Simulating the contribution of medial olivocochlear efferents to amplitude-modulation unmasking in humans

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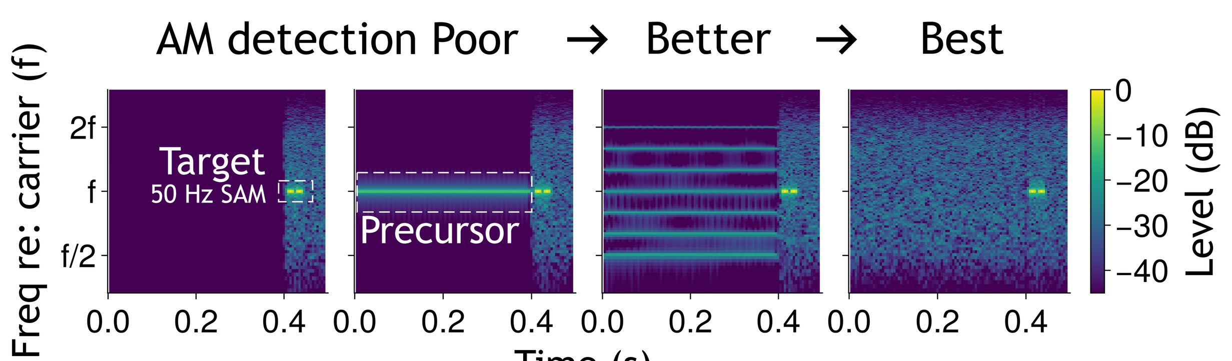
1 Introduction

Amplitude-modulation (AM) unmasking

AM detection thresholds for a modulated tone in noise sometimes improve when the signal is preceded by a precursor sound [1, 2]

Broadband tone/noise precursors produce more AM unmasking than pure-tone precursors [1]

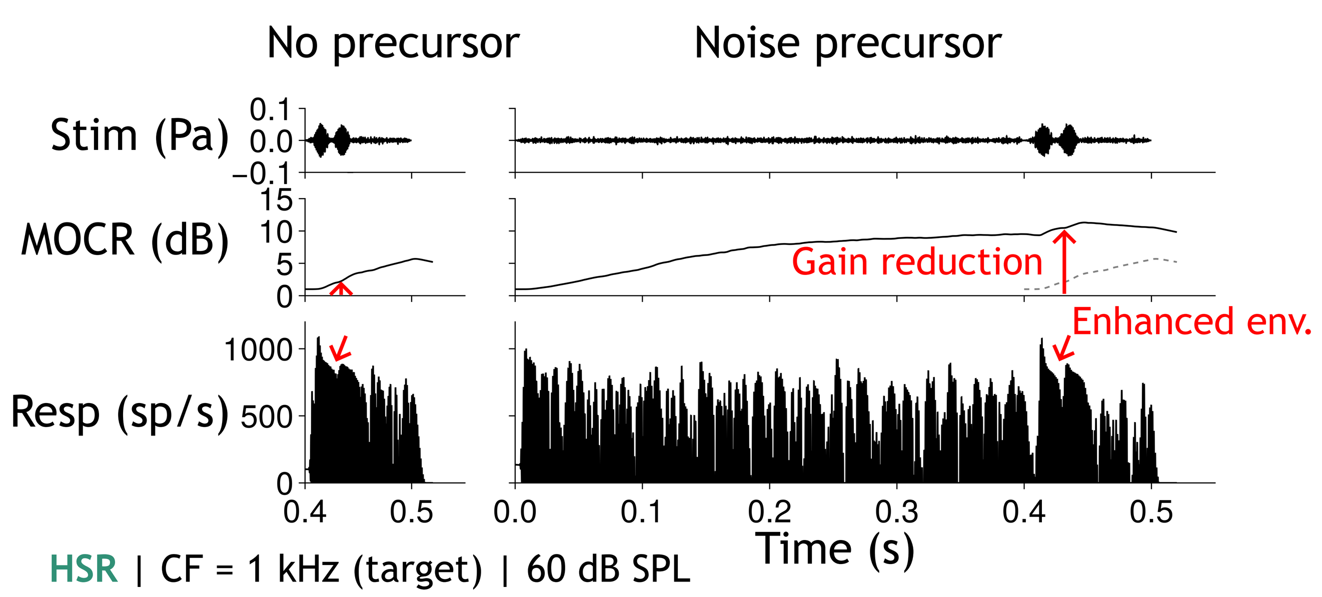


Standard: Pure tone
Target: SAM tone (50 Hz) | 40/60/80 dB SPL | 1/6 kHz
Masker: Gaussian noise | ±1 octave re: target | −15 dB SNR
Precursor: Pure tone/complex tone/noise matching masker level

Neural origins — MOCR?

