Multi-Voxel Pattern Represenation of Binaural Cues in Human Auditory Cortex

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Background

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Auditory cortex (AC): plays a key role in sound localization.
Responses are sensitive to interaural time and level differences (ITD and ILD).
fMRI: strong contralateral preference to ILD, weak contralateral preference for ITD.
fMRI, MEG, EEG, lesion studies support partially overlapping ITD, ILD representations.

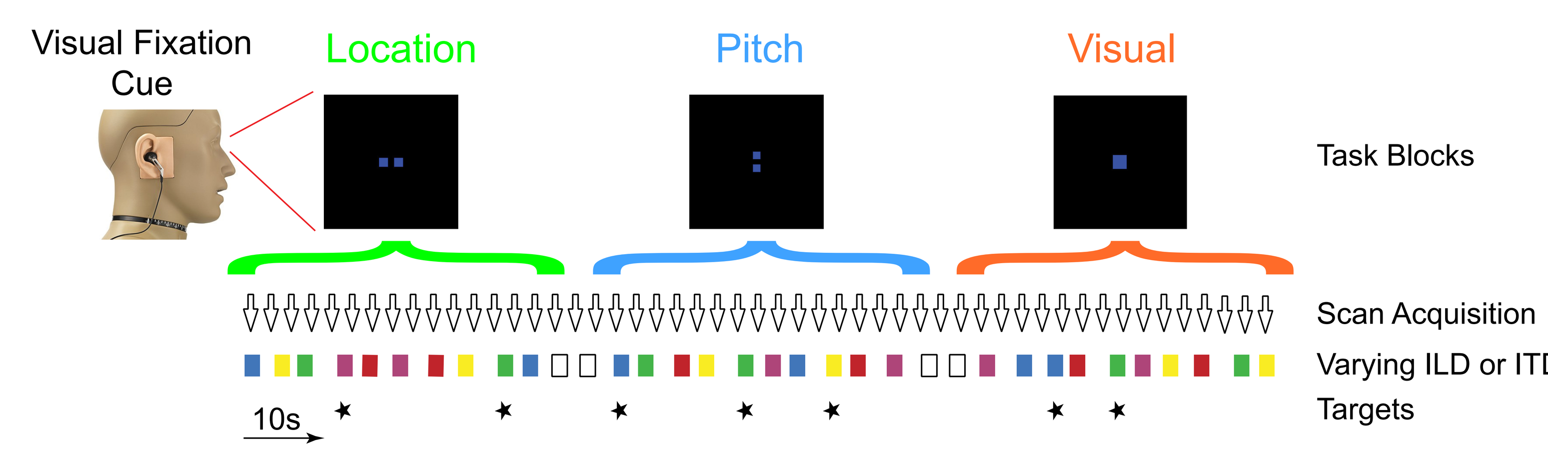
Questions

1. How does task-related attention effect voxel patterns in auditory cortex?
2. Can voxel patterns classify the specific task a listener is performing?
3. Can voxel patterns classify the binaural cue (ILD/ITD) a listener hears?
4. Can ILD voxel patterns classify ITD voxel patterns, and vice versa?

Approach

Multi-voxel pattern analysis (MVPA) using support-vector machines (SVM).
- few assumptions regarding response magnitude.
- consistently weak responses can contribute as much as consistently strong responses.
- allows for functional interpretation of results.

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).

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

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).

