

Frequency magnification in primary auditory cortex predicts group-average but not individual frequency discrimination thresholds

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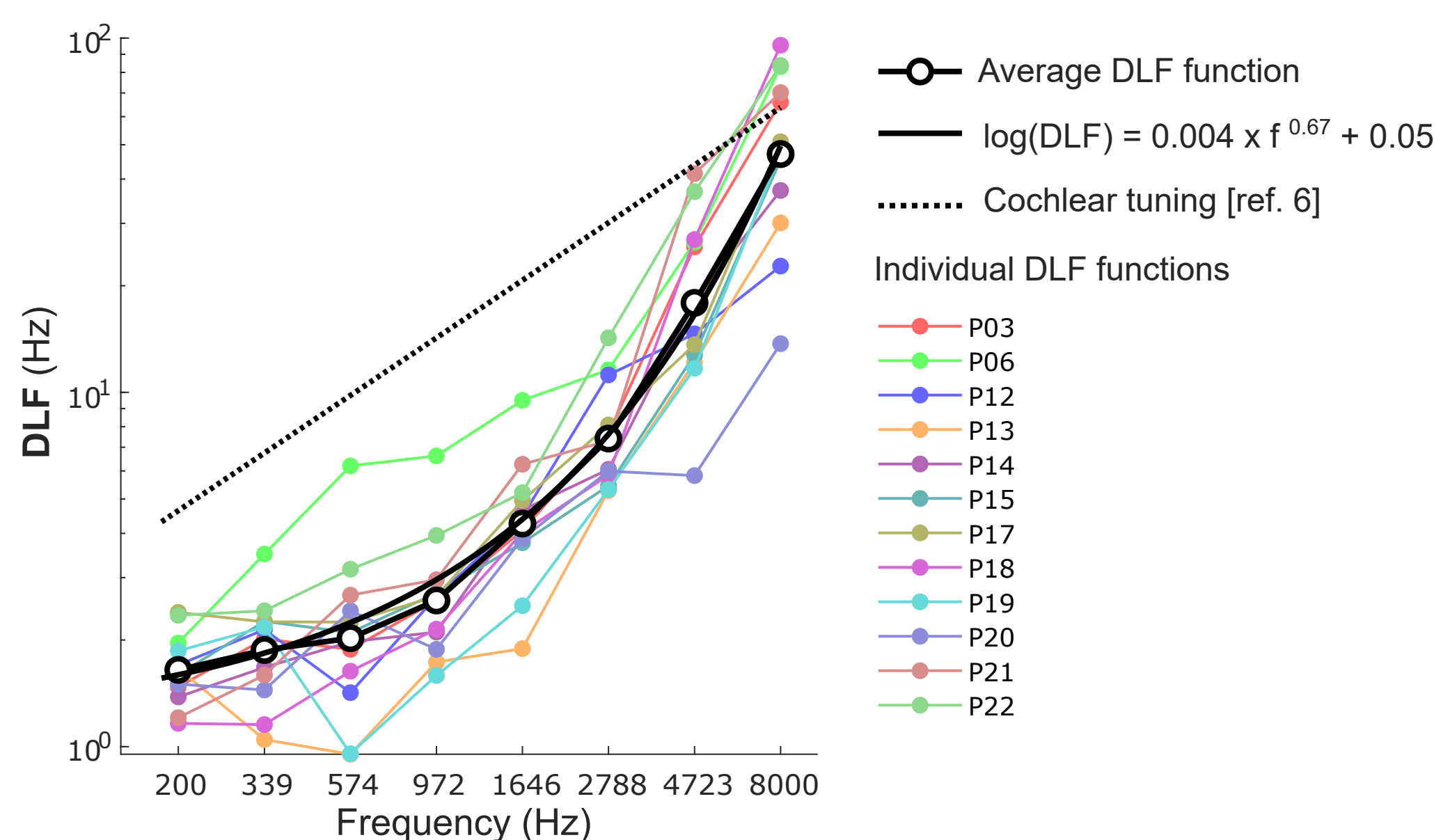
Introduction

The primary auditory cortex (A1), like the cochlea, magnifies low frequencies compared to high frequencies. Previously, we showed that the cortical frequency magnification measured in A1 using fMRI is better predicted by published estimates of frequency discrimination thresholds than by cochlear frequency magnification [1]. Thus, frequency discrimination may be primarily constrained by cortical rather than cochlear processes, as for visual and tactile hyperacuity [2,3]. If so, frequency discrimination thresholds should be inversely proportional to cortical magnification across individual participants. Here we tested this idea by measuring both frequency discrimination performance and cortical magnification in the same 12 participants.

