Using frequency selectivity to examine category-informative dimension-selective attention

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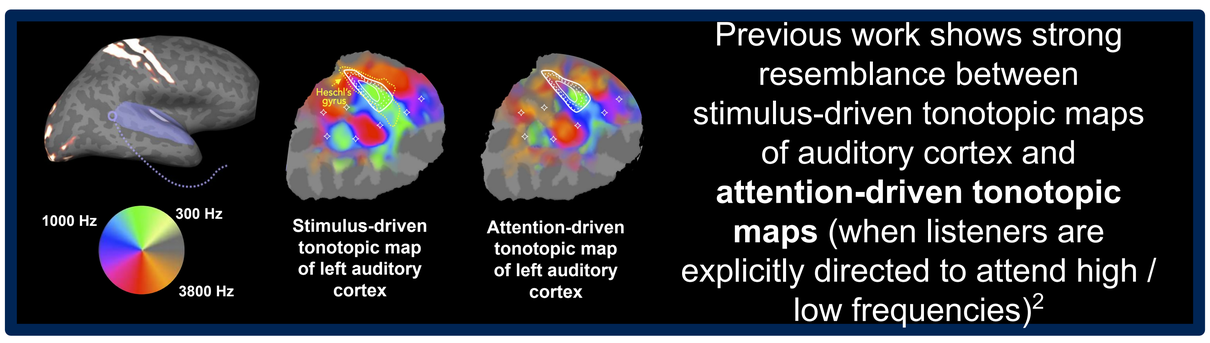
Introduction

Auditory categorization, including speech categorization, may rely on selective attention to diagnostic acoustic dimensions, like frequency[1]

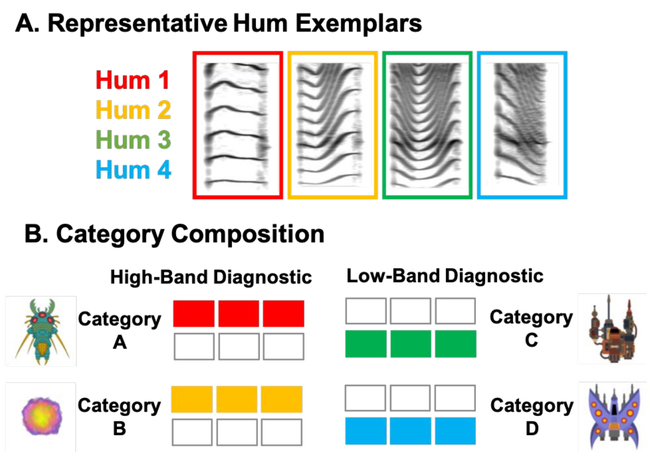
To test whether selective attention underlies auditory categorization, we examine cortical activation when categorization depends on diagnostic information conveyed in particular frequency bands



- We train listeners to categorize four novel non-speech auditory categories defined in a multidimensional space that includes patterns in high/low frequency bands
- We compare concordance of tonotopic and attention-driven tonotopic maps with activation driven by categorization tasks that solicit analysis of patterns in high vs. low frequency bands

Methods

- Dual frequency-band stimuli where each band (high/low) consists of 3 sequential nonspeech hums (derived from Mandarin tone contours)[3]
- For A vs B, listeners must discover variable hum patterns in high frequencies; for C vs D, listeners must discover patterns present in low frequencies
- 5 days training w/ feedback to learn the "alien" associated with each category; had to reach at least 75% (2AFC) for all categories to qualify for fMRI session
- 95 adult listeners (age 18-40; fluent in English, no experience with tonal languages) completed training, of whom 54 reached criterion-level behavior for fMRI session. After excluding 5 for non-compliance, final **N = 49**. (Results reflect only these participants.)