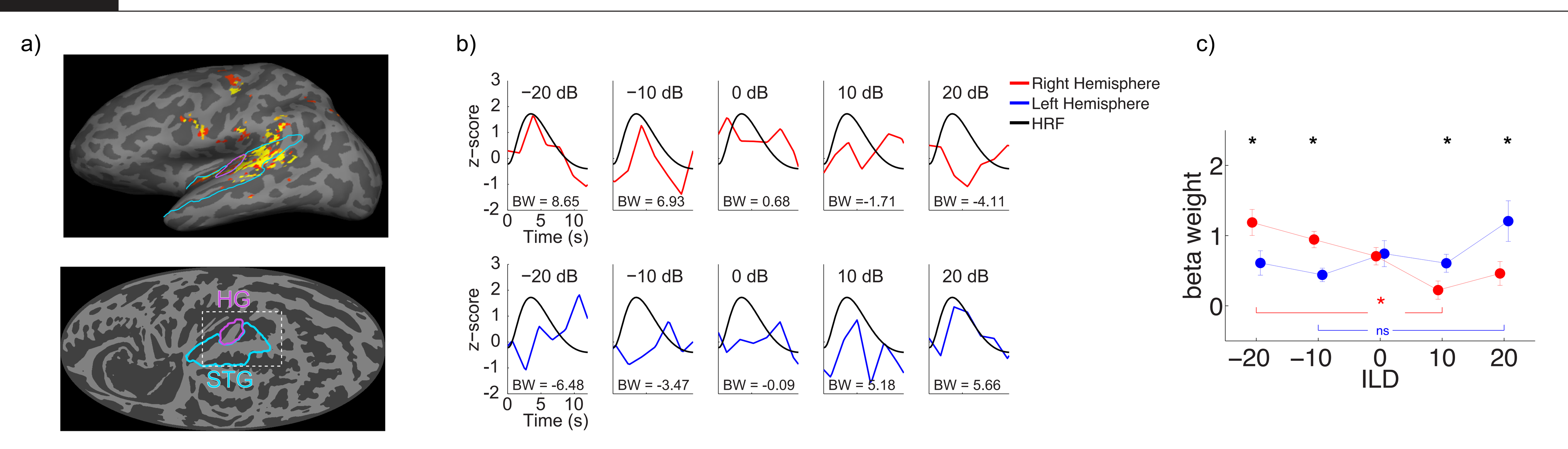
Targets: The 3 target "types" are presented throughout the run regardless of the task cue; participants are instructed to respond only when detecting the specifically cued target.

- 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).

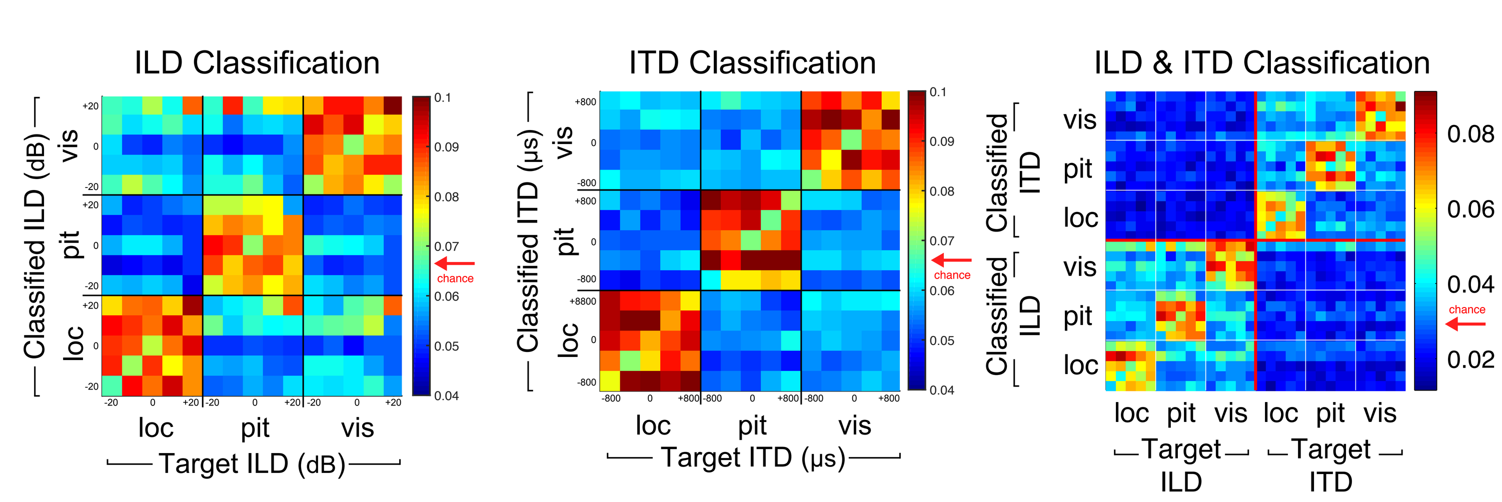
Voxel Based ROI Analysis

Methods

- Standard preprocessing: motion correction, high pass filtering (0.01 Hz), individual subject registration using FSL (a).
- Z-transform the signal timecourse in each voxel; interpolate and extract 12-s response following each trial (b).
- Regress single-trial timecourse with 12-s standardized hemodynamic response function (HRF from Glover 1999) (b).
- Regression (beta) weights quantify single-trial response magnitudes in each voxel (c).
- A region of interest (ROI) defined the auditory cortex (AC) based on Desikan et al. (2006) parcellation of Heschl's Gyrus (HG) and posterior Superior Temporal Gyrus (STG) (a).
- Voxels within ROI define patterns for MVPA with `libsvm` (Chang and Lin 2011).



