The Effect of Task on Localization Cues in Human Auditory Cortex

Higgins NC and Stecker GC

Department of Hearing and Speech Sciences Vanderbilt University

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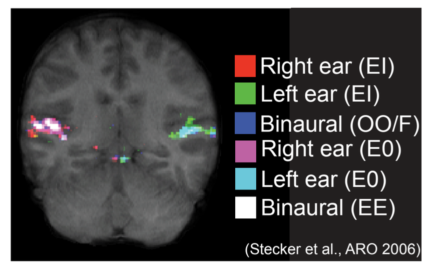
Background

Binaurally tuned auditory cortical (AC) neurons prefer contralateral stimulation.

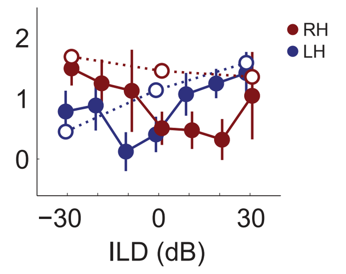
Contralaterality of BOLD fMRI in Human AC is not fully established.

Engagement in task shapes responses of cortical neurons in cats (Lee and Middlebrooks 2011), and influences cortical activation in lateral parts of auditory cortex (Petkov et al. 2004; Woods et al. 2009).

Goal: to understand the spatial tuning of AC BOLD response within the context of task related attention using fMRI.

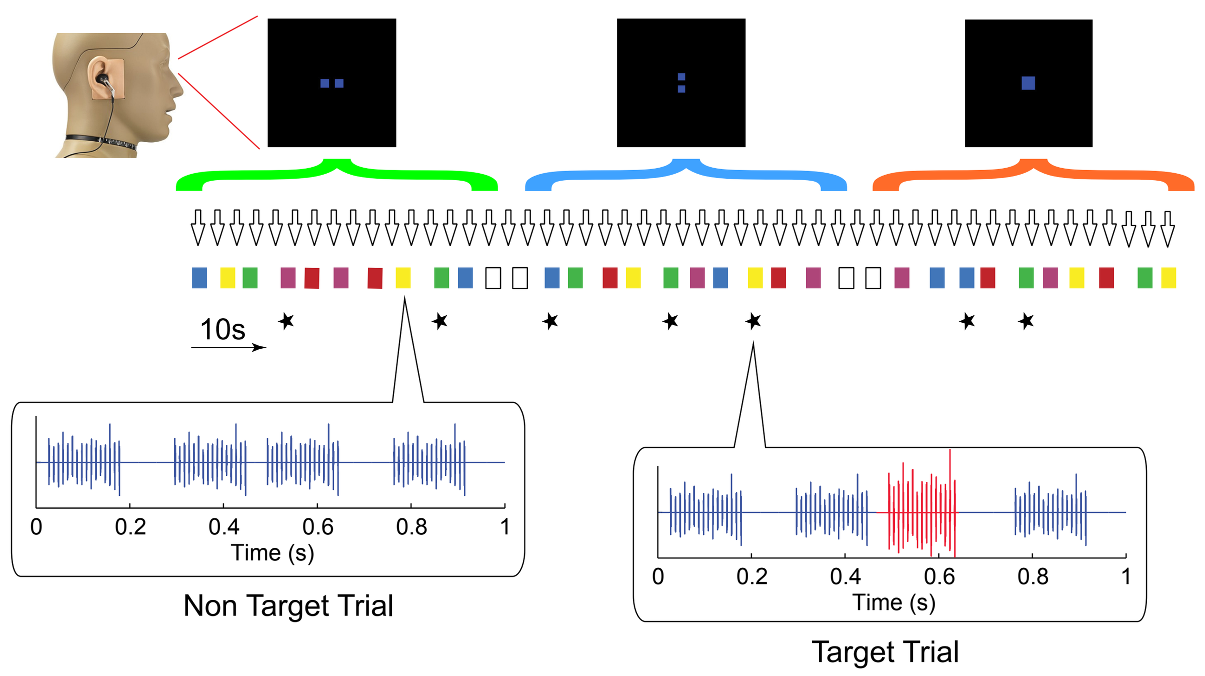


fMRI responses in human AC and inferior colliculus appear dominated by monaural (E0) input. Diotic responses (blue) closely coincide with regions and magnitude of contralateral responses (e.g., red in LH). [Stecker, Rinne, Herron, Liao, Kang, Yund, and Woods, ARO 2006]



