Multi-voxel pattern analysis of sensitivity to binaural level configuration in human auditory cortex

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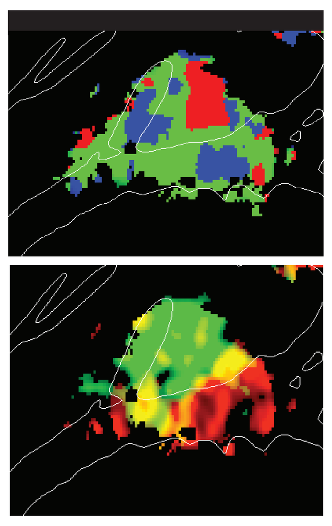
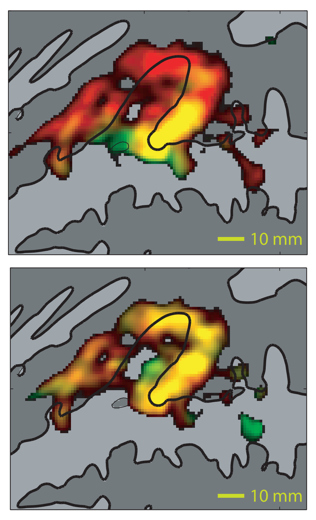
Multiple parametric markers for AC field mapping

Woods et al. (2009)

Tone-frequency mapping
Red: 3600 Hz
Green: 900 Hz
Blue: 225 Hz

Effects of intensity (green)
90 dB SPL > 70 dB SPL
Effects of attention (red)
auditory > visual task
Yellow: overlap





McLaughlin & Stecker (2009)

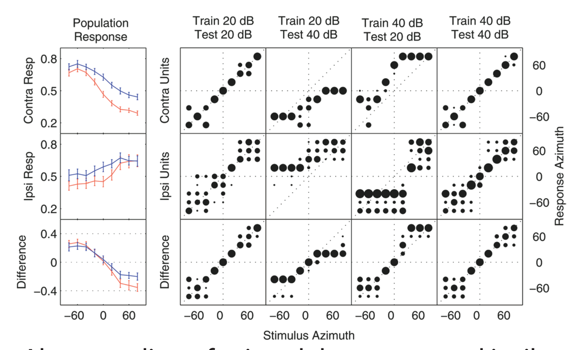
Response to 4000 Hz click trains (red)
Slow rate > fast rate (green)
(5x32 or 40x4 clicks / s)
Yellow: overlap

Contralateral ILD > silence (red)
Ipsilateral ILD > silence (green)
Yellow: overlap

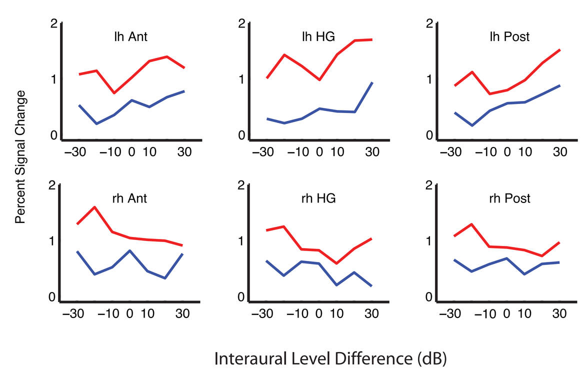
Multivariate detection of population differences in neural and fMRI data

Comparison of response across neural populations with different tuning
- -stable coding over "nuisance" parameters
- -robust detection of sensitivity to primary dimension

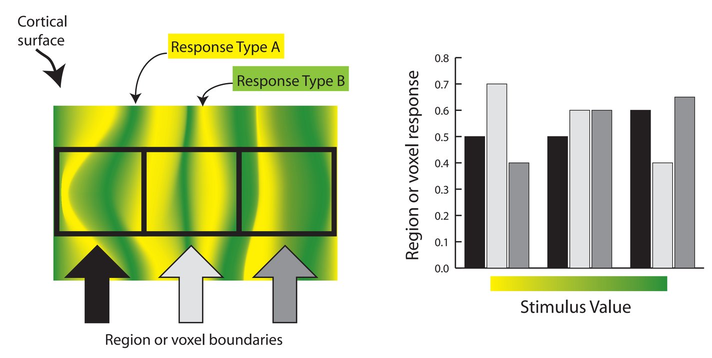
Spatial scale of comparison may be large (hemispheres, cortical fields) or small (cortical columns, fMRI voxels).