Multi-Cue, Multi-Task Classification



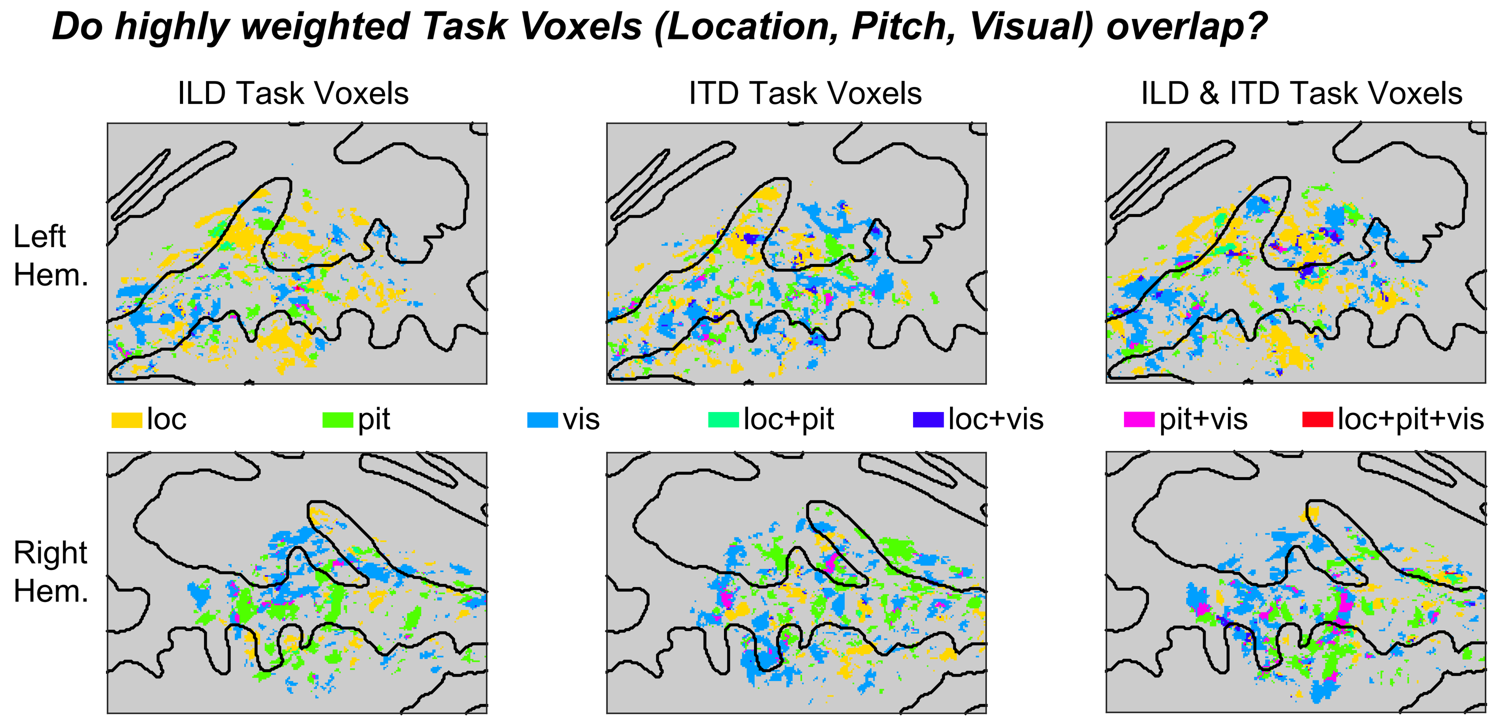
Classification Matrix

- Confusion matrices plot classification probability for each combination of target and classified prediction.
- Classification routine utilizes dataset from combined left and right hemispheres

