

Data-driven individual functional parcellations of IFG reveal entangled systems for language, speech, and working memory

Rebecca Belisle¹, Emily Stephen², Tyler Perrachione³

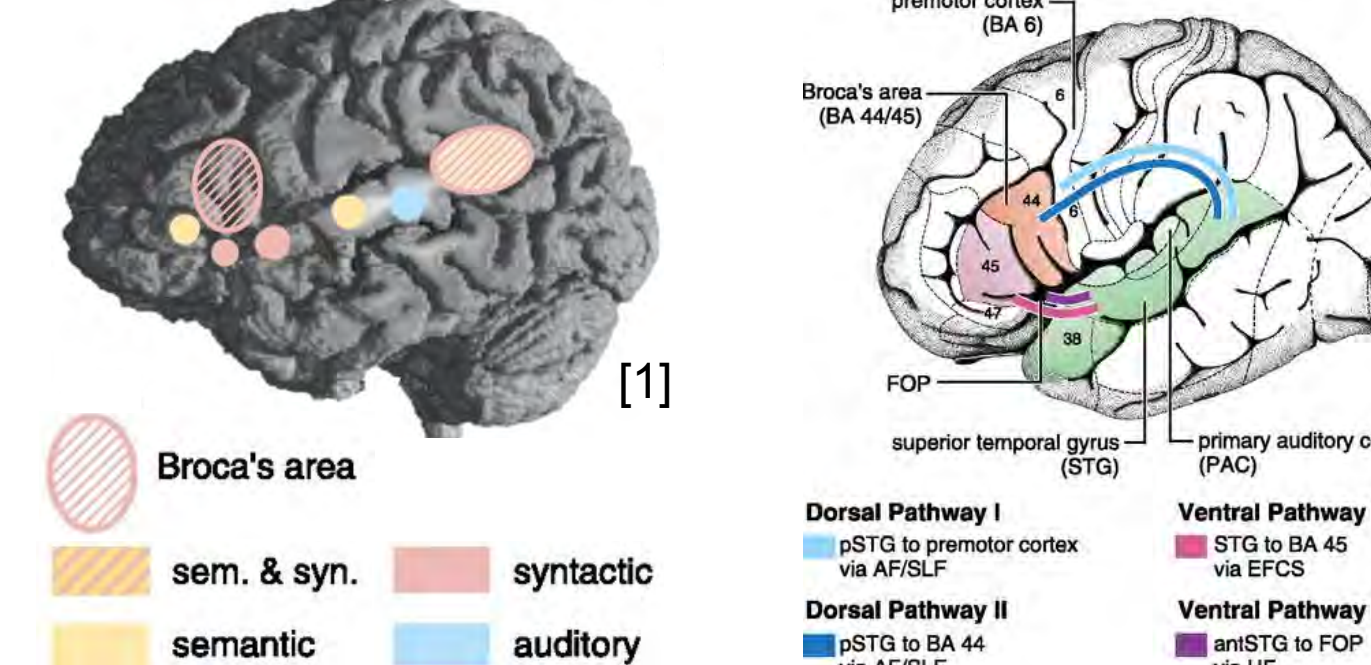
¹Graduate Program for Neuroscience, ²Dept. of Mathematics & Statistics, ³Dept. of Speech, Language & Hearing Sciences, Boston University