Results

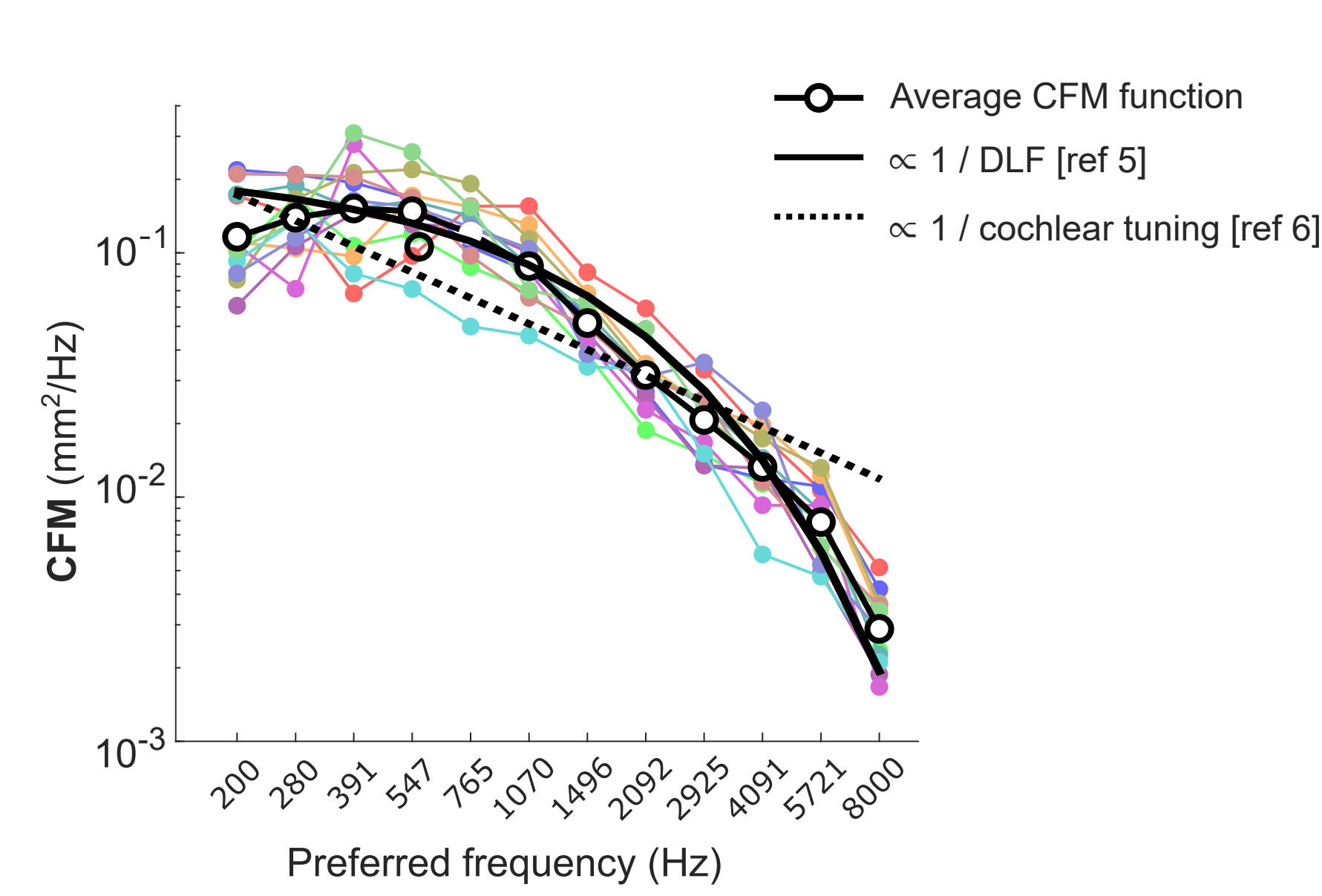
Average functions and fits

Difference limens for frequency (DLF)



