

# Frontal Cortex Modulation of Frequency Tuning in Auditory Cortex

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## Introduction

Cingulo-opercular (CO) regions in frontal cortex exhibit increased activity during challenging listening tasks, suggesting a supportive role in auditory perception.

Evidence for a supportive role includes associations between higher pre-stimulus CO activity and more accurate auditory perception [1-2], as well as evidence that manipulation of cingulate function can affect auditory perception in animals [3].

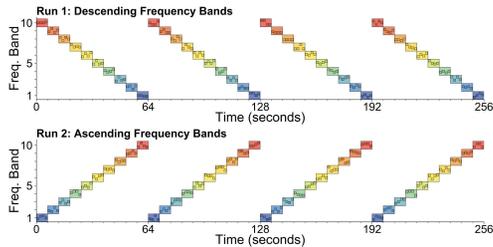
The mechanisms for CO support are not yet clear, including the extent to which cingulate activity within the CO network modulates response gain in primary auditory cortex.

We tested the hypothesis that pre-stimulus cingulate activity modulates gain in auditory cortex in a sample of younger to middle-aged adults who performed a tone listening task, which was designed to characterize frequency tuning in auditory cortex.

## Methods: Retrospective Data Sets

We performed retrospective analyses with data from younger to middle-aged participants in a tonotopy study (N = 36; 17 females; ages 18-45 years, M = 28.4; normal hearing by self-report [4-5]).

- MPRAGE anatomical images and tonotopic mapping fMRI data (multiband echo-planar imaging, acceleration factor = 4; TR = 1000 ms; 265 images per run) were collected with a 3T MRI scanner at the Birkbeck/UCL Centre for Neuroimaging (BUCNI).
- Stimuli consisted of 4-tone motifs (6.4 s per trial) within 10 frequency bands (each 1/2-octave) spanning 175-5286 Hz.
- Attention was maintained using a one-back task, with instructions to push a button whenever a tone was repeated.



Above. Tone stimuli swept across 10 frequency bands in descending or ascending order, with four sweeps per run.

## Method: fMRI Analyses

fMRI data were motion corrected, co-registered, spatially normalized, smoothed, and adjusted for global signal variation.

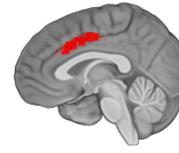
Pre-stimulus activity was measured from cingulate cortex (HCP-MMP1 atlas [6]) during the tonotopic mapping experiment [4-5], to assess differences in tuning for trials with high versus low pre-stimulus activity (i.e., above vs. below the median fMRI signal).

General linear models estimated voxel-level responses to each frequency band for high and low pre-stimulus CO activity trials.

Characteristic frequency (CF) was defined for each voxel in auditory cortex based on the largest response across frequency bands (HCP-MMP1).

Frequency tuning curves were based on the response to each frequency band for the voxels in each CF.

Peak responses from tuning profiles were compared between high and low pre-stimulus activity conditions (above/below average) to assess frontal modulation.



Above. Cingulate cortex region of interest shown on the study-specific template.

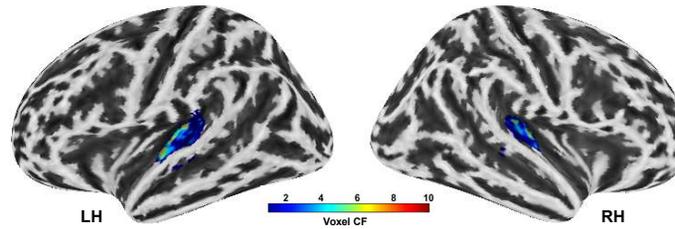
## Results: Main Experiment Effects

### Task Performance

The participants showed high sensitivity to repeated tones [d-prime = 2.5 ± 0.1; mean ± standard error]. Task accuracy increased modestly but significantly across runs [d-prime = 2.3 ± 0.2; 2.6 ± 0.1; t(34) = 2.79, p = 0.009].

### Tonotopic Mapping

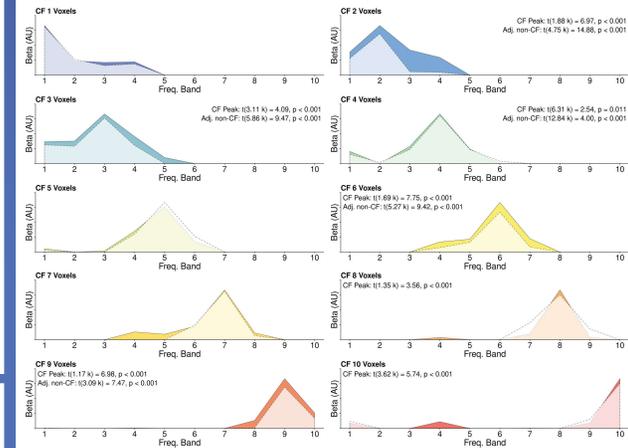
The CF mapping in auditory cortex followed a typical high-to-low frequency gradient from anterior to posterior across auditory cortex.



Above. High-to-low frequency gradients were observed across auditory cortex for group averaged CF labels.

## Results: Frequency Tuning Modulation

Elevated pre-stimulus cingulate activity was associated with significantly higher auditory cortex responses across participants.



Above. Higher pre-stimulus cingulate activity was associated with significantly higher CF peak (7/10) and adjacent non-CF (5/10) responses. Tuning curves are shown for the low (dashed/white) and high (solid/colored) pre-stimulus activity conditions.

## Conclusions

Pre-stimulus activity in the cingulate cortex appeared to modulate frequency tuning in auditory cortex by enhancing responsiveness to CF and adjacent non-CF bands.

Ongoing analyses aim to characterize regional differences in both the magnitude and timing of pre-stimulus CO effects on frequency tuning.

These preliminary findings suggest that cingulate modulation of auditory cortex tuning underlies CO support of auditory perception.

**References:** [1] Vaden KI, Kuchinsky SE, Cute SL, Ahlstrom JB, Dubno JR, Eckert MA (2013). The cingulo-opercular network provides word-recognition benefit. *J Neurosci*, 33 (48) 18979-18986. [2] Vaden KI, Eckert MA, Dubno JR, Harris KC (2020). Cingulo-opercular adaptive control for younger and older adults during a challenging gap detection task. *J Neurosci Res*, 98(4):680-691. [3] Anbuhi KL, Diez Castro M, Lee NA, Lee VS, Sanes DH (2025). The cingulate cortex facilitates auditory perception under challenging listening conditions. *Proc Natl Acad Sci USA* 122 (14) e2412453122. [4] Levchenko E, Chow-Wing-Born H, Dick F, Tierney A, Skipper JI (2025). A neuroimaging database combining movie-watching, eye-tracking, sensorimotor mapping, and cognitive tasks. *bioRxiv* 2025.09.25.678556v2. [5] Published dataset from Levchenko et al. <https://openneuro.org/datasets/ds006642/versions/1.0.1> [6] Glasser MF, Coalson TS, Robinson EC, Hacker CD, Harwell J, Yacoub E, et al. (2016). A multi-modal parcellation of human cerebral cortex. *Nature*, 1-11.

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