The Effect of Task on Localization Cues in Human Auditory Cortex

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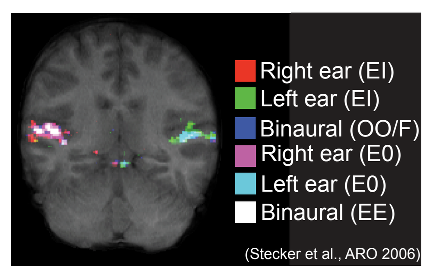
Background

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

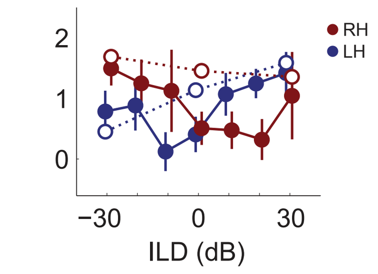
Contralaterality of BOLD fMRI in Human AC is not fully established.

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.

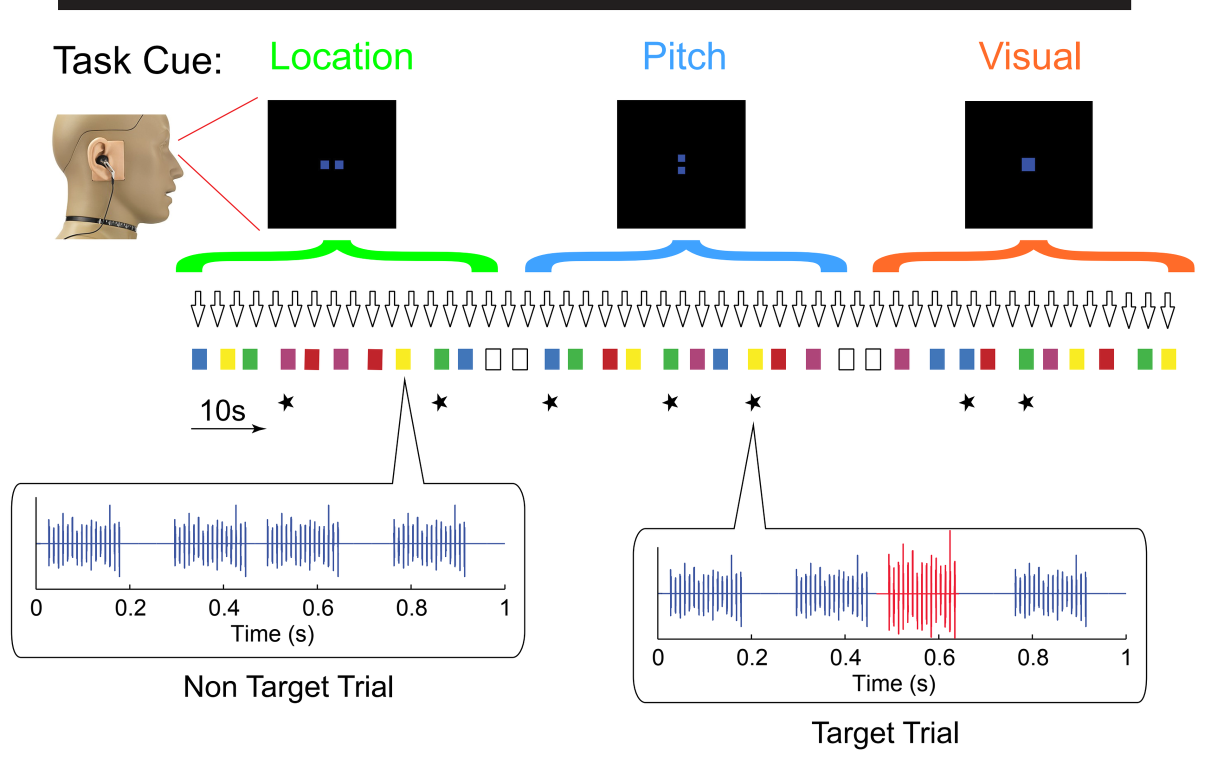


fMRI responses in human AC and inferior colliculus appear dominated by monaural (E0) input. Diotic responses (blue) closely coincide with regions and magnitude of contralateral responses (e.g., red in LH). [Stecker, Rinne, Herron, Liao, Kang, Yund, and Woods, ARO 2006]



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).

