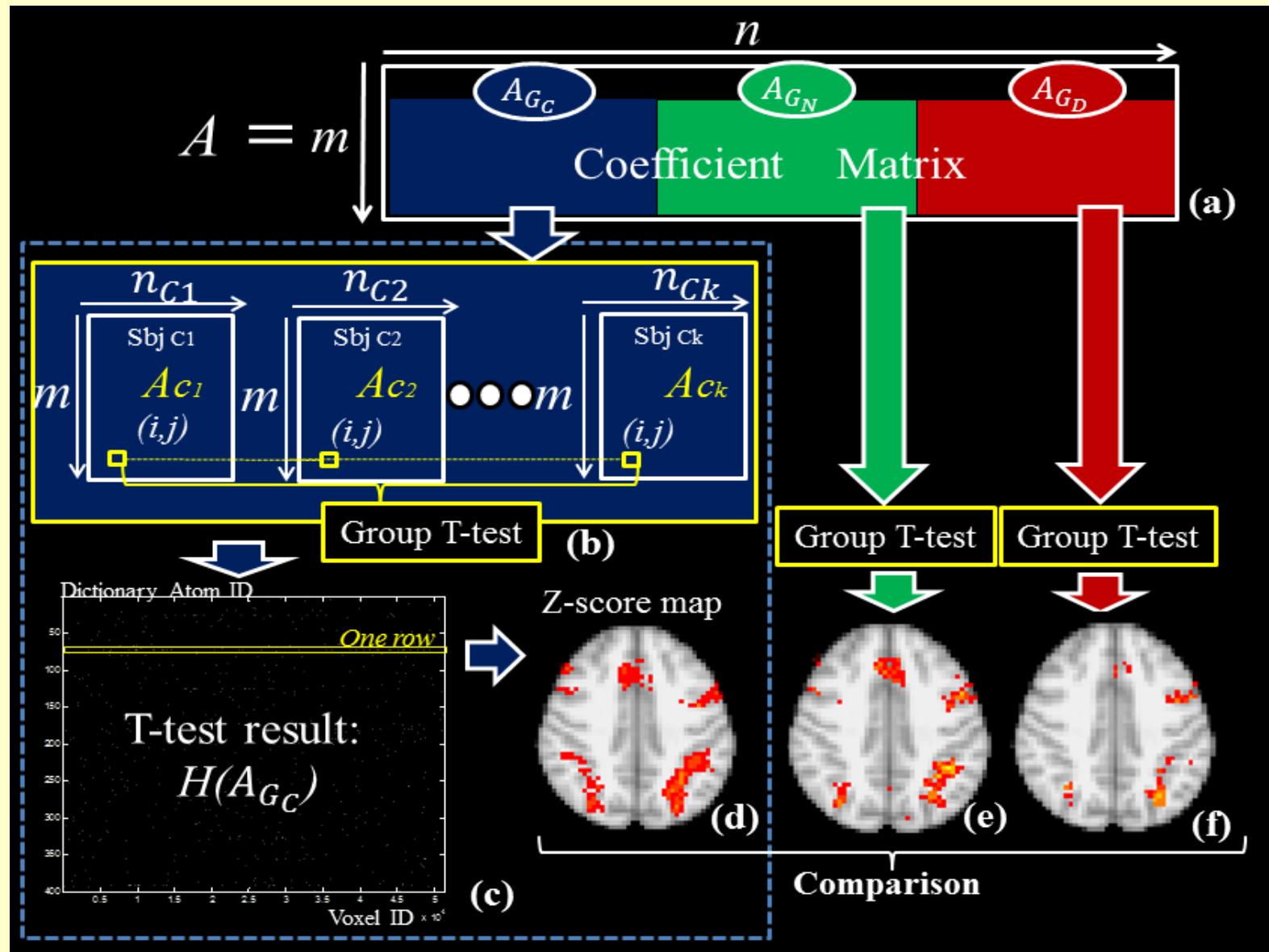


Group-wise Sparse Representation

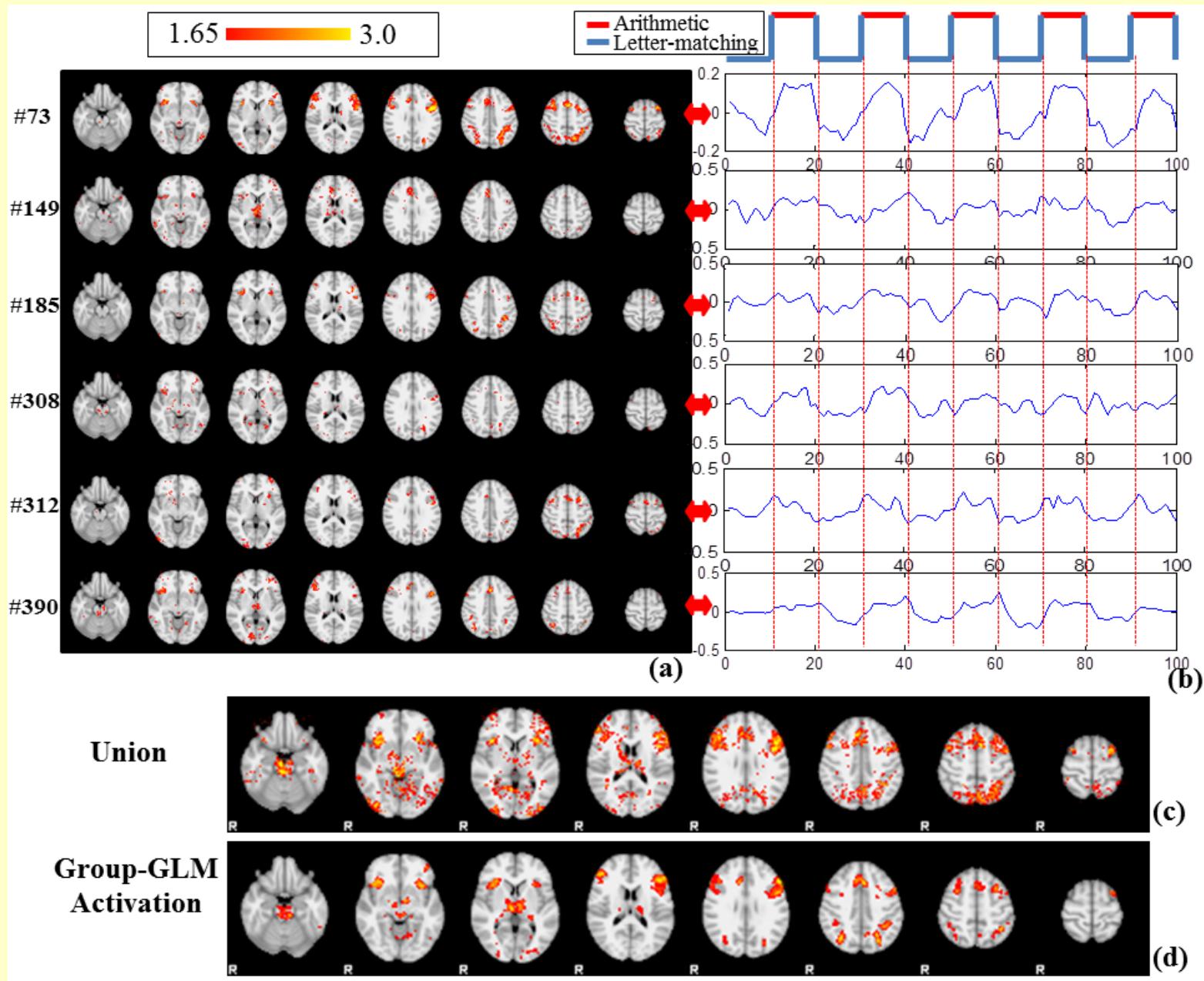


G_C : Healthy control, G_N : Non-dysmorphic PAE, G_D : Dysmorphic PAE