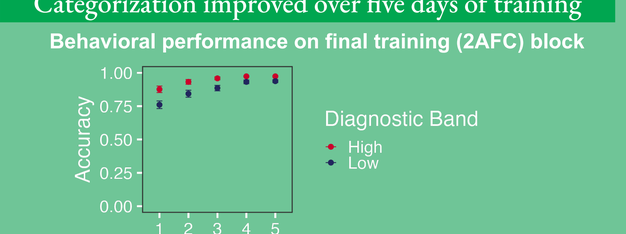


In an fMRI session, each listener completed three tasks in this order:

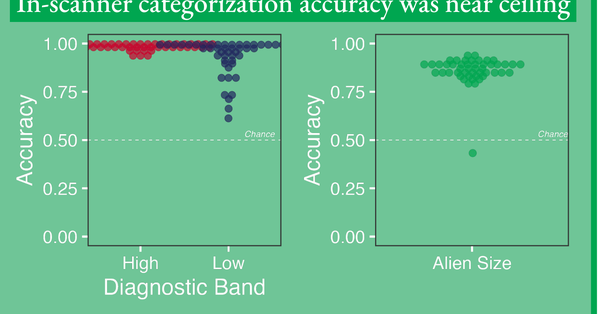
1. **Tonotopy.** Listeners heard ascending/descending pure tone sequences and performed a one-back repetition task. This yields a **stimulus-driven tonotopic map**.
2. **Alien 2AFC categorization.** Listeners categorized aliens, with trials blocked by diagnostic band frequency. In a control task, listeners made judgments about "alien size" (big/small aliens differentiated by stimulus amplitude).
3. **Attention-o-tonotopy.** Listeners simultaneously heard high-frequency and low-frequency tone sequences and were explicitly directed to attend to high tones / low tones / amplitude (control task). This yields an **attention-driven tonotopic map**.

Behavior: Listeners learned novel nonspeech categories defined by complex patterns situated in high versus low frequency bands

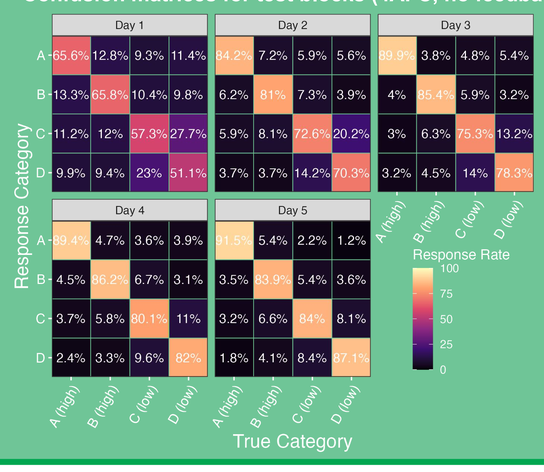
Categorization improved over five days of training



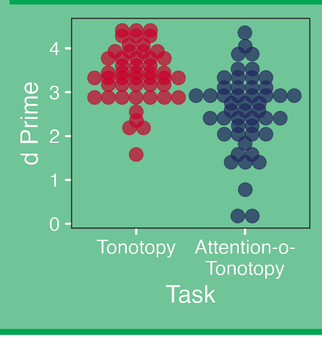
In-scanner categorization accuracy was near ceiling



Confusion matrices for test blocks (4AFC, no feedback)



In-scanner accuracy was high for both tonotopy and attention-o-tonotopy tasks



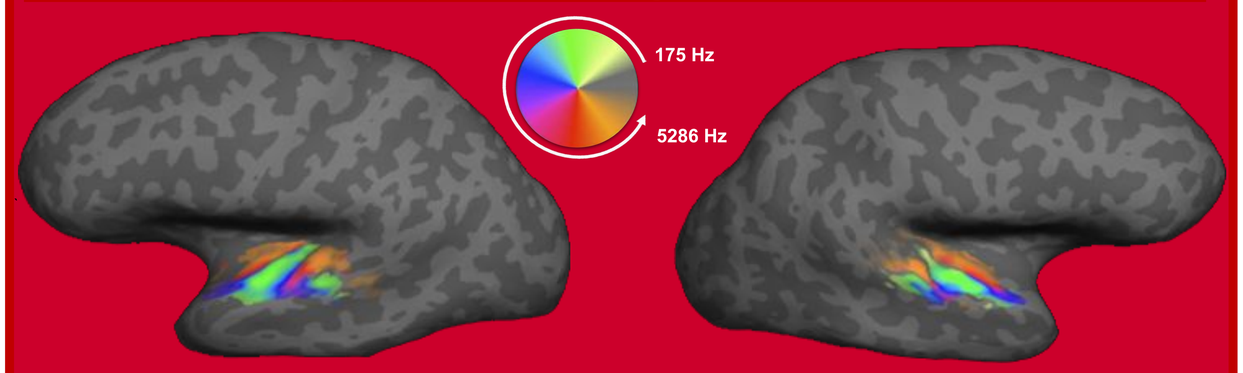
Tonotopy:
Mean d': 3.40 (SE: 0.09)