The medial olivocochlear reflex (MOCR) is a sound-activated reduction in cochlear gain [3]

A precursor eliciting the MOCR would reduce cochlear gain during AM signal, enhancing neural representation of AM



Problems

Some AM-unmasking effects seem qualitatively inconsistent with an MOCR-based account [1, 2]

Otoacoustic-emission-based measures of AM unmasking do not support MOCR hypothesis [1]

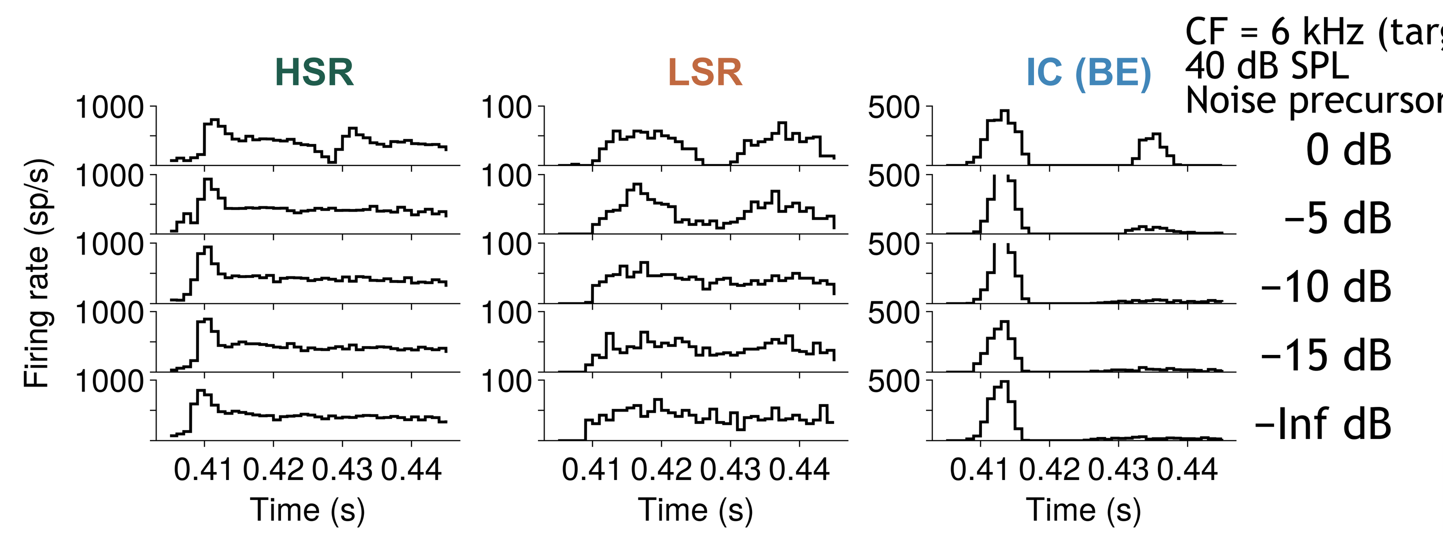
Question: Can a physiological auditory model with MOCR explain key features of behavioral AM unmasking?
- Magnitude (~5 dB)
- Modest effect of carrier sound level
- Modest effect of carrier frequency
- Large effect of precursor type
  (noise > complex tone >> pure tone)

2 Simulating AM detection

Simulate response across range of depths (−30 to 0 dB)
- 71 CFs spanning 0.33-18 kHz
- 2.5 dB depth steps (25 reps)
- 100 spike trains simulated, pooled to one PSTH per rep

