University of Rochester
Hearing & Balance Research Collective

Simulating effects of contralateral acoustic stimulation using an auditory efferent model

Daniel R. Guest[1], Afagh Farhadi[2], Laurel H. Carney[1]
1 University of Rochester, Rochester, NY, USA
2 Purdue University, West Lafayette, IN, USA

1 Introduction and model architecture

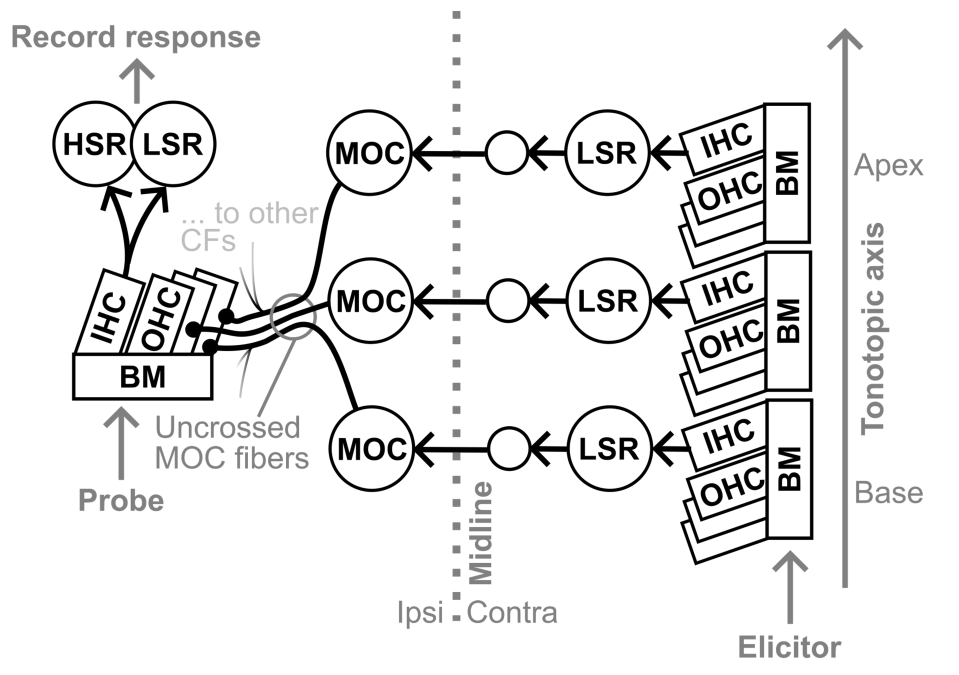
A computational model of the auditory system that includes efferent pathways is necessary for "closing the loop"

One source of data to inform model development is the effects of **contralateral acoustic stimulation** (CAS) on ipsilateral auditory-nerve (AN) responses [Warren1989a]

Contralateral sound excites medial olivocochlear (MOC) neurons that provide efferent innervation to outer hair cells (OHCs) in the cochlea and reduce cochlear gain

Key question: Can our sound-driven efferent model capture general trends in AN CAS experiments?

- Time course
- Magnitude
- Threshold
- Trends with CF

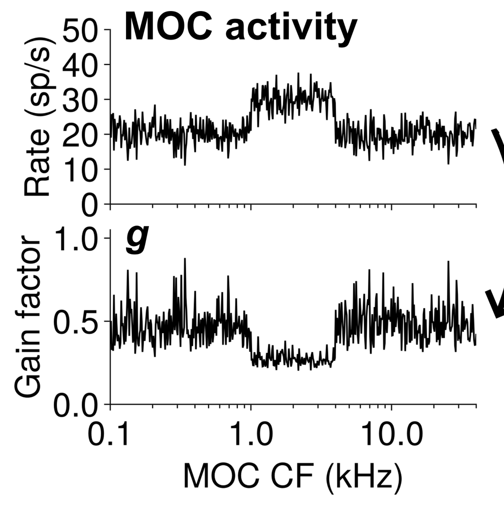


Some MOC neurons innervate OHCs over wide (>1 oct) cochlear spans [Brown2014]