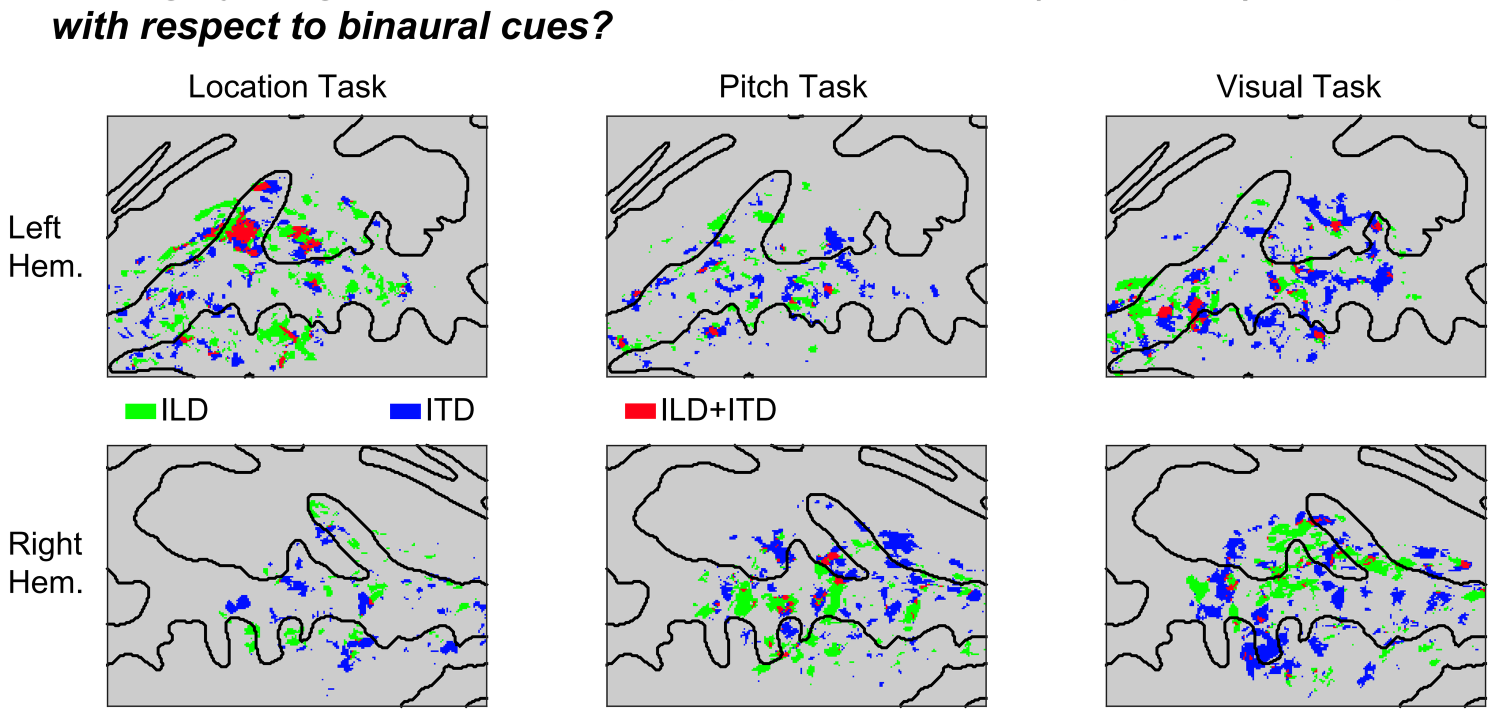
Classification Maps

- Voxels (top 20% per subject) with highest classification weights projected to cortical surface.
- Colored regions indicate overlap of 6+ subject maps.

Do highly weighted Task Voxels (Location, Pitch, Visual) overlap?



Are highly weighted voxels that arespecific to a task (loc, pit, vis), overlap with respect to binaural cues?



Task Results

- Task was reliably classified in both runs (ILD and ITD); different region consistently contributed to classification of each task.
- Location-task classification involved similar regions in ITD, ILD runs; pitch and visual-task classification was less consistent across runs.
- Hemispheric lateralization: LH voxels contributed most to localization-task classification; RH voxels to pitch and visual.