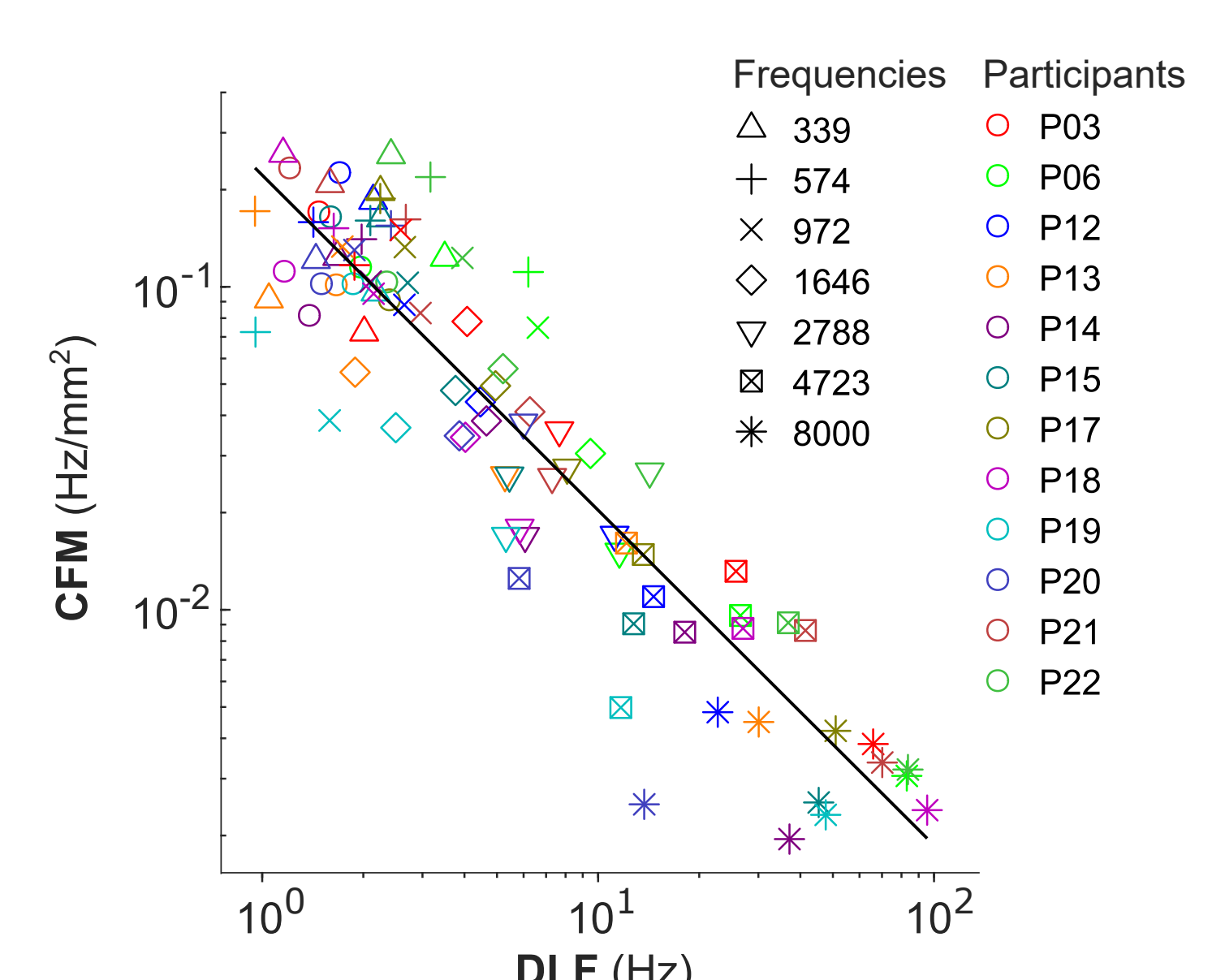
- DLFs increased with frequency
- smaller than cochlear bandwidth at low frequencies
- well fit by $\log(\text{DLF}) = b \times f^c + a$ [4,5]

Cortical frequency magnification (CFM)



- CFM decreased with frequency
- better fit by 1/DLF than 1/cochlear tuning (Bayes Factor: $\text{BF}_{\text{DLF,ERB}} = 2.9 \times 10^6$)