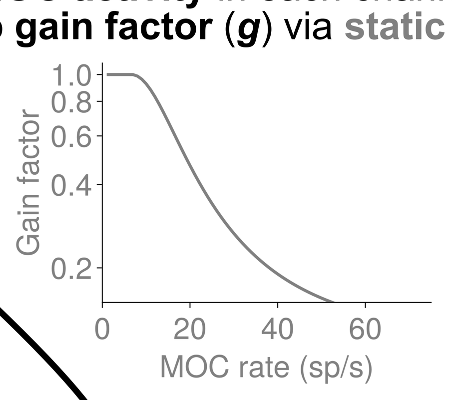
We extended an existing efferent model [Farhadi2023] to simulate CAS with wide-span innervation of OHCs

Our model simulates a tonotopic population of MOC neurons driven by contralateral sound and a single ipsilateral afferent nerve fiber

Here we focus on modeling the role of uncrossed MOCs in CAS

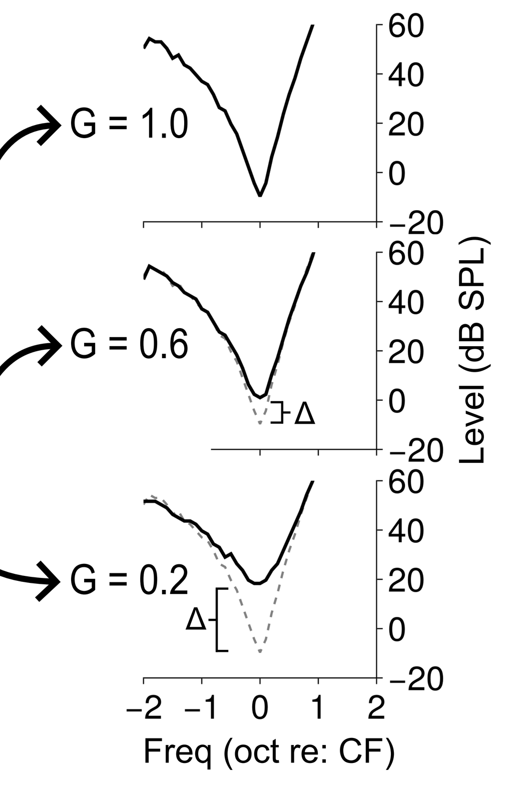


MOC activity in each channel mapped to **gain factor** (*g*) via **static nonlinearity**



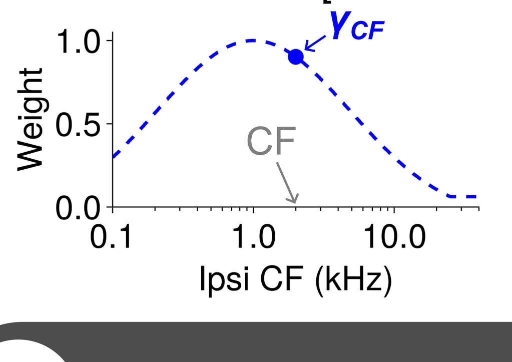
Gain at single cochlear location (G_{CF}), e.g., at **ipsi CF = 2 kHz**, determined by:

$$\gamma_{CF} \frac{1}{\sum_i w_i} \sum_i w_i \log g_i = \log G_{CF}$$

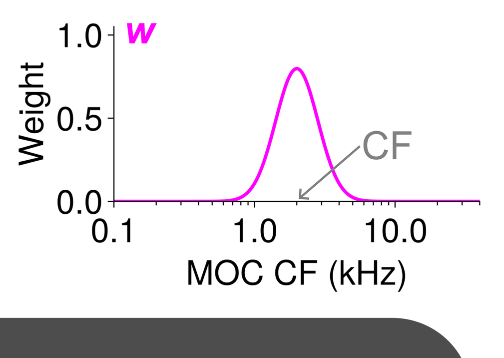


Effects of different gain factors are visible in iso-response tuning curves, as shown above; CF = 2 kHz, HSR fiber

