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

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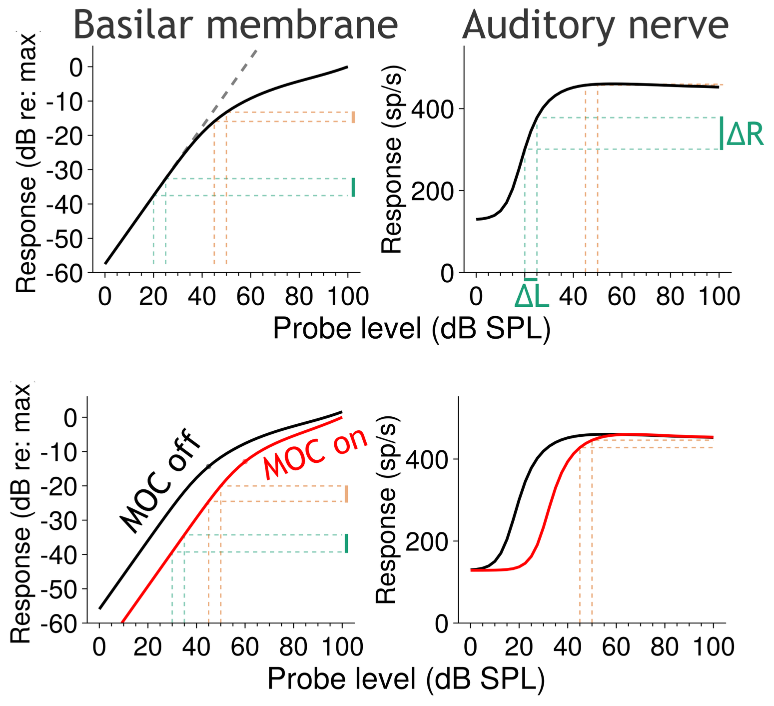
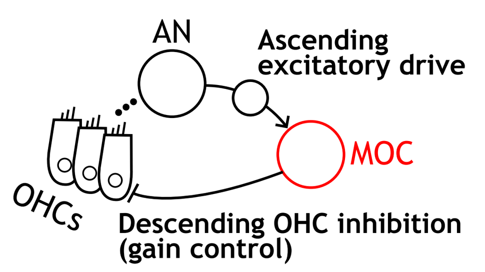
This poster

INTRODUCTION

Peripheral compression and auditory-nerve (AN) saturation both impact rate codes for sound level (Heinz et al., 2001)



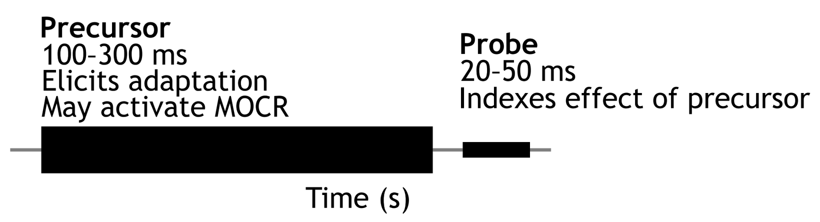
The medial olivocochlear (MOC) system may improve coding by reducing cochlear gain — ***but does it?***



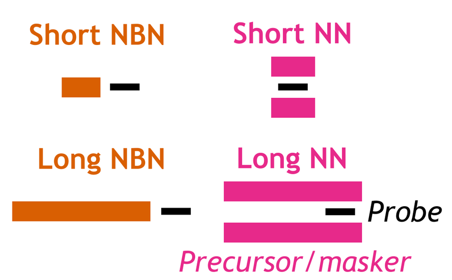
METHODS

Stimuli

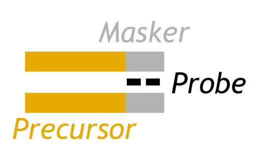
Stimuli matched those used in several behavioral studies that may reflect efferent effects. All studies used **precursor-probe design** where precursors may activate the MOCR and enhance perception.