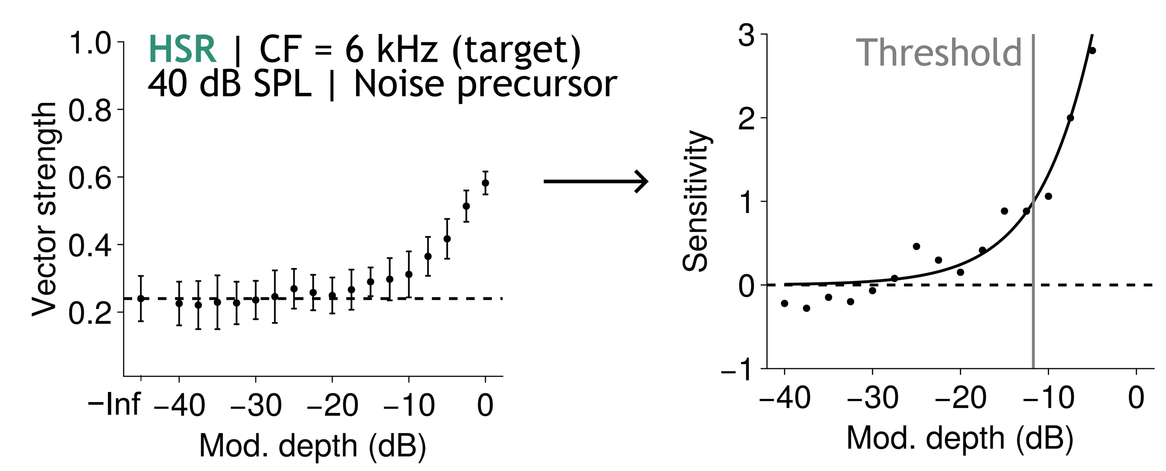
Auditory-nerve model [4]:
- High spont rate (HSR)
- Low spont rate (LSR)

Inferior-colliculus (IC) model:
- Band-enhanced (BE) [5] (inputs from HSR model)

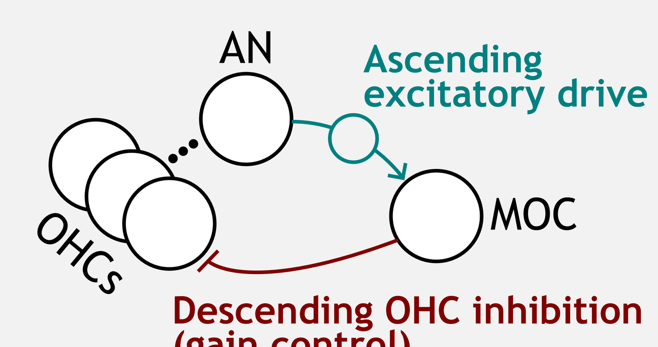


Extract decision variable and estimate sensitivity
- Vector strength (excluding tone onset) used as DV
- d′ re: standard (−Inf dB) computed at each step
- Logistic function fit to d′; threshold := depth where d′=1
- Population sensitivity determined as:

*with bias correction $d'_{\text{pop}} = \left(\sum_{i=0}^{N} d_i'^2\right)^{1/2}$

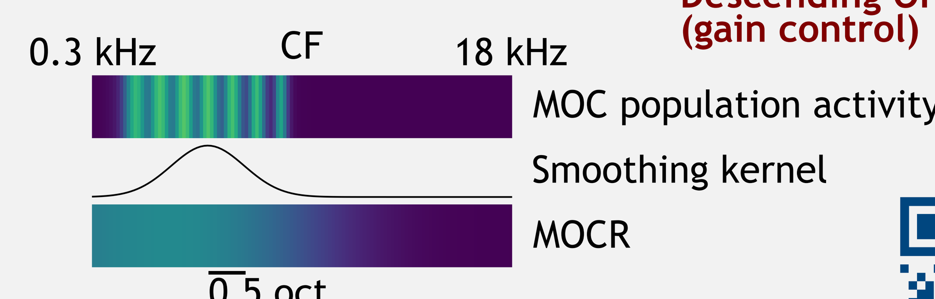


3 Simulating MOCR

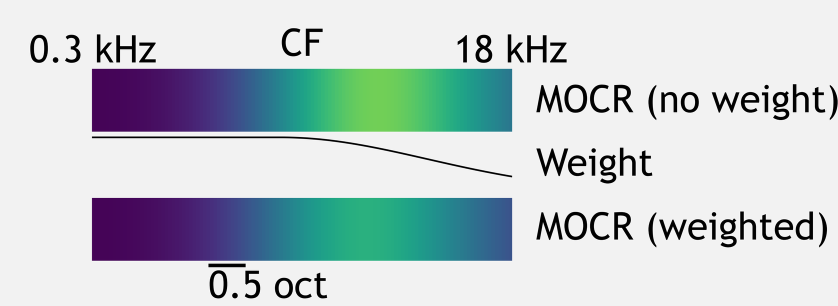


Extended prior auditory models [4, 5, 6] to include MOCR with two key features; **model was fit only to physiological [8] data and not to behavior!**

Multichannel
Individual MOC channels influence gain over range of CFs, reflecting broad innervation of individual MOC neurons in the cochlea [7]



CF-weighted
MOCR weighted by CF to reproduce variation in MOCR threshold and magnitude across CF [8]