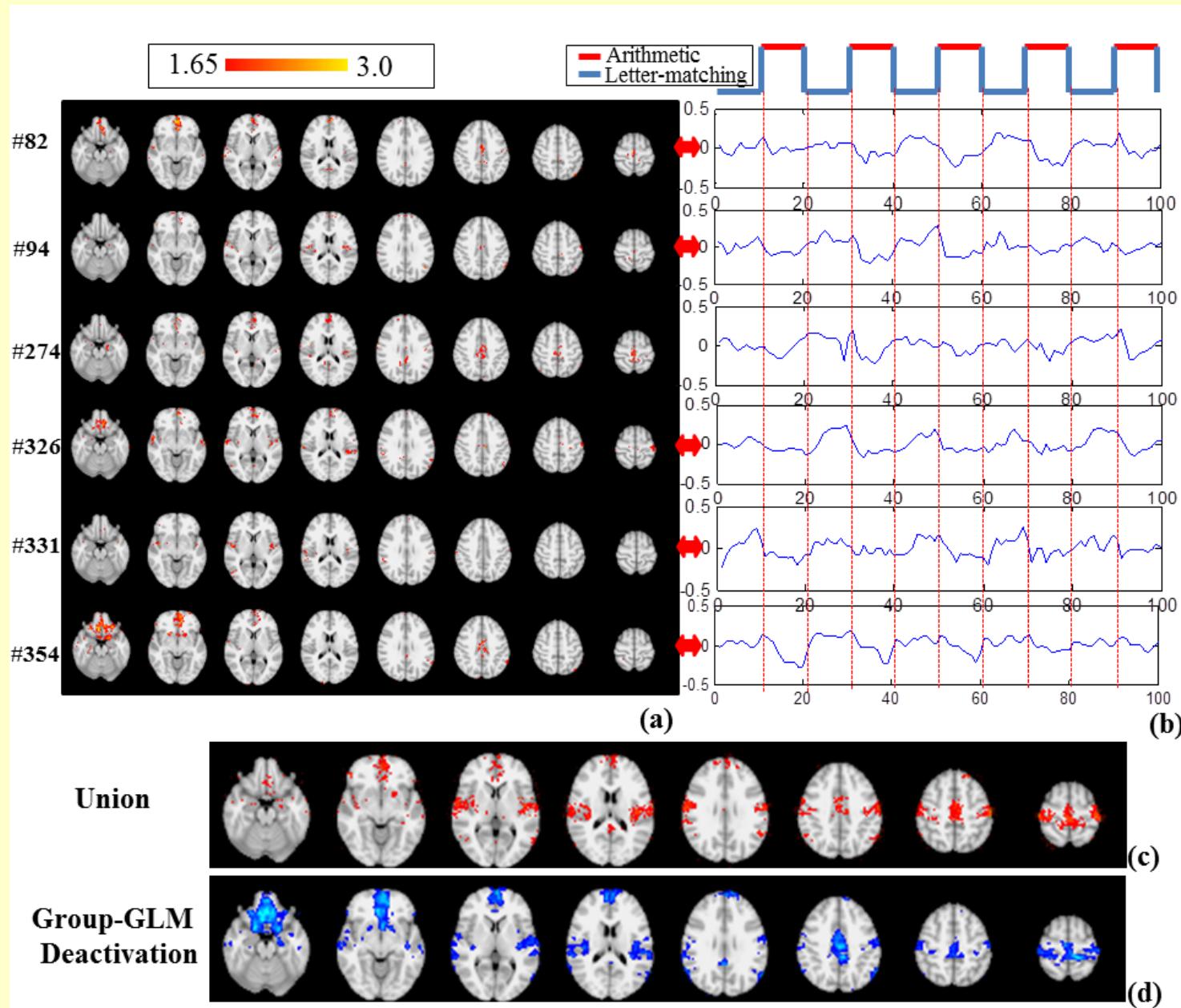
Group-wise Sparse Representation



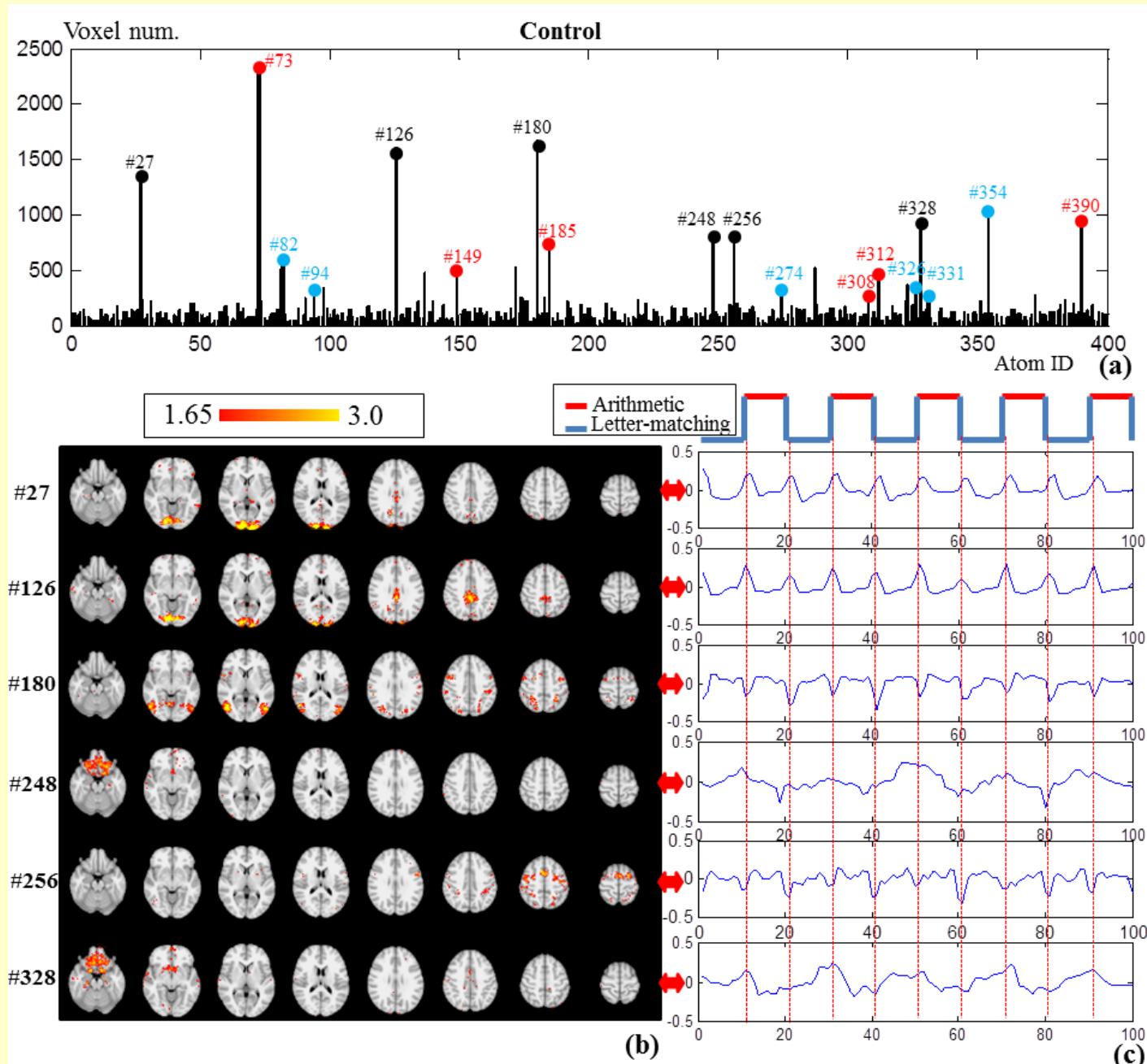
Group-wise Sparse Representation



Group-wise Sparse Representation

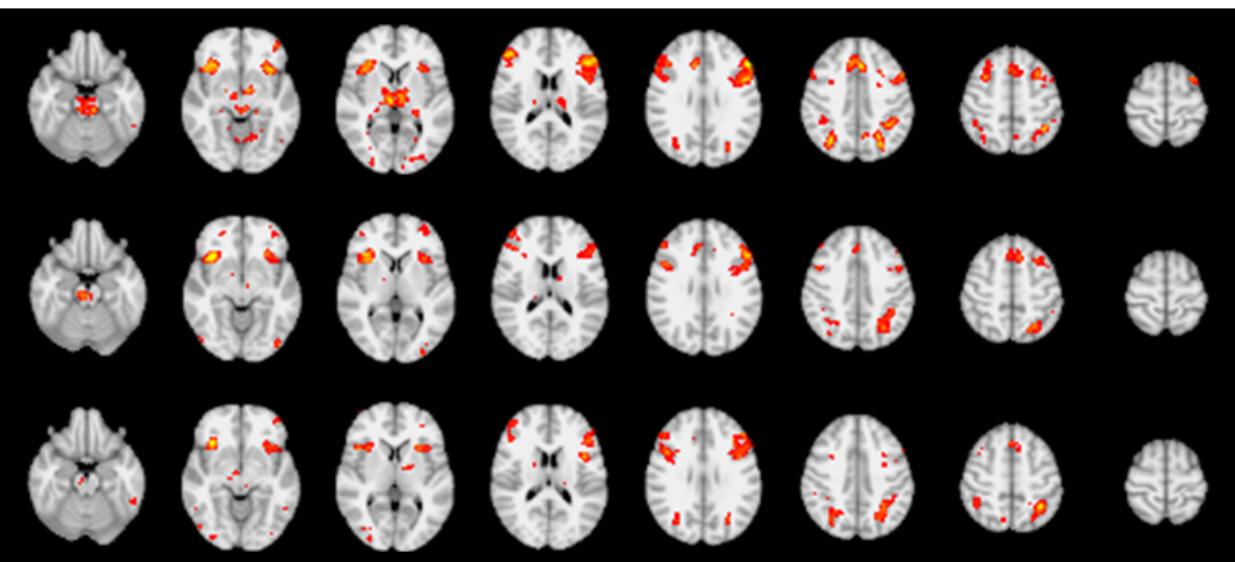


