A structural connectivity-based parcellation of the human superior temporal lobe

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Methods

Subjects: N=24 adults with typical hearing, language, and cognition.

MRI Data Acquisition: Structural images (T1-weighted, T2-weighted, and diffusion), and three T2*-weighted functional tasks (spoken language comprehension, nonword repetition, auditory short-term memory) (details in Scott, 2019) collected on the Siemens Trio 3T scanner at MIT.

MRI Data Analysis: Anatomical segmentation via *FreeSurfer* 6.0.0; diffusion analysis via *FSL* (6.0.4) *probtrackx*; fMRI analysis via *Lyman* 1.0.0 (details in Scott, 2019); myelin analysis as in Ganzetti et al. (2014).

Probabilistic Tractography-Based Clustering & Parcellation:

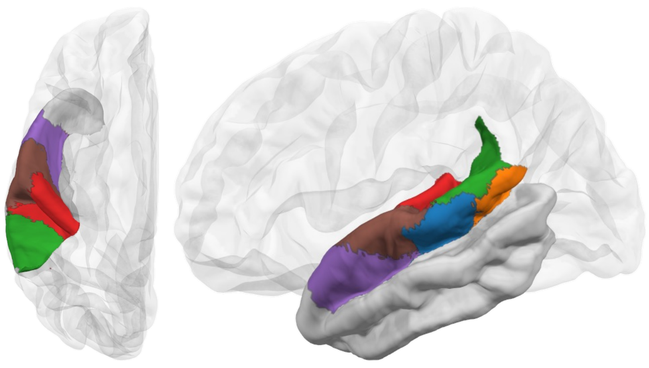
1. For each subject, we masked the entire superior temporal lobe surface using the Tourville-Guenther atlas (2013) automatic parcellation.
2. For each seed vertex in the mask, we obtained the magnitude of its connectivity to every other nonlocal (>2cm) gray matter voxel in the entire brain (including subcortical and cerebellum) using probabilistic tractography, yielding an ~8000 x 35000 connectivity matrix per subject.
3. Using spectral clustering on pairwise similarity between all STG seeds (~8000 x 8000 Spearman correlation matrix), we identified six clusters of temporal lobe vertices with similar connectivity patterns per subject.
4. Clusters were projected to a standard space, and common clusters across subjects were identified based on patterns of spatial overlap.

Summary

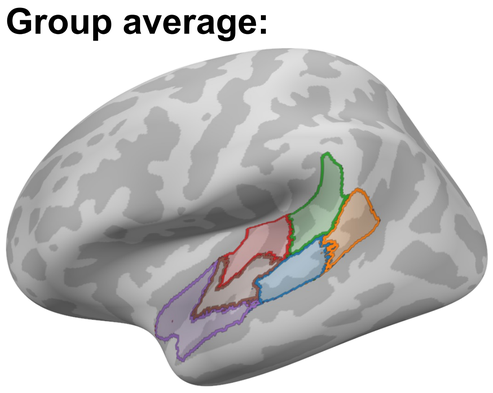
We report a parcellation of the superior temporal lobe into six areas based on similar patterns of structural connectivity to the rest of the brain. We characterize these regions using their patterns of white matter projections, their microstructural tissue properties, and their response to three fMRI tasks. This approach offers a novel, data-driven avenue to investigate the functional neuroanatomy of human auditory cortex and temporal lobe.

Clustering Results

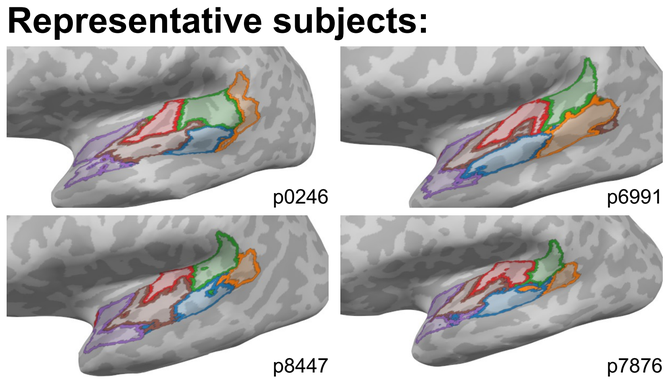
The group average parcellation based on connectivity patterns yielded 6 anatomically coherent clusters: **Heschl's gyrus**; **planum temporale & parietal operculum**; **caudal STG**; **lateral STG**; **rostrolateral STG**; and **rostral STG & planum polare**.



