

Beyond Diagnostic Classification of Autism: Neuroanatomical, Functional, and Behavioral Phenotypes

Tom Fletcher¹, Bei Wang², Jeff Anderson³, Brandon Zielinski⁴, Keri Anderson², Sourabh Palande², Kris Campbell²
1. University of Virginia. 2. School of Computing and SCI Institute, University of Utah. 3. Radiology, University of Utah. 4. Neurology and Pediatrics, University of Utah.

OVERVIEW: Correlating shape and topological features with cognitive measures

1. Shape Analysis

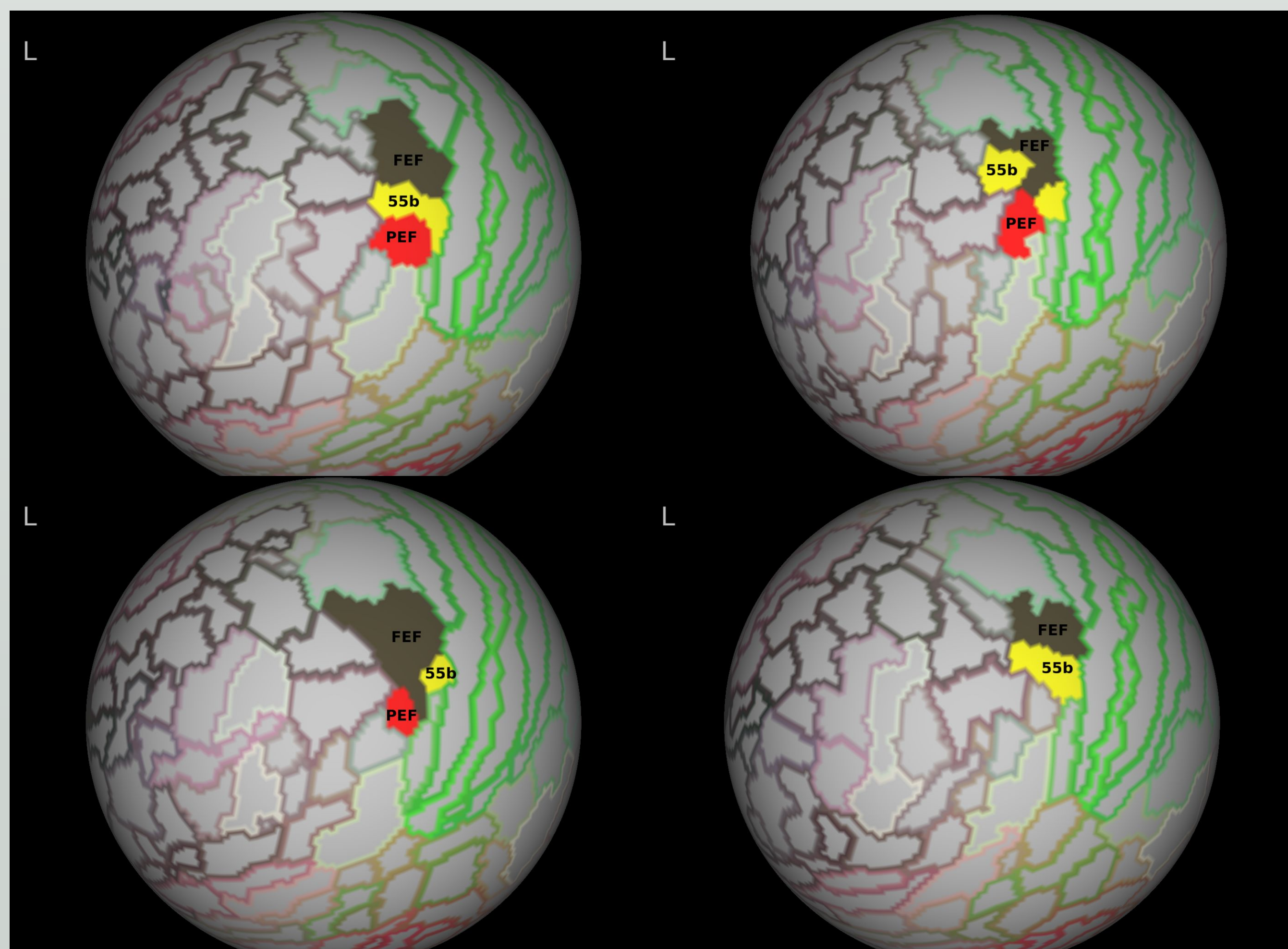
- Comparison of cortical regions derived from structural and functional MRI with cognitive measures
- Novel ISPM metric allows for topological variants of shape
- ISPM shape differences have significant correlation with individual differences in fluid cognition

