Intrinsic Functional Networks within Visual Cortex Supports Naturalistic Visual Perception

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Introduction:

Despite the multi-scale functional organization of the brain [1], resting state fMRI has been almost exclusively applied to the whole-brain scale for mapping large-scale intrinsic networks. Complex activity patterns in relatively smaller spatial scales and information flows across different scales remain poorly known and rarely explored [2]. Towards filling this gap, we aimed to characterize the spatiotemporal patterns of spontaneous activity within the visual cortex, and to evaluate their spatial organization, inter-subject reproducibility, and functional relevance to naturalistic visual perception.

Methods:

Two 3-T fMRI datasets were used in this study. Dataset 1 included resting state fMRI data from randomly selected 45 subjects publicly released by the Human Connectome Project (HCP). For dataset 2, we acquired data from 14 subjects, each having two resting state fMRI sessions and two task fMRI sessions during free viewing of a 5.5-min movie (The Good, Bad and Ugly). The nominal spatial and temporal resolution was 2×2×2 mm3 and 0.72 sec for dataset 1, and 3.5×3.5×4 mm3 and 2 sec for dataset 2. Individuals' data in both datasets were transformed and aligned onto a cortical surface template, and spatially smoothed with 2-mm FWHM. A cortical mask was used to only select the surface area of the visual cortex (Fig. 1). The standardized fMRI data within the selected visual cortex were temporally concatenated and then analyzed by using spatial independent component analysis (ICA) with 70 components. This analysis was done separately for three equal subsets of resting state fMRI data for dataset 1, and resting state and task fMRI data for dataset 2. Following ICA, k-means clustering was applied to the resulting ICA weights to group cortical locations into 15 parcels. The ICA maps and parcels within the visual cortex were compared across different subsets of resting state fMRI data, and importantly, between resting and task conditions, in order to evaluate their reproducibility and functional relevance, respectively.

Results:

20 out of 70 spatially independent components within the visual cortex were reproducible (spatial cross correlation larger than 0.6) across three subsets of resting state fMRI (Fig. 2). Twelve of these components exhibited bilaterally symmetric spatial patterns; the other eight were lateralized (Fig. 3). K-means clustering, informed by these ICA patterns, gave rise to clearly defined parcellation of the visual cortex (Fig. 4). These intrinsic activity patterns and parcels were consistent to those extracted with the same method but during naturalistic movie stimulation.

Conclusions:

Brain activity at rest exhibits reliable network patterns not only in the whole-brain scale, but also in much smaller scales. Such intrinsic network patterns in the visual cortex are robust and reproducible across subjects. These patterns provide an informative basis to divide the visual cortex into small parcels. While the resulting parcels do not exactly match the classical

visual areas defined with retinotopic mapping or cytoarchitecture, they are consistently preserved during naturalistic visual stimulation, suggesting their roles in supporting brain functioning for vision. Therefore, characterizing small-scale or multi-scale intrinsic functional networks holds potential to reshape existing understanding of the brain's functional organization and parcellation that support various sensory, behavioral or cognitive functions.

Imaging Methods:

BOLD fMRI

Modeling and Analysis Methods:

fMRI Connectivity and Network Modeling [2]