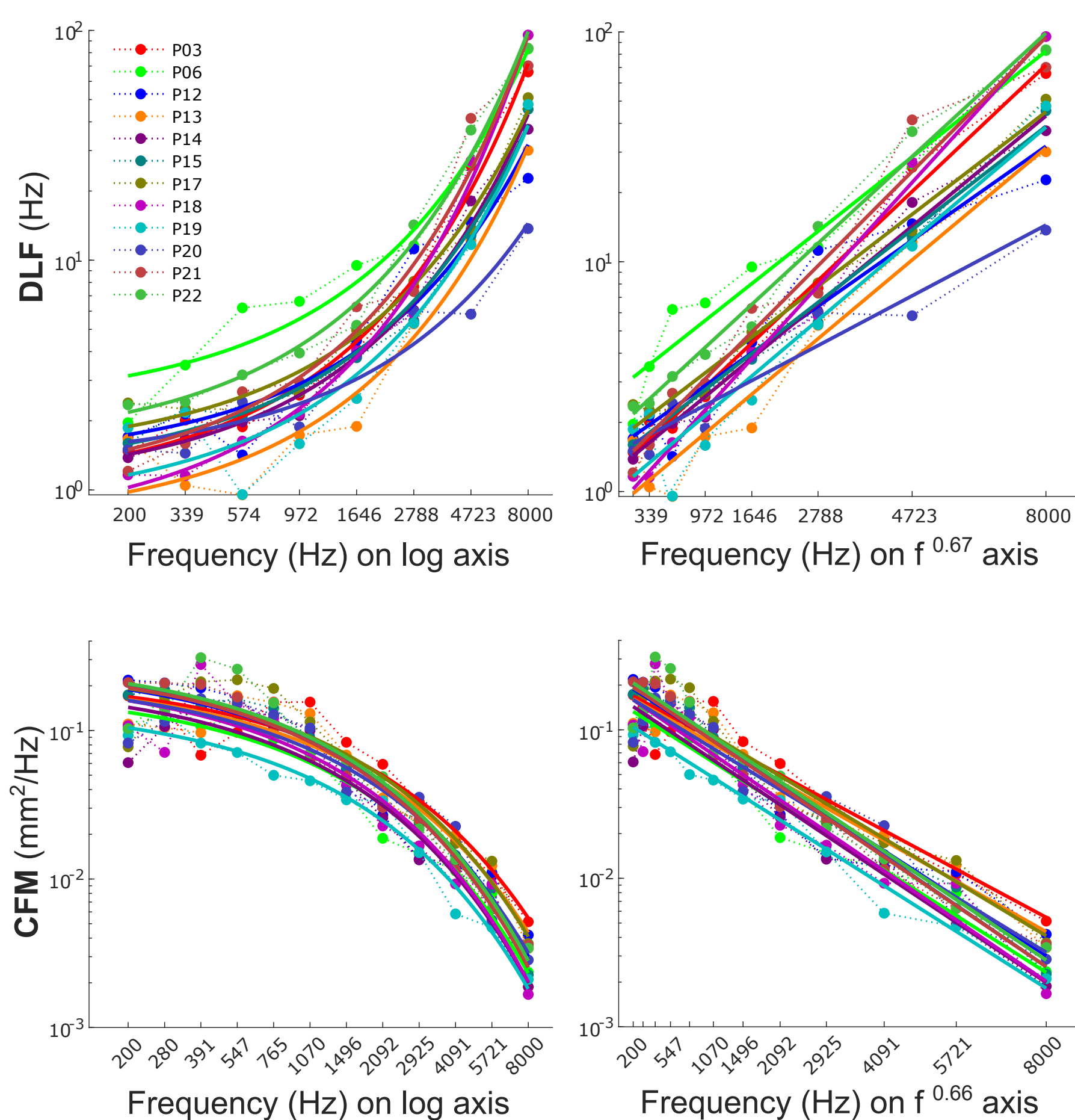
DLF-CFM correlation across frequencies



- Very strong evidence for an inverse relationship
- log-log slope = -0.9
- Bayes Factor: $\text{BF}_{10} = 1.2 \times 10^{34}$.

Individual fits

We fitted individual DLF and CFM curves as: $\log(\text{DLF or CFM}) = b \times (f - 1000)^c + a$, where c was estimated from average DLF and CFM functions ($c_{\text{DLF}} = 0.67$; $c_{\text{CFM}} = 0.66$).

