Toward assessing language lateralization with resting-state fMRI

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Introduction

Determining the lateralization of language functions is of high importance in cognitive and particularly clinical neuroscience.

In the clinical domain, Wada testing [1] is generally considered to be the gold standard for assessing language lateralization, but it is invasive, not without danger, and not always interpretable [2]. Alternative non-invasive task-based fMRI approaches [3] are also often ambiguous, due to a number of methodological and statistical issues, particularly at the single-subject level [4].

Here, we take a first step in developing a new indicator of language lateralization, using a new data analysis, called ConGrads [5], applied to fMRI data acquired at rest.

Connectopic Mapping (ConGrads)

- Rearrange the resting-state FMRI data within a ROI into a time-by-voxels matrix A, do the same for the data outside the ROI (matrix B).
- Reduce the dimensionality of B using singular value decomposition (SVD).
- For every voxel within the ROI, compute the correlation between its time-series and the SVD-transformed data (matrix C).
- Compute the similarity between the rows in C (matrix S).
- Represent S as a graph to derive the Laplacian L and the degree matrix D.
- Solve $Ly = \lambda Dy$ to find the dominant modes of connectivity change.

Data

- 60 subjects of the WU-Minn HCP [7]
- rfMRI pre-processing as detailed in [8].
- IFG ROIs obtained using Freesurfer.
- Language vs. Math tfMRI according to [9].

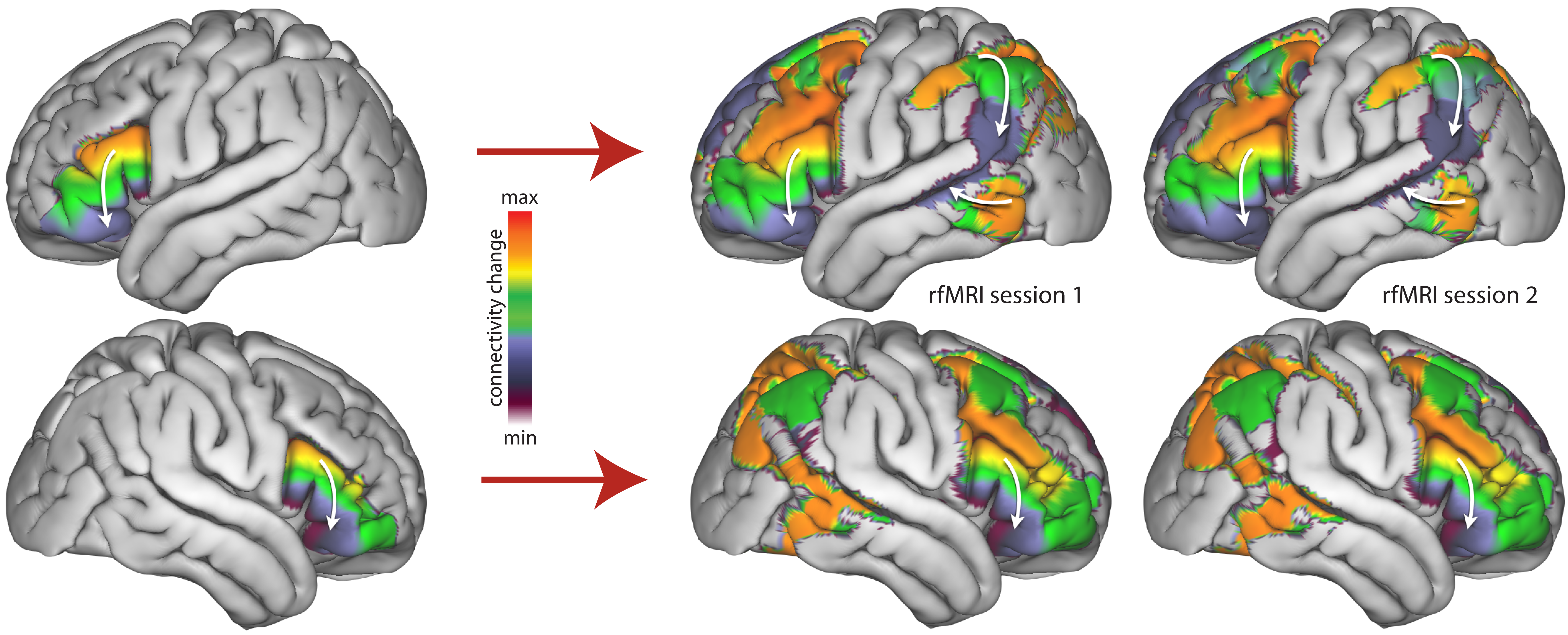
Assessing topographic connectivity

- Apply ConGrads to left and right IFG ROIs to find the second-dominant mode of connectivity change within each of these areas.
- Color-code voxels outside the IFG ROIs according to the voxels within the IFG ROI that they correlate the most with (thresholded at max[z] = 10).