Group-wise Sparse Representation



GLM Results

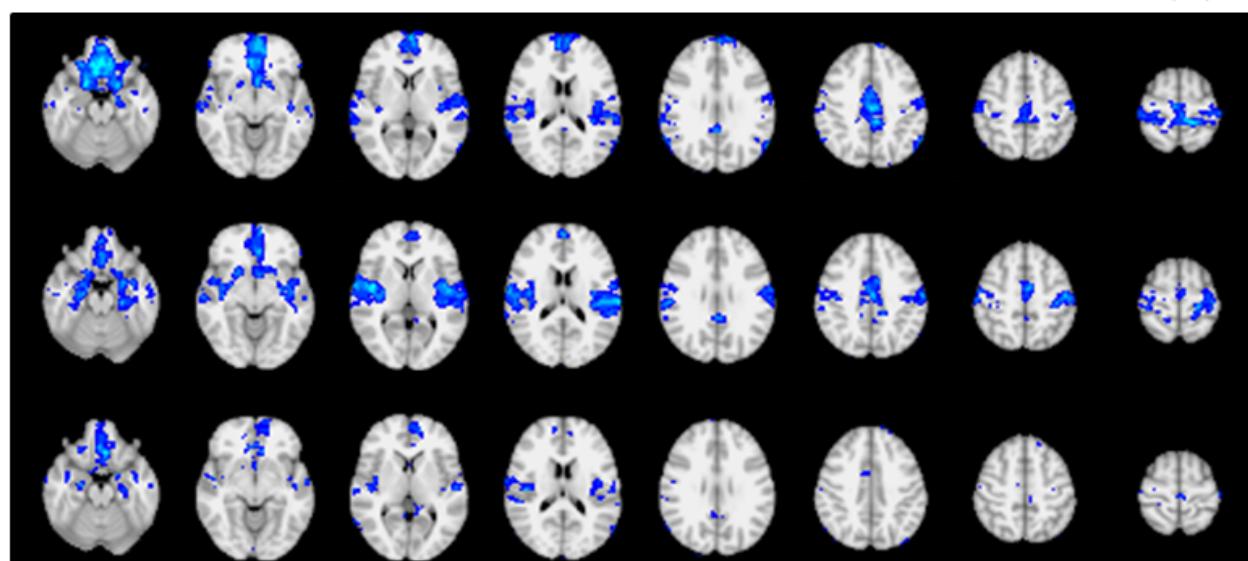
Control



Group-wise Activation

(a)

Control



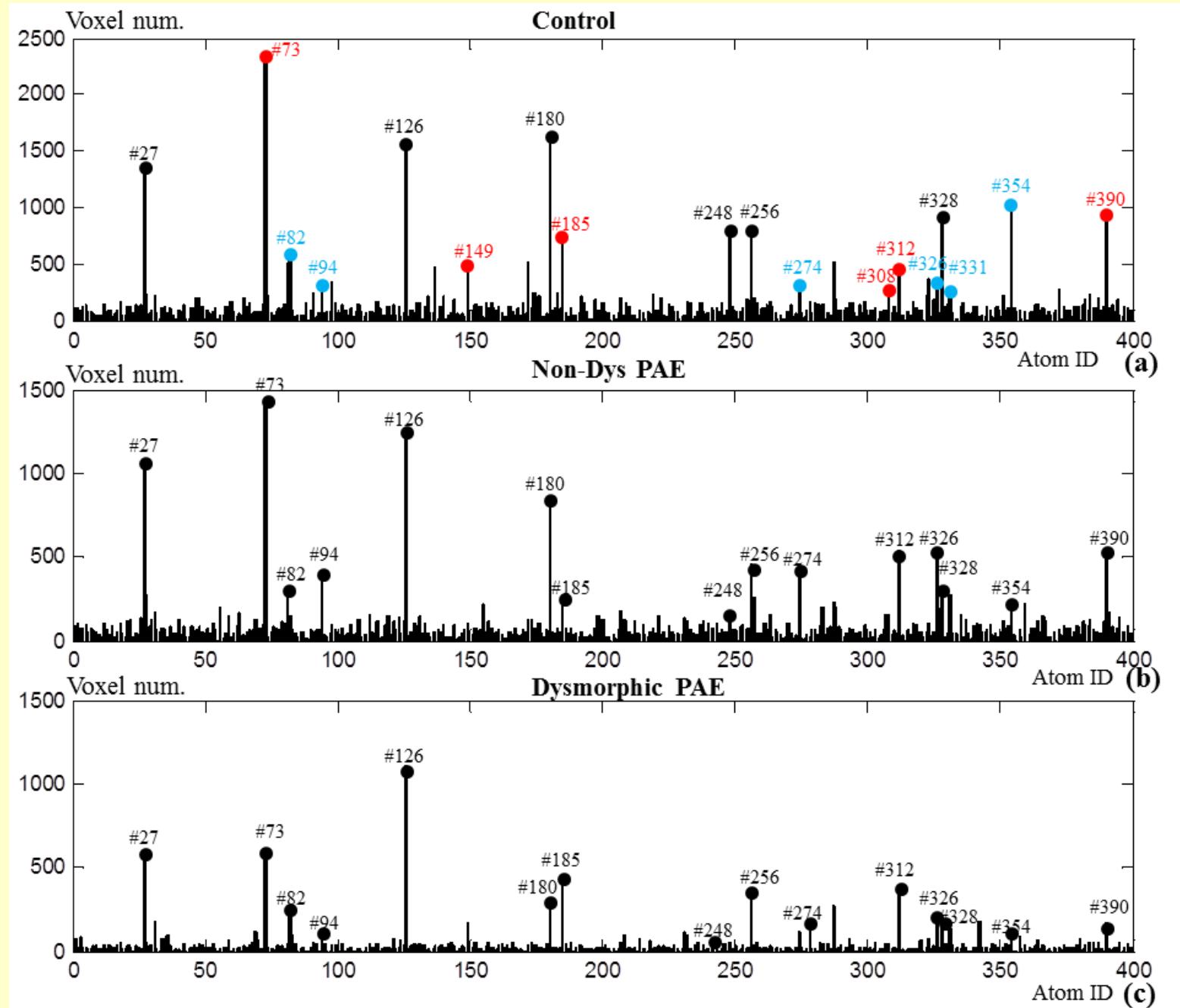
Group-wise Deactivation

(b)