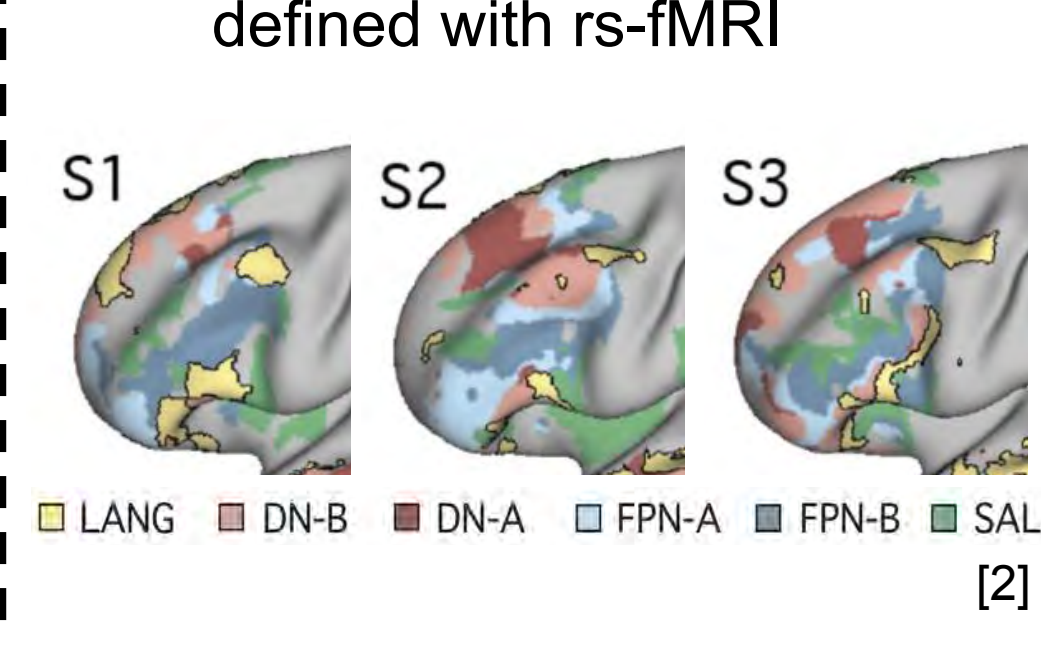
Background

Functional parcellations of IFG

Proposed IFG subdivisions

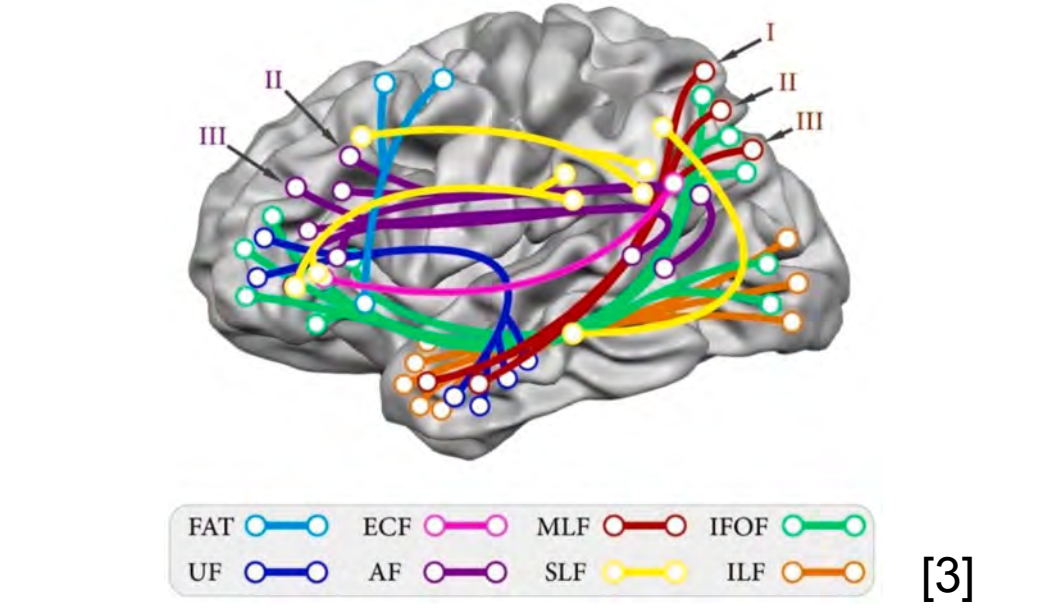


Individuals' functional networks defined with rs-fMRI

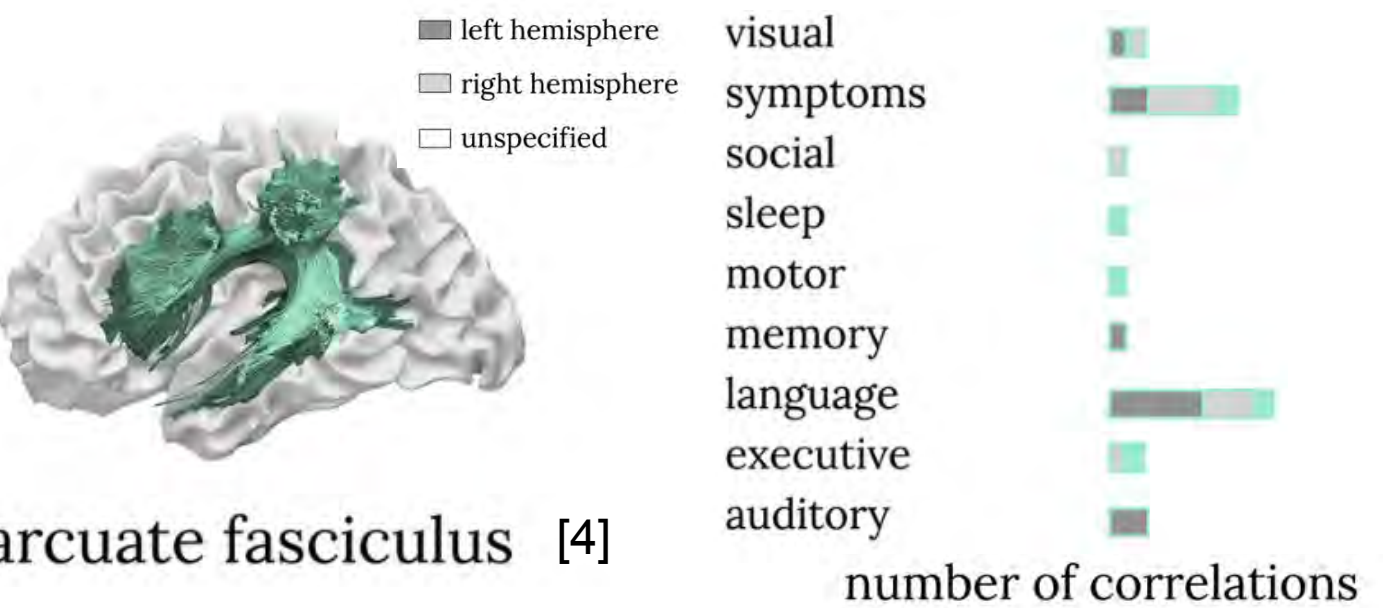


Structural basis of IFG subdivisions?

Language-related WM Pathways



Myriad functional associations of AF



Q: Where is language-specific IFG relative to other functional areas? Which structural features distinguish it?

Methods

Methods overview:

- Functional clustering of vertices by response to 6 fMRI tasks
- Identify unique structural profile that distinguishes each cluster
- Structural & functional MRI data:**
- N=24, mean age=23.4 y/o, typical language & hearing
- Anatomical, diffusion-weighted, and functional volumes
- fMRI: 6 tasks (passive language listening, nonword / real-word repetition, nonword discrimination, spatial sequence memory, auditory digit sequence memory), 2-3 runs each
- k-Means clustering of task-fMRI response values in IFG:**
- For each subject, contrast parameter estimate maps z-scored within IFG, then individuals' feature vectors concatenated across subjects; separate data matrices + clustering for each hemi.
- k-means clustering (*scikit-learn*, 20 initializations)
- Optimal *k* selection – holistic consideration of SSE, silhouette score (average & cluster-specific for consistent clusters across *k*)