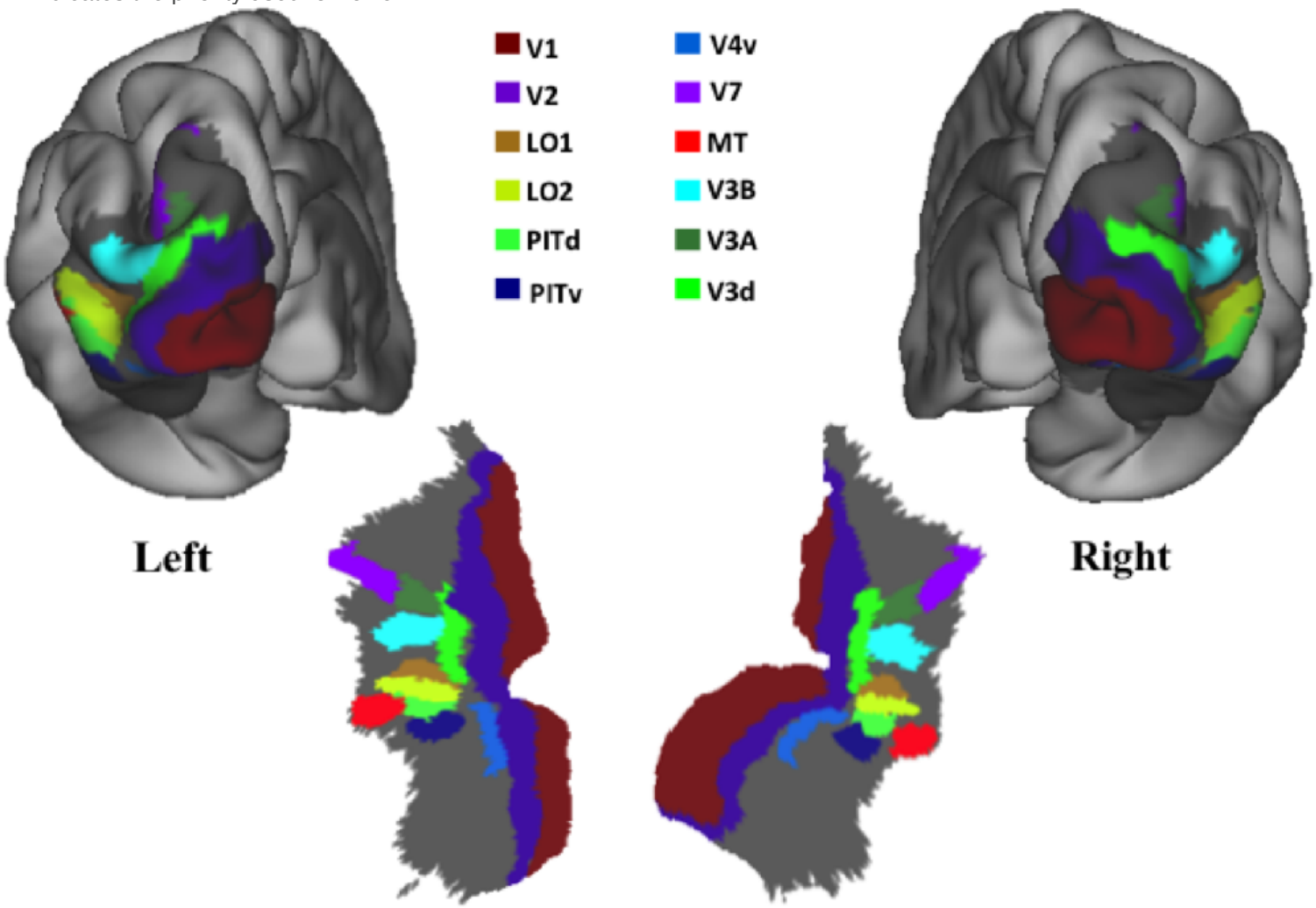
Perception and Attention:

Perception: Visual [1]