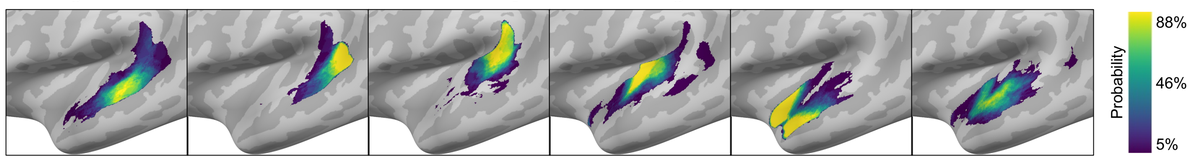
Group average:



Representative subjects:

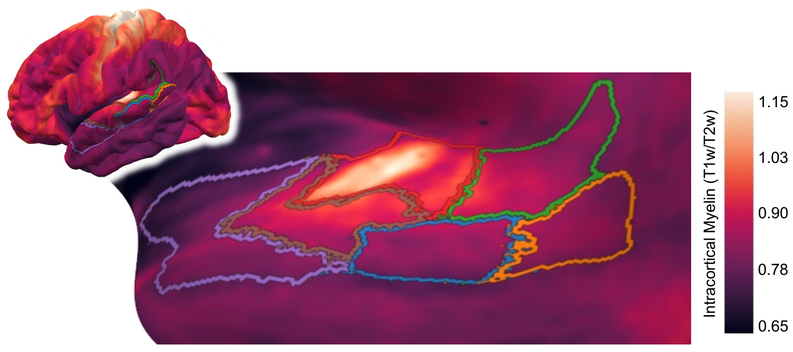


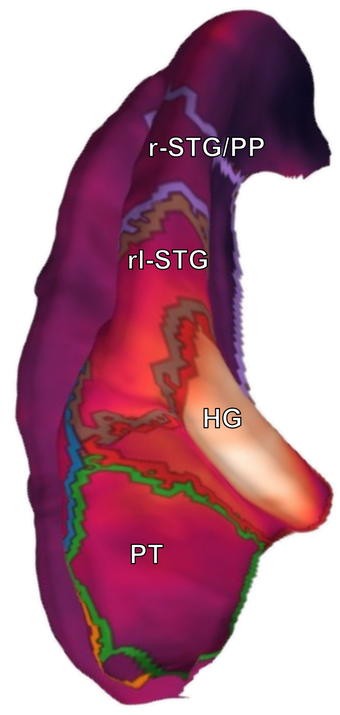
Subject-level cluster location probability:



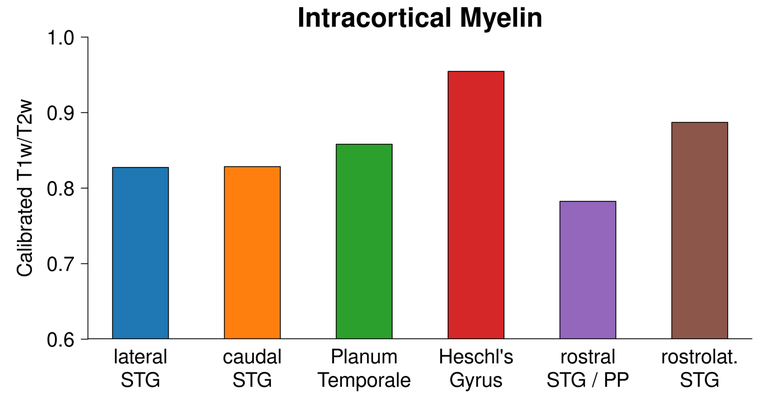
Myeloarchitecture

The six parcels exhibit distinct patterns of intracortical myelin, indexed by the T1w/T2w ratio (Glasser & Van Essen, 2011). Gray matter in Heschl's gyrus was most heavily myelinated vs. other clusters (Sigalovsky et al., 2006). Cluster boundaries largely follow T1w/T2w intensity transitions.