2. Topological Data Analysis

- Analysis of functional connectivity, in time and space domain
- Comparison of different rs-fMRI preprocessing strategies
- Independent component based nuisance regression has best reproducibility.
- Topological features are significantly correlated to individual differences in cognition and personality, with high reproducibility

SHAPE ANALYSIS

We compare **shape complexes of cortical regions** using a **novel metric (ISPM)** that allows for **topological variants**: split, shifted and missing regions



Examples of topological variation in the premotor cortex: areas 55b, Frontal Eye Field (FEF) and Premotor Eye Field (PEF), in the Glasser Multi-Modal Parcellations based on structure and function.

Hypothesis: Subjects with similar cortical shapes will have similar cognitive ability

Data: 27 Test/ReTest Glasser MMP parcellations from HCP

Method: **distance correlation (dCor)** between **shape** (cortical thickness, surface area, Jaccard Index, and ISPM) and **cognition** (processing speed and fluid cognition composite score)

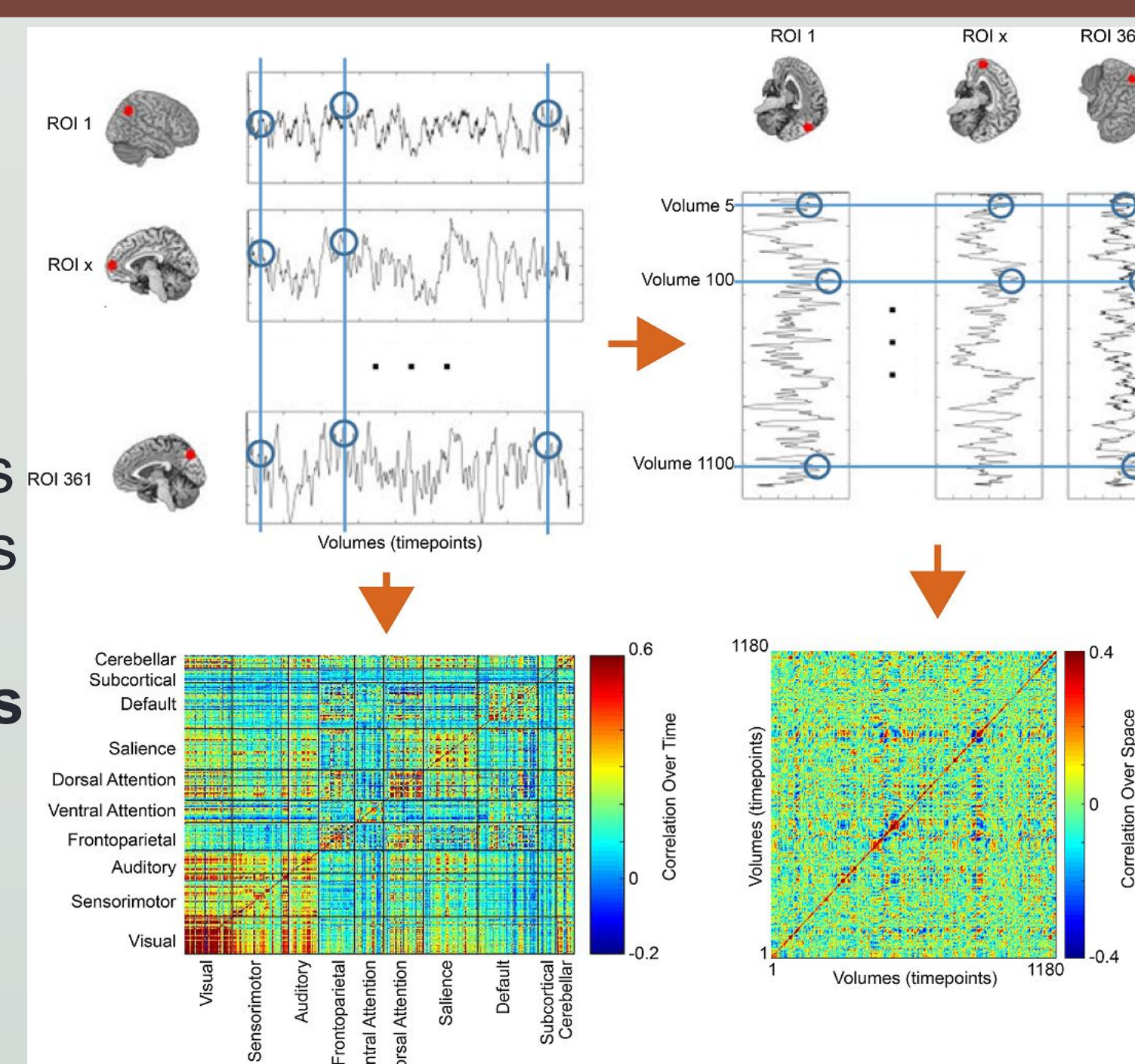
SHAPE ANALYSIS RESULTS

Test Name	Test dCor	Test P-Value	ReTest dCor	ReTest P-value
Thickness vs Processing Speed	0.109	0.279	0.024	0.958
Thickness vs Fluid Cognition	0.053	0.836	0.107	0.314
Surface Area vs Processing Speed	0.048	0.732	0.088	0.161
Surface Area vs Fluid Cognition	0.099	0.431	0.165	0.00967**
Jaccard Index vs Processing Speed	0.102	0.106	0.022	0.787
Jaccard Index vs Fluid Cognition	0.154	0.0156*	0.179	6.95e-3**
ISPM vs Processing Speed	0.117	0.0494*	0.044	0.509
ISPM vs Fluid Cognition	0.212	3.26e-4***	0.211	7.37e-4***

TOPOLOGICAL DATA ANALYSIS

Functional brain networks:

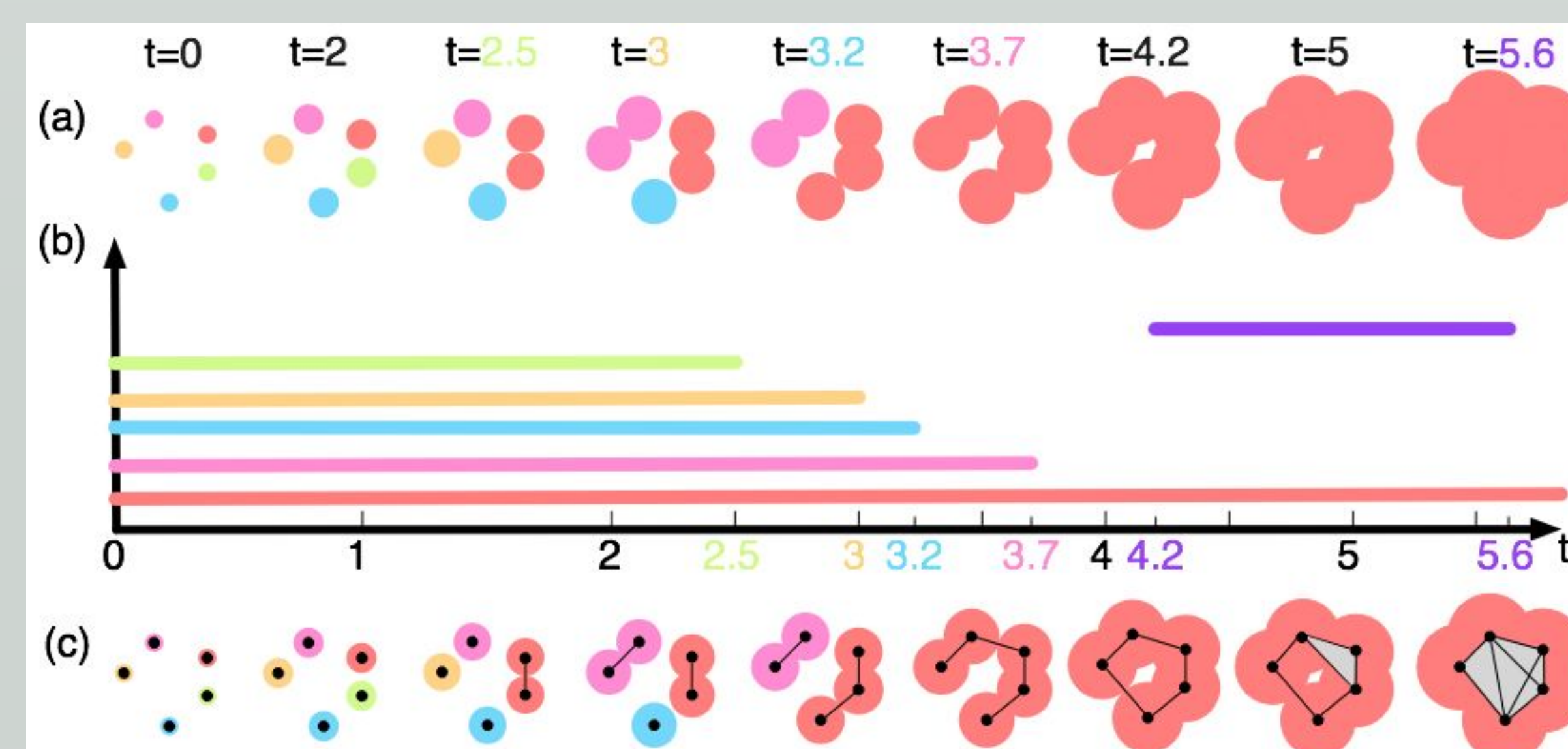
- Space domain: Similarity (correlation), measured over time, between two ROIs
- Time domain: Similarity (correlation), measured across ROIs, between two time-points