Above: coding of azimuth by contra- and ipsilaterally tuned neurons (Stecker et al. 2005).



Above: sensitivity to ILD in three regions of auditory cortex (Anterior, Heschl's Gyrus (HG), Posterior) in each hemisphere. Responses vary between fast (40 x 4-click trains/s, blue) and slow (5 x 32-click trains/s, red) presentation rates. (McLaughlin & Stecker 2009).



Above: use of multi-voxel techniques in fMRI detect stimulus-dependent changes in pattern of activity across voxels. Those changes may reflect cortical organization much smaller than voxel dimensions (e.g., cortical columns: Kamitani & Tong 2005, Haynes & Rees 2005).

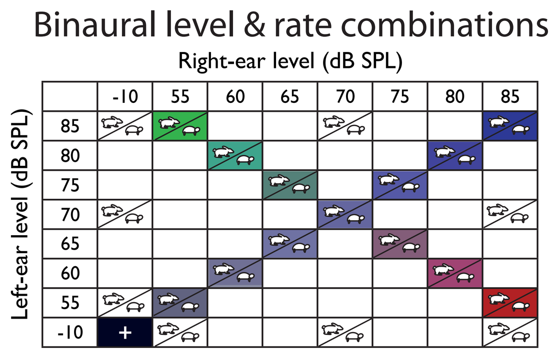
Methods

Stimulus presentation

- -Gabor click trains (4 or 32 clicks/train)
- -4000 Hz carrier, 3 ms ICI
- -Train rate: 40x4 (fast) or 5x32 (slow) trains/s
- -Random inter-train gap (0-30 ms or 0-200 ms)
- -Average binaural level (ABL) 55-85 dB SPL
- -Interaural level difference (ILD) range +/-30 dB

-Presented via piezoelectric inserts (Sensimetrics, Malden MA) in ear defenders

Binaural level & rate combinations



Binaural level combinations tested. Parametric ABL (blue) and ILD (green to red) values presented at slow and fast rates (tortoise/hare). Cross: "silent" block (-10 dB SPL).

Imaging methods

- -BOLD echoplanar imaging (3T, 3x3x4.5mm, 32 slices)
- -Block design (ILD x ABL x Rate), "sparse" (TR=12s)
  - -Every 4th block "silent" (-10 dB SPL)

