The Influence of Feature-Based Task Effects on Binaural Cue Representation in Human Auditory Cortex

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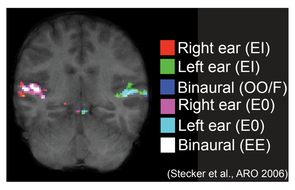
(1) Background

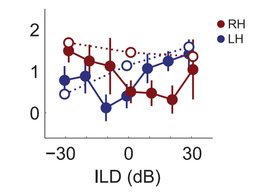
Auditory cortical (AC) neurons typically respond more strongly to contralateral than ipsilateral stimuli. This response pattern is manifested in human fMRI as increased activation in each hemisphere to sound in the contralateral hemifield.

Task engagement and attention to sound shapes responses of cortical neurons in cats (Lee and Middlebrooks, 2011), and modulates auditory activations human (Petkov et al. 2004; Rinne et al. 2012; Woods et al. 2009).

Question: How is cortical activity, in response to spatial cues (interaural time [ITD] and level [ILD] differences), influenced by the context of selective attention modulated by task engagement?

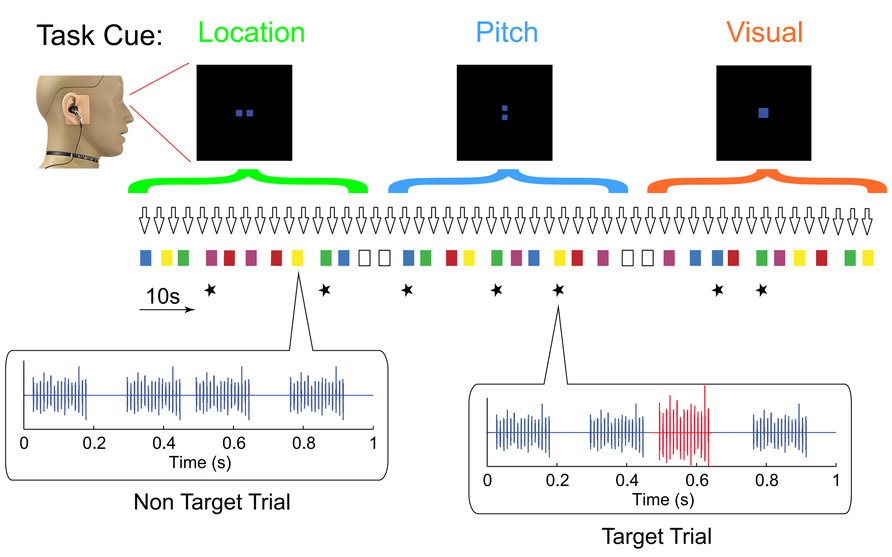


fMRI responses in human AC and inferior colliculus appear dominated by monaural (E0) input. Diotic responses (blue) closely coincide with regions and magnitude of contralateral responses (e.g., red in LH). [Stecker, Rinne, Herron, Liao, Kang, Yund, and Woods, ARO 2006]



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]

(2) 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 carry-over 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.