Map networks to metric spaces

$$d(x,y) = \sqrt{(1 - \text{Corr}(x,y))}$$

Persistent homology captures topological changes in functional brain networks across all scales (correlation thresholds)



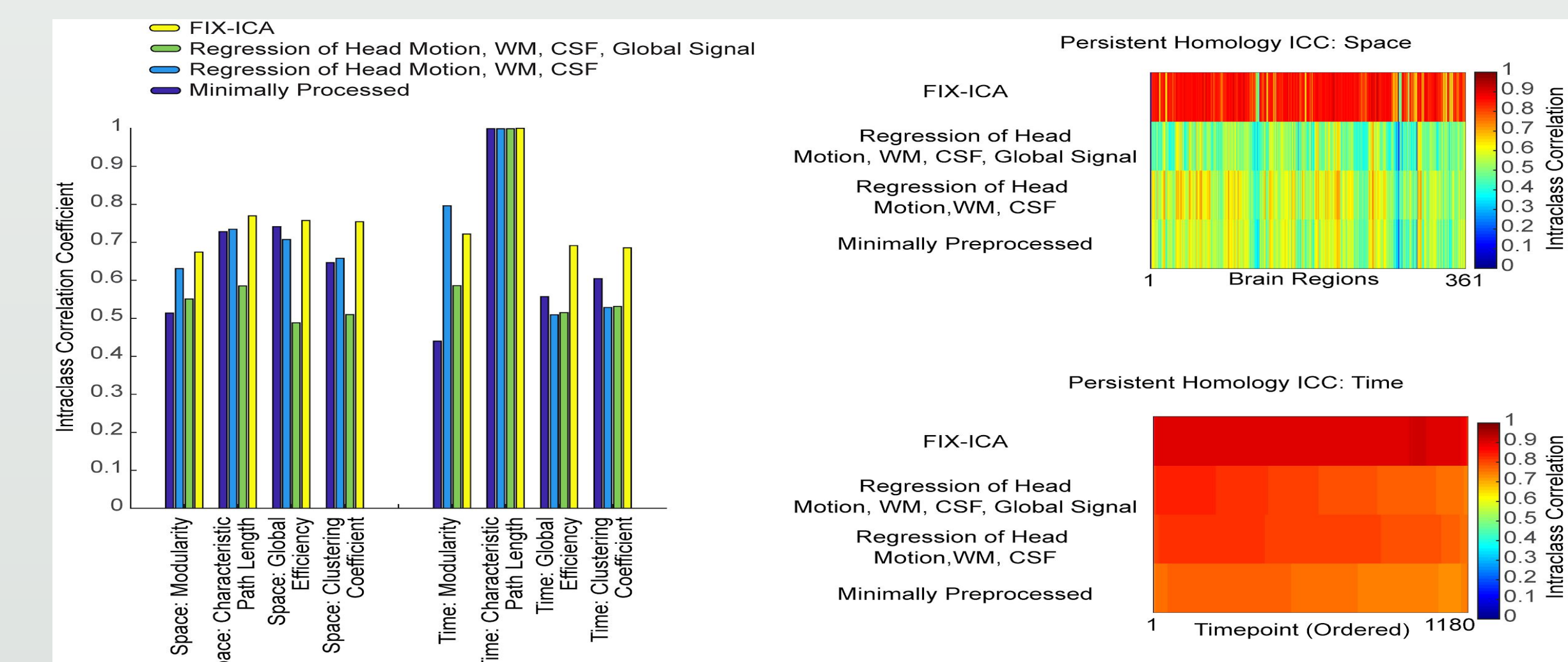
Persistent homology computation. Persistence barcodes represent births and deaths of topological features as the correlation threshold varies