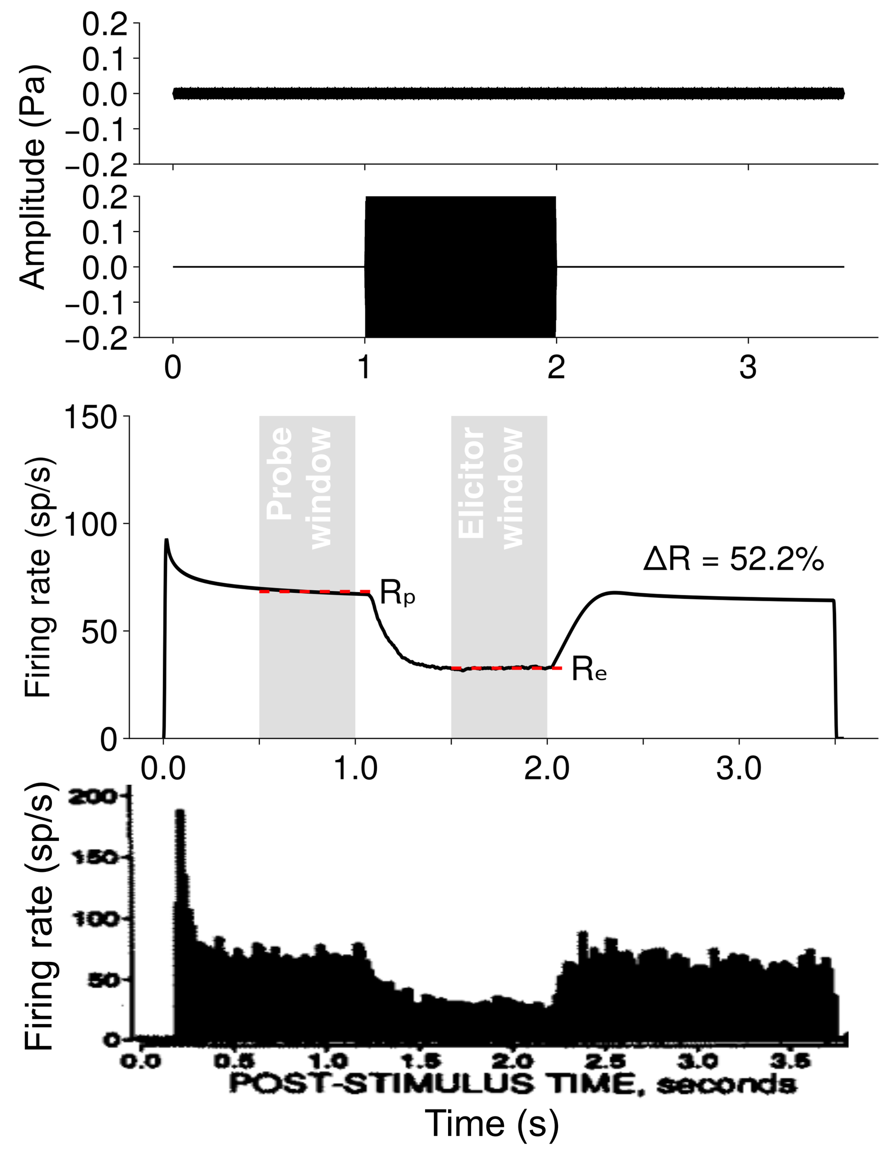
Adjust for innervation patterns
Scale result by CF-specific parameter *γ*, motivated by size & quantity of efferent synapses vs cochlear location [Liberman1990]



Combine across MOC fibers
Inputs averaged with weights *w*, motivated by overlapping spans of innervation from tonotopically nearby MOC fibers [Brown2014]