Roverud and Strickland (2015)
- **Task:** Level discrimination in noise
- 30-ms pure-tone probes
- Narrowband (NBN) or notched-noise (NN)
- Short and long temporal configurations
- Varying SNRs and levels

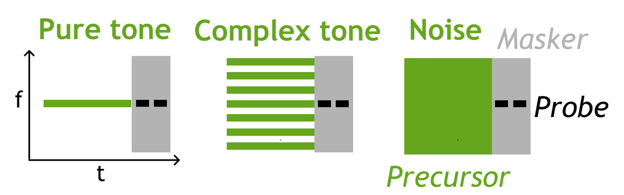


Almishaal, Bidelman, and Jennings (2017)
- **Task:** AM detection in NN
- 50-ms SAM-noise probes
- Low-fluctuation-noise carriers
- NN precursor and simultaneous masker
- 50-85 dB SPL



Wojtczak, Klang, and Torunsky (2019)
- **Task:** AM detection in noise
- 40-ms SAM-tone probes
- Varied precursors
- 1 or 6 kHz carriers
- 50 Hz modulation rate
- Individualized SNRs
- 40, 60, or 80 dB SPL

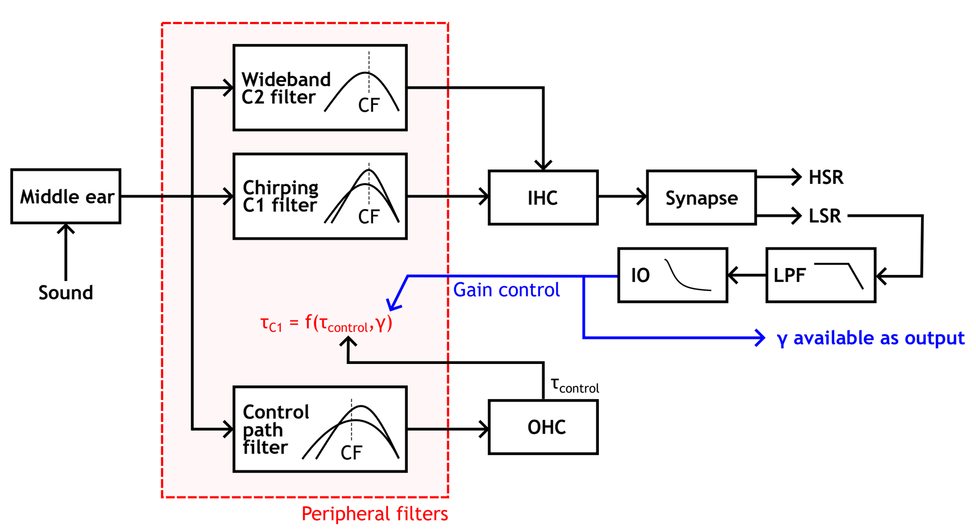
Data previously modeled in ASA 2025 poster



Computational model

Responses to acoustic stimuli simulated using modified version of Zilany, Bruce, and Carney (2014) model that includes an **energy-driven MOC reflex** (MOCR; see QR codes for prior model posters)

Cochlear gain can be fixed at user-specified values or be updated dynamically based on energy-driven feedback loop