Tuning of fMRI responses in human AC to ILD appear non-monotonic, but overall biased to favor contralateral ear. Relative to monotic response (open symbols), both hemispheres (red for RH, blue for LH) show significant reductions for moderate ipsilateral ILD values. [Stecker and McLaughlin, ASA 2012]

Experimental Design



Task Cue: Detect intermittently presented targets consisting of a change in Location (right/left), Pitch (higher/lower), or Visual cue (brighter/darker).

- Task blocks presented in random order, 30 seconds duration, 7 blocks per run, 10 trials in each block.

Scan Acquisition: Continuous event-related imaging paradigm (TR = 2s, 42 slices, 2.75 x 2.75 x 3mm), at 3T (Phillips).

Acoustic Stimuli: trains of 16 white noise bursts, 1 ms burst duration, burst rate = 100 Hz at 90 dBpe SPL. Trains presented in 1 second "trials", each with 4 stimulus intervals. Intertrial interval range from 1-5 s.

- Interaural Level Difference (ILD) [-20, -10, 0, 10, 20 dB] or Interaural Time Difference (ITD) [-800, -400, 0, 400, 800 μs] varied across trials. Only ILD or ITD presented within a run, and trial order was counterbalanced (continuous carryover design).

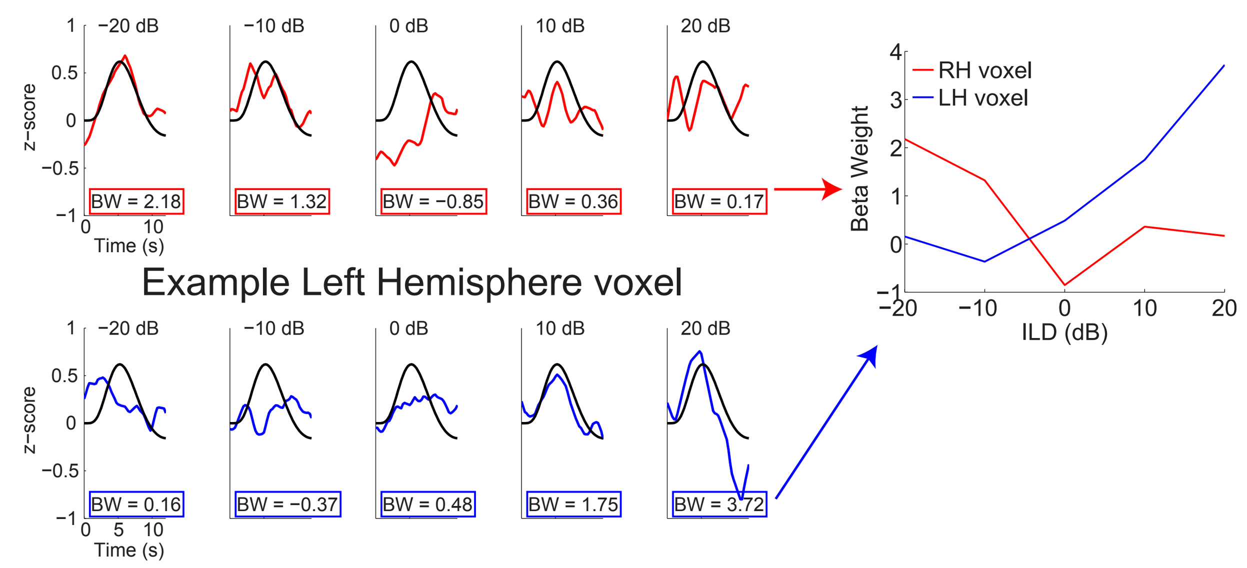
Targets: The 3 target "types" are presented throughout the run regardless of the task cue; participants are instructed to respond only when detecting the specifically cued target.