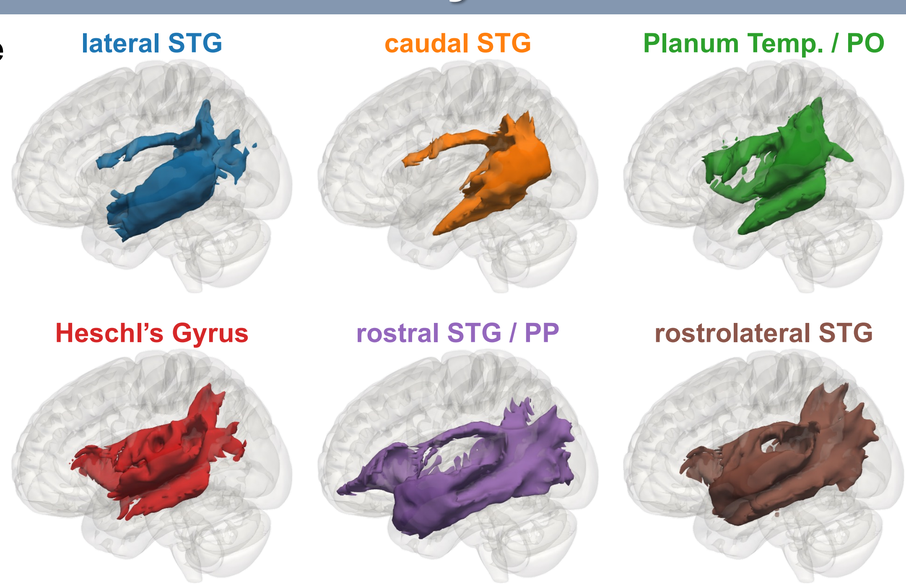


Intracortical Myelin



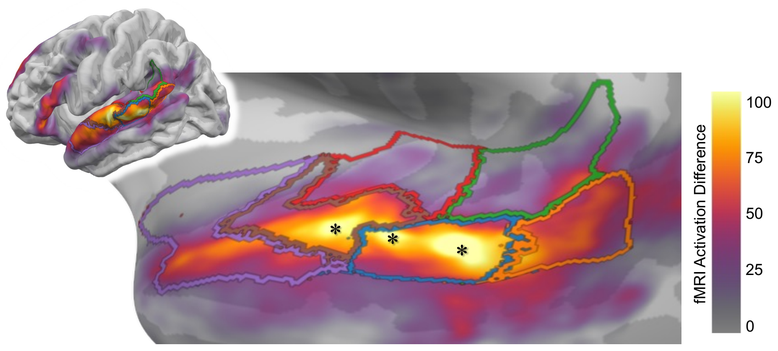
Connectivity

The STG's diverse connectivity is revealed through the distinct patterns of white matter projections from each parcel, showing major tracts (SLF, ILF) and targets (IFG, vPMC, IPL, MTG, and thalamus).