Language localizer subject-specific fROI delineation:

- Individualized fROIs: elbow of *lang. localizer activation values* (percentiles) vs. *effect size curve* within-parcel was used as fROI cutoff (activation significance %ile) [5]
- Jaccard index (intersection / union) for overlap (fROI vs. cluster)
- Structural features:** (all ipsilateral to parcel)
- Curvature (<0 = more gyral), cortical thickness (*FreeSurfer*)
- Intracortical myelination (T1w/T2w) [6]
- Diffusion tensor metrics: FA, AD (*FSL DTIFIT*)
- Connectivity with atlas regions [7], surface seed (*FSL ProtrackX*)

Classification model: Multinomial Regression with Elastic Net [8]

- glmnet* in R: (i) performs feature selection (if $\alpha > 0$), (ii) handles correlated predictors
- Objective function (negative log-likelihood):
$$\ell(\beta_0, \beta_1, \beta_2) = -\frac{1}{N} \sum_{i=1}^N \left(\sum_{k=1}^K y_{ik} \log(\beta_0 + \sum_{j=1}^p \beta_j x_{ij}) \right) + \lambda \left((1-\alpha) \|\beta\|_2^2 + \alpha \sum_{j=1}^p \|\beta_j\|_1 \right)$$
- Leave-one-subject-out nested cross-validation:**
- inner loop: find α (LASSO vs. Ridge) & λ (penalty strength) that maximize AUC-ROC for left-out subject
- outer loop: fit optimal model (from inner loop) and get predictions for left-out subject