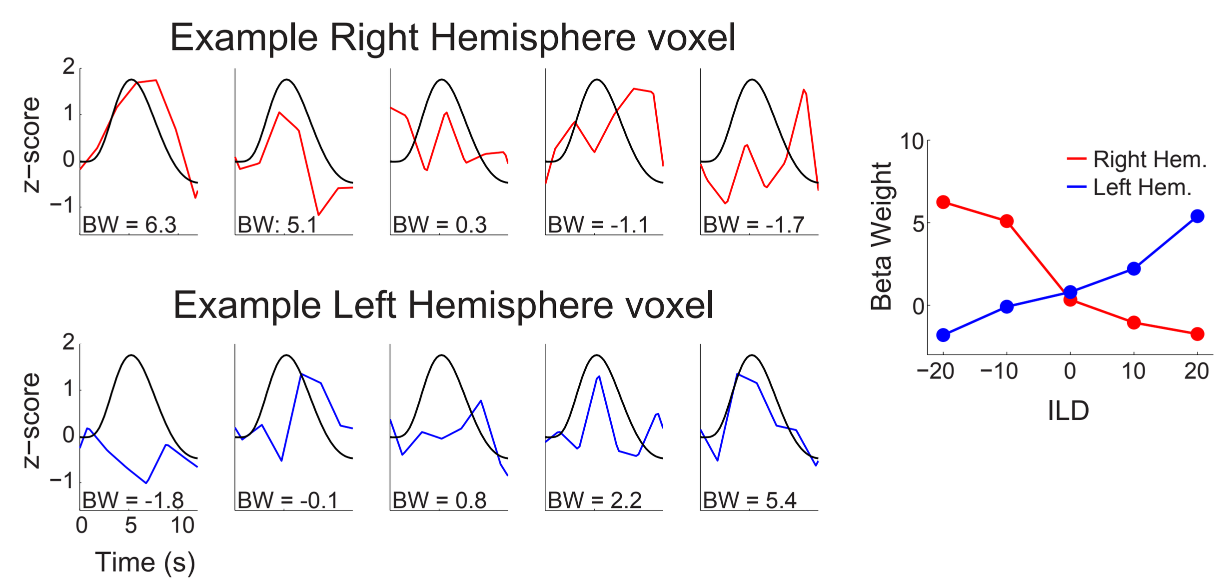
Acoustic Stimuli: trains of 16 white noise bursts, 1 ms burst duration, burst rate = 100 Hz at 90 dBpe SPL. Trains presented in 1 second "trials", each with 4 stimulus intervals. Intertrial interval range from 1-5 s.
- Interaural Level Difference (ILD) [-20, -10, 0, 10, 20 dB] or Interaural Time Difference (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).