(3) Results

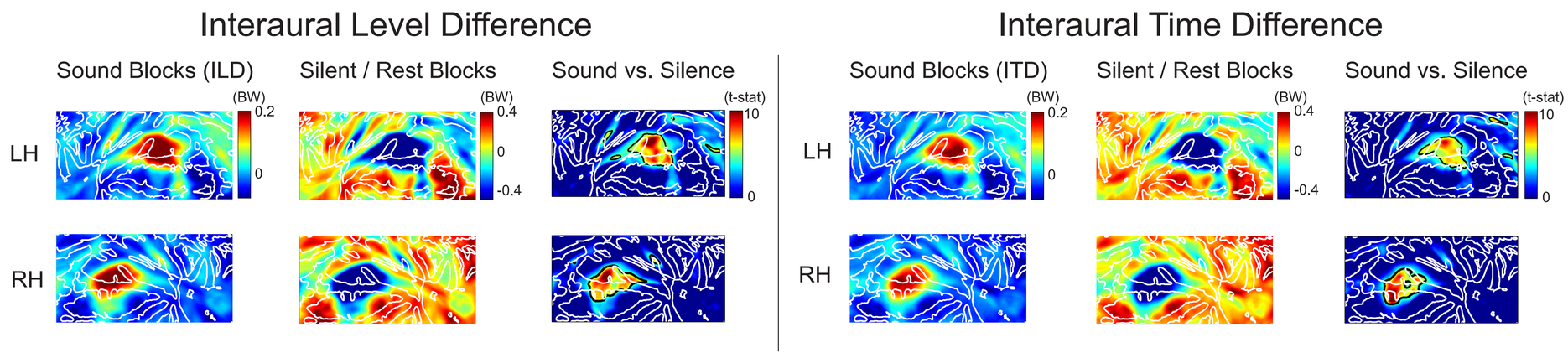
Results - Panel Right

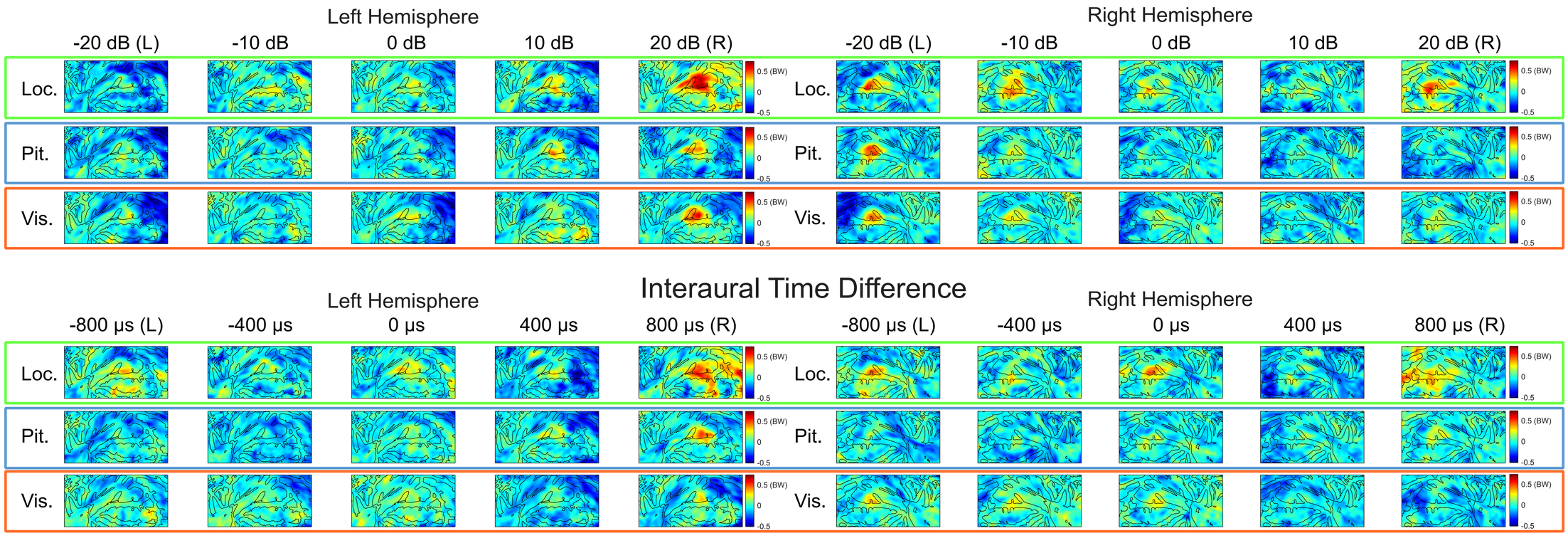
Activation observed in Heschl's Gyrus and posterior Superior Temporal Gyrus in response to blocks of sound (left column) and silence (center column), and comparison of Sound vs. Silence (right column) for left (LH) and right (RH) hemisphere.

- Colors in Sound and Silence figures represent mean beta weights. White contours reflect anatomical features projected onto surface (Mollweide equal area projection).
- Right column represents t-statistic values for sound vs. silence comparison at each point on the map, across subjects. Area of significant difference indicated by black contour (thresholded with FDR q=0.001).

Results - Panel Below

- Beta weights plotted as a function of task, ILD (above) and ITD (below) for both right and left hemisphere.