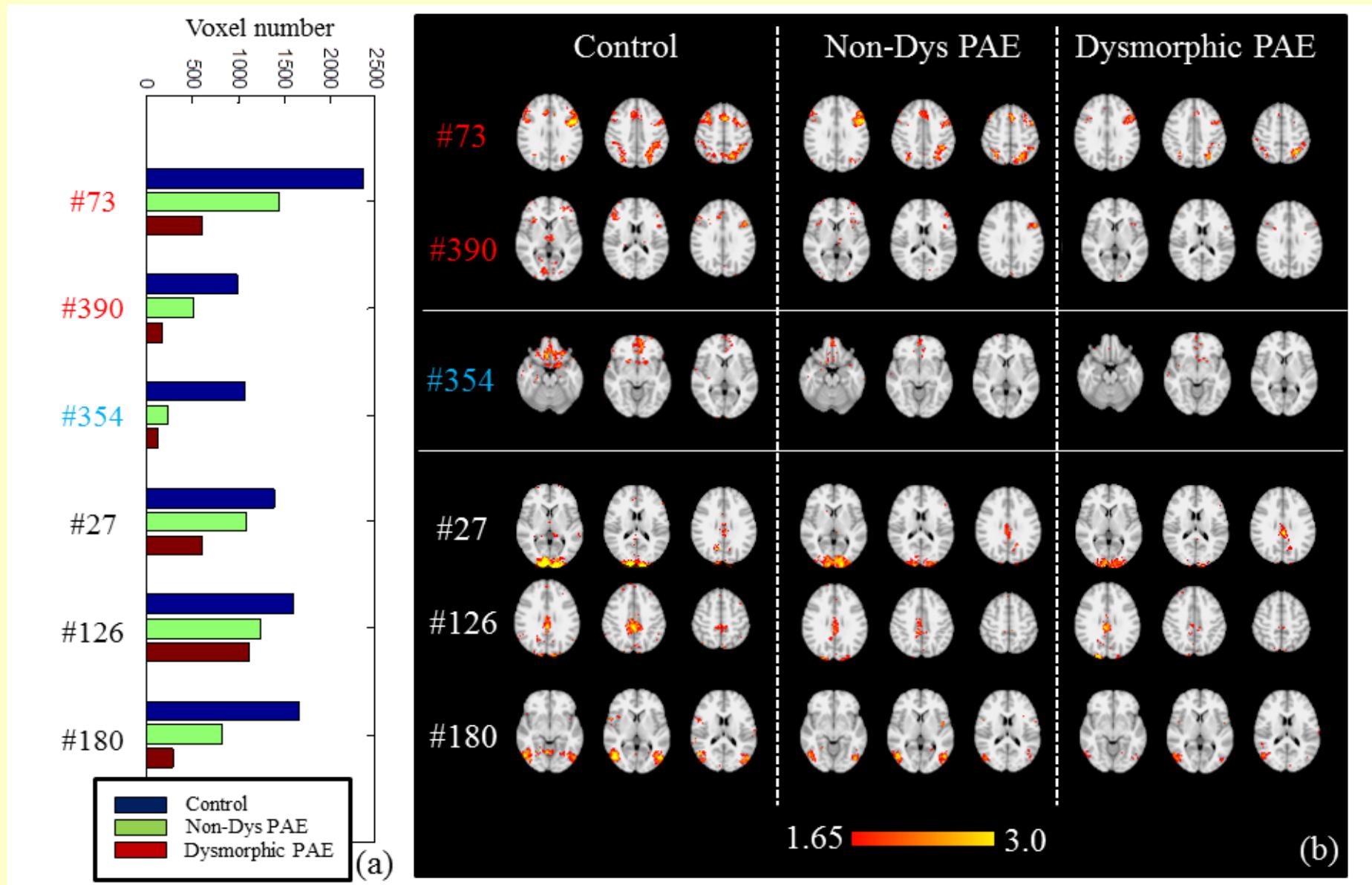
Dysmorphic
PAE

Non-Dys
PAE

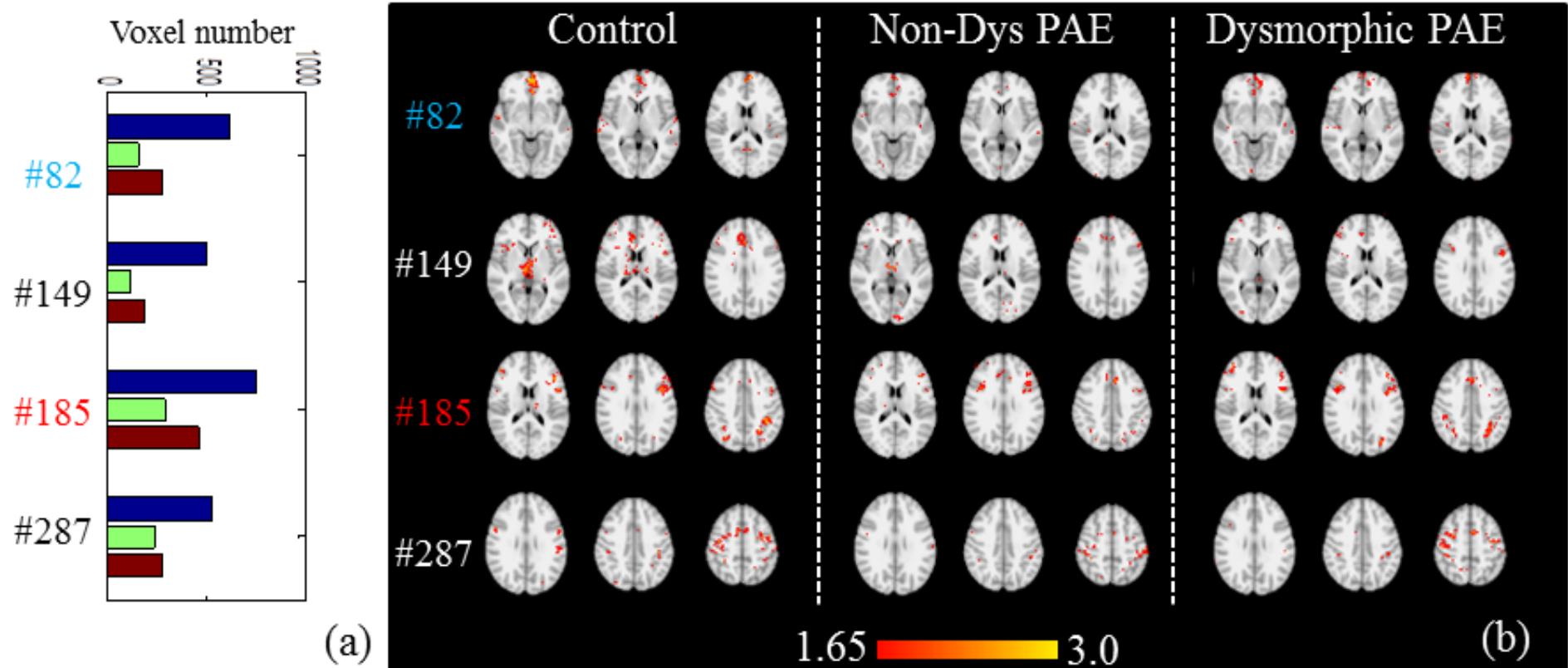
Group-wise Sparse Representation



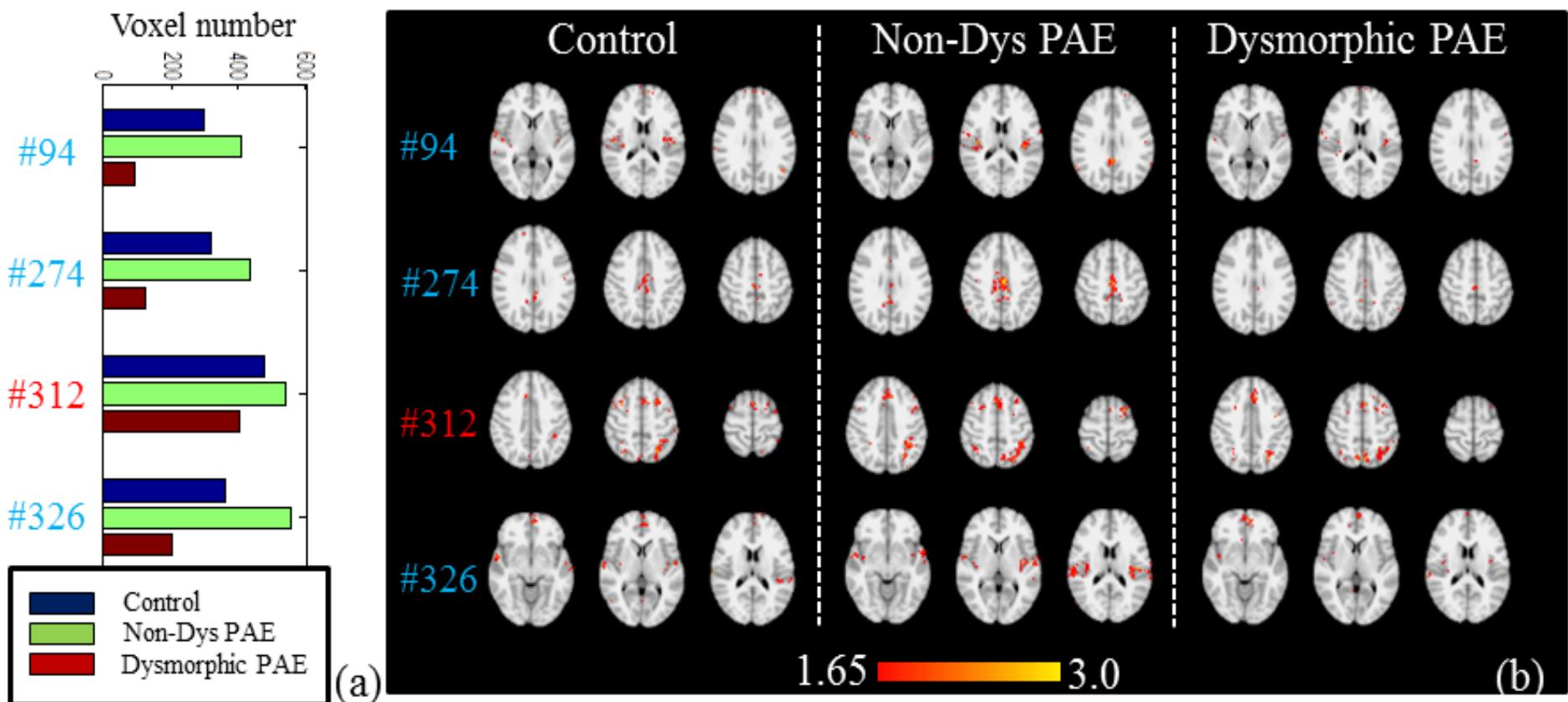
Group-wise Sparse Representation



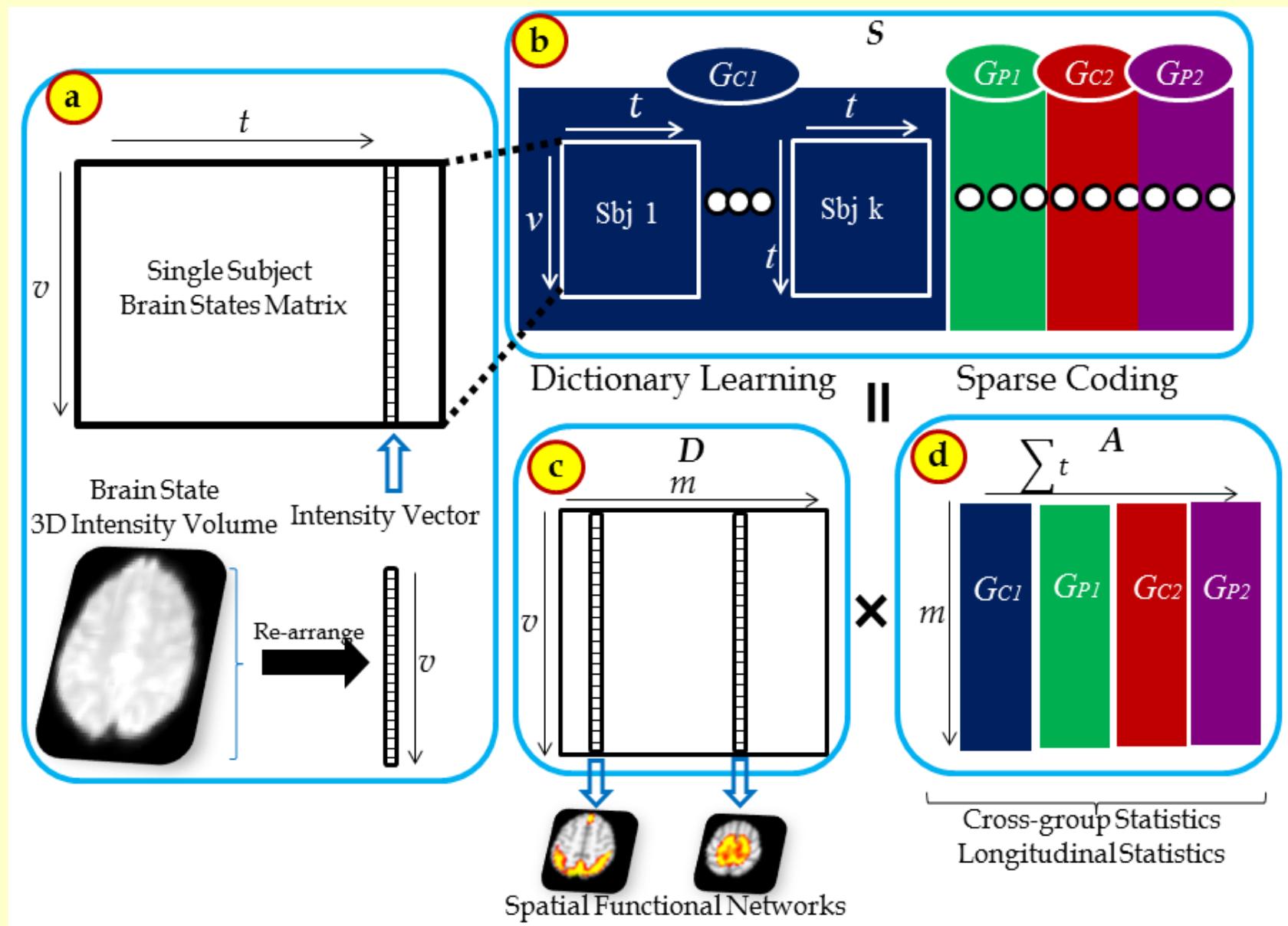
Group-wise Sparse Representation



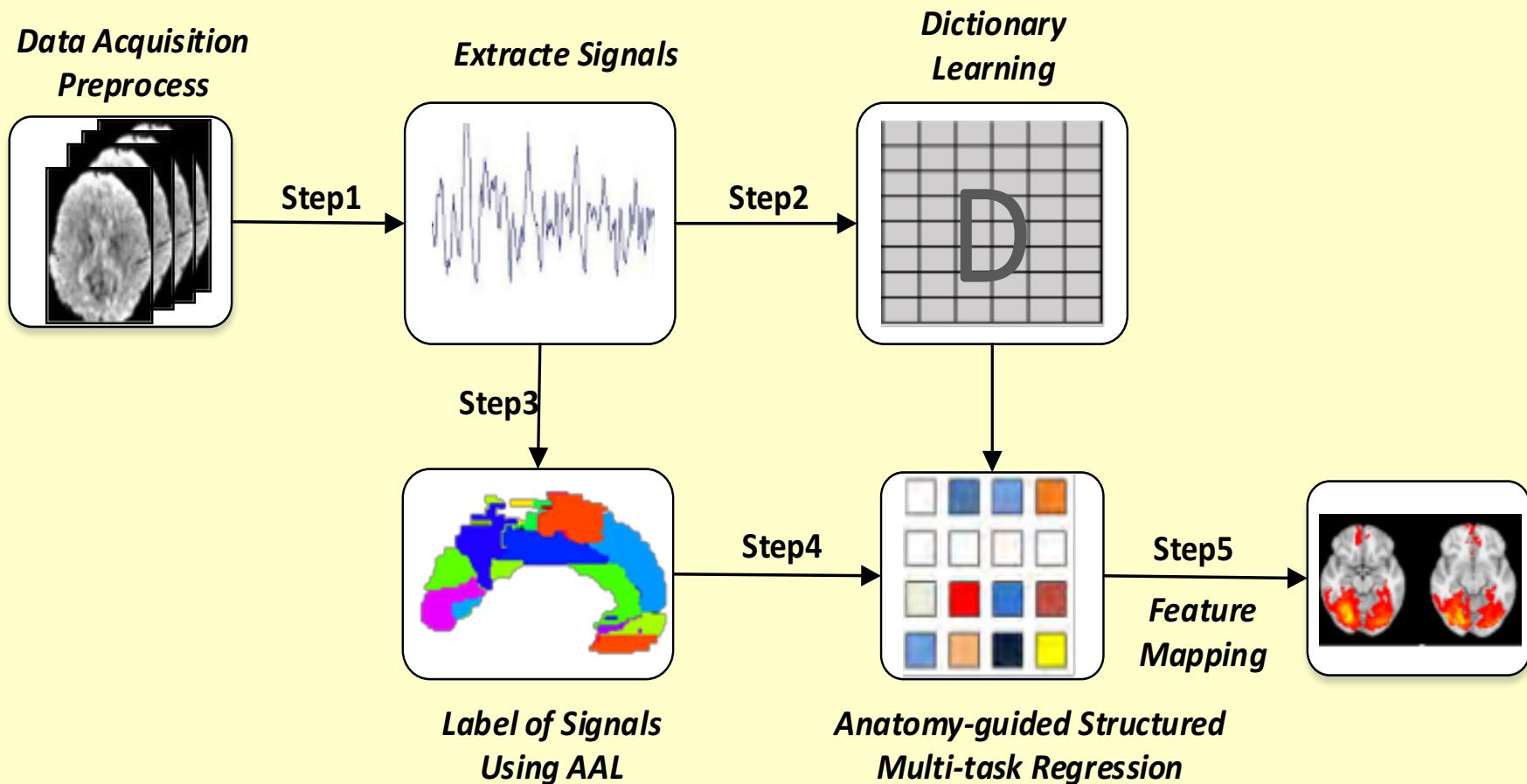