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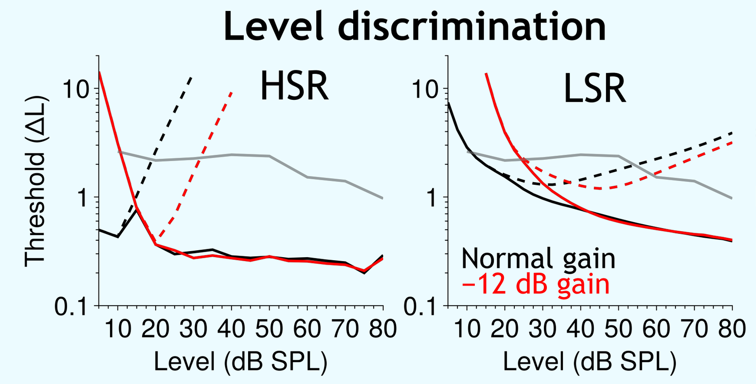
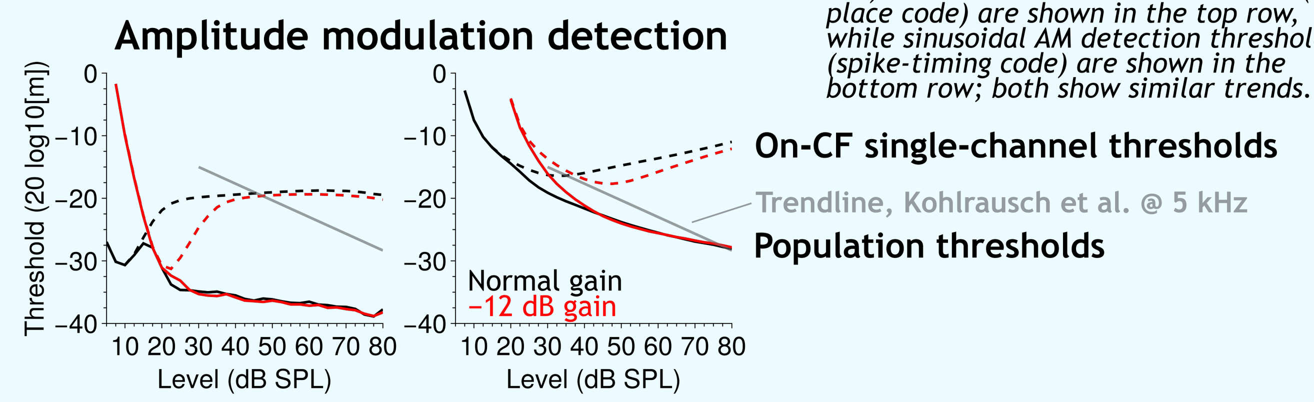
RESULTS

Do reductions in cochlear gain improve coding of sound level or AM in quiet?

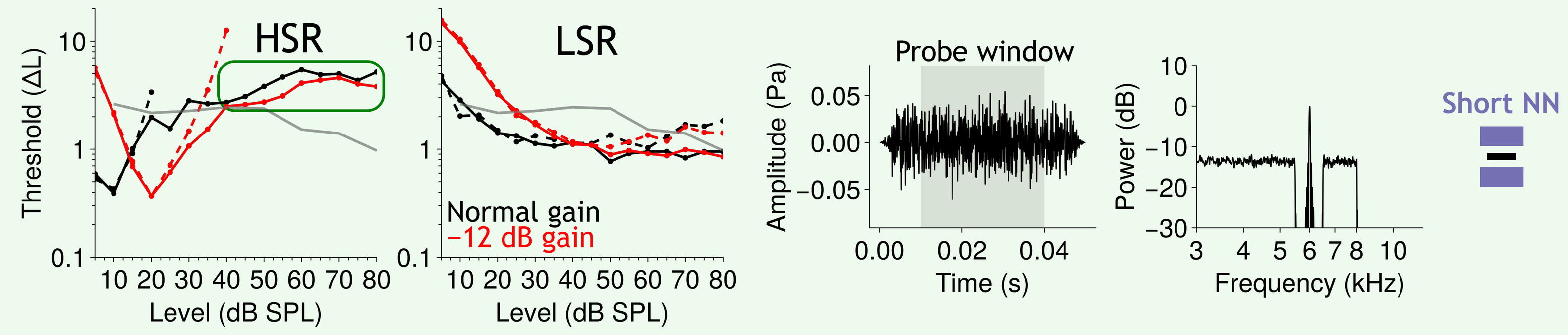


Ideal-observer thresholds for 30-ms 6-kHz pure tone in quiet derived by Cramér-Rao lower-bound analysis (# fibers per CF = 100). Level-discrimination thresholds (rate-place code) are shown in the top row, while sinusoidal AM detection thresholds (spike-timing code) are shown in the bottom row; both show similar trends.