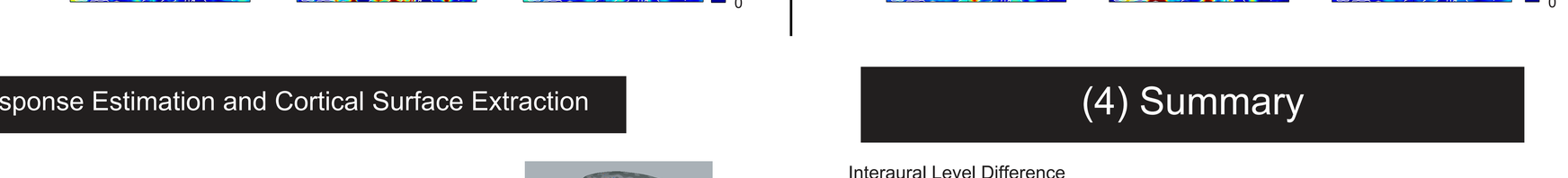




Results - Panel Right

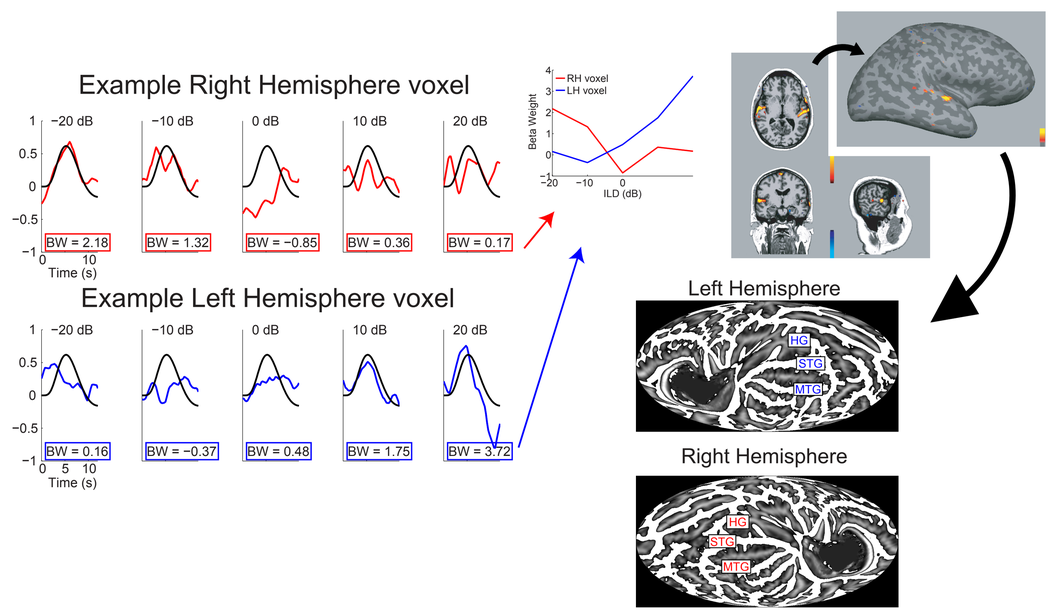
Repeated measures ANOVA with factors of spatial cue (ILD or ITD, separated by vertical line) and task (location, pitch, visual), projected to cortical surface (as above) for left and right hemisphere.

- Colors represent F-statistic for:
  - Main effect of cue (left column)
  - Main effect of task (center column)
  - Interaction of cue X task (right column)



Methods: Voxel-based Response Estimation and Cortical Surface Extraction

- 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
- Cortical surface extraction and surface based smoothing (10 mm FWHM) using Freesurfer and projected to equal area (Mollweide) map.



(4) Summary

Interaural Level Difference
- Both hemispheres exhibited strong contralateral dominance
  - greater in LH than RH
- ILD-dependent activation loci consistent with:
  - Heschl's Gyrus
  - posterior sections of Superior Temporal Gyrus
- Task Effects:
  - minimal in Heschl's Gyrus
  - increased activation in RH posterior STG during auditory tasks

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
  - a small cortical region in posterior STG
  - a subregion of sound and ILD-sensitive areas
- Strong task effects for ITD
  - suggests a significant role of behavioral context in cortical processing of ITD cues

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.
Rinne et al. (2012), Neuroimage; 59: 4126-4131
Woods et al. (2009),PLoS One 4(4); e5183.

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