Data and Methods:

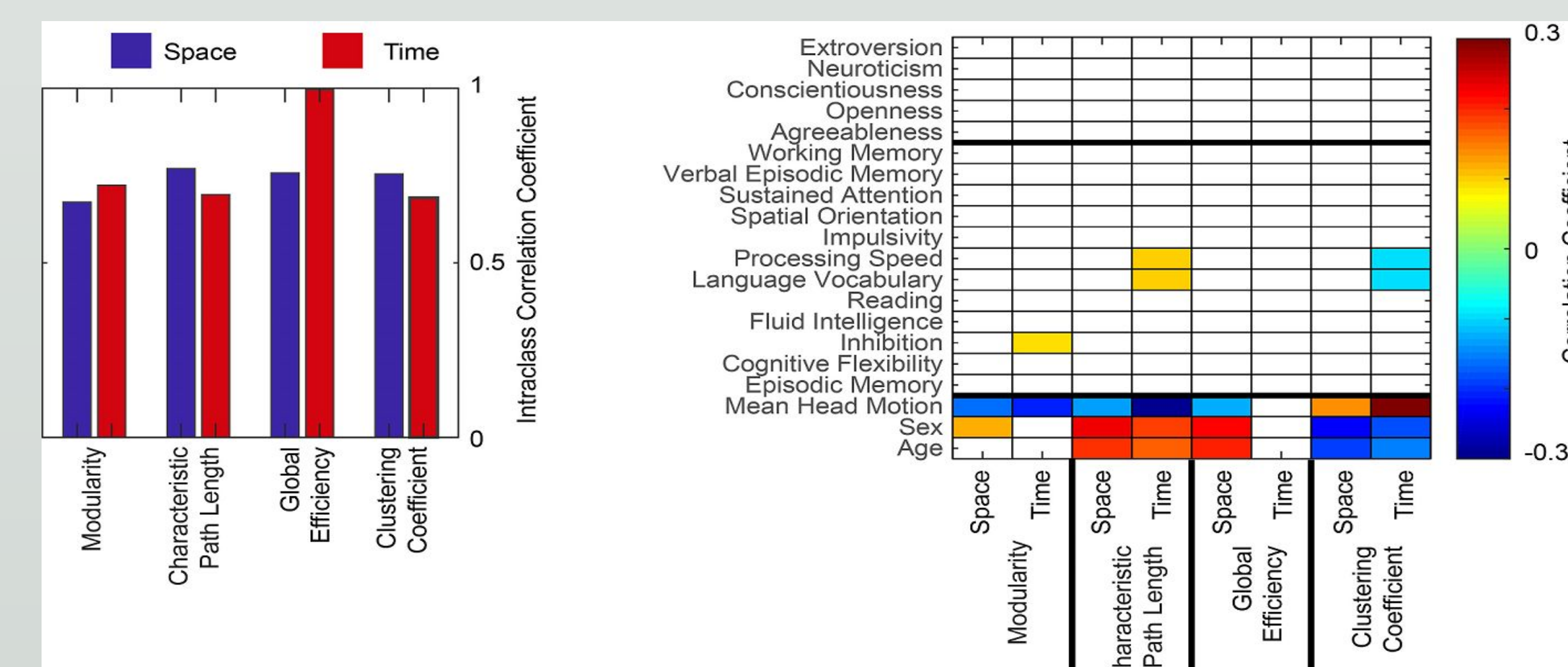
- 1003 subjects, 4 rs-fMRI scans each, 4 preprocessing strategies
- Construct space and time domain functional connectivity networks
- Derive graph-theoretic measures & persistence barcodes
- Measure reproducibility of features by intra-class correlation
- Relate network features to cognitive measures