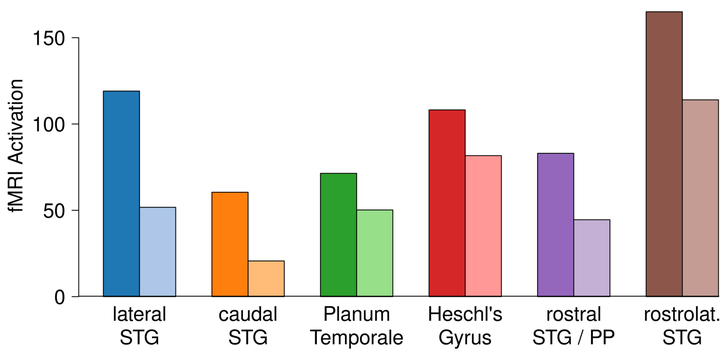


Functional Response Profiles

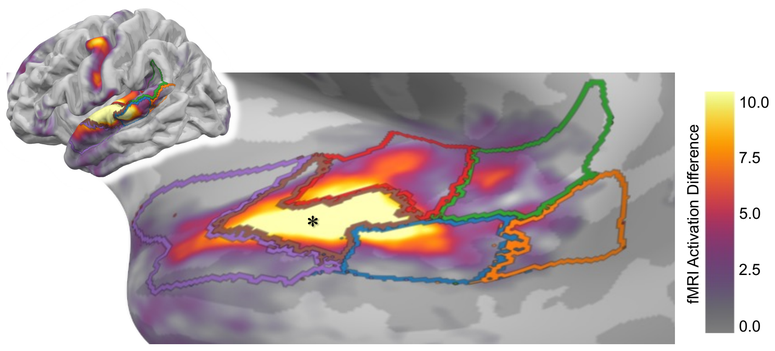
Three peaks (*) of highly selective functional response to intelligible (vs. degraded) speech fall neatly within the rostrolateral STG (1) and lateral STG (2 & 3) clusters, but not HG or PT.



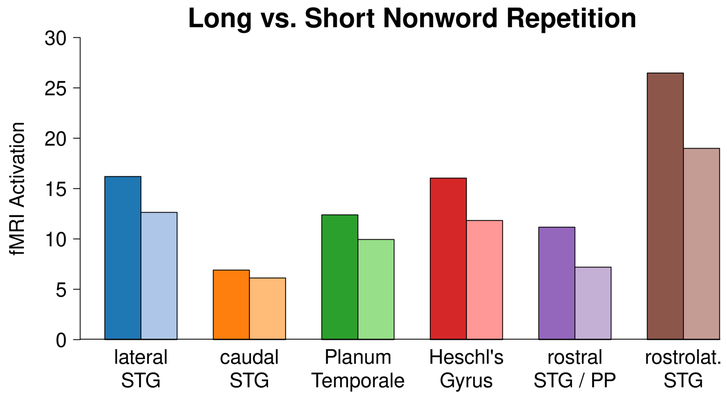
Speech vs. Degraded Speech



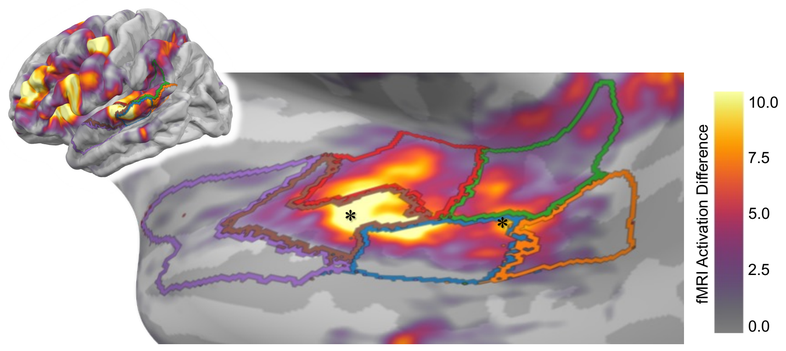
Repeating longer vs. shorter nonwords elicited the greatest response in the rostrolateral STG cluster, but less so in other clusters, notably even those with strong speech activity.



Long vs. Short Nonword Repetition



Greater auditory short-term memory load (6- vs. 3-digit spans) increased activity in frontal lobe, but also in auditory clusters that did not fall cleanly within these structural parcels.



Long vs. Short Digit Span