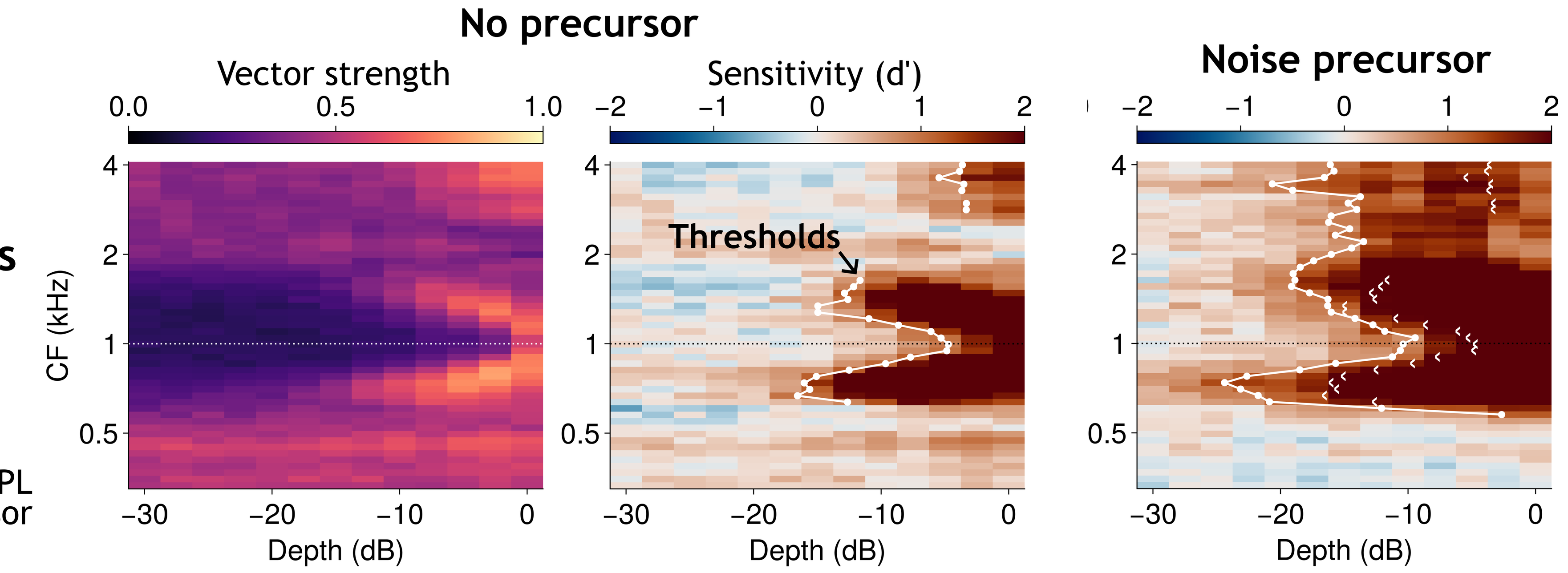
See poster for details

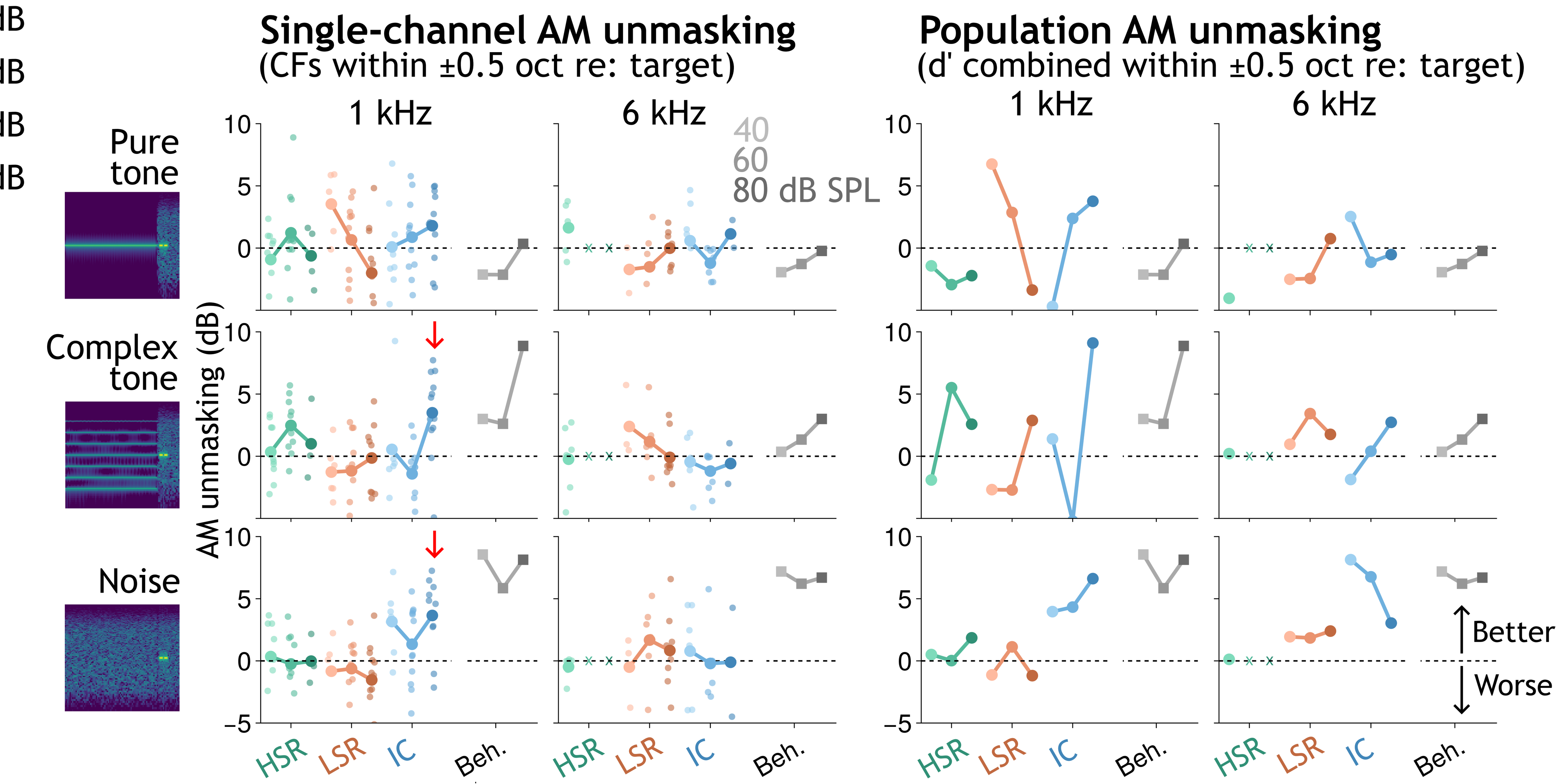
4 Results

MOCR activation induces complex changes in AM cues across tonotopic axis

(Right) Vector strength and sensitivity across tonotopic axis for example simulation

IC | 1 kHz | 80 dB SPL
Noise precursor





Auditory model with MOCR accounts for some trends in behavioral data

(Left) Behavioral AM unmasking from [1] vs model AM unmasking, defined as the difference in AM detection thresholds with and without precursors

HSR and LSR models
Inconsistent/small AM unmasking in single channels

IC model
Single-channel AM unmasking larger and more consistent; noise precursor and high-level complex-tone precursor yield greatest unmasking, as in behavior (**red arrows**)

5 Conclusions

The **MOCR likely contributes to AM unmasking**; our physiological model with MOCR predicted some features of the behavioral data [1]:
- ✓ Magnitude (up to 10 dB in population decoding)
- ✗ Effects of carrier sound level and frequency (mixed results)