Accuracy of structural classifier:

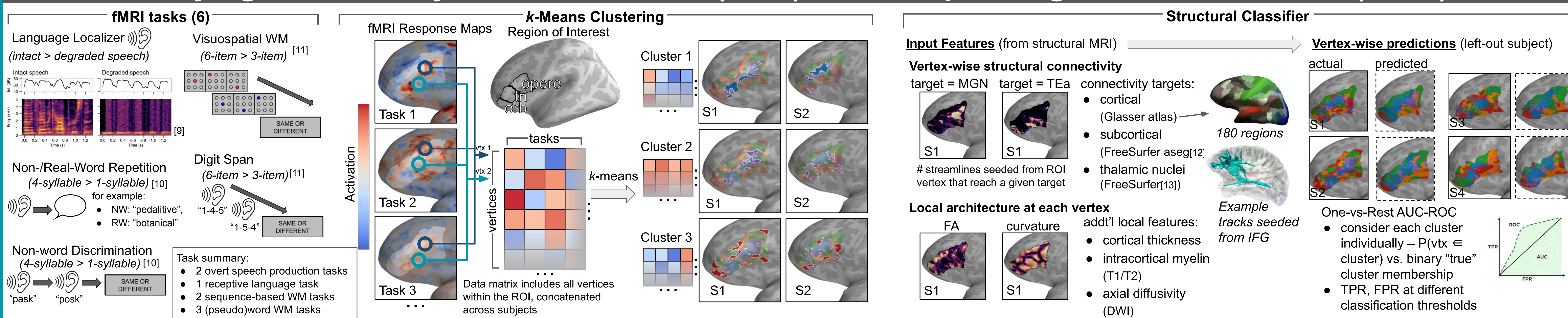
- AUC-ROC for left-out subject predictions (chance = 0.5)

Contact: rbelisle@bu.edu., lab: sites.bu.edu/cnrlab; bluesky: @beckybelisle

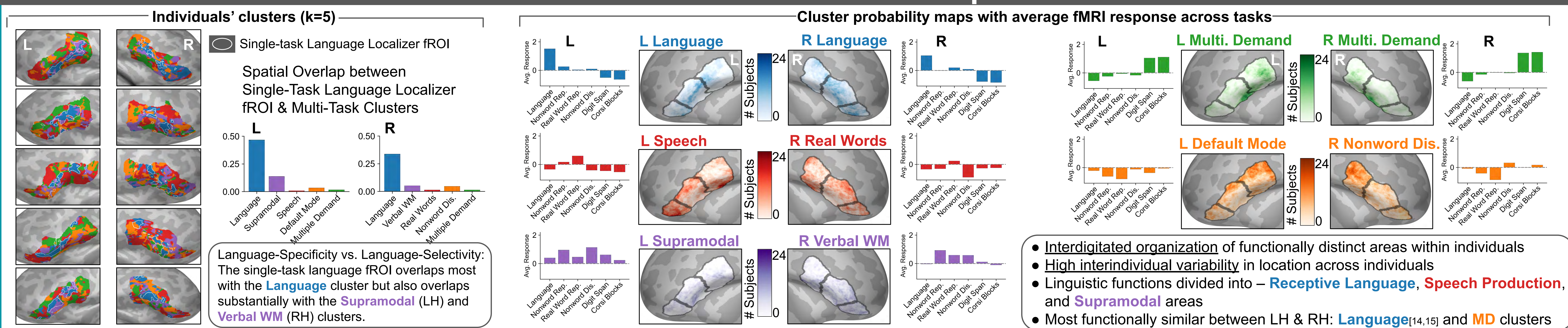
Support: This work was supported by NIH T32DC01301, F31DC022801 (RB), R03HD096098, R03DC014045 (TP), BU Dept. of Mathematics and Statistics and BU Center for Systems Neuroscience (ES).