Group-wise Sparse Representation



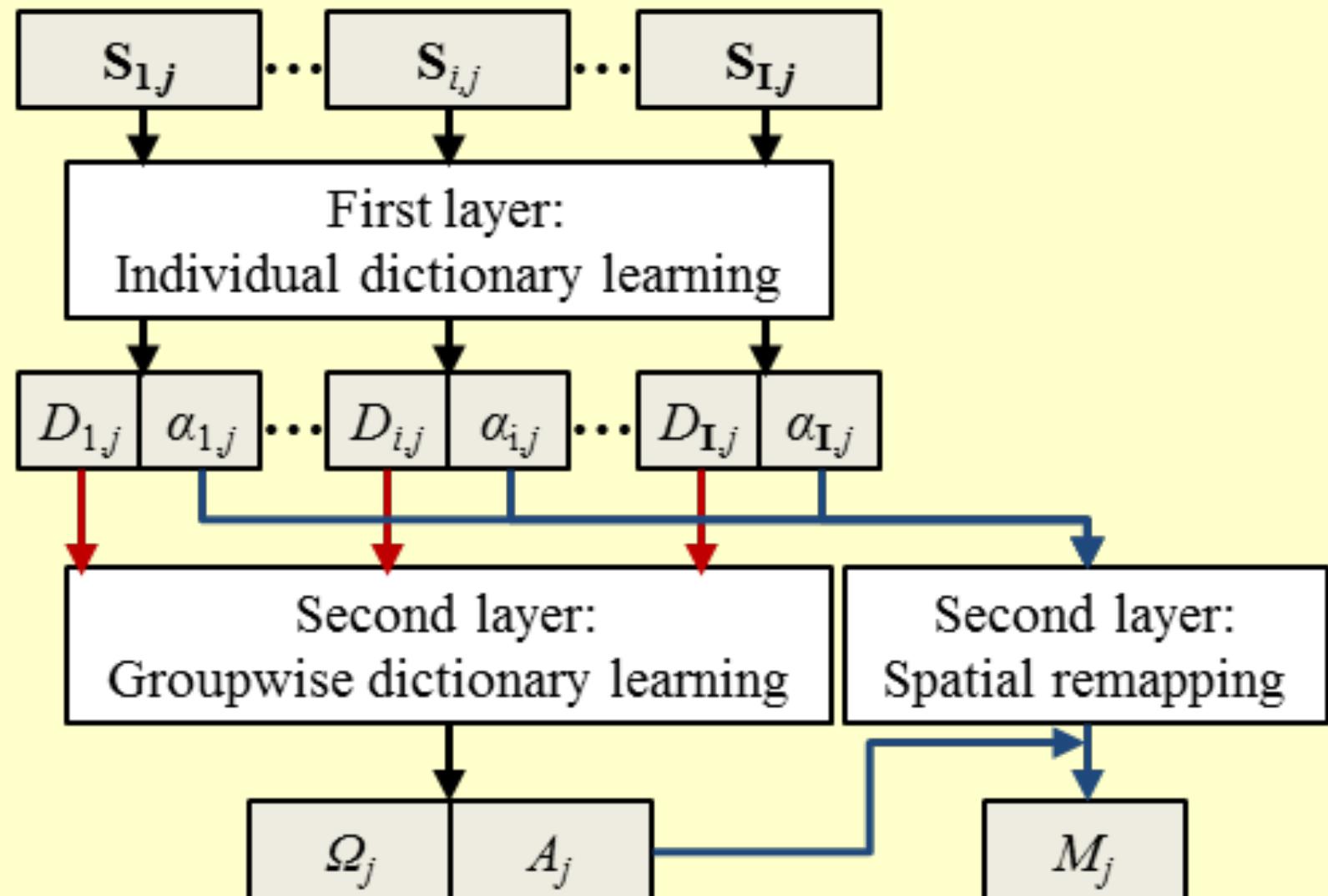
HAFNI: Spatial Sparsity



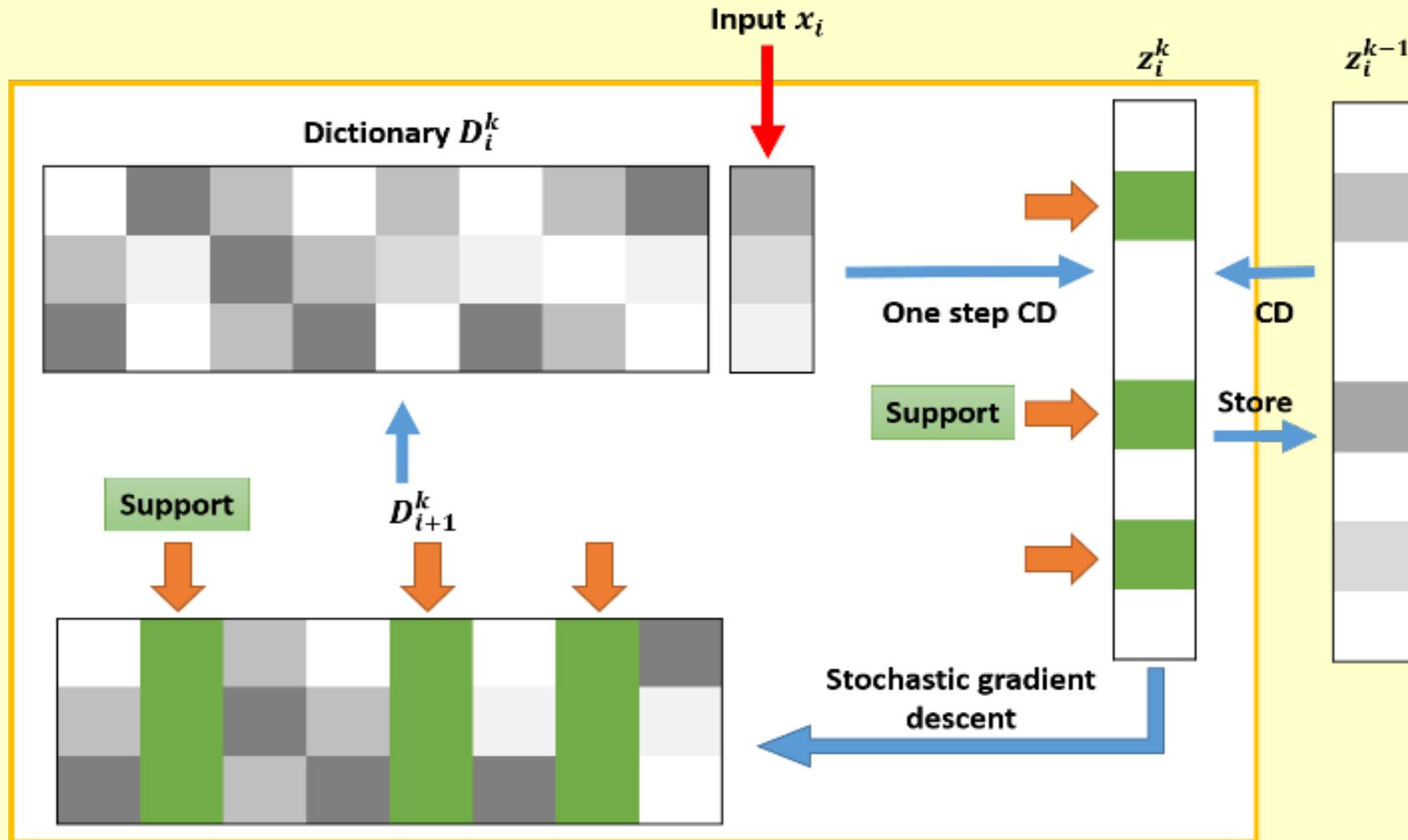
HAFNI: Structured Sparsity



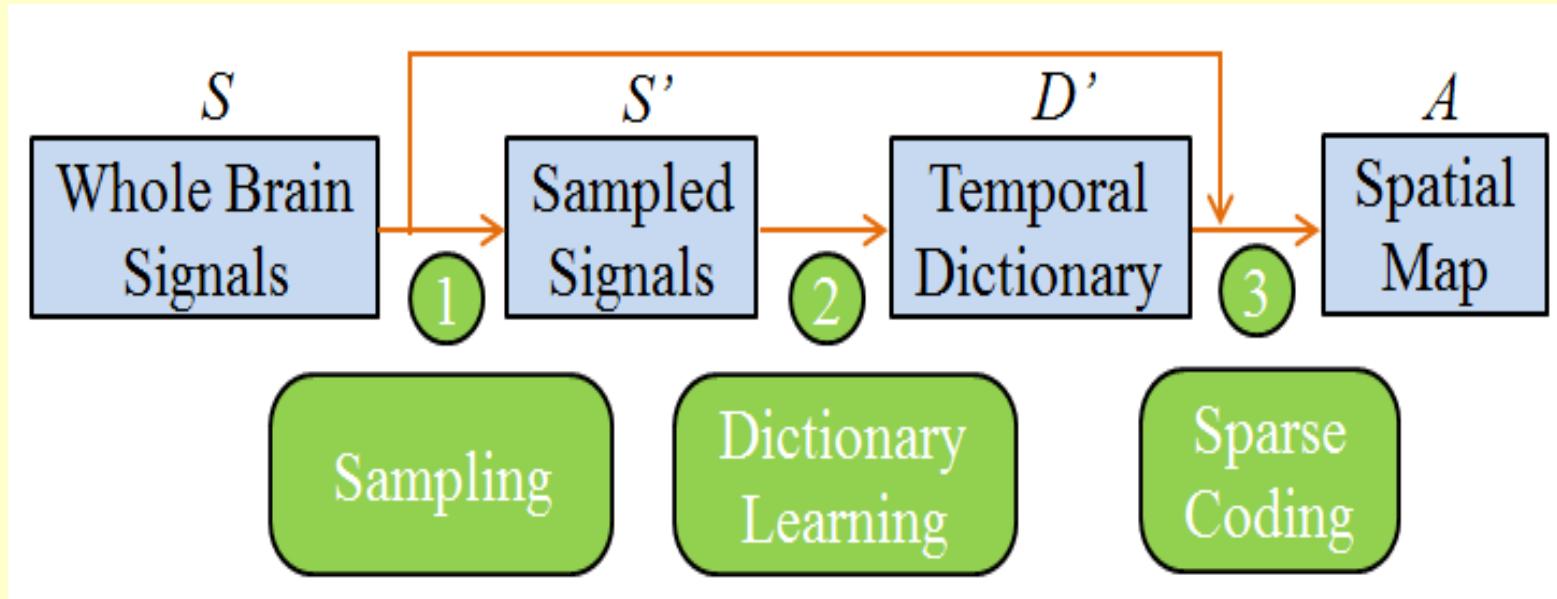
HAFNI: Nested Dictionary Learning



HAFNI: Stochastic Coordinate Coding



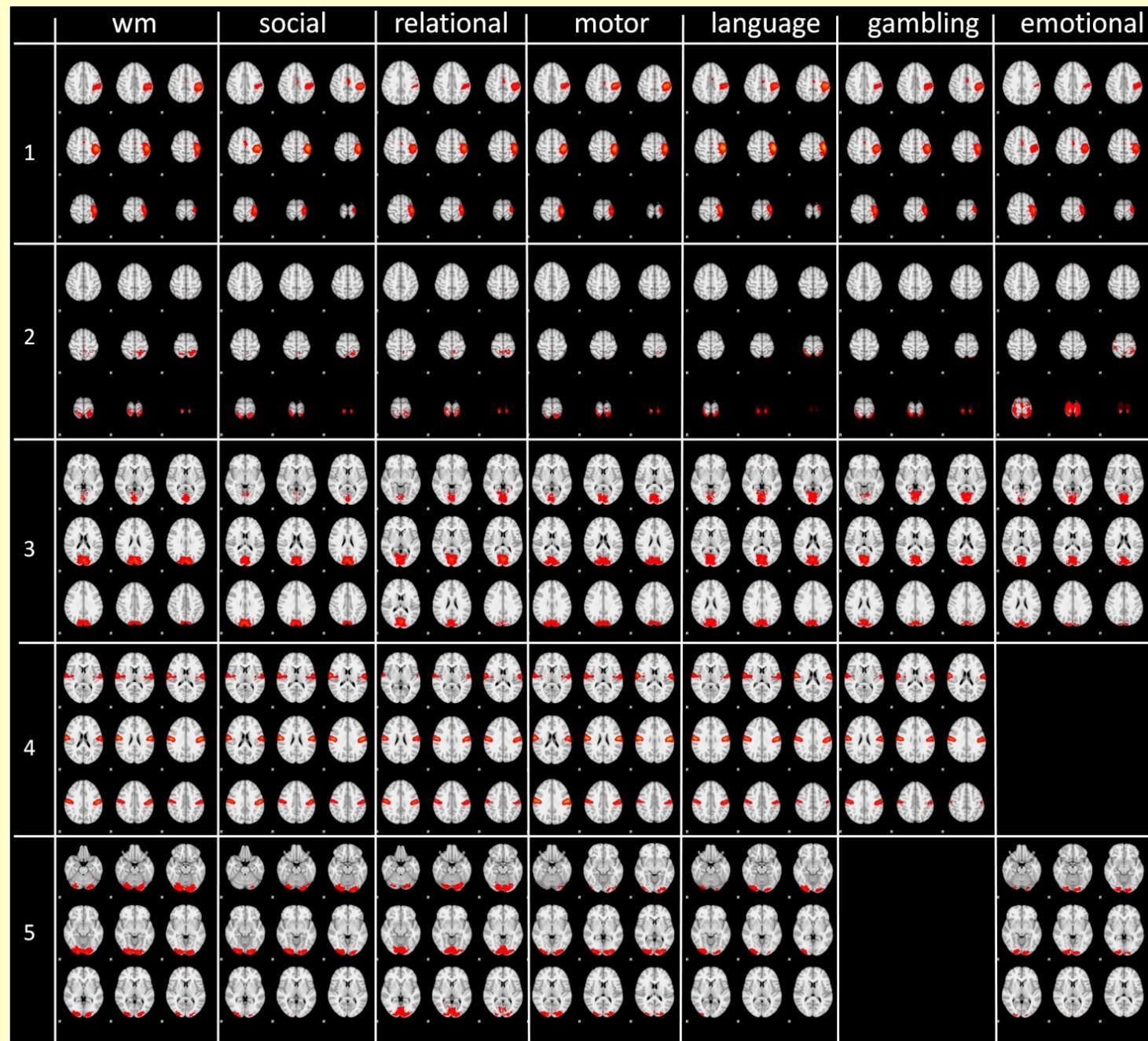
HAFNI: Sampling



$$\begin{aligned} S' &= D' \times A' \\ S &= D' \times A \end{aligned}$$

The equations show the mathematical representation of the sampling process. The first equation, $S' = D' \times A'$, represents the sampled signals as a product of the temporal dictionary and the spatial map. The second equation, $S = D' \times A$, represents the original whole brain signals as a product of the same temporal dictionary and spatial map. An orange arrow points from the D' box in the first equation down to the D' box in the second equation, indicating that the sampled signals are used to reconstruct the original signals.