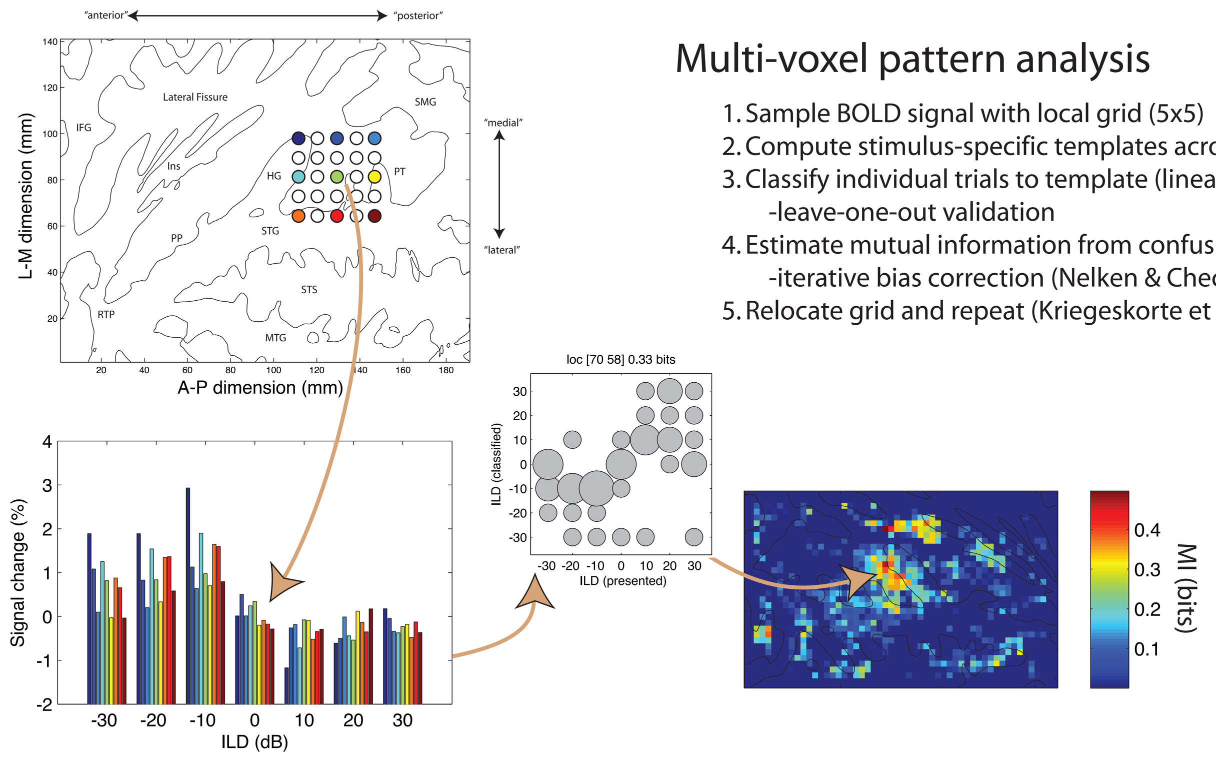
-Task: detect rare pitch change (2 ms ICI)

Image processing

- -Anatomical space analysis (Kang et al. 2007)
  - -Initial resample 3D functional to 1x1x1 mm
- -Extraction to cortical surface (1x1 mm projection)
- -Individual-subject analyses

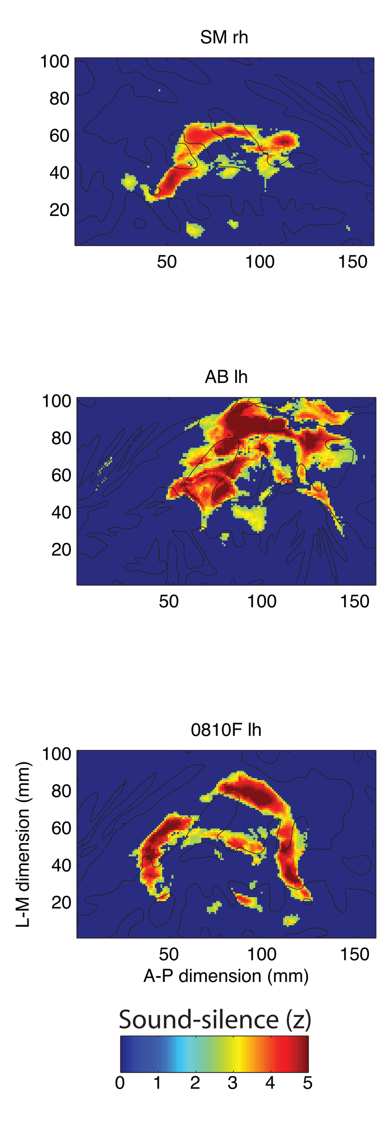
Multi-voxel pattern analysis

1. Sample BOLD signal with local grid (5x5)
2. Compute stimulus-specific templates across grid
3. Classify individual trials to template (linear)
   - -leave-one-out validation
4. Estimate mutual information from confusion data
   - -iterative bias correction (Nelken & Chechik 2007)
5. Relocate grid and repeat (Kriegeskorte et al. 2006)

