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Binaural sensitivity in human auditory cortex: analyzing the time course and spatial pattern of activity in fMRI

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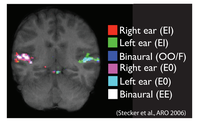
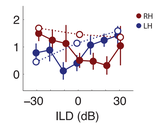
Background

Binaurally tuned auditory cortical (AC) neurons prefer contralateral stimulation
Contralaterality of BOLD fMRI in Human AC is not fully established

Goal: to understand the role of binaural and monaural sensitivity in shaping spatial tuning of AC BOLD response



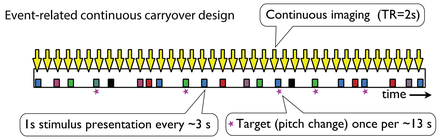
fMRI responses in human AC and inferior colliculus appear dominated by monaural (E0) input. Diotic responses (blue) closely coincide with regions and magnitude of contralateral responses (e.g., red in LH). [Stecker, Rinne, Herron, Liao, Kang, Yund, and Woods, ARO 2006]



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]

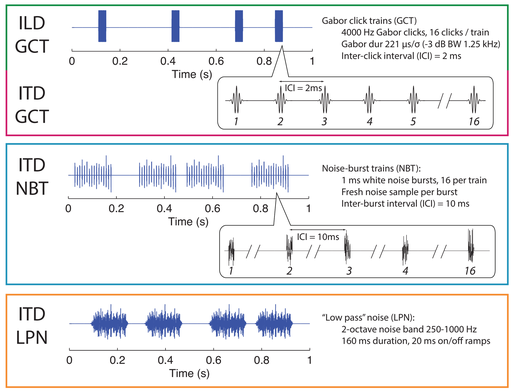
Methods

Event-related continuous carryover design



10 normal-hearing subjects per condition (18-35 yo, right handed)
Stimuli presented via piezo insert earphones (Sensimetrics S14) in ear defenders
Task: press button in response to infrequent pitch change

Stimulus conditions tested in 4 separate experiments:

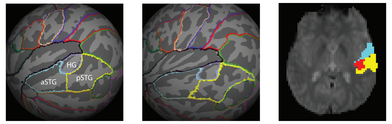


Imaging methods

Echo-planar imaging at 3T (Philips), TR=2s, 42 3-mm slices, 2.75 x 2.75-mm in-plane resolution
Pre-processing: motion correction, .01 Hz high pass filtering, no smoothing
ICA-based denoising in MELODIC (FSL)
ROI-based univariate analysis in FEAT (FSL); timecourse, multivoxel analysis in MATLAB

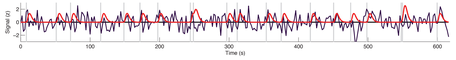
Regions of interest (ROI) defined using Freesurfer following Desikan et al. (2006, Neuroimage 31:968-80)
HG: Heschl's gyrus (red)
aSTG: Anterior half of Superiror Temporal Gyrus, excluding HG (cyan)
pSTG: Posterior half of Superior Temporal Gyrus excluding HG (yellow)

ROIs defined on average cortical surface | Transformed to individual subject's cortical surface | Mapped to 3D coordinates for each functional scan



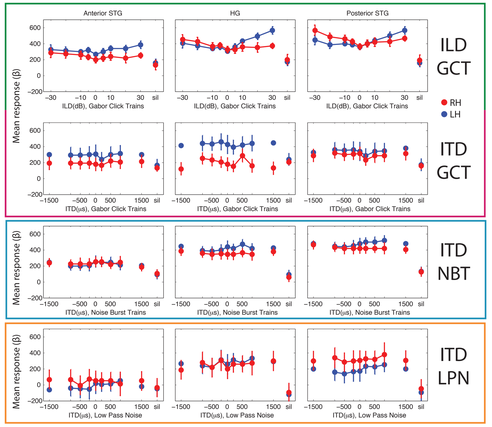
Univariate analysis

fMRI waveform should correlate to timing of preferred stimuli



Voxelwise general linear model (GLM) implemented in FSL
Predictors were stimulus type (9 binaural cue values + silence), target, and response to target
Predictor timecourse convolved with standard hemodyamic response function (HRF, red) before regression
Beta weights averaged across sound-responsive (z>2.3, uncorr) voxels in each ROI

Results: clear tuning to ILD, not for ITD regardless of stimulus



Tuning functions plot mean response (beta weight) +/- s.e.m. across subjects for each stimulus value.

Summary

AC BOLD shows tuning... to ILD, but not ITD?

Is it the stimulus? ← Probably not.