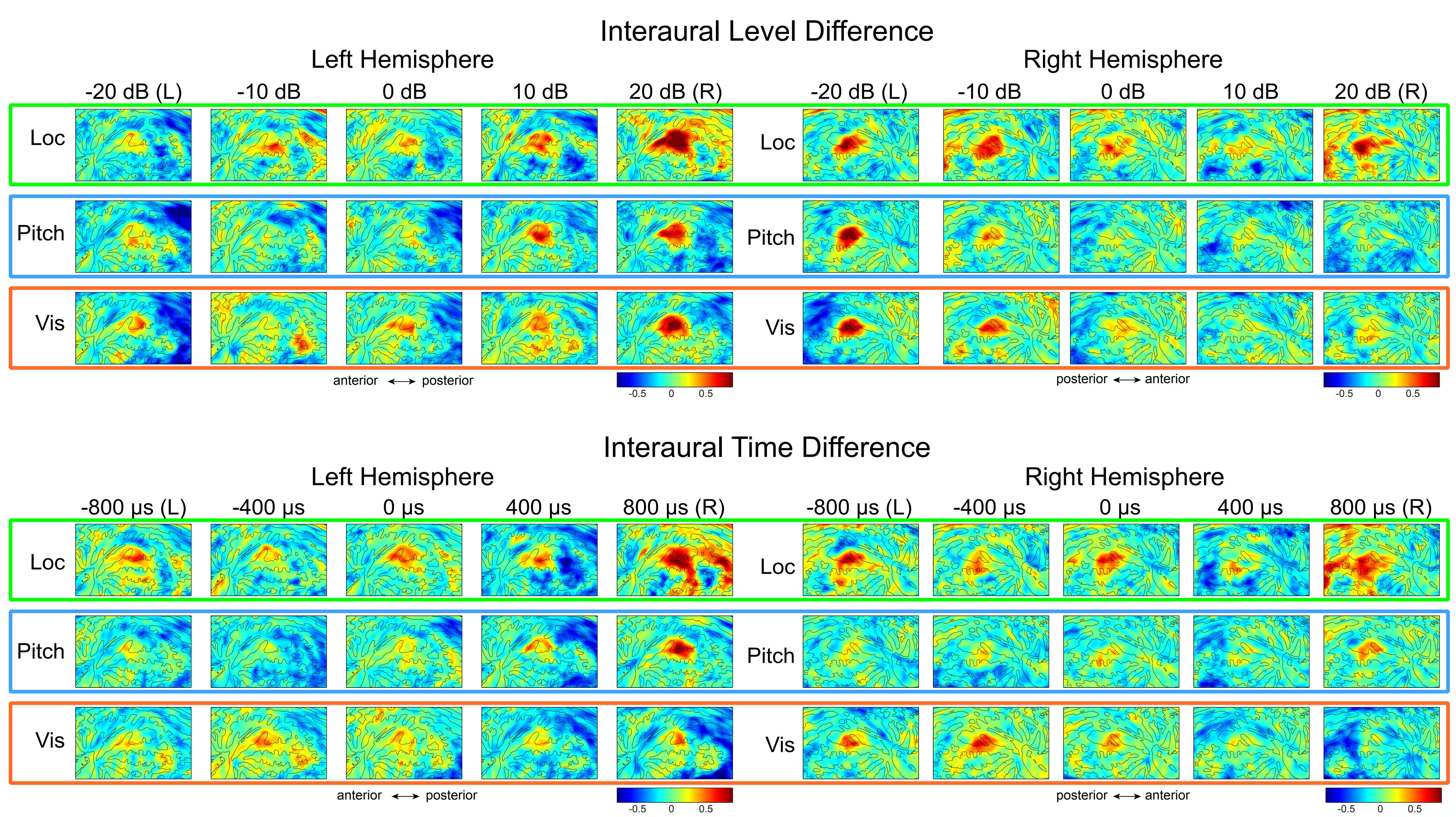
Participants: N=10 total (3 male, 7 female) normal hearing adults (22-35 years), right handed native English speakers.

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 standard HRF.
- The resulting beta weight from the regression analysis quantifies single-trial stimulus-related activation for each voxel.
- Functional data projected to cortical surface using Freesurfer, Desikan-Killiany parcellation.



Cortical Organization of Spatial Cues and Task



Results - Panels Above

- Colors represent mean beta weights (N=10 subj) for five spatial cues across three tasks. White contours reflect anatomical features projected onto surface (Mollweide equal area projection).