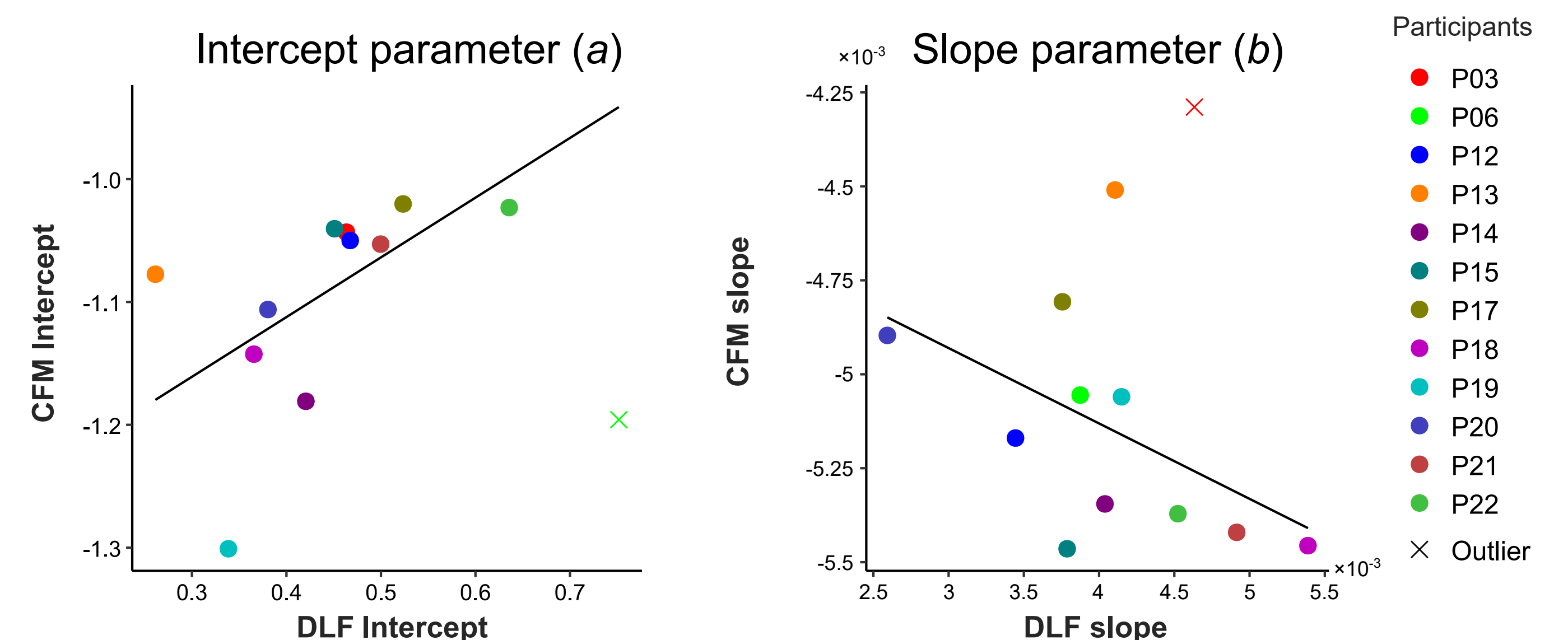


Left: log-log axis
Right: X axis scaled as f^c

Intercept (a):
Discrimination performance (or cortical magnification) at 1 kHz.

Slope (b):
Relative performance (or magnification) at low vs. high frequencies.

Correlation between individual DLF and CFM fit parameters



- Little evidence for a relationship between DLF and CFM intercepts ($\text{BF}_{10} = 1.88$) or slopes ($\text{BF}_{10} = 1.26$).
- Correlation for intercept in the direction opposite to predicted