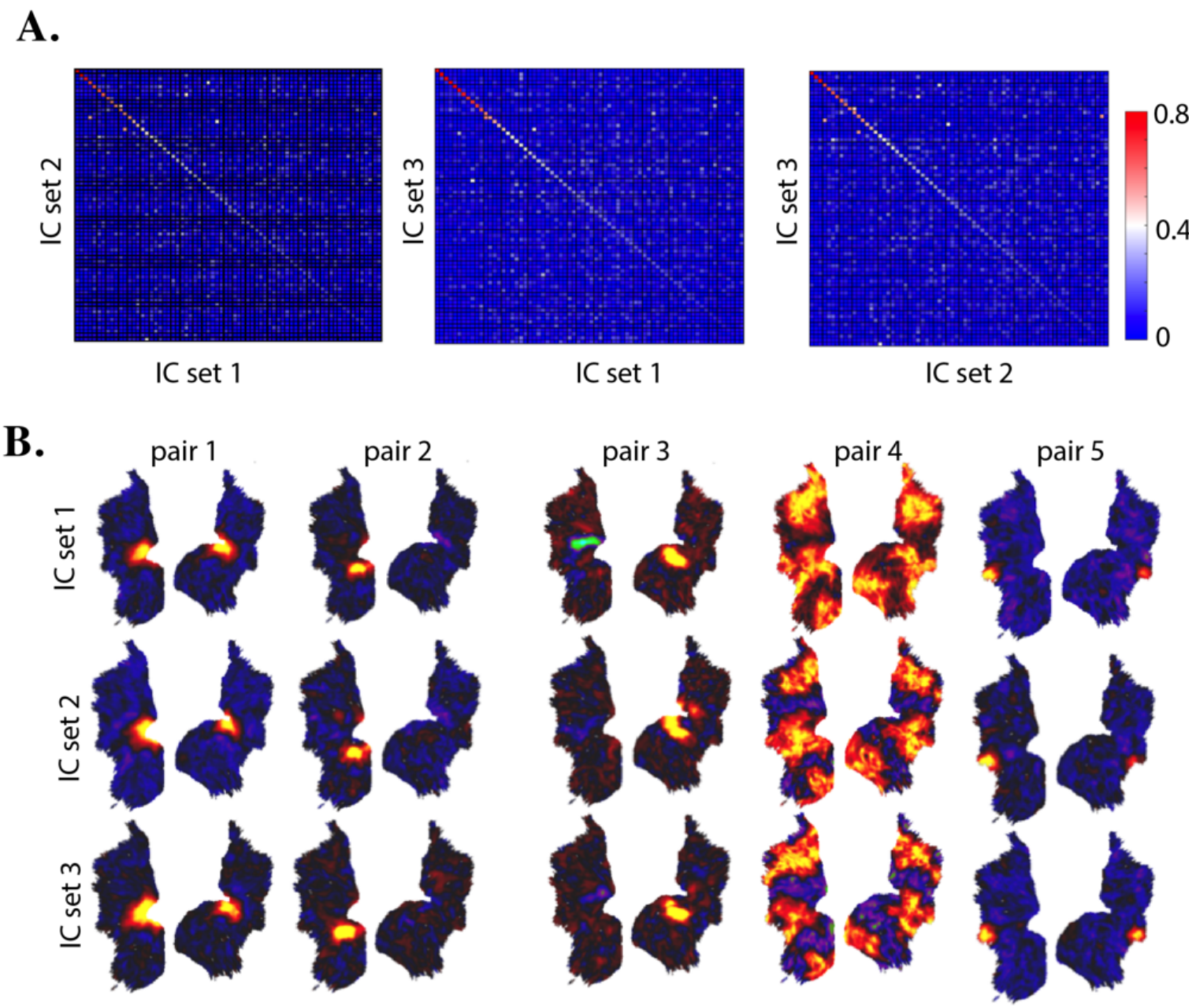
Keywords:

Data analysis
FUNCTIONAL MRI
Perception
Vision

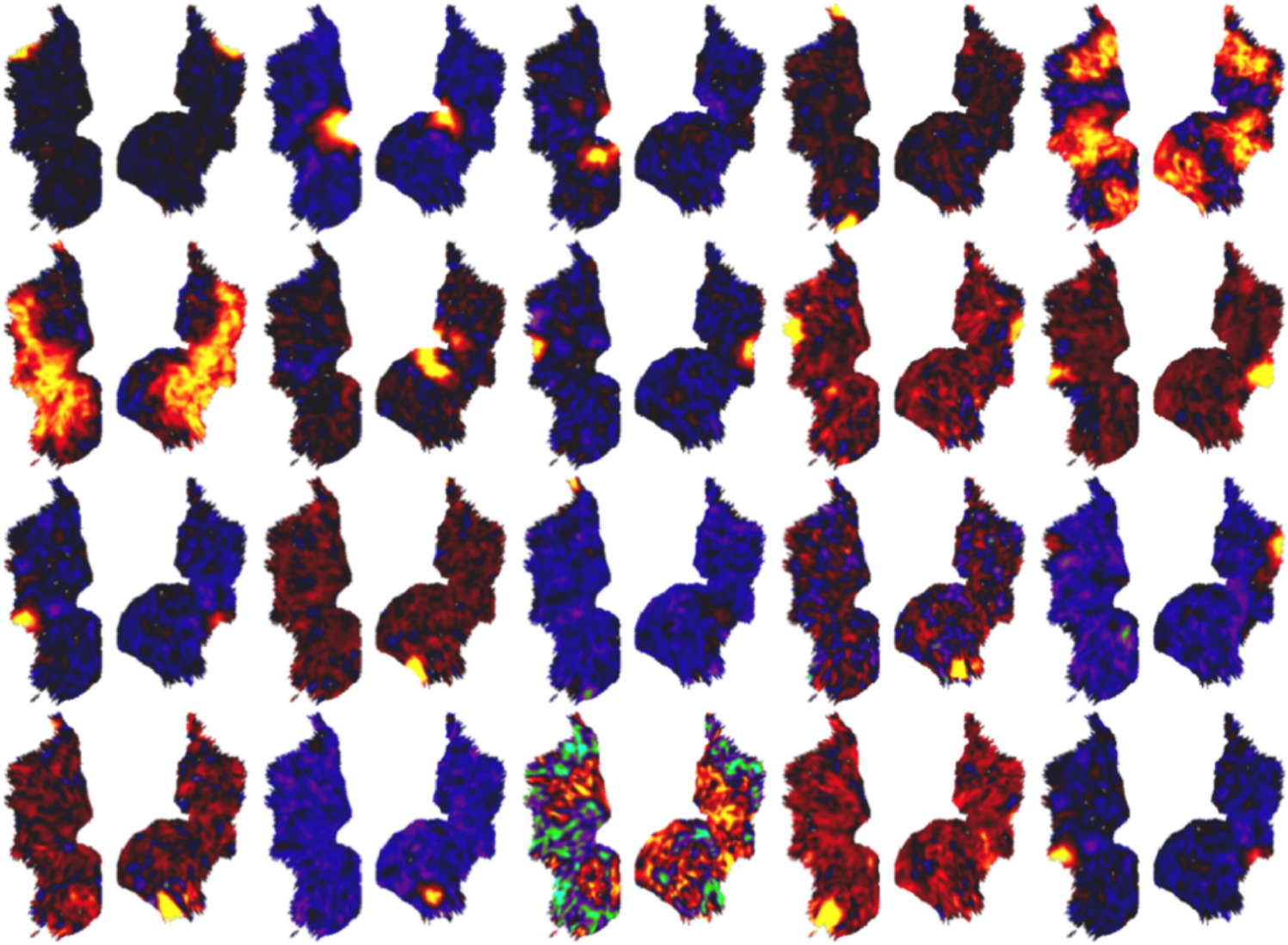
[1][2]Indicates the priority used for review