2 CAS time course example



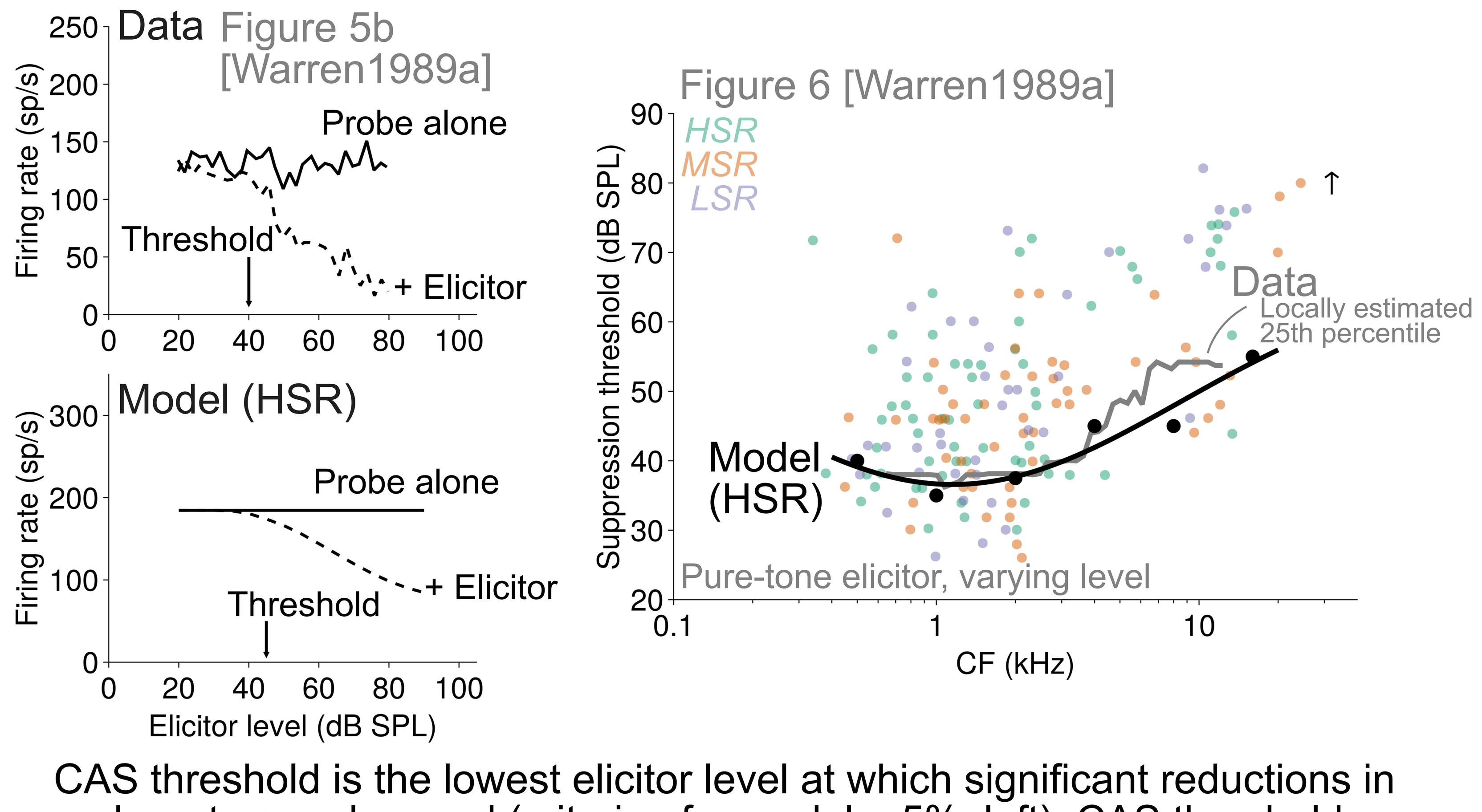
Ipsi stimulus (probe)
Pure tone at CF
Level = rate-level function midpoint

Contra stimulus (elicitor)
OR { 1) Broadband Gaussian noise
2) Pure tone
+20–30 dB re: ipsi probe level

Ipsi response (simulation)
LSR fiber, CF = 4.37 kHz
Gaussian-noise elicitor
$\mathbf{R_p}$ rate in probe-alone window
$\mathbf{R_e}$ rate in +elicitor window
ΔR = 100 × ($[R_e-R_p]/R_p$)