- Targets presented at rate of 2/7 trials.
- Location targets: 5 dB change in ILD runs, 200 μs change in ITD runs. Pitch targets: 40% increase or decrease in burst rate. Visual targets (fixation box brighter or dimmer).

Participants: N=10 total (3 male, 7 female) normal hearing adults (22-35 years), right handed native English speakers.

Voxel-based Response Estimation

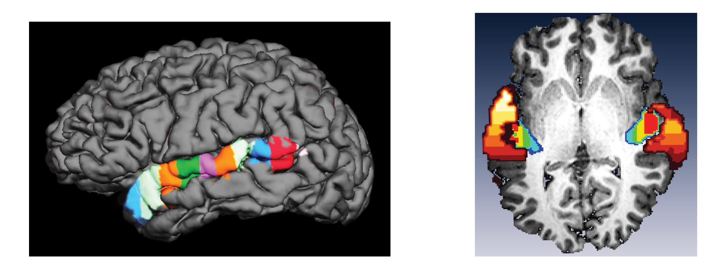
- Standard preprocessing: motion correction, high pass filtering (0.01 Hz), individual subject registration using FSL
- Z-transform timecourse of the Hemodynamic Response Function (HRF) for each voxel and interpolate for each trial
- Regress 12 s HRF post-stimulus with standardized HRF (Glover 1999).
- The resulting beta weight from the regression analysis quantifies single-trial stimulus-related activation for each voxel



ROI Analysis

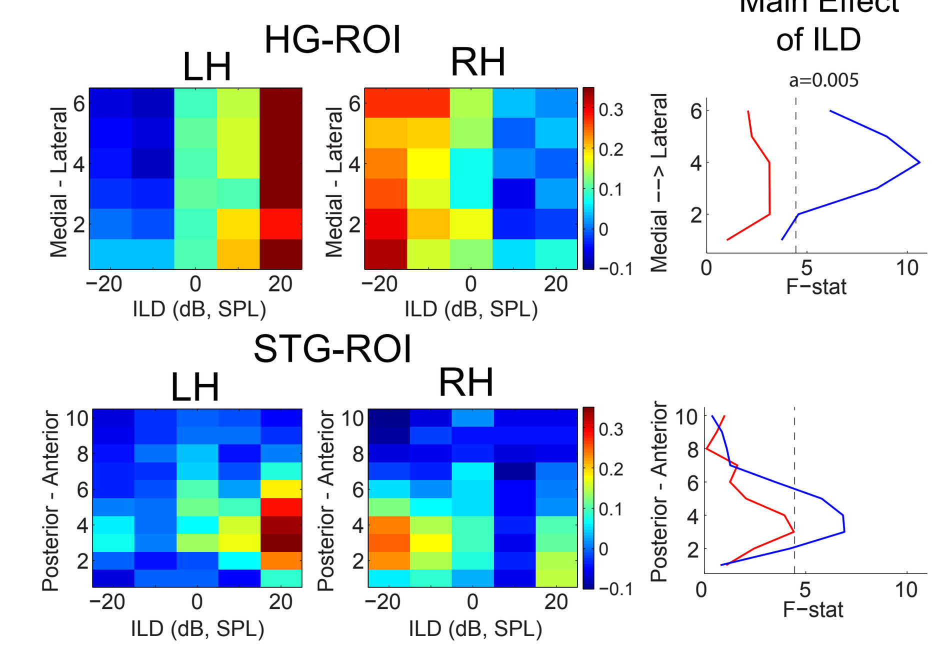
Two regions of interest (ROIs) defined using Freesurfer following Desikan et al. (2006); divided into evenly distributed non-overlapping sections:

1) Heschl's Gyrus (HG)
   6 sections; medial - lateral
2) Superior Temporal Gyrus (STG)
   10 sections; posterior - anterior