HAFN: Representation of Brain Function





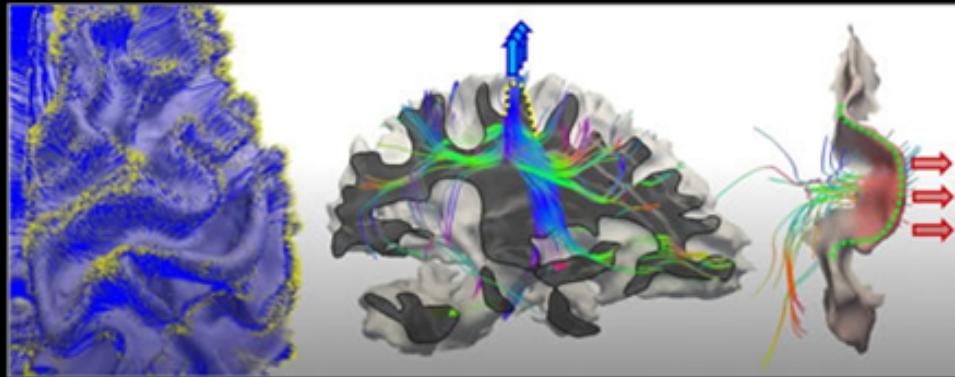
Brain Networks, Functional Interactions, and Dynamics

Representative Publications:

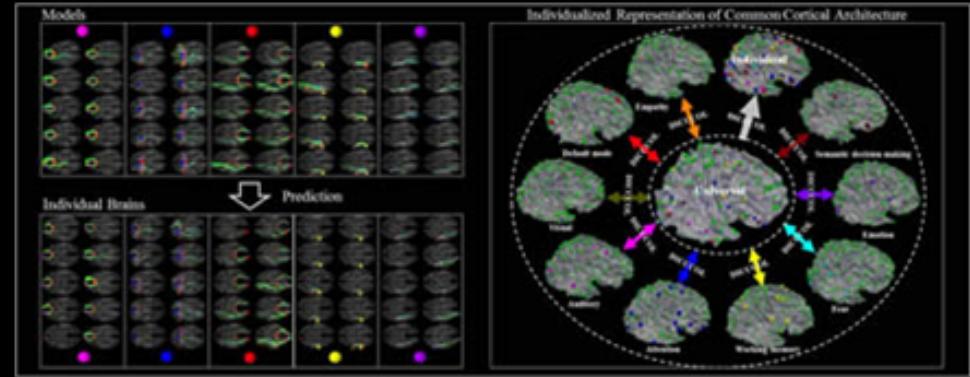
- Jinli Ou*, Zhichao Lian*, Li Xie, Xiang Li, Peng Wang, Yun Hao, Dajiang Zhu, Rongxin Jiang, Yufeng Wang, Yaowu Chen, Jing Zhang**, Tianming Liu**, Atomic Dynamic Functional Interaction Patterns for Characterization of ADHD, **Human Brain Mapping**, 2014. in press. *Joint first authors, **Joint corresponding authors.PDF
- Xiang Li, Dajiang Zhu, Xi Jiang, Changfeng Jin, Xin Zhang, Lei Guo, Jing Zhang, Xiaoping Hu, Jingjiang Li, Tianming Liu. Dynamic functional connectomics signatures for characterization and differentiation of PTSD patients, **Human Brain Mapping**, 2013. vol. 35(4), pp. 1761 - 78.PDF
- Hanbo Chen, Kaiming Li, Dajiang Zhu, Xi Jiang, Yixuan Yuan, Peili Lv, Tuo Zhang, Lei Guo, Dinggang Shen*, Tianming Liu*. Inferring Group-wise Consistent Multimodal Brain Networks via Multi-view Spectral Clustering, **IEEE Transactions on Medical Imaging**, 2013. vol. 32(9), pp. 1576 - 1586. *Joint corresponding authors.PDF
- Xin Zhang, Lei Guo, Xiang Li, Tuo Zhang, Dajiang Zhu, Kaiming Li, Hanbo Chen, Jinglei Lv, Changfeng Jin, Qun Zhao, Lingjiang Li, Tianming Liu. Characterization of Task-free and Task-performance Brain States via Functional Connectome Patterns, **Medical Image Analysis**, 2013. vol. 17(8), pp. 1106 - 22.PDF
- Jing Zhang*, Xiang Li, Cong Li, Zhichao Lian, Xiu Huang, Guocheng Zhong, Dajiang Zhu, Kaiming Li, Changfeng Jin, Xintao Hu, Junwei Han, Lei Guo, Xiaoping Hu, Lingjiang Li, Tianming Liu*. Inferring Functional Interaction and Transition Patterns via Dynamic Bayesian Variable Partition Models, **Human Brain Mapping**, 2013. in press. *Joint corresponding authors.PDF
- Bao Ge, Lei Guo, Tuo Zhang, Xintao Hu, Junwei Han, Tianming Liu. Resting State fMRI-guided Fiber Clustering: Methods and Applications, **Neuroinformatics**, 2013. vol. 11(1), pp. 119-133.PDF
- Xiang Li*, Chulwoo Lim*, Kaiming Li, Lei Guo, Tianming Liu. Detecting Brain State Changes via Fiber-Centered Functional Connectivity Analysis, *Joint first authors, **Neuroinformatics**, 2013. vol. 11(2), pp. 193-210.PDF
- Jiehuan Sun*, Xintao Hu*, Xiu Huang, Yang Liu, Kaiming Li, Xiang Li, Junwei Han, Lei Guo, Tianming Liu**, Jing Zhang**. Inferring Consistent Functional Interaction Patterns from Natural Stimulus FMRI Data, **NeuroImage**, 2012. vol. 61(4), pp. 987–999. *Joint first authors, **Joint corresponding authors.PDF

Research Themes

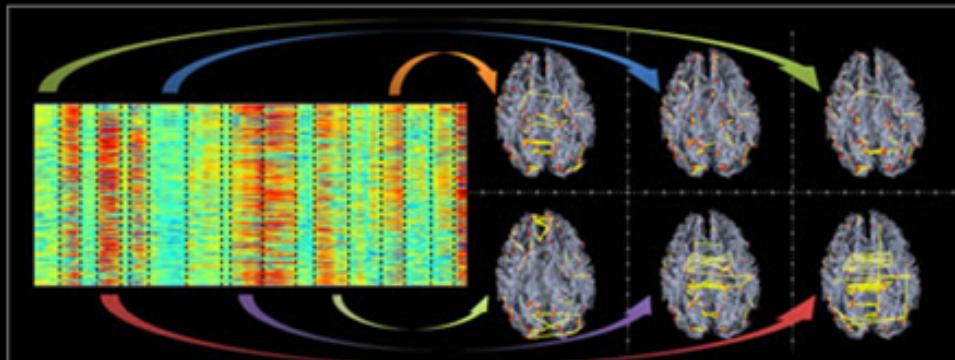
Research Themes



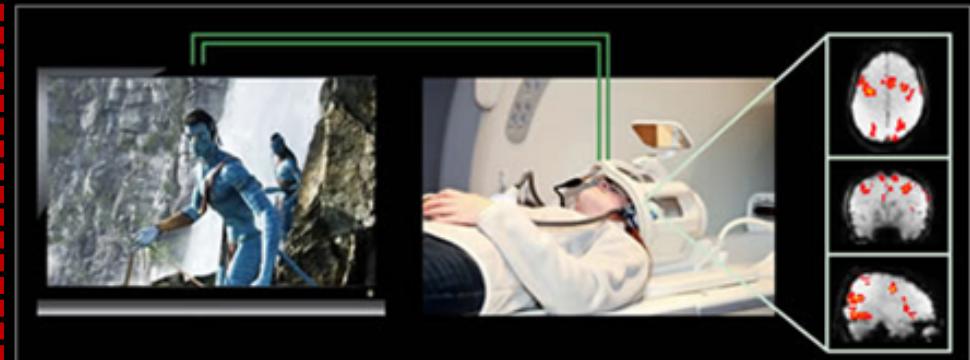
Axonal Pushing Theory of Cortical Folding



DICCCOL



Brain Networks, Functional Interactions, and Dynamics



Neuromediomics

Acknowledgements: Funding

- NIH Career Award (EB-006878, 2007-2012, PI)
- NSF CAREER Award (IIS-1149260, 2012-2017, PI)

- NIH R01 DA033393 (2012-2017, PI)
- NIH R01 R01AG042599 (2013-2018, PI)
- NSF CBET 1302089 (2013-2016, PI)
- NSF BCS 1439051 (2014-2017, PI)
- NIH R01 HL087923-03S2 (2010-2012, Co-Investigator)

Acknowledgements: Collaborators

- Xiaoping Hu and Clair Coles, Emory
- Lei Guo, Junwei Han, NWPU, China
- Lingjiang Li, CSU, China
- Stephen Miller, UGA
- Jennifer McDowell, UGA
- Xiaoping Hu and Clair Coles, Emory
- Dinggang Shen, UNC Chapel Hill
- Jeff Browndyke, Duke Univ.
- Jing Zhang, Yale
- Joe Tsien, GRU
- ...

Acknowledgements: Students

- Kaiming Li
- Fan Deng
- Tuo Zhang
- Xintao Hu
- Dajiang Zhu
- Chul Woo Lim
- Jinglei Lv
- Shu Zhang
- ...
- Hanbo Chen
- Yixuan Yuan
- Carlos Faraco
- Xi Jiang
- Xiang Li
- Degang Zhang
- Yu Zhao
- Wei Zhang

Thank You !



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