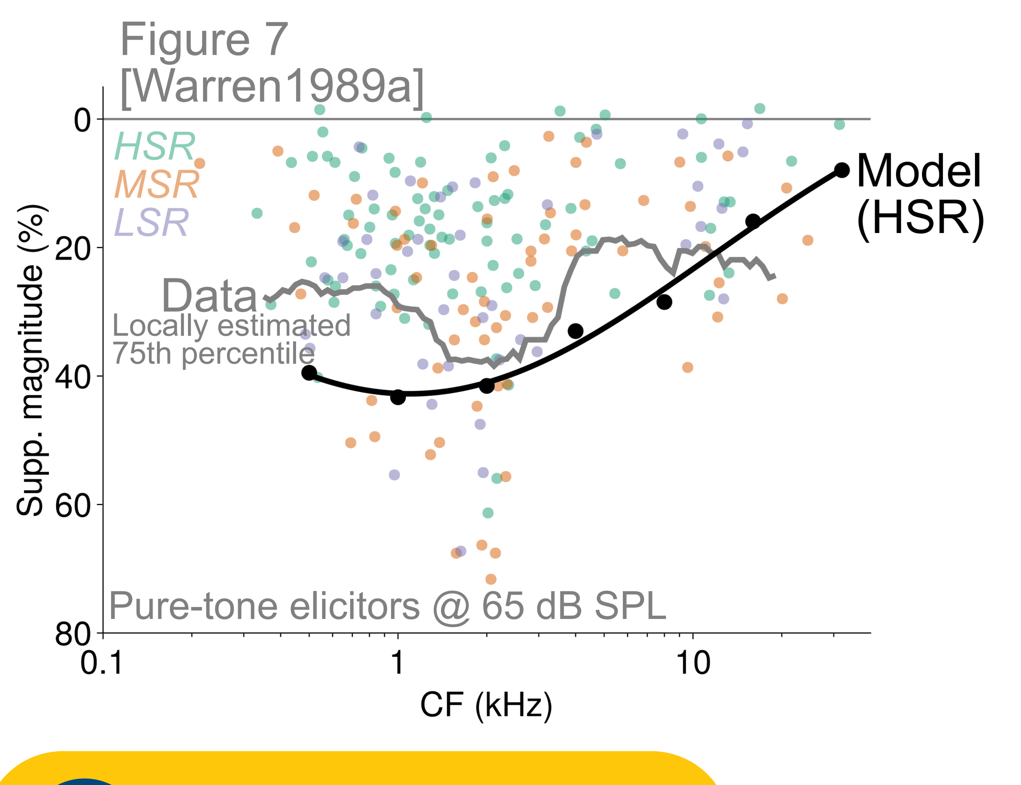
Ipsi response (data)
Figure 3 [Warren1989a]
LSR fiber, CF = 4.37 kHz
Anesthetized cat
Dial in urethane (75 mg/kg)
Severed middle-ear muscle