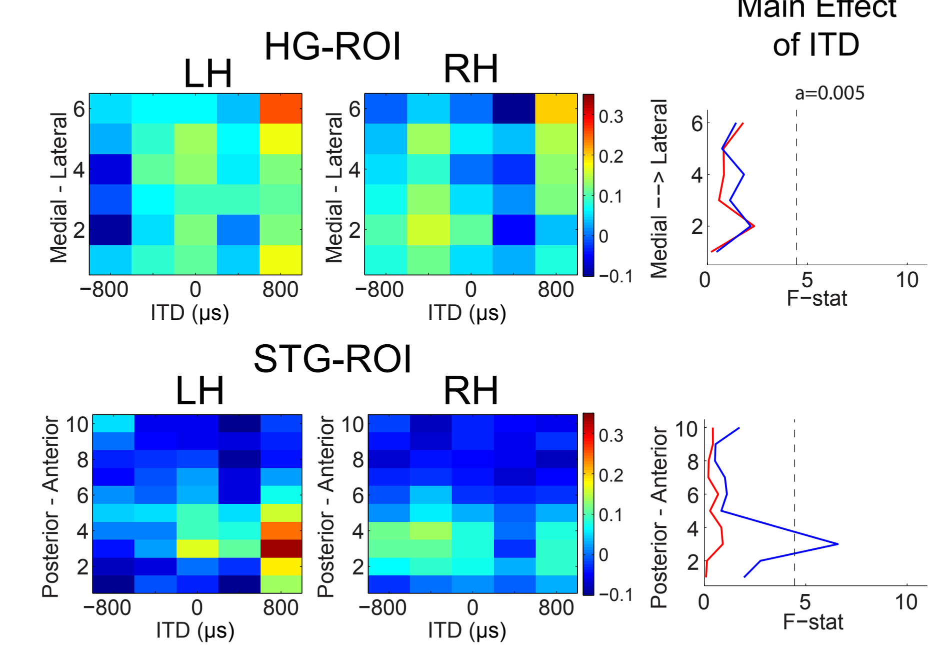


Stimulus Dependent Activation

Interaural Level Difference



Interaural Time Difference



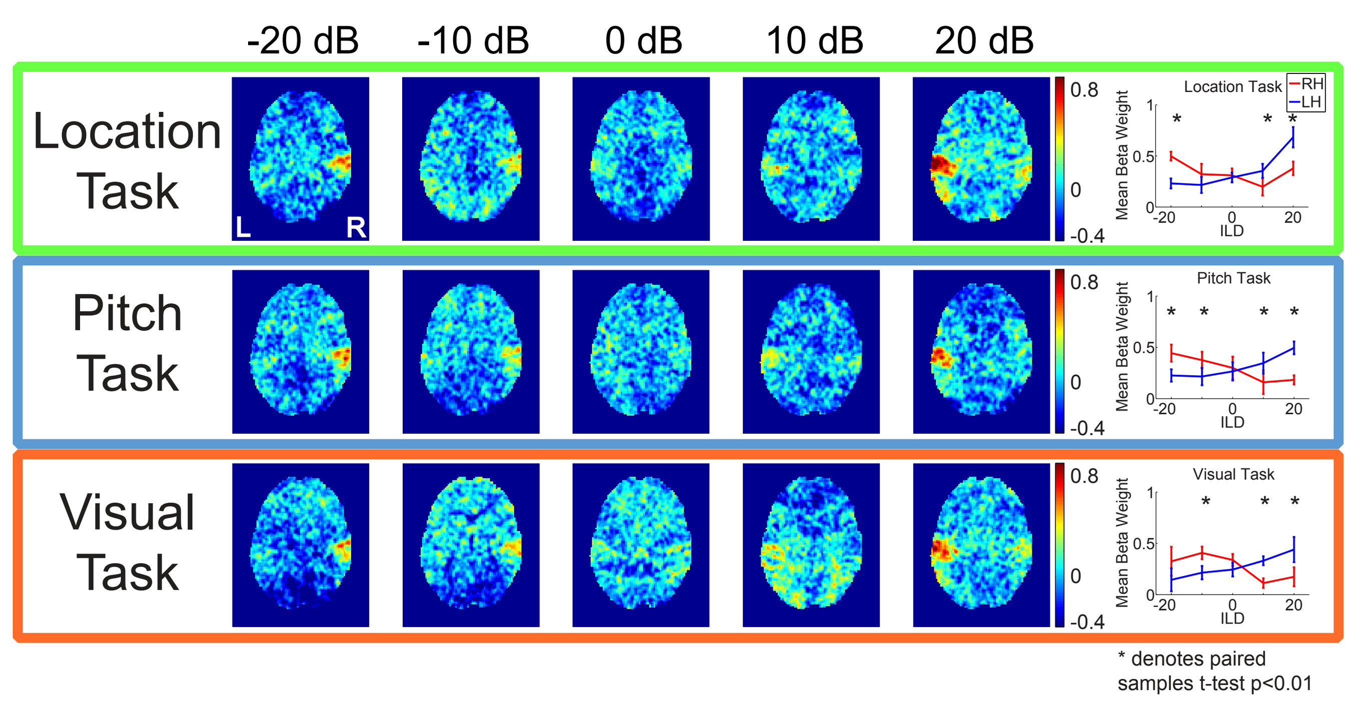
Summary:

Clear contralateral dominance observed across medial-lateral extent of HG in response to ILD, but typically only lateral sections of HG for ITD. Both ILD and ITD stimuli show increased activation isolated to posterior sections of STG.

Task Effects

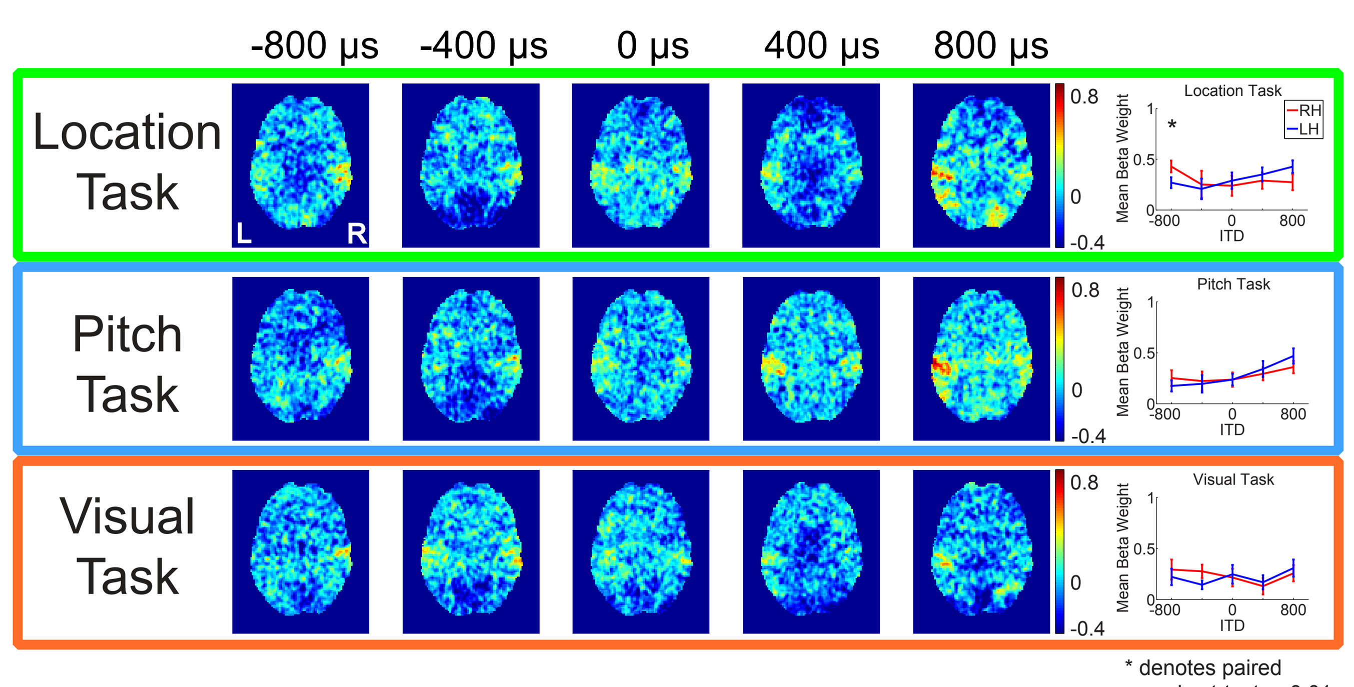
Whole Brain Analysis: betaweight datasets individually registered to standard MNI structural map and collapsed by condition across trials and participants. Response functions and statistics are based on sound-responsive voxels (z > 2.3) within whole hemisphere (right or left), and reflect differences across participants.

