467 Effects of Continuous Broadband Noise on Tone-Evoked Activations in Human Auditory Cortex

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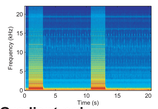
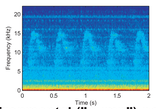
Background: the problem of acoustic noise in fMRI

Uncontrolled acoustic noise presents a major challenge to auditory fMRI. Although intense scanner noise can be minimized through sparse imaging procedures and passive attenuation, some residual environmental noise (e.g., "pump noise") remains audible. Pump noise varies acoustically from scanner to scanner, complicating between-study comparisons, and its spectrotemporal complexity may interfere with activations caused by complex acoustic stimuli. A potential means for controlling the effects of pump noise is to present sounds mixed with a low-level continuous broadband masking noise. Here we examine the effects of such maskers on tone-evoked BOLD fMRI activations in human auditory cortex.

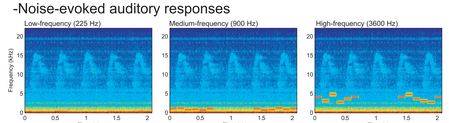


Gradient noise
- -During image acquisition
- -Intense (>100 dB SPL)
- -Sparse imaging



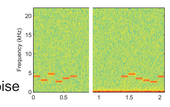
Environmental ("pump") noise
- -Coolant pump & support equipment
- -65-70 dB SPL
- -Intense low-frequency content
- -Spectrotemporally complex high-frequency content

Concerns
- -Energetic and/or informational masking
- -Noise-evoked auditory responses



Acoustic effects of pump noise on tone sequences of 225 (left), 900 (middle), and 3600 (right) Hz mean frequency.

Approaches
- -Attenuation
  - -Headphones / Earplugs
- -Regularization of environment with low-level broadband (BB) noise

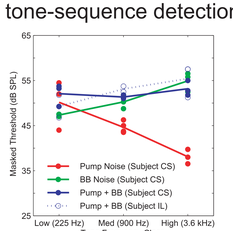


Acoustic effects of broadband noise on tones presented in silence (left) or pump noise (right).

The question:

How does continuous broadband (masking) noise affect tone-evoked activations observed in auditory fMRI?

Effects of pump noise and broadband noise on tone-sequence detection

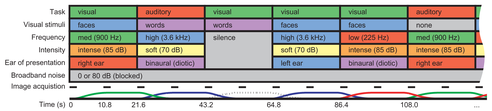


At 80 dB SPL broadband noise level:

- -Masking is dominated by broadband, not pump, noise
- -Thresholds similar across frequency ~55 dB SPL

Thresholds for detection of tone sequences (see right) masked by pump noise (red), broadband (BB) noise (green), or both (blue). Pump noise was recorded in the scanner using a B&K head and torso simulator, and presented over headphones at 70 dB SPL. Broadband noise was presented at 80 dB SPL with zero interaural correlation. Threshold values (symbols) are averages of reversals 4-7 in a 1 up / 2 down adaptive 2I2AFC procedure. Lines represent mean across runs at each combination of masker type and tone frequency.

Methods: a factorial design for mapping auditory cortex

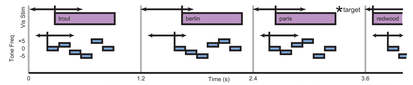


- -Factors vary pseudorandomly by 21.6-s blocks, balanced over run

Task: visual (green) / auditory (red)	Visual Stim: faces (blue) / words (red)
Frequency: L (red) / M (green) / H (blue)	Intensity: soft (yellow) / intense (orange)
Ear: R (red) / L (blue) / diotic (violet)	

- -Continuous broadband noise (80 dB SPL) presented on alternating runs
- -Curves plot hypothetical BOLD response for frequency (r/g/b) and silence (dotted).