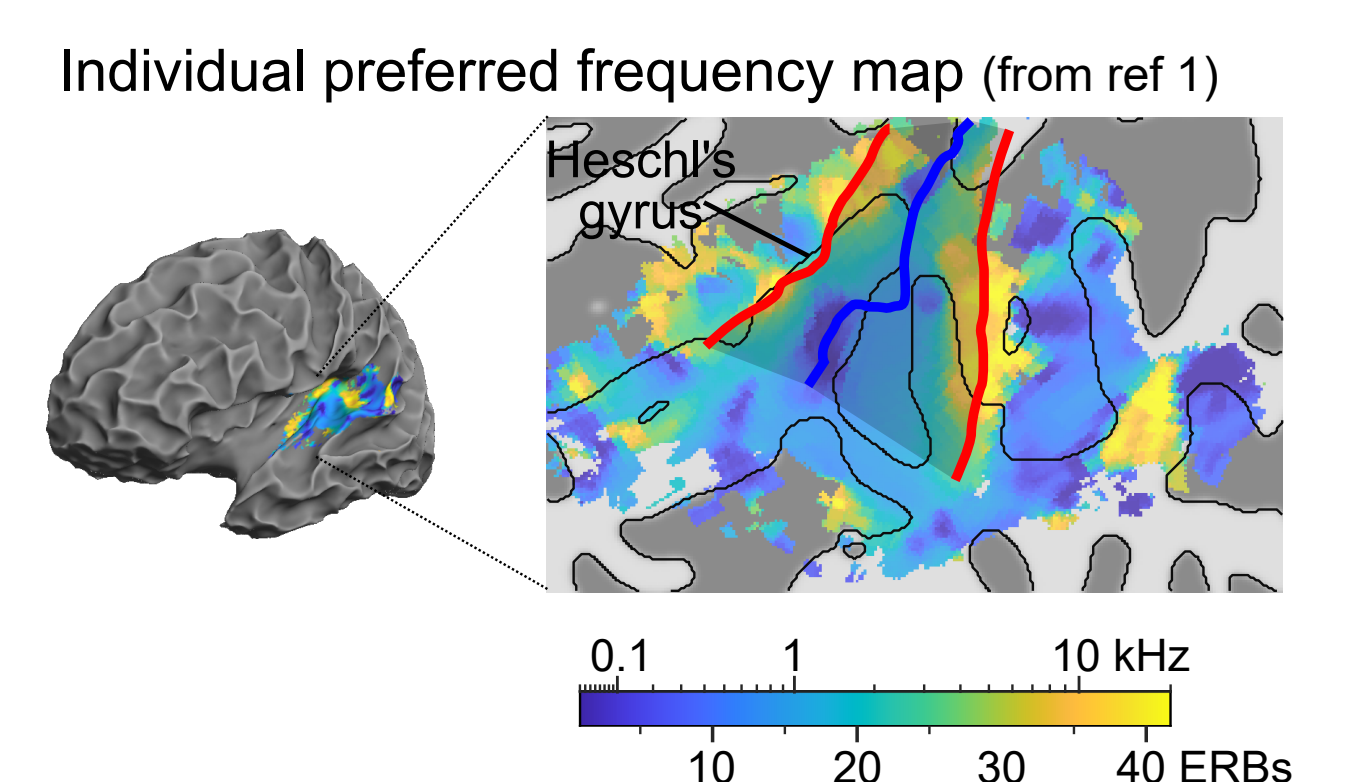
Methods

Frequency discrimination

- Pure tone DLFs at 8 log-spaced frequencies from 0.2 to 8kHz
- Two-interval 8S2A task (AAAA vs. ABAB)
- Practice session: updated maximum likelihood (UML) method [7]
- Sessions 2 & 3: UML or method of constant stimuli, counter-balanced
- 150 trials per frequency per session
- **DLF** = 79% threshold averaged across sessions 2 and 3

Cortical magnification

- 3T fMRI, sparse GE-EPI (TR = 8s), 1.5 mm resolution
- 4.5-s trains of pure tones around 8 log-spaced frequencies, 0.2 - 8 kHz
- Participants watched silent movie and ignored sounds
- Voxelwise preferred frequency = mode of Gaussian fitted to BOLD tuning curve
- A1 defined as 2 mirror-reversed tonotopic maps aligned with Heschl's gyrus
- **CFM** = surface area tuned to a given frequency (in mm^2/Hz)



Discussion

As expected, frequency magnification in human A1 varied approximately inversely to frequency discrimination performance across frequencies. Despite this, cortical magnification did not predict frequency discrimination at an individual level in this sample. This lack of relationship could be due to either the CFM or the DLF measurements being insufficiently reliable, or to other shortcomings of the current analysis (e.g., suboptimal parametrization of the DLF/CFM function, averaging across functionally distinct cortical areas). If confirmed, however, these results suggest that A1 magnification does not determine frequency discrimination performance, unlike what has been observed in V1 and S1 for visual and tactile hyperacuity.

References

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