Results - Panels Right

- Main effect of spatial cue and task calculated with multifactor repeated-measures ANOVA
- Colors represent F-values corresponding to main effect of indicated factor above statistical significance. Significance determined using random field theory (alpha = 0.01)
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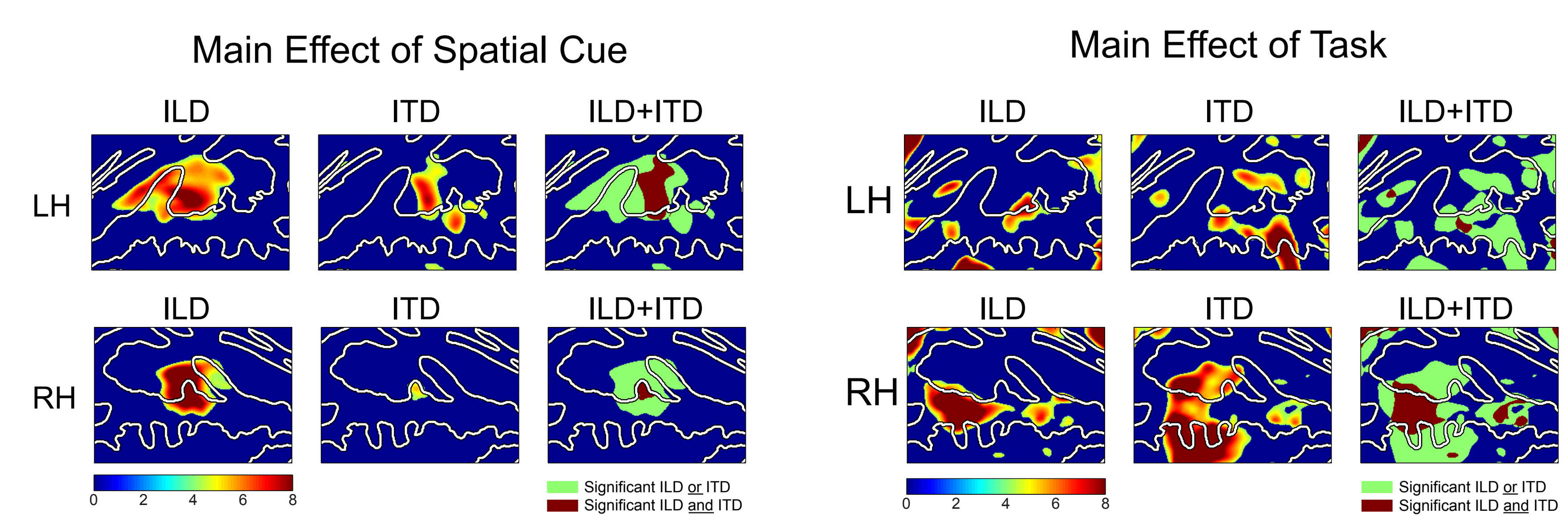
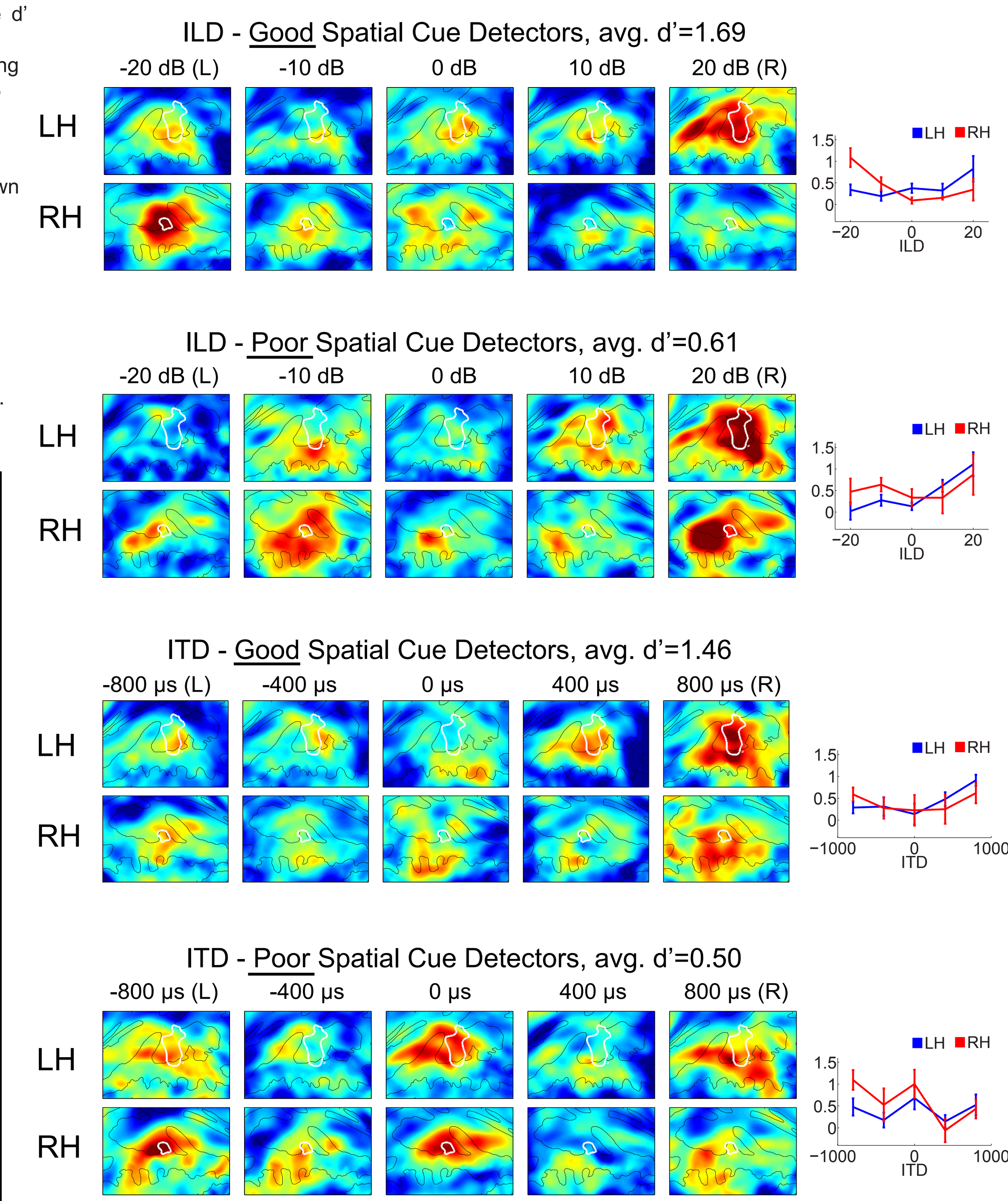