Stimuli
- -Auditory: 6-tone sequences
  - -Mean frequency: 225 Hz (Low), 900 Hz (Med), 3600 Hz (High)
  - -Individual 120-ms tones: -5, -2.5, 0, +2.5, +5 semitones
  - -Level: 70 dB (Soft) or 85 dB (Intense) SPL
- -Visual: typewritten words or faces

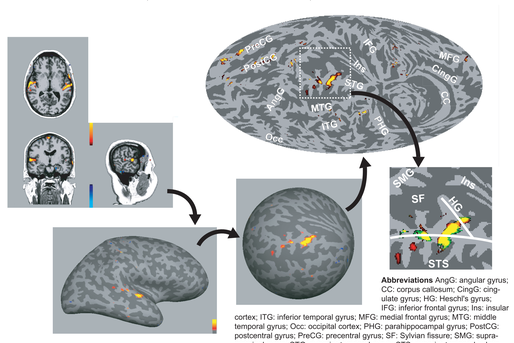


Time-course of 3 trials (visual words task). Stimulus onsets jittered by +/- 500 (visual) or +/- 300 (auditory) ms within each 1.2-s trial. Individual tone frequencies vary by +/- 5 semitones. Visual target: one-back semantic category match.

Task (cued auditory or visual)
- -Visual: one-back category or face match (across exemplars)
- -Auditory: one-back tone-sequence match

Methods: 2-D projection of auditory cortical activation

Imaging parameters
- -Sparse echo-planar imaging, TR=10.8 s, TE=40 ms, at 1.5 Tesla
- -Whole-brain acquisition, 24 slices (5mm + 1mm gap)
- -128 x 128 voxels (1.8 x 1.8 x 6.0 mm resolution)

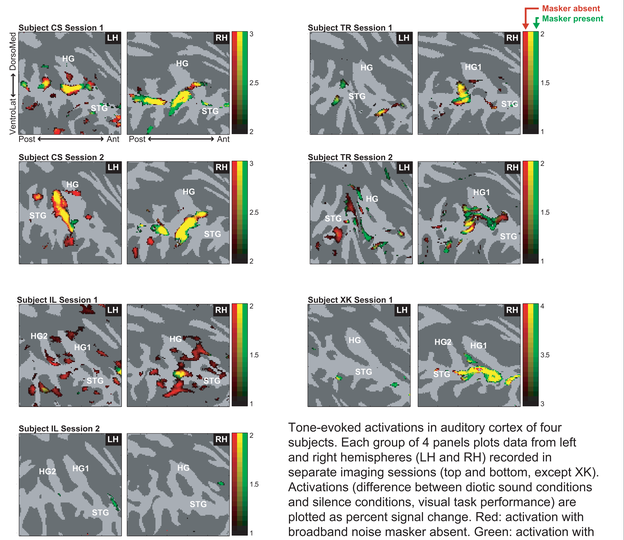


Abbreviations AngG: angular gyrus; CC: corpus callosum; CingG: cingulate gyrus; HG: Heschl's gyrus; IFG: inferior frontal gyrus; Ins: insular cortex; ITG: inferior temporal gyrus; MFG: medial frontal gyrus; MTG: middle temporal gyrus; Occ: occipital cortex; PHG: parahippocampal gyrus; PostCG: postcentral gyrus; PreCG: precentral gyrus; SF: Sylvian fissure; SMG: supramarginal gyrus; STG: superior temporal gyrus; STS: superior temporal sulcus

Data Analysis
- -Cortical surface extraction (using Freesurfer) to spherical coordinates
- -Visualization of entire hemisphere using equal-area Mollweide projection
- -Extraction of region of superior temporal and Heschl's gyri (STG & HG)
  - -Left hemisphere reflected to match right hemisphere display
- -Within-subjects comparison between conditions
- -Visual task performance; percent signal increase for sound above silent baseline

1. Tone-evoked activations are similar with, without continuous noise

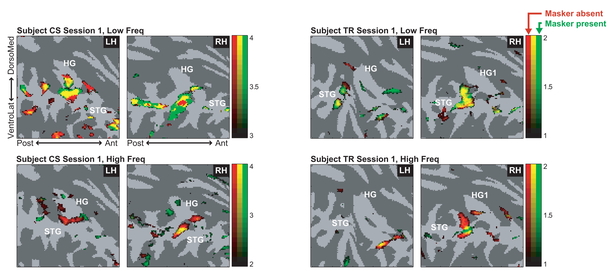
- -Activations (averaged across frequency & intensity) overlap substantially
- -Some regional and individual differences