3 CAS thresholds vs CF



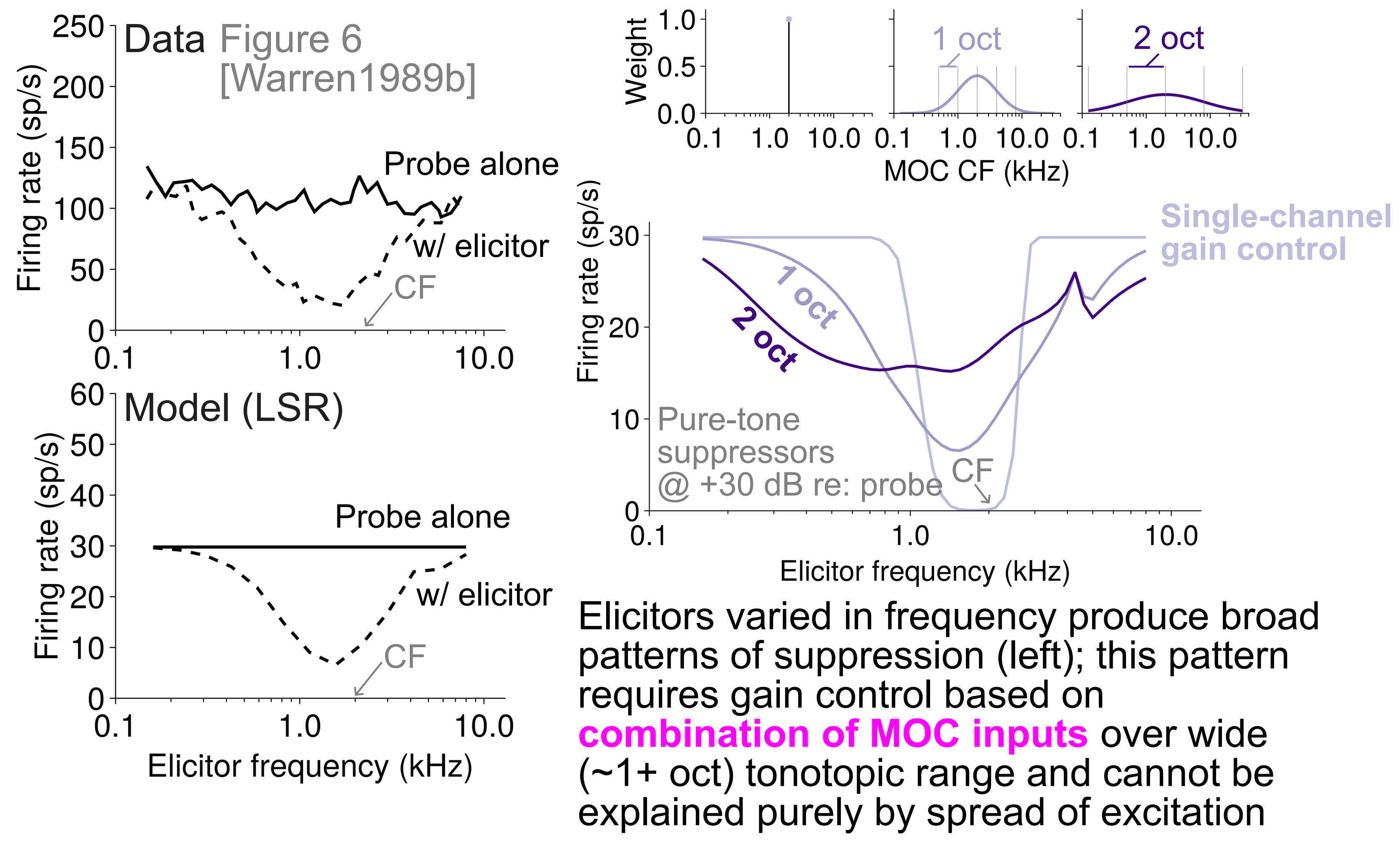
CAS threshold is the lowest elicitor level at which significant reductions in probe rate are observed (criterion for model = 5%, left). CAS thresholds vary with CF (right). **CF-specific innervation strength** (*γ*) was needed in the model to account for elevation of thresholds at higher CFs.

4 CAS magnitude vs CF



The magnitude of CAS effects (ΔR, as in Panel 2, measured for elicitors at 60–70 dB SPL) varies with CF, peaking at ~2 kHz. Using the same **CF-specific innervation strength** (*γ*) as before, we observe weaker efferent effects at higher CFs, as in the data. Significant variance in the data complicates quantitative assessment of the model fit.

5 CAS frequency tuning



Elicitors varied in frequency produce broad patterns of suppression (left); this pattern requires gain control based on **combination of MOC inputs** over wide (~1+ oct) tonotopic range and cannot be explained purely by spread of excitation

6 Conclusions

Our sound-driven efferent model reproduced trends in CAS data:
Thresholds (Panel 3), magnitudes (Panel 4), tuning (Panel 5)

Two key ingredients were needed:
[1] A **CF-weighting function** (*γ*) that tapers off at high CFs, possibly reflecting biases in efferent innervation [Brown2014, Liberman1990]

[2] Gain control that reflects a **combination of MOC inputs** from a wide (~1+ oct) tonotopic neighborhood around the ipsilateral CF

7 Bibliography, acknowledgements

References
[1] Warren and Liberman (**1989a**). Hear. Res., **37**, 89–104 doi:10.1016/0378-5955(89)90032-4
[2] Warren and Liberman (**1989b**). Hear. Res., **37**, 105–121 doi:10.1016/0378-5955(89)90033-6
[3] Brown (**2014**). J. Neurophys., **111**, 2177–2186 doi:10.1152/jn.00045.2014
[4] Farhadi et al. (**2023**). J. Acoust. Soc. Am., **154**, 3644–3659 doi:10.1121/10.0022578
[5] Guinan and Gifford (**1988**). Hear. Res., **33**, 97–113. doi:10.1016/0378-5955(88)90023-8
[6] Liberman et al. (**1990**). J. Comp. Neurol., **301**, 443–460 doi:10.1002/cne.903010309

This work was supported by:
NIH R01-DC010813 (LHC) &
NIH F32-DC022143 (DRG)

Scan for poster PDF