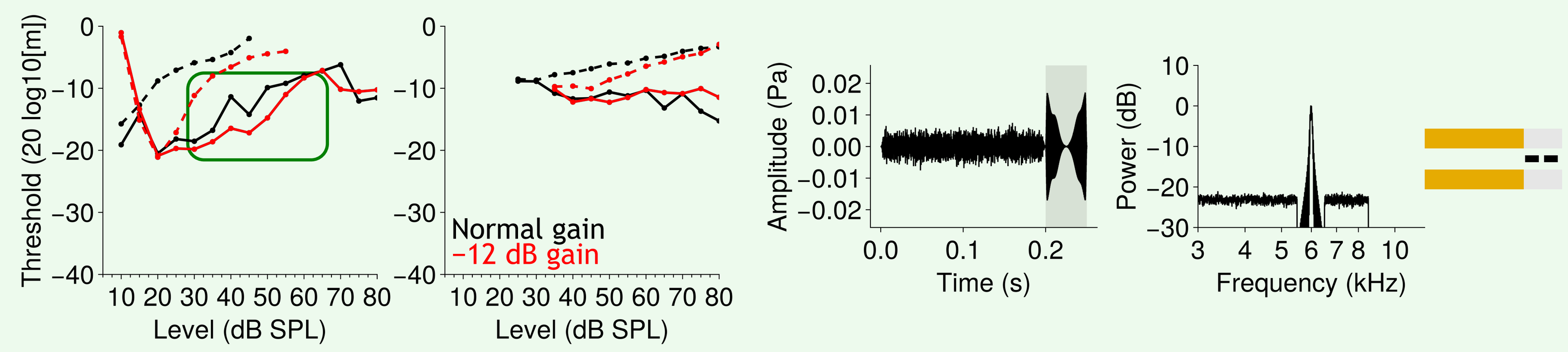


If listeners do not use off-frequency listening, reductions in cochlear gain enhance coding of sound level and AM.

Do reductions in cochlear gain improve coding of sound level or AM in noise?



Simulated level-discrimination thresholds (Roverud and Strickland, 2015; top) or AM-detection thresholds (Almishaal et al., 2017; bottom) in notched noise (# fibers per CF = 100). The decision variable was average rate (level discrimination) or vector strength (AM detection) in the probe window. Sensitivity was determined for many ΔL/m values and then interpolated before identifying a threshold at d' = 1.



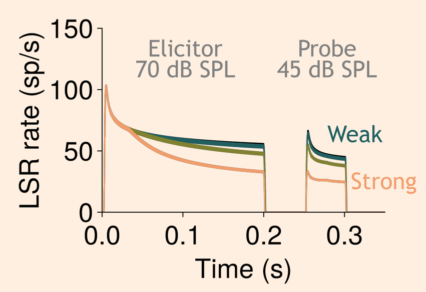
Yes, gain reduction enhances level and AM coding when notched noise is present

Do precursors used in behavioral studies likely activate the MOCR at the probe CF?

Two key parameters to consider:

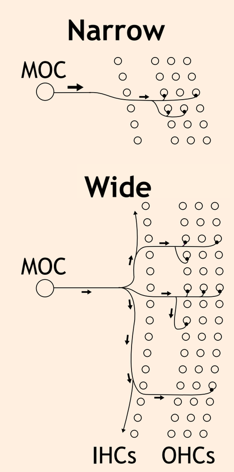
Overall strength

An MOCR strength parameter was calibrated to data from contralateral elicitors under anesthesia (Warren & Liberman, 1989). For simulating awake human data with ipsilateral elicitors, a suitable value for the strength parameter is not immediately clear.

