Investigating the Perceptual Mechanism of Ambiguous Stimuli in Auditory Cortex


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Introduction

The perception of an auditory stimulus can be modified by its surrounding context in multiple ways. Context effects can be best studied using ambiguous stimuli where the stimulus is held fixed while the context is varied. A compelling example of such a stimulus is a sequence of two Shepard tones spectrally shifted by half an octave, which can be perceived as ascending or descending in pitch. Chambers et al. found that preceding this pair by a “biasing” sequence of appropriately shifted tones leads to stable shifts in perception.

To investigate the neural representation of this phenomenon, we recorded MEG responses in human subjects listening to these sequences. In order to measure the effect of the biasing sequence, we inserted “diagnostic” tone sequences between the bias and test so as to measure the effects of the bias tones on cortical responses.

We find that responses collocated in frequency bands activated by the biasing sequence are reduced relative to other regions, consistent with neurophysiological data we have obtained in the ferret auditory cortex (B. Englitz et al.). Furthermore, matching the behavioral responses of the subjects to their neural response, we see that the suppression is only there for congruent trials and it’s lost in incongruent cases, supporting the hypothesis that suppression and “contrast enhancement” mechanisms underlie the biasing effect.

Stimulus Paradigm

**Construction** (Chambers, Shamma, Pressnitzer, in prep.)
- Shepard tone sequence provides a perceptually ambiguous, tritone pair
- Tones in sequence are located within half-octave above or below the first tone in the pair

**Perception**
- Tones above lead to ascending percept
- Tones below lead to descending percept

Choosing the best “rate” and “tone length” for probe tones:
- Maximizing the effect of probe tones on preserved direction in each trial
- Neural response to different modulation rates decreases with 1/f
- 4 Hz leads to stronger neural response
- Corresponding approximate tone length would be 35 ms.

How to measure corresponding neural correlates with MEG?
- Probing the spectral regions after playing the biasing tones, using an AM-modulated sequence
- Study the power increase/decrease of the response to the probe sequence in presence/absence of the biasing tones

Neural response power to the probe sequence (4 Hz):
- The response to the probe, suppressed in congruent trials where the suppression is lost in incongruent ones
- In the suppression preserved at all time points during the maintenance period?

Orientation Variation of pitch circle

**Shepard Tones and Tritone Paradox**
- Shepard tones: Superposition of sinusoids separated by an octave
- Tritone paradox: Listener dependent perception of tritone-spaced Shepard pair

**Ambiguous pitch assignment according to circular structure**
- Strong individual differences in perceived direction, among subjects

Preserving Information in auditory short-term memory

**Suggested model:** Differential adaptation of directionally selective cells
- Different response to the same test stimulus after bias allocation time
- Can be described by directional preference and relative location to test tone per cell
- Generally, these results suggest a role of adaptation as a storage mechanism for sensory information, which can be stabilized for longer maintenance periods.

**MEG findings consistent with single-unit recordings from animals:**
- During auditory change detection, frequency-specific suppression protects short-term memory representations from being overwritten by inhibiting the encoding of interfering sounds
- The frequency-specific index is calculated as the overall difference in similarity of within- vs. across-frequency pattern comparisons.

Acknowledgements

The authors thank Hao Ling and Ibolya Molnár for interesting discussions and technical support. This project was supported by NIH grants, P01 AG052654.
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To investigate the neural representation of this phenomenon, we recorded MEG responses in neurons of the ferret auditory cortex (B. Englitz et al.)

Psychophysics
We tested the hypothesis that the suppression is only there for congruent trials.

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Stimulus paradigm

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Preservation of information within auditory short-term memory

MEG findings consistent with single-unit recordings from animals:
- Bias-induced modulation is present in neural data recorded from ferrets
- Probing with delayed onset leading to a shift in population response maximum away from bias

Acknowledgements

The authors thank Nai Ding and Majid Mirbagheri for interesting discussions and technical support.

This project was supported by NIH grant, 1R01AG036424.