Individual Differences in Spatial Cue Detection

- Hit Rate and False Alarm rate used to calculate d' during location task.
- Participants divided into "good" and "poor" performing groups based on median d' for each spatial cue (N=5 for each group).
- activation for each map measured within the region with significant main effect for both ILD and ITD (brown region indicated below).

Results:

- Good performers exhibit increased activity for contralateral spatial cues.
- Poor performers show high levels of activation at a variety of spatial locations with no discernible pattern.



Conclusion

Spatial Cues

Interaural Level Difference
- Both hemispheres exhibited strong contralateral dominance; greater in LH than RH.
- Right hemisphere activation for both contralateral and ipsilateral ILD values.
- ILD-dependent activation loci consistent with Heschl's Gyrus and posterior sections of Superior Temporal Gyrus

Interaural Time Difference
- Left hemisphere exhibited strong contralateral dominance
- Right hemisphere activation for both large contralateral and ipsilateral ITD values
- ITD-dependent activation loci more limited than for ILD. Specifically, a small cortical region in posterior STG

Task
- Significant main effect of task observed in posterior STG in both hemispheres. Effect is strongest in right hemisphere.
- Suggests behavioral context plays a significant role in cortical processing of spatial cues.

Individual Differences in Spatial Detection

- Good performers exhibit ILD/ITD cortical response functions with dominance by contralateral cues, in a manner consistent with the opponent-channel model.
- Poor performers show increased activity across spatial cue stimulus space, including ipsilateral locations.

References and Acknowledgements

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