Comodulation Masking Release: A Computational Model

Matthew Ning, Antje Ihlefeld

New Jersey Institute of Technology, Newark, NJ

Abstract

Previous work establishes that for tone detection in background noise, normal-hearing (NH) listeners have better behavioral thresholds when the temporal envelope of that background noise is gated as opposed to stationary.

However, hearing impaired listeners and cochlear implant users typically benefit much less or not at all from temporal fluctuations in background sound.

Sensory deficits under hearing loss can in part explain this reduced perceptual benefit. However, the role of the central nervous system in processing masked tones remains incompletely understood.

Here, we test a **computational model of central nervous system (CNS) function to account for decreased tone detection performance in background noise under hearing loss**.

Comodulation Masking Release