- ✓ Effect of precursor type (noise >> complex tone > pure tone)

- Future work will explore other decision variables (e.g., mean rate, sync rate) and how to combine them across the tonotopic axis
- Work continues on the underlying MOC model:
  - Parameters will be refined based on physiological data [8]
  - Role of descending connections from IC will be revisited [6]

[1] Wojtczak et al. (2019). J Assoc Res Otolaryngol, 20, 395–413. doi:10.1007/s10162-019-00722-6
[2] Mesik and Wojtczak (2020). J Acoust Soc Am, 148, 3581–3597. doi:10.1121/10.0002879
[3] Guinan (2018). Hear Res, 362, 38-47. doi:10.1016/j.heares.2017.12.012
[4] Zilany et al. (2014). J Acoust Soc Am, 135, 283–286. doi:10.1121/1.4837815
[5] Nelson and Carney (2004). J Acoust Soc Am, 116, 2173–2186. doi:10.1121/1.1784442
[6] Farhadi et al. (2023). J Acoust Soc Am, 154, 3644–3659. doi:10.1121/10.0022578
[7] Brown (2014). J Neurophys, 111, 2177–2186. doi:10.1152/jn.00045.2014
[8] Warren and Liberman (1989). Hear Res, 37, 89–104. doi:10.1016/0378-5955(89)90032-4

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