Ideal-observer analysis of the effects of medial olivocochlear gain control on neural coding of sound level and amplitude modulation in quiet

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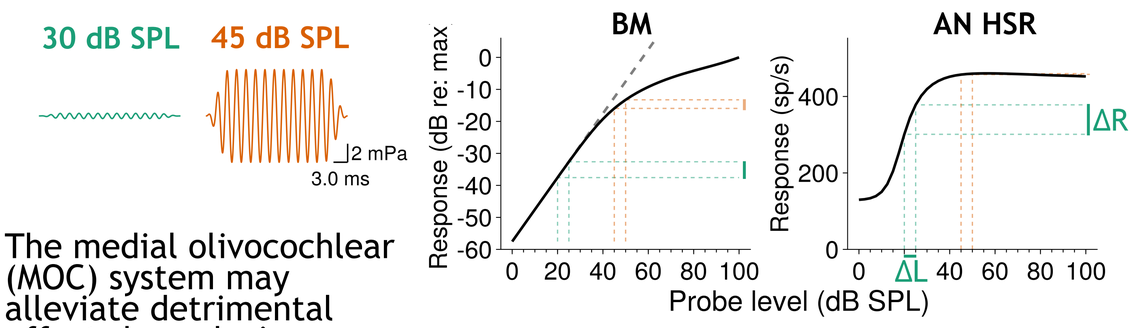
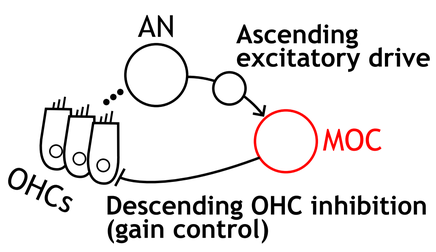
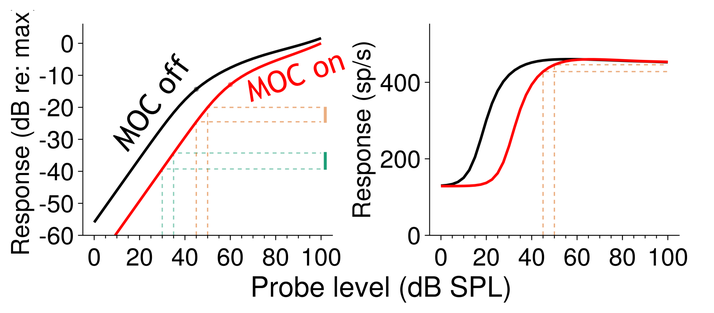
1 Introduction

Peripheral compression and auditory-nerve (AN) saturation both impact rate codes for sound-level information [1]



The medial olivocochlear (MOC) system may alleviate detrimental effects by reducing cochlear gain [2] — ***but does it?***





Long-term question: Can MOC physiology be quantitatively reconciled with MOC psychophysics via a sound-driven efferent model?

- Do MOCR effect sizes seen in physiology yield measurable changes in behavior?
- Under what conditions/tasks should MOC effects be most easily observed in behavior?

We used a computational auditory model [4] to simulate (in quiet):
[1] Level discrimination (LDLs) &
[2] Amplitude-modulation detection (AMDLs)

This poster relates to recent work on the MOC reflex ([5] and QR codes to right) but only considers classical energy-driven circuit

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Ideal observer analysis was used to predict thresholds based on simulated responses (***r***) [1, 3]

All-information (AI) thresholds use all available information

Rate-place (RP) thresholds are constrained to using time-averaged (rate) information