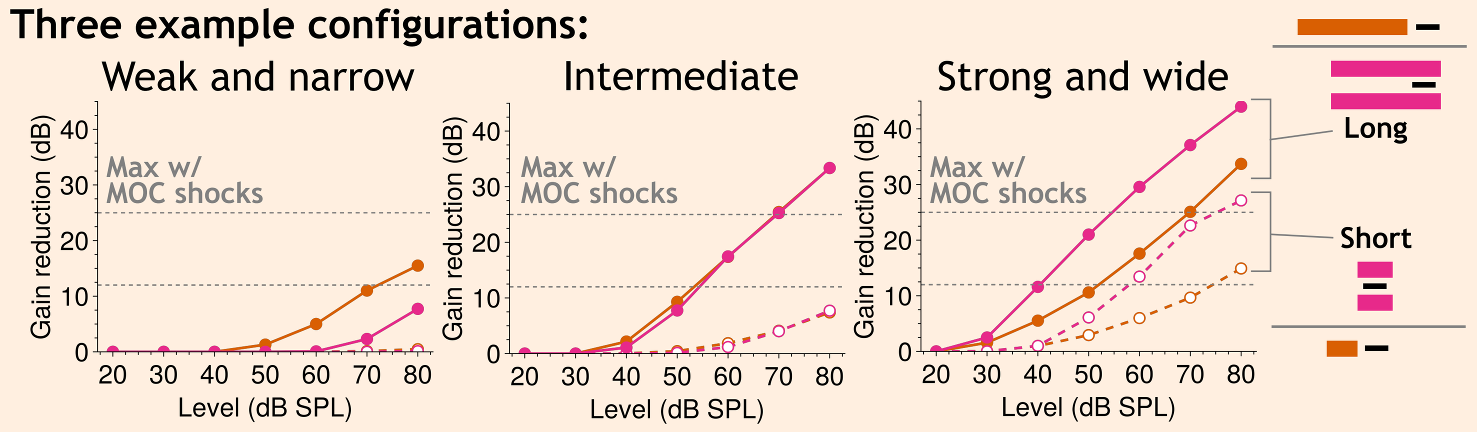


Tonotopic "spread"

A parameter governing the tonotopic extent to which MOC activity in one channel can influence gain in other channels was also calibrated based on Warren & Liberman (1989). Preliminary simulations suggest that this span is broad (>> tuning bandwidth, < octave). Its value is uncertain but has influence on the effects of behavioral precursors.



Three example configurations:

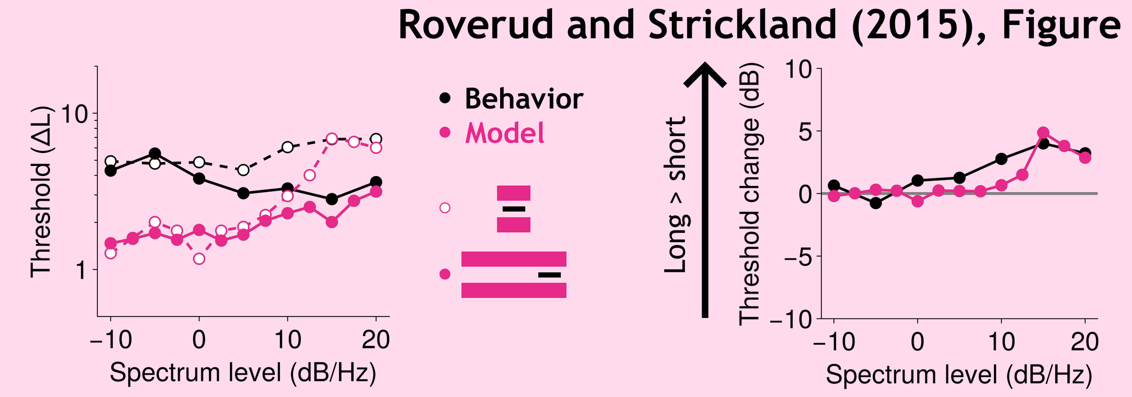


Simulated reduction in cochlear gain during probe window for precursor stimuli from Roverud & Strickland (2015) versus probe level (noise spectrum level = 30 dB below probe level; frequency = 6 kHz). We compare three parameter configurations: left, MOC effects are restricted to within-channel effects and strength was set to match contralateral acoustic stimulation physiology under anesthesia (Warren and Liberman, 1989); middle, intermediate; right, strength was increased and MOC effects spread over a tonotopic range indicated by off-frequency data from Warren & Liberman (1989).

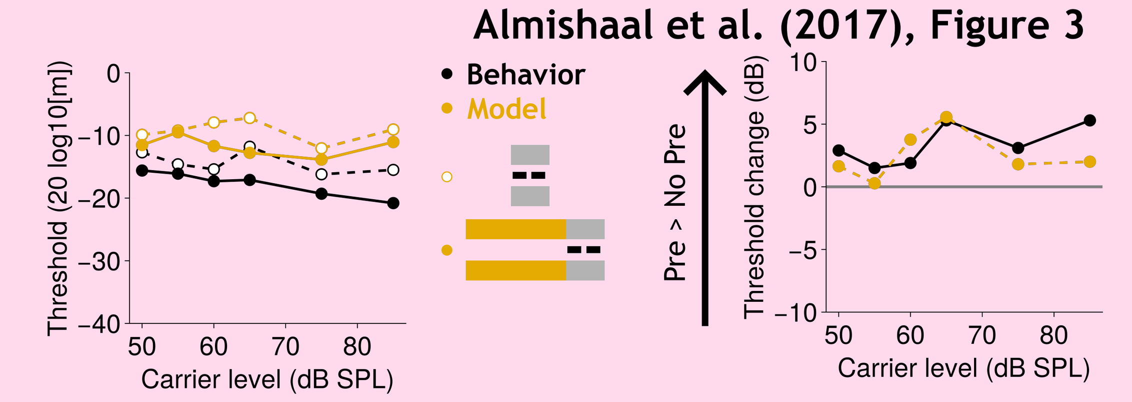
Unclear; predicted precursor effects depend on parameters that are not yet well constrained

Does our sound-driven model predict key behavioral trends?

Roverud and Strickland (2015), Figure 6



Almishaal et al. (2017), Figure 3



Behavioral level-discrimination thresholds (Roverud and Strickland, 2015; Figure 6) or AM-detection thresholds (Almishaal et al., 2017; Figure 3 for a short versus long NN configuration. Model parameters were set to the "Strong and Wide" configuration (see parameter panel). Raw thresholds are shown on the left; the threshold improvement due to the longer precursor is shown on the right. Decision variables matched those used above, but here cochlear gain was determined based on the simulated MOCR and not fixed at a specific value.

Yes! Our model shows qualitatively similar precursor effects as behavioral paradigms.

CONCLUSIONS

Simulations are consistent with the idea that **efferent gain control enhances coding of sound level and amplitude modulation in noise at moderate levels** (~40-70 dB SPL)
→ See comparison to behavioral data

However, these effects only manifest in our efferent model when:

1) **Off-frequency listening is restricted** by noise maskers
→ Compare ideal-in-quiet to in-noise results

2) The **strength of the awake ipsilateral MOCR** is greater than indicated by contralateral effects under anesthesia (Warren & Liberman, 1989)
→ See underlying parameters

Future work will explore the impact of different decision variables and readout strategies and potential contributions of descending input from the midbrain to MOC

REFERENCES & ACKNOWLEDGEMENTS

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Wojtczak, Klang, & Torunsky (2019). *JARO*, 20(4), 395-413.
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