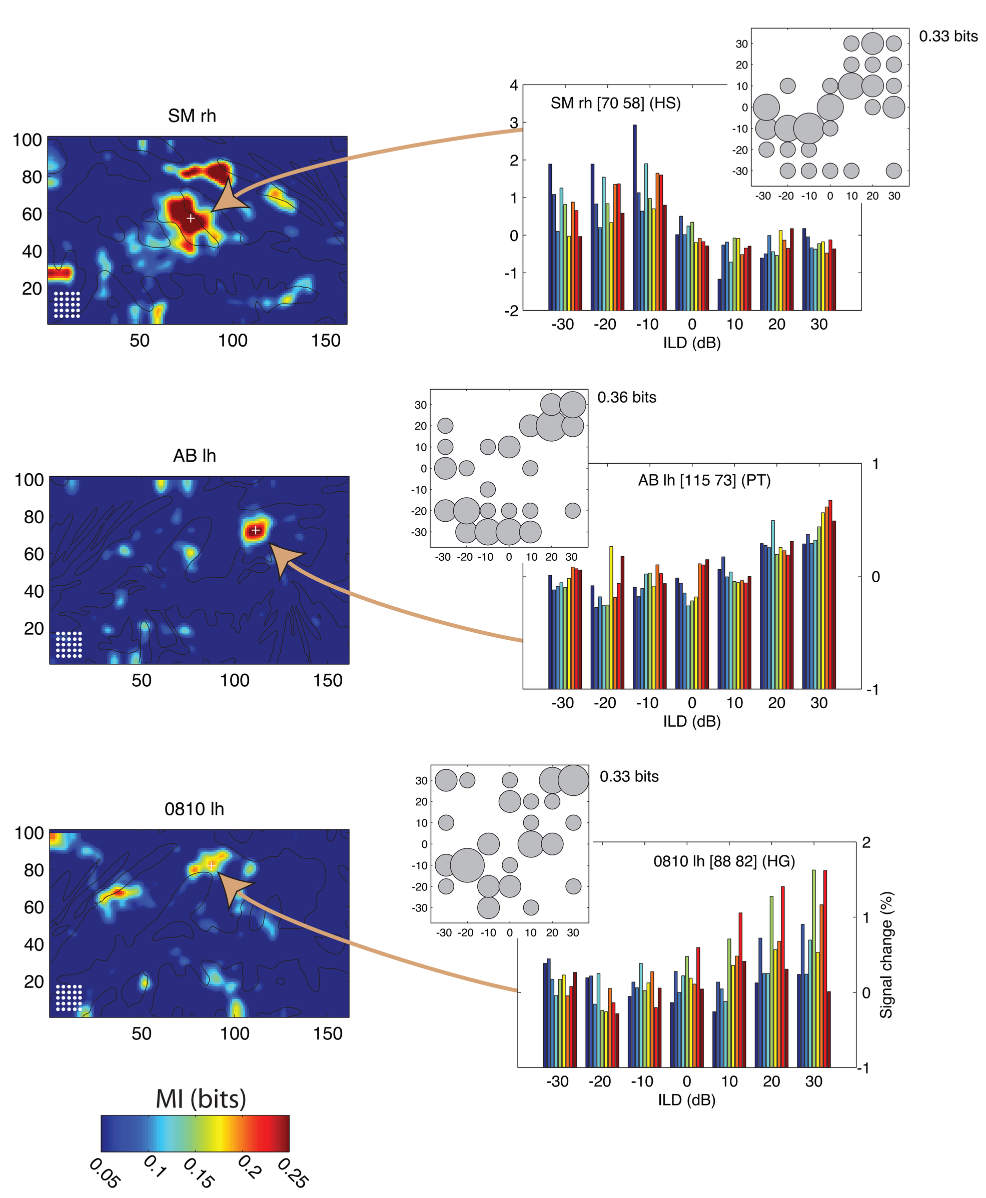


Results

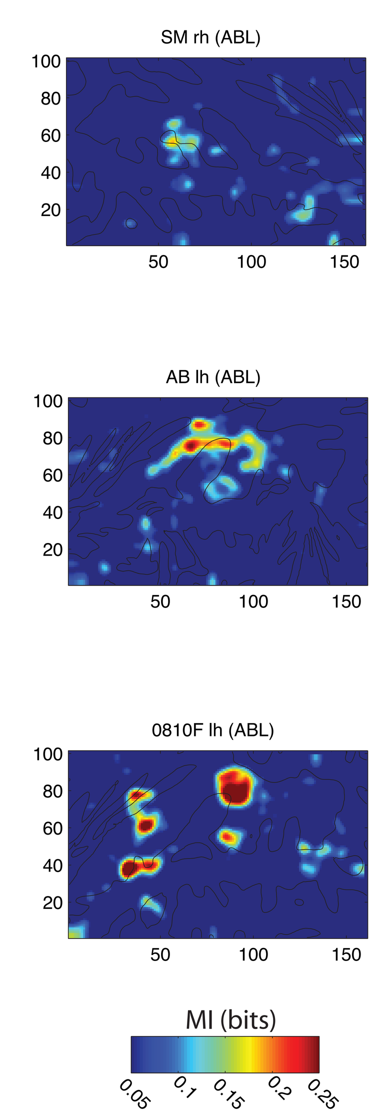
Response to sound



Interaural-level classification



Intensity classification



Example individual-subject data, selected hemispheres. Left: plots of sound-related BOLD change (z-score, p<.01 thresholded) versus silent blocks. Center: plots of bias-corrected mutual information (MI) for classification of ILD. MI maps smoothed (2D Gaussian, 6mm FWHM) for display. Bars plot mean response in individual voxels (colored bars) within local grid centered on indicated point, as a function of parametrically varied ILD (x-axis of bar plot). Inset shows confusion matrix summarizing classifier performance (linear classifier using 5x5 point templates). Right: plots of bias-corrected MI for classification of average binaural level (ABL).