Number of fibers per channel

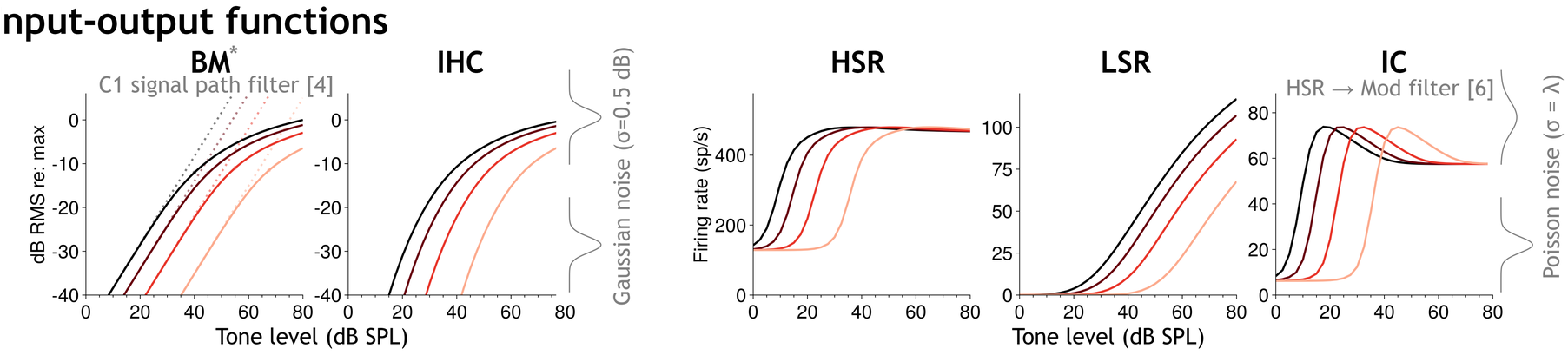
$$\mathrm{JND}_\theta \geq \left(\sum_i \frac{N}{r_i(\theta)} \left[\frac{\partial r_i(\theta)}{\partial \theta} \right]^2 \right)^{-1/2}$$

Summation over channels — Change in response w.r.t. θ

Rate-place observer with Poisson noise

2 Results

Input-output functions

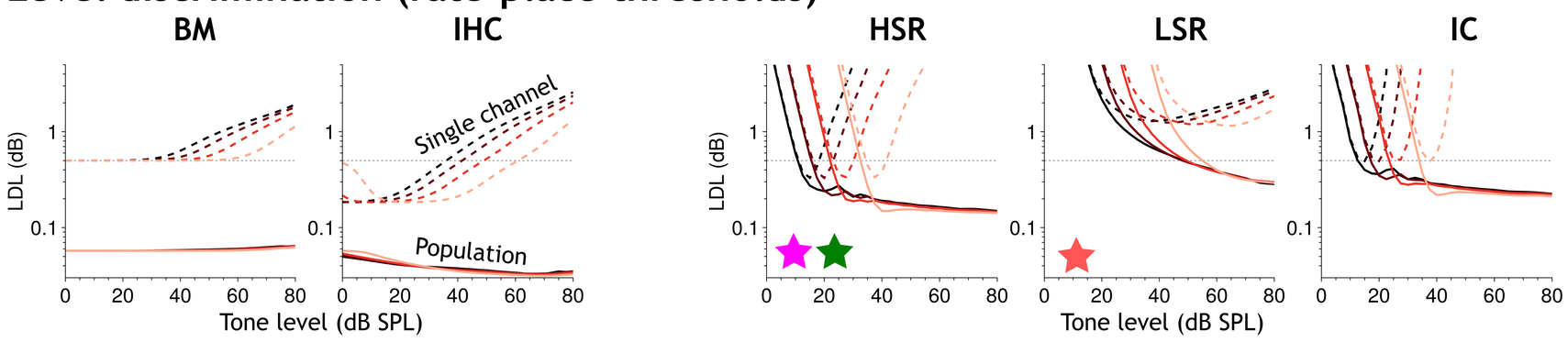


Input-output functions at each model stage as a function of the model control parameter that governs **cochlear gain (C_{OHC})**

C_{OHC}	Gain reduction (approx.)
1.0	0 dB
0.75	−5 dB
0.5	−10 dB
0.25	−20 dB

Stimulus: 30-ms pure tone at 10 kHz
BM = basilar membrane; IHC = inner hair cell; HSR = high spontaneous rate; LSR = low spontaneous rate; IC = inferior colliculus

Level discrimination (rate-place thresholds)