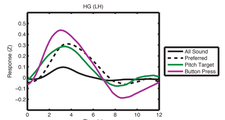
Is it the timing of AC BOLD response? No. →

Is it the spatial scale of response patterns? Possibly. → →

Is it the task listeners engage in? ↓

Future directions

Effects of stimulus history?
(See talk #893, Tues PM)
Classification of multi-voxel patterns
Task / attention effects?

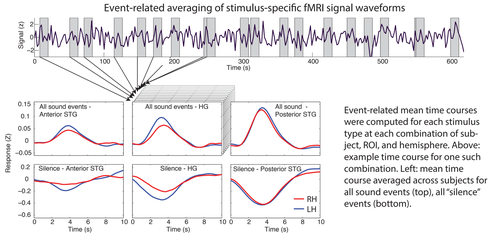


Greater amplitude of BOLD response to sound targets (green) or behavioral responses (violet) than to sound overall (black) suggests influence of attended stimuli. Preferred stimuli (+30 dB ILD, dashed) similar to targets.

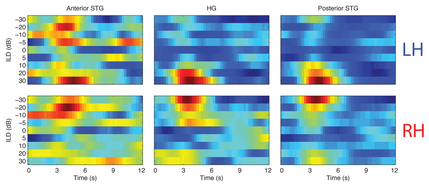
Time-course analysis

Preferred stimuli should invoke stereotypical response waveforms

Event-related averaging of stimulus-specific fMRI signal waveforms



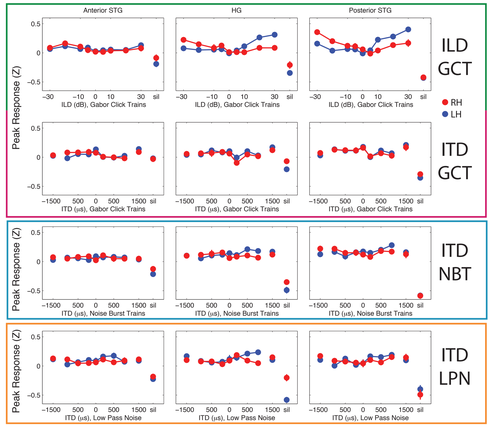
Event-related mean time courses were computed for each stimulus type at each combination of subject, ROI, and hemisphere. Above: example time course for one such combination. Left: mean time course averaged across subjects for all sound events (top), all "silence" events (bottom).



Stimulus-specific BOLD timecourse (above) used to quantify peak response occuring 3-9 s post-stimulus.
Upper panels: left hemisphere; lower panels: right hemisphere.

Results: clear tuning to ILD, but not ITD (again)

Lack of ITD tuning seen with univariate analysis was not due to temporal mismatch of HRF

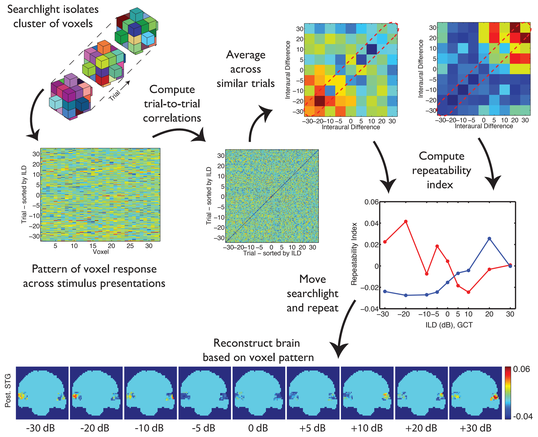


Tuning functions plot mean peak response magnitude +/- s.e.m. across subjects for each stimulus value.

Multi-voxel pattern analysis

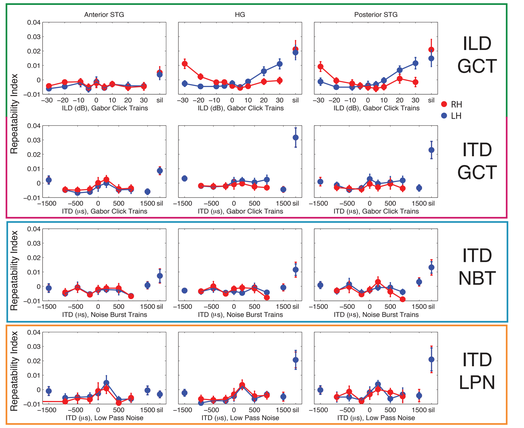
Preferred stimuli should produce stable patterns of response across voxels

Spherical searchlight consists of 33 voxels (6.75 mm radius)
Repeatability Index: voxel pattern correlation for same-same stimuli



Results: repeatable patterns for contralateral ILD and silence

Some indication that near-zero ITD also produce stable patterns



Tuning functions plot mean repeatability index +/- s.e.m. across subjects for each stimulus value.

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