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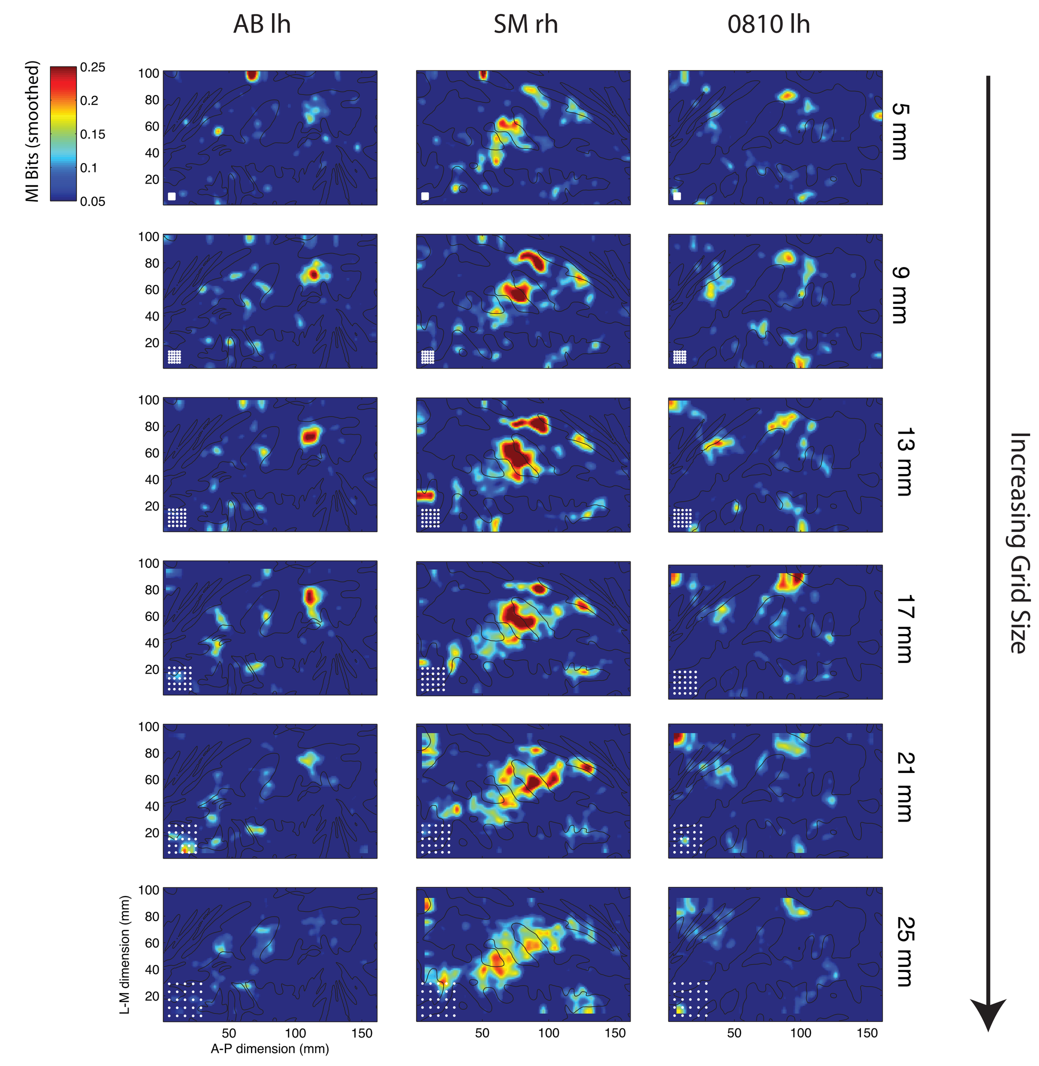
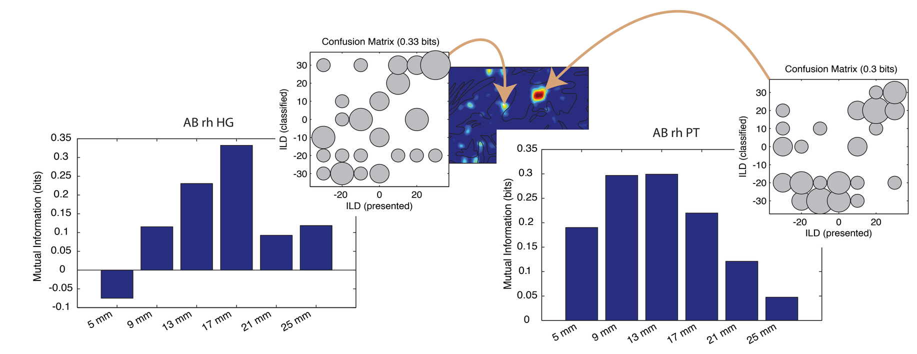
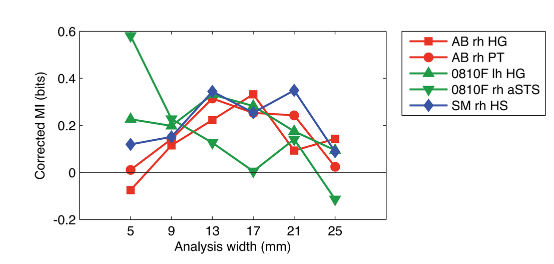
Spatial scale of the analysis