Group-level Results: left-lateralized topographic resting-state connectivity between language areas

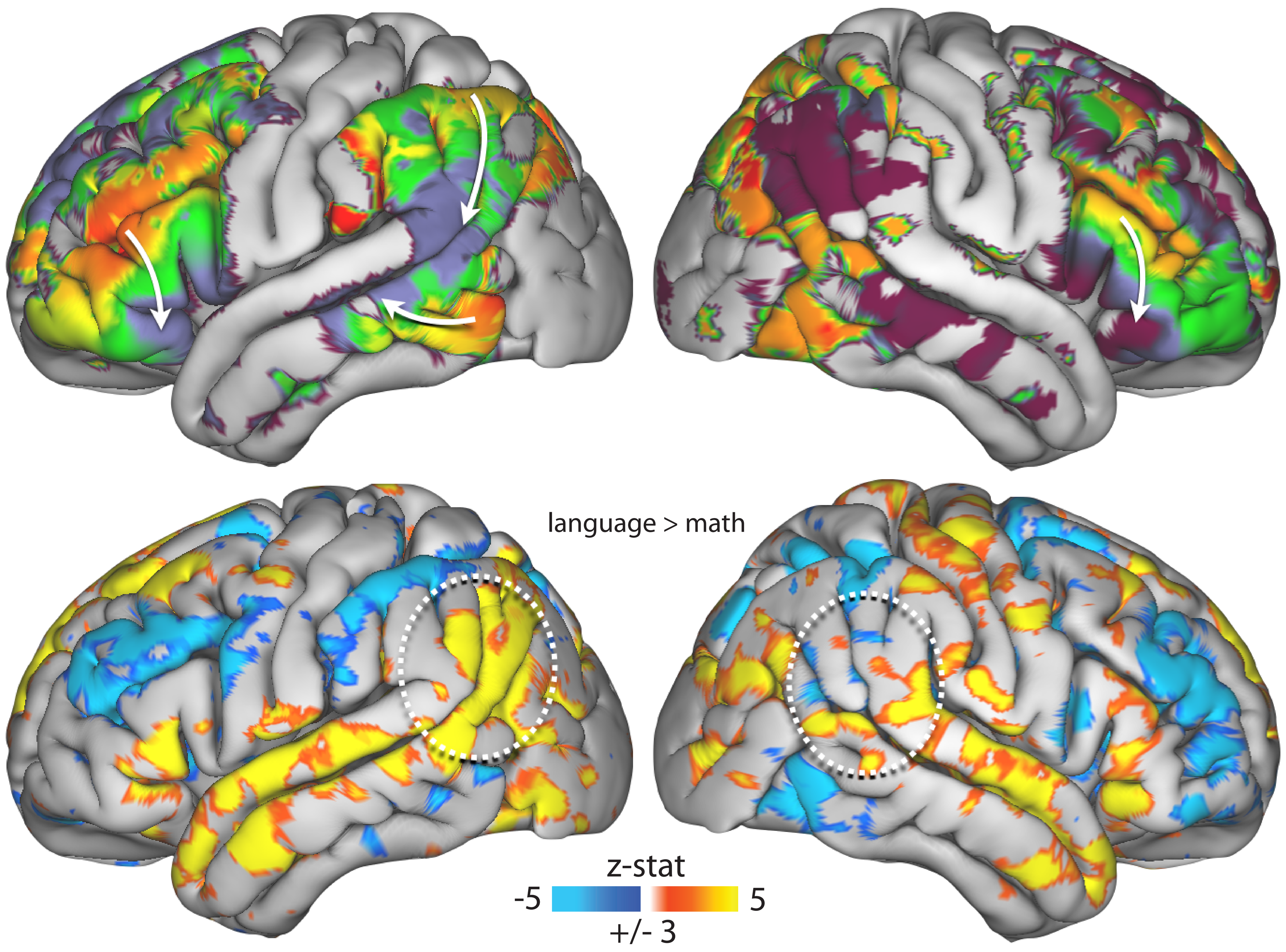
Second-dominant mode of connectivity change within the left (top) and right (bottom) inferior frontal gyrus (IFG). Similar colors indicate similar connectivity profiles:

Color-coding all other voxels according to the IFG voxels that they correlate the most with revealed that the left IFG (top), but not the right IFG (bottom), maintains an orderly topographic organization of connectivity (arrows) with the inferior parietal lobe:



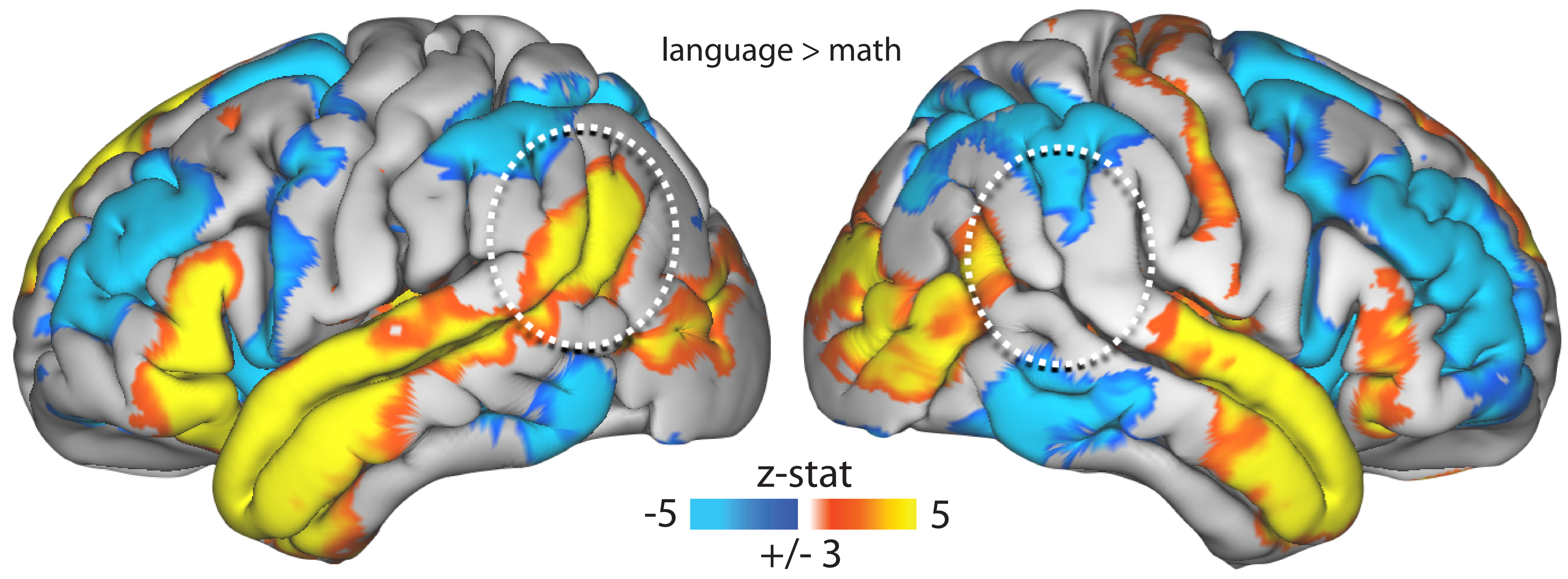
Individual Example

The lateralized preservation of topographic organization is also detectible at the individual level (shown data are from HCP subject #100307, session 1):



Task-based fMRI: Story > Math (Group-Level)

The lateralized topographic connectivity is consistent with the activation patterns evoked when the same subjects performed a language vs. math comprehension task [9]:



Conclusions

- We found topographically organized connectivity between language related brain regions in the left but not the right cerebral hemisphere, consistent with left brain language dominance.
- Notably, Congrads revealed less ambiguous lateralization than HCP task-based fMRI.
- This may overcome paradigm-dependence of language lateralization results as well as the arbitrary choice of statistical thresholds.

References: [1] Wada J, Rasmussen T (1960), Journal of Neurosurgery. 17, 266-282. [2] Meador KJ, Loring DW (1999), Neurology. 52, 1535-6. [3] Binder JR (2011), Epilepsy Behaviour. 20, 214-222. [4] Abbott, et al. (2010) Neuroimage. 50, 1446-1455. [5] Navarro-Schroeder T, Haak KV, et al., (2015) eLife. 4, e06738 [6] Van Essen DC, et al. (2013), NeuroImage 80, 62-79. [7] Smith SM, et al. (2013), NeuroImage 80, 144-168. [8] Barch DM, et al. (2013), Neuroimage. 80, 169-189.

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