Attention-o-Tonotopy
Mean d': 2.57 (SE: 0.13)

No significant differences in performance as a result of attentional locus (high/low/volume)

Selective attention to diagnostic dimensions, as indexed by recruitment of frequency-selective auditory cortex, may support auditory categorization

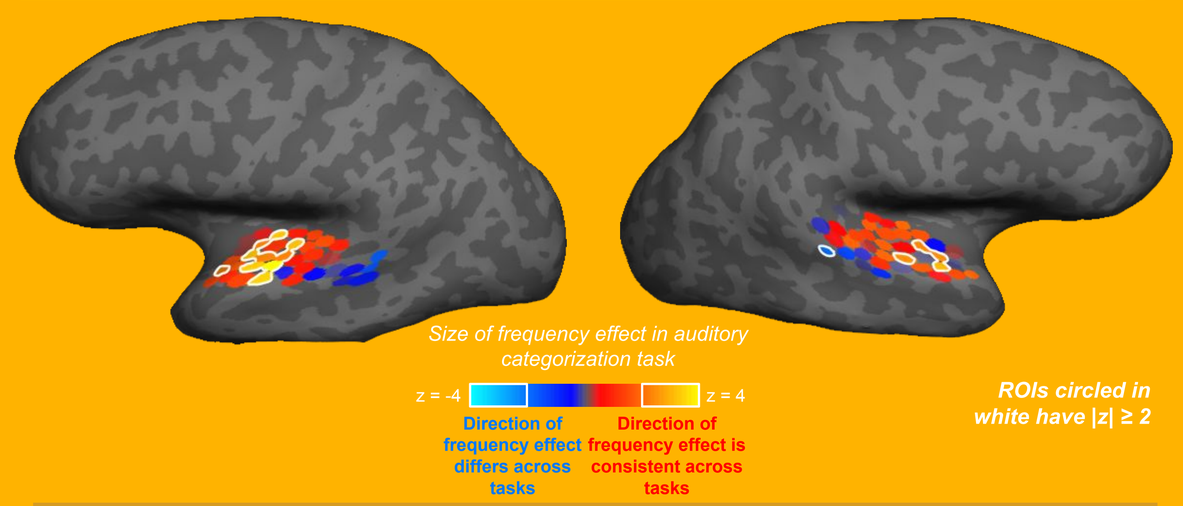
Tonotopy: Frequency-selective organization in auditory cortex



Different frequency bands were presented with consistent phase lag during each run, following previous work[4]. The phase lag with maximal BOLD response (i.e., frequency range) was averaged across participants and masked anatomically.

Cross-task concordance: Listeners recruit tonotopic regions in auditory cortex during frequency-selective auditory categorization

Concordance of auditory categorization and tonotopy



Concordance of auditory categorization and attention-o-tonotopy

Summary and Future Directions

Categorization may drive selective attention to category-diagnostic dimensions

- Listeners were accurate in labeling novel nonspeech categories defined by complex patterns situated in high versus low frequency bands.
- Cortical activation during categorization was modulated by (1) whether the category-diagnostic information was in the high or low frequency band (2) the tonotopic organization of auditory cortex
- Concordance maps indicate that activation during the auditory categorization task is predicted by tonotopic organization of auditory cortex and recapitulates explicit "attention-o-tonotopic" maps

Ongoing analyses will leverage control tasks (loudness judgments) to test if selective attention also involves suppression of non-diagnostic frequency bands[4]

References

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