RESULTS

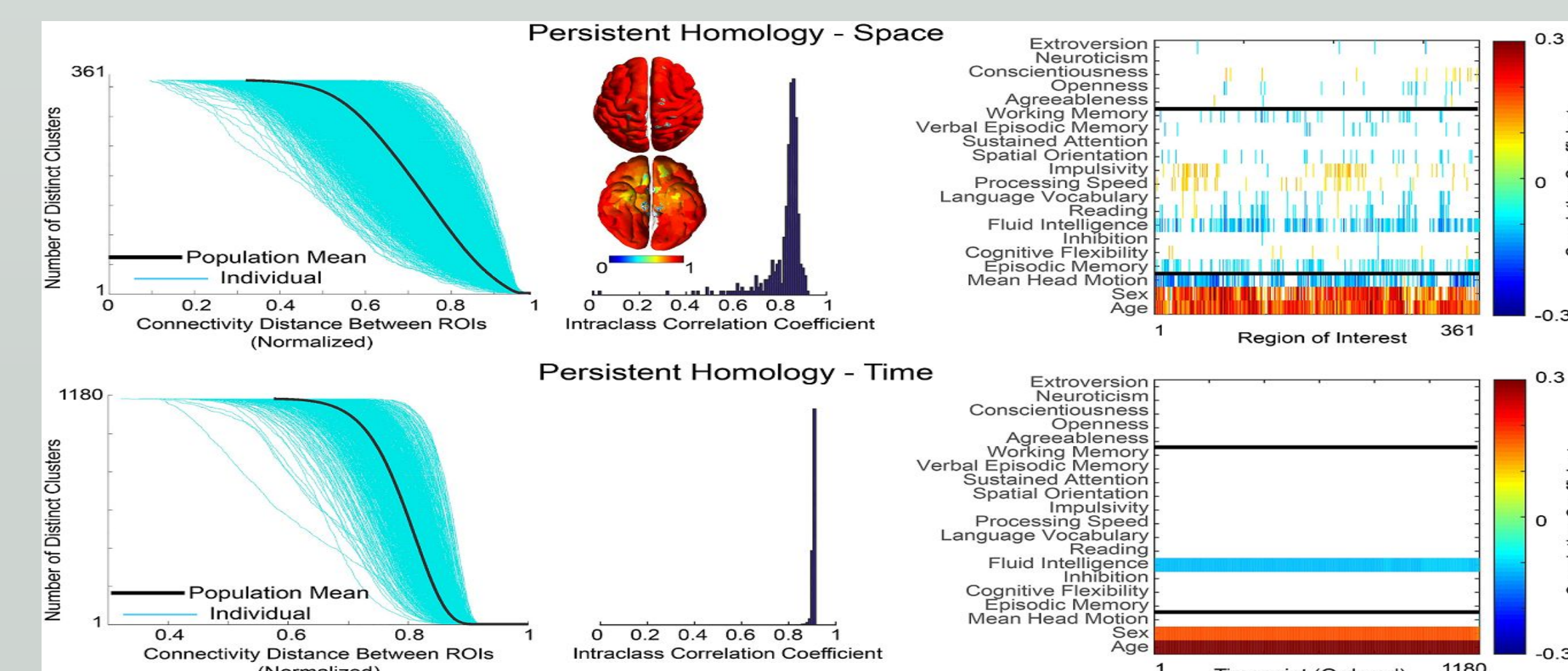
- FIX-ICA based nuisance regression has best reproducibility
- Functional connectivity in time and space encodes distinct cognitive aspects
- Persistence barcodes have high reproducibility and significant correlation with individual differences in cognition and behavior



Reproducibility with respect to various rs-fMRI preprocessing strategies graph-theoretic measures (L) and persistence barcodes (R)



Graph theoretic measures: reproducibility (L) and cognitive correlation (R)



Persistence barcodes(L): reproducibility(C) and cognitive correlation (R)

REFERENCES

- Anderson K, Anderson J, Palande S, and Wang B: "Topological data analysis of functional MRI connectivity in time and space domains". MICCAI CNI 2018. Best paper Award.
- Campbell K, Anderson J, and Fletcher PT: "Surface-Based Spatial Pyramid Matching of Cortical Regions for Analysis of Cognitive Performance". Under Review.

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