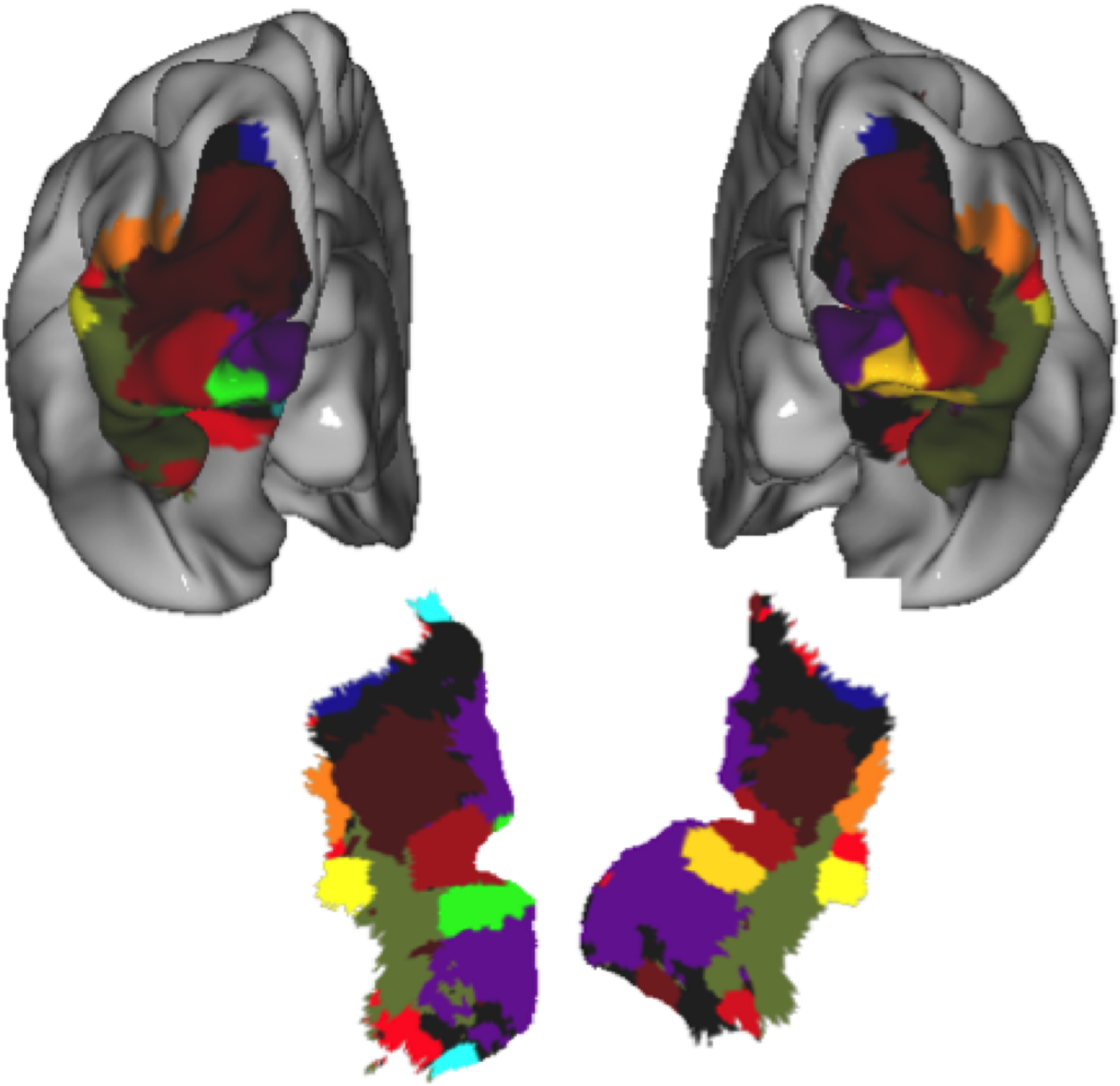
·Figure 1. Inflated and flat surface representation of visual cortex marked in dark gray and color.



·Figure 2. Consistent functional networks found in different data sets. (A) Cross correlation of small-scale ICA maps derived from three different groups of subjects. (B) Five selected consistent ICA m



·Figure 3. The top twenty reproducible ICA maps.



·Figure 4. Inflated and flat surface representation of the new functional parcellation based on the top twenty reproducible ICA maps.

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Please indicate below if your study was a "resting state" or "task-activation" study.

Resting state

Task-activation

Healthy subjects only or patients (note that patient studies may also involve healthy subjects):

Healthy subjects

Internal Review Board (IRB) or Animal Use and Care Committee (AUCC) Approval. Please indicate approval below. Please note: Failure to have IRB or AUCC approval, if applicable will lead to automatic rejection of abstract.

Yes, I have IRB or AUCC approval

Please indicate which methods were used in your research:

Functional MRI

For human MRI, what field strength scanner do you use?

3.0T

Which processing packages did you use for your study?

AFNI
FSL
Free Surfer

Provide references in author date format

[1] Ohiorhenuan, I. E., Mechler, F., Purpura, K. P., Schmid, A. M., Hu, Q., & Victor, J. D. (2010). Sparse coding and high-order correlations in fine-scale cortical networks. Nature, 466(7306), 617-621.
[2] Wilf, M., Strappini, F., Golan, T., Hahamy, A., Harel, M., & Malach, R. (2015). Spontaneously Emerging Patterns in Human Visual Cortex Reflect Responses to Naturalistic Sensory Stimuli. Cerebral Cortex, bhv275.