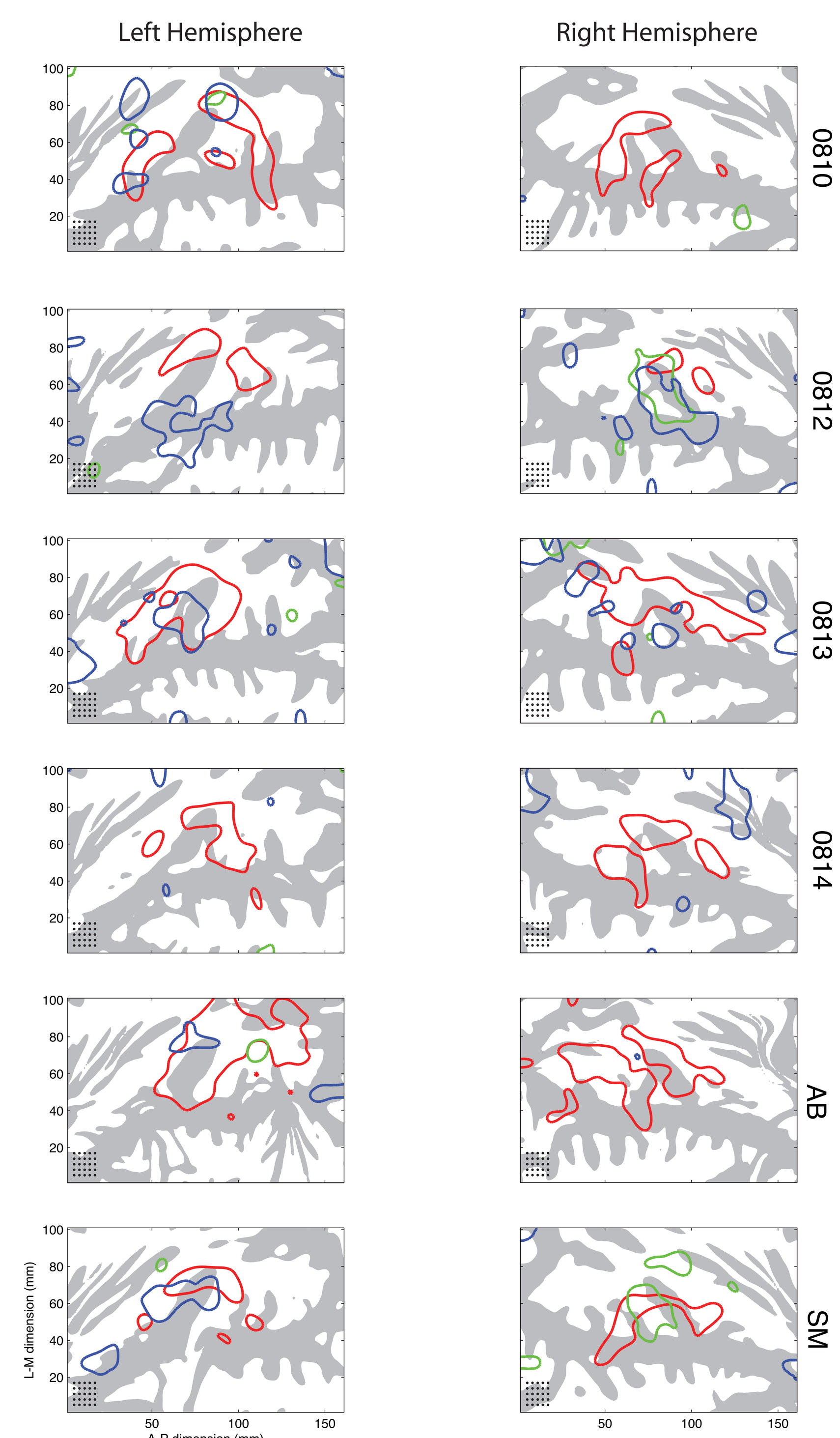




Upper plots: bias-corrected MI for ILD classification as a function of grid size (shown in lower left of each plot) from 5x5mm (top) to 25x25mm (bottom). Grid samples 5x5 points in each case. Middle bar plots indicate MI trend with grid size for two loci in one example hemisphere (AB lh). Right: MI trend for additional example loci.



Comparison across subjects



Contour plots depicting regions of sound-related response (p < .01, red), ILD-related information (MI > .15 bits, green), and ABL-related information (MI > .15 bits, blue) in both hemispheres (columns) of individual subjects (rows). Maps smoothed (2D Gaussian, 9 mm FWHM) prior to contour estimation. Note that regions of best ILD & ABL classification do not necessarily overlap the area of sound-evoked response.

Directions

- More data for classification
  - -Stable templates
  - -Cross-validation
  - -Comparison across runs
- Imaging parameters
  - -Increase functional resolution
  - -BOLD time course
- Classifier selection
  - -Grid seleciton
  - -Classifier algorithm/distance metric

References

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Acknowledgements

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