References: [1] Friederici, 2011, *Physio. Rev.*, [2] Braga et al., 2020, *J. Neurophysiol.*, [3] Kargar & Jalilian, 2024, *J. Neurolinguistics*, [4] Forkel et al., 2022, *Brain Struct. Funct.*, [5] Belisle et al., 2026, *bioRxiv*, [6] Glasser & Van Essen, 2011, *J. Neurosci.*, [7] Glasser et al., 2016, *Nature*, [8] Zou & Hastie, 2005, *J. R. Stat. Soc., B: Stat. Methodol.*, [9] Lee et al., 2024, *NeuroImage*, [10] Scott & Perrachione, 2019, *NeuroImage*, [11] Scott, 2020, Doctoral dissertation, Boston University, [12] Fischl et al., 2002, *Neuron*, [13] Iglesias et al., 2018, *NeuroImage*, [14] LaCroix et al., 2021, *Front. Hum. Neurosci.*, [15] Martin et al., 2022, *Neurobiol. Lang.*, [16] Passingham, 2002, *Nat. Rev. Neurosci.*, [17] Petersen et al., 2024, *Neuron*, [18] Fedorenko et al., 2024, *Nat. Rev. Neurosci.*, [19] Lohse et al., 2026, *Nat. Rev. Neurosci.*, [20] Wernke et al., 2026, *J. Neurosci.*, [21] Hickok et al., 2023, *Brain*, [22] Kearney & Guenther, 2019, *Lang. Cogn. Neurosci.*, [23] Barbas et al., 2013, *Brain Lang.*, [24] Tobynne et al., 2025, *J. Neurosci.*, [25] Assem et al., 2020, *Cereb. Cortex*, [26] Camilleri et al., 2018, *NeuroImage*, [27] Kawabata et al., 2021, *iScience*

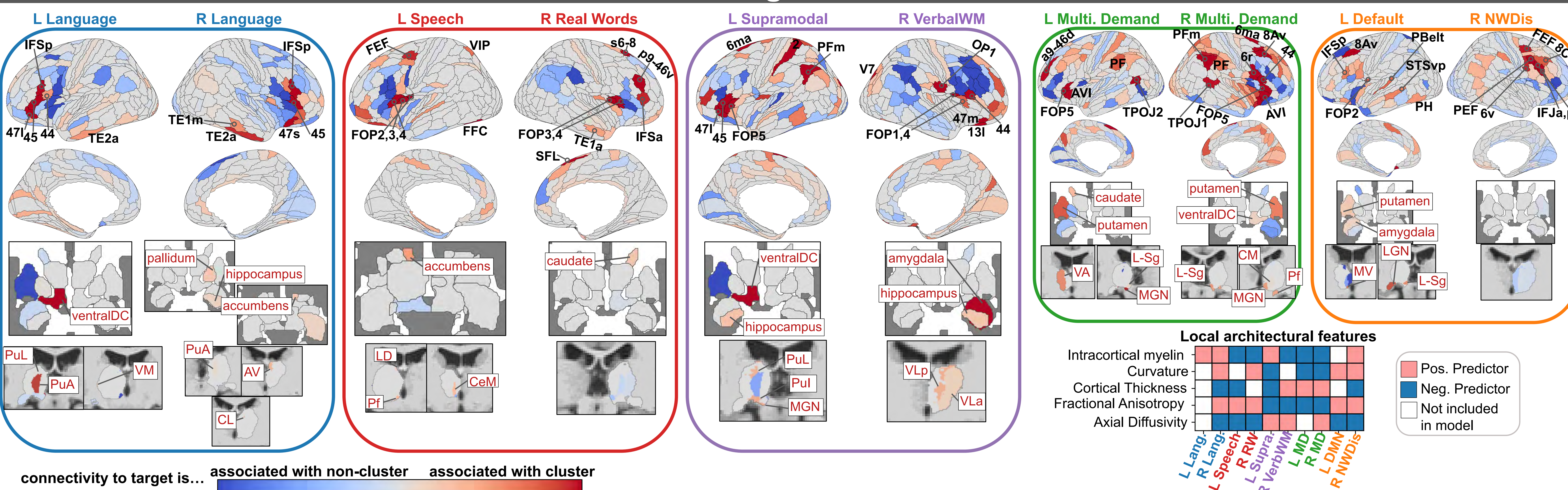
Identifying Functionally Distinct Clusters (fMRI) & Corresponding Structural Profiles (sMRI)



Five IFG Clusters with Distinct fMRI Response Profiles



Structural Features that Distinguish Each Functional Cluster



Conclusions