Interaural Level Difference



* denotes paired samples t-test p<0.01

Interaural Time Difference



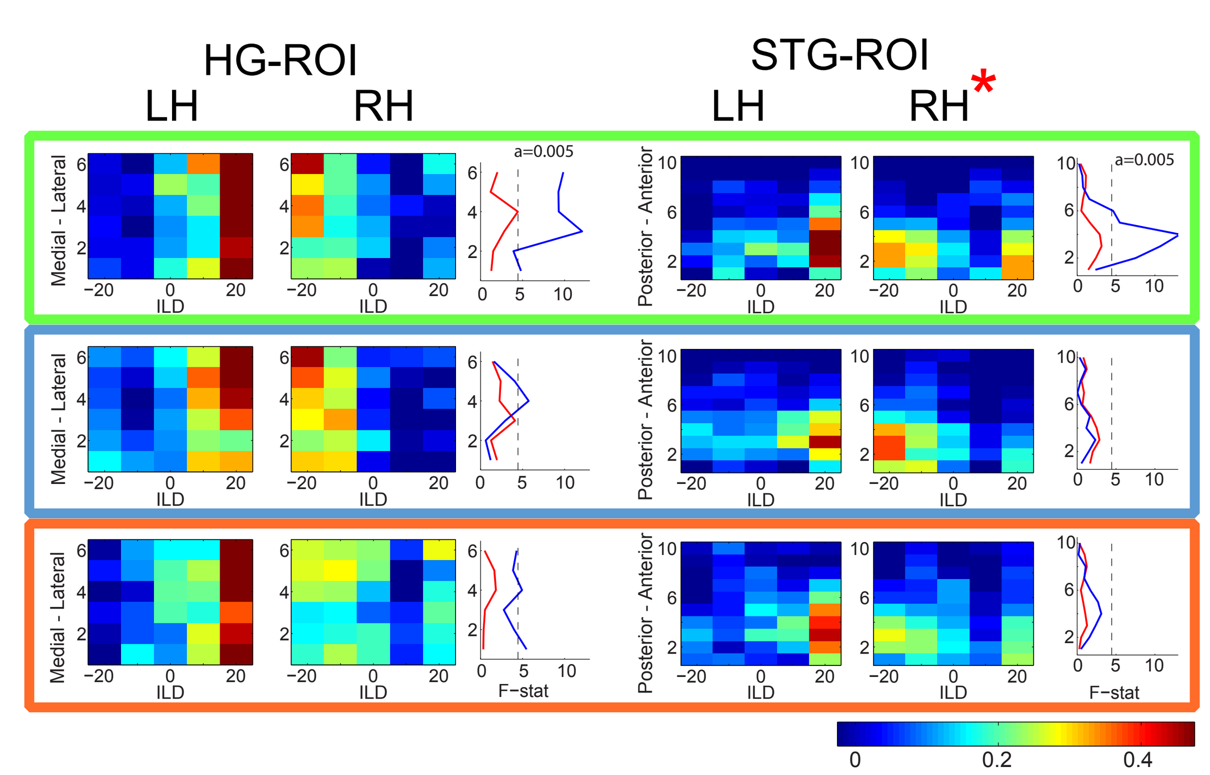
* denotes paired samples t-test p<0.01

Summary:

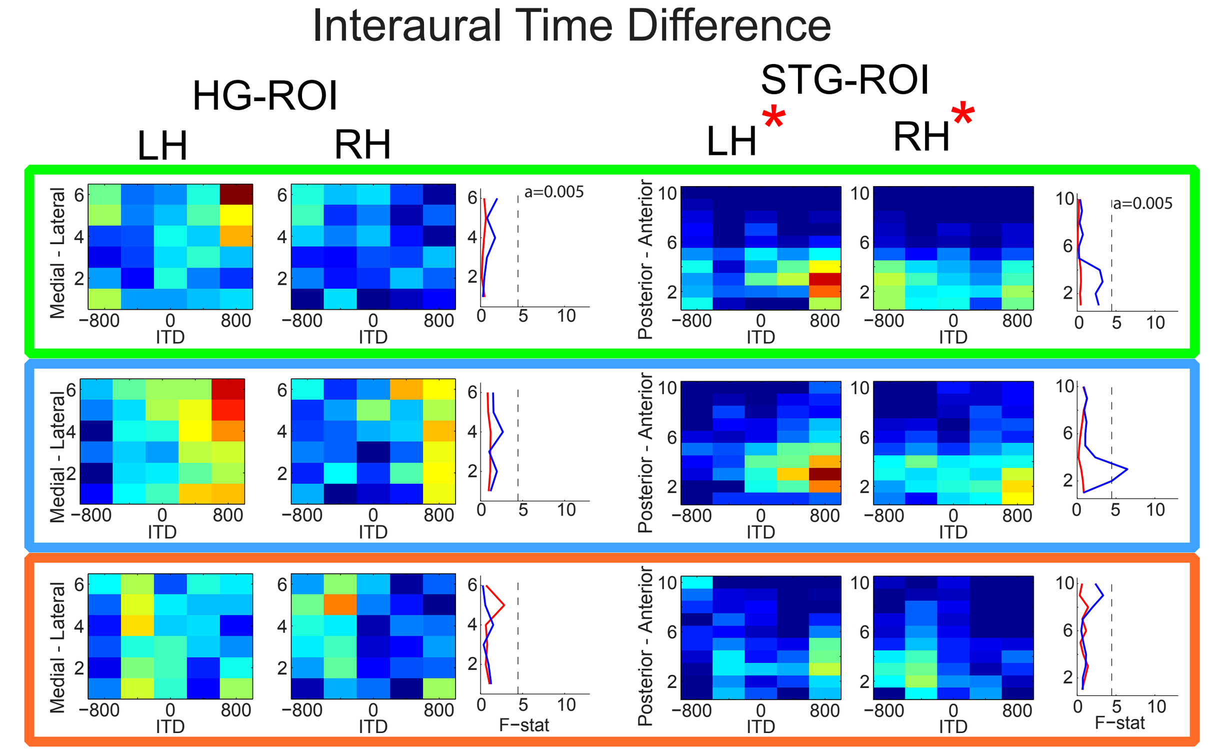
Contralateral bias clearly observed; right hemisphere exhibits stronger response to negative ILD/ITDs, left hemisphere to positive ILD/ITDs

ROI Analysis: mean beta weights calculated for every voxel in each section of the subdivided ROI, and averaged across stimulus condition. Statistical metrics reflect differences across participants.

Interaural Level Difference



Interaural Time Difference



Summary:

Auditory tasks (location and pitch) tend to evoke stronger responses than non-auditory task (visual). This effect is most evident in STG during ITD runs. denote

* p<0.05 (Main effect of task tested with repeated measures ANOVA)

Conclusion

Interaural Level Difference

- increased activation in contralateral auditory cortex
- activation observed along the medial-to-lateral extent of Heschl's Gyrus, and posterior sections of the Superior Temporal Gyrus in both hemispheres
- most dominant in left hemisphere
- engagement in auditory tasks results in minimal effect in Heschl's Gyrus, but increased activation in RH posterior STG

Interaural Time Difference

- whole brain analysis reveals little sensitivity to ITD
- activation pattern within sectioned ROI suggests a small cortical region in posterior STG is most sensitive to ITD
- participant engagement in varying tasks, reveals that the context of an individuals' task-related-attention plays a significant role in cortical processing of ITD cues

References and Acknowledgements

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Desikan et al. (2006), Neuroimage 31; 968-80.
Glover (1999), Neuroimage 9; 416-429.
Lee and Middlebrooks (2011), Nat. Neurosci. 14(1); 108-114
Petkov et al. (2004), Nat. Neurosci. 7(6); 658-663.
Woods et al. (2009),PLoS One 4(4); e5183.

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