Tone-evoked activations in auditory cortex of four subjects. Each group of 4 panels plots data from left and right hemispheres (LH and RH) recorded in separate imaging sessions (top and bottom, except XK). Activations (difference between diotic sound conditions and silence conditions, visual task performance) are plotted as percent signal change. Red: activation with broadband noise masker absent. Green: activation with masker present. Yellow (red+green mixture): activation in both conditions.

2. Noise has largest effect on responses to high-frequency tones

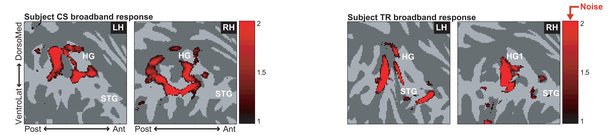
- -Low-frequency activations maintained with broadand noise
- -High-frequency activations substantially reduced in some regions
- -Upward spread of masking? (But masked thresholds were roughly equated)
- -Threshold increase due to adaptation (sharper apparent tuning)?



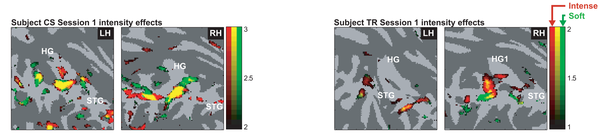
Tone-evoked activations in auditory cortex of two subjects. Top and bottom panels plot activations recorded during low (225 Hz) and high (3600 Hz) frequency diotic stimulation, respectively. Otherwise, plotting conventions follow figures above. Extensive red regions in lower panels indicate responses evoked by high-frequency tones but reduced by masking noise.

3. Differential sensitivity of regional activations to stimulus features

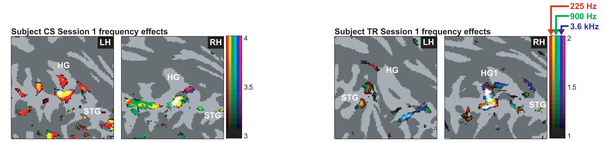
Goal of identifying cortical regions by functional characteristics
- -Sensitvity to stimulus parameters, attentional modulation, etc.
- -Individual subjects, repeated sessions, factorial designs



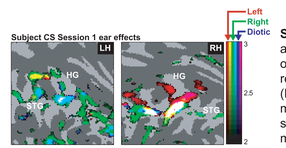
Broadband response in two subjects (separate imaging session). Stimuli were diotic ~90 dB SPL iterated-rippled-noise (IRN) melodies (as used by Griffiths et. al. 2001, Nat Neurosci 4:633-7).



Intensity sensitivity. Comparison of activations to soft (green, 70 dB SPL) and intense (red, 85 dB SPL) diotic tones.



Frequency sensitivity. Comparison of activations to high (blue), medium (green), and low-frequency (red) diotic tones. Color mixtures (magenta, cyan, yellow, white) indicate sensitivity to a range of frequencies. Tonotopy with sharp frequency tuning (red-green-blue pattern) is less apparent than are broad regions of low-frequency sensitivity that encompass more restricted high-frequency activations (white-yellow-red).



Sensitivity to ear of presentation. Comparison of activations to tones presented monotically to the left (red) or right (green) ear, or diotically to both ears (blue). White regions indicate activation regardless of presentation type (EE-type interaction). Magenta and cyan mixtures indicate monotic activations that were maintained during diotic stimulation (generally E0). Red and green correspond to monotic activations that were reduced diotically (i.e., potentially EI-type).

Conclusions

Broadband masking noise can be used to control pump-noise effects
- -Helps to match stimulus detectability
- -Did not substantially reduce activation by suprathreshold tones
- -May interact with stimulus level (altering thresholds)
  - -Sharpened tuning

Acknowledgments

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