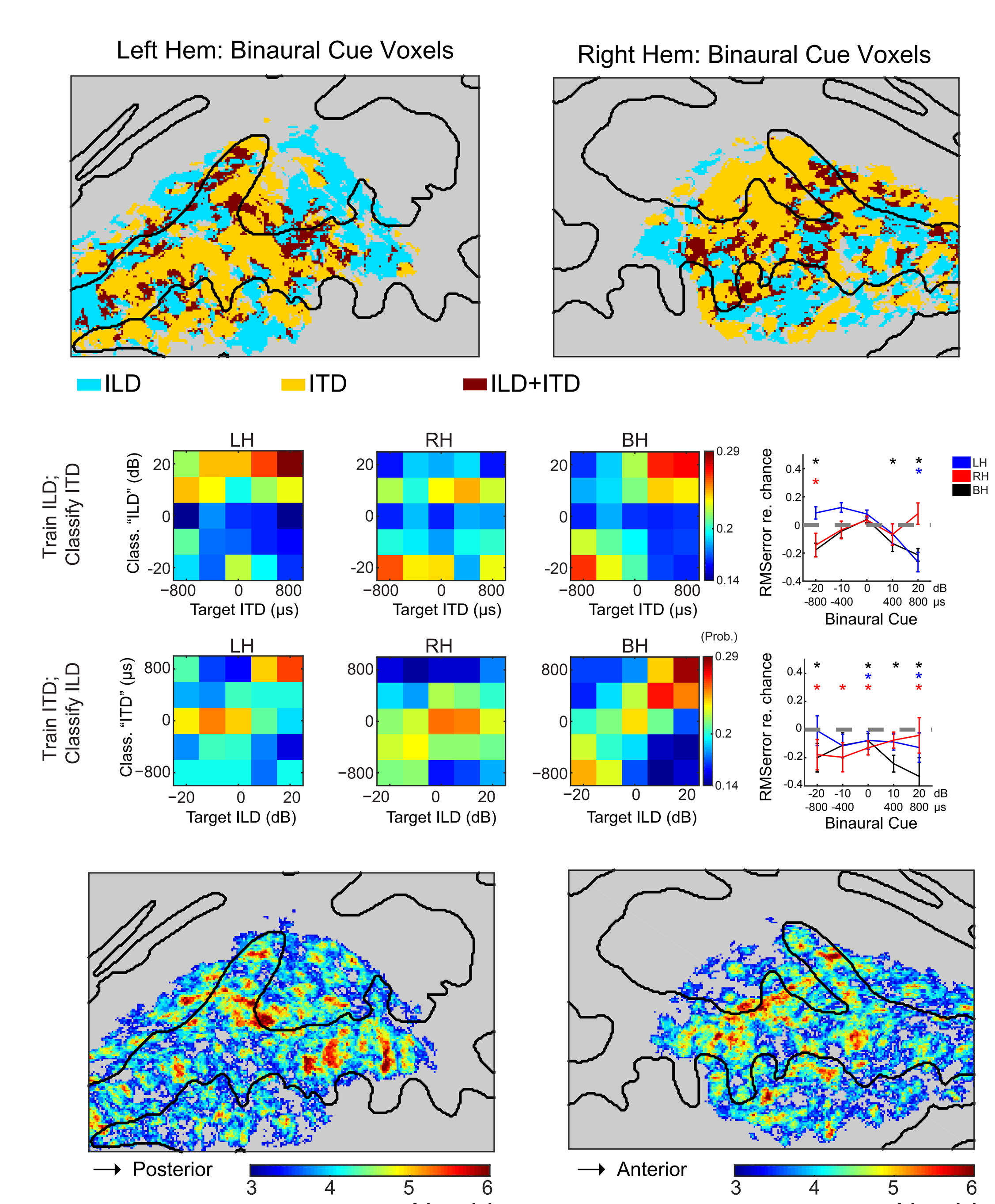
Binaural Cue Classification Results: 2 Approaches

1) Classification weights for ILD and ITD from the full multi-cue, multi-task dataset overlap across subjects in medial HG and posterior STG.
2) Train SVM with one cue (ILD or ITD) and accurately classify the other.
- accurately classify one cue with the other
- highly weighted voxels have a consistent pattern across subjects located in HG and posterior-lateral STG

Conclusions

- Voxels with high classification weights during location, pitch, and visual tasks are non-overlapping in auditory cortex.
- Unique patterns for each task are generally consistent across subject
- Voxel patterns in response to the ILD and ITD stimulus are most consistent during the location task.
- ILD patterns can accurately classify ITD trials, and vice versa.
- Highly weighted voxels for ILD and ITD classification show consistent patterns across subjects.

Binaural Cue Classification



References

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Desikan et al., (2006), Neuroimage 31; 968-80.
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Acknowlegements

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