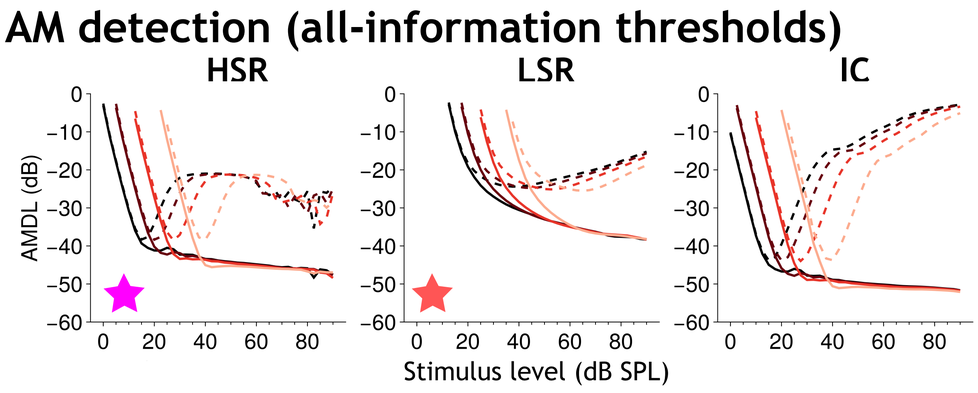
Standard — Target

Task: "Which is louder?"

Stimulus: 30-ms pure tone at 10 kHz

Changes in cochlear gain should only change LDLs if listeners are restricted to on-frequency channels

AM detection (all-information thresholds)



Standard — Target

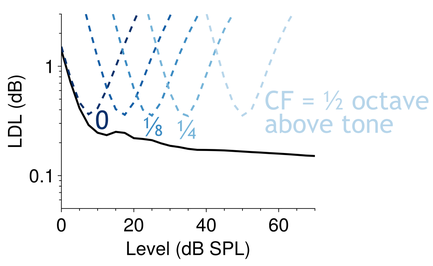
Task: "Which is modulated?"

Stimulus: 200-ms SAM tone at 10 kHz / 20 Hz mod rate

Effects of cochlear gain on AMDLs similar to LDLs; effects large in single channels but minimal in population

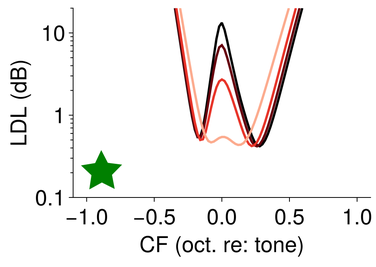
3 Insights

In quiet, there is always somewhere to listen!



LDL vs tone level for HSR fiber as function of CF relative to tone frequency

Changes in cochlear gain mainly affect neural thresholds near tone freq.



LDL vs CF relative to tone frequency for HSR fiber with 40 dB SPL at 4 kHz as function of **cochlear gain**
−5 dB −10 dB −20 dB

Takeaways for psychophysicists

- Off-frequency listening compromises potential of tasks in quiet for probing MOCR
- Techniques to constrain or measure listening strategy are important; could use a notched-noise masker to worsen off-frequency SNR [2], but this may add new neural cues and is more difficult to model!

Takeaways for physiologists

- Small changes in gain should result in large changes in single-fiber HSR LDL/AMDLs, but only within ~30 dB of abs. threshold
- In non-saturating LSR fibers, effects of cochlear gain on single-fiber LDL/AMDLs should be comparatively modest
- CF estimates must be precise for interpretable results
- Results in central nuclei likely less predictable due to CF convergence

4 References and future directions

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[2] Roverud and Strickland (2015). J Acoust Soc Am, 138, 3245-3261. doi:10.1121/1.4935515
[3] Siebert (1970). Proc. IEEE, 58, 723-730. doi:10.1109/PROC.1970.7727
[4] Zilany et al. (2014). J Acoust Soc Am, 135, 283-286. doi:10.1121/1.4837815
[5] Farhadi et al. (2023). J Acoust Soc Am, 154, 3644-3659. doi:10.1121/10.0022578
[6] Nelson and Carney (2004). J Acoust Soc Am, 2173-2186. doi:10.1121/1.1784442

- Preliminary model release w/ paper soon!
- Results with sound-driven simulations at ARO 2026!

UR EAR (left)

Scan to access our web-based model tools!

MATLAB model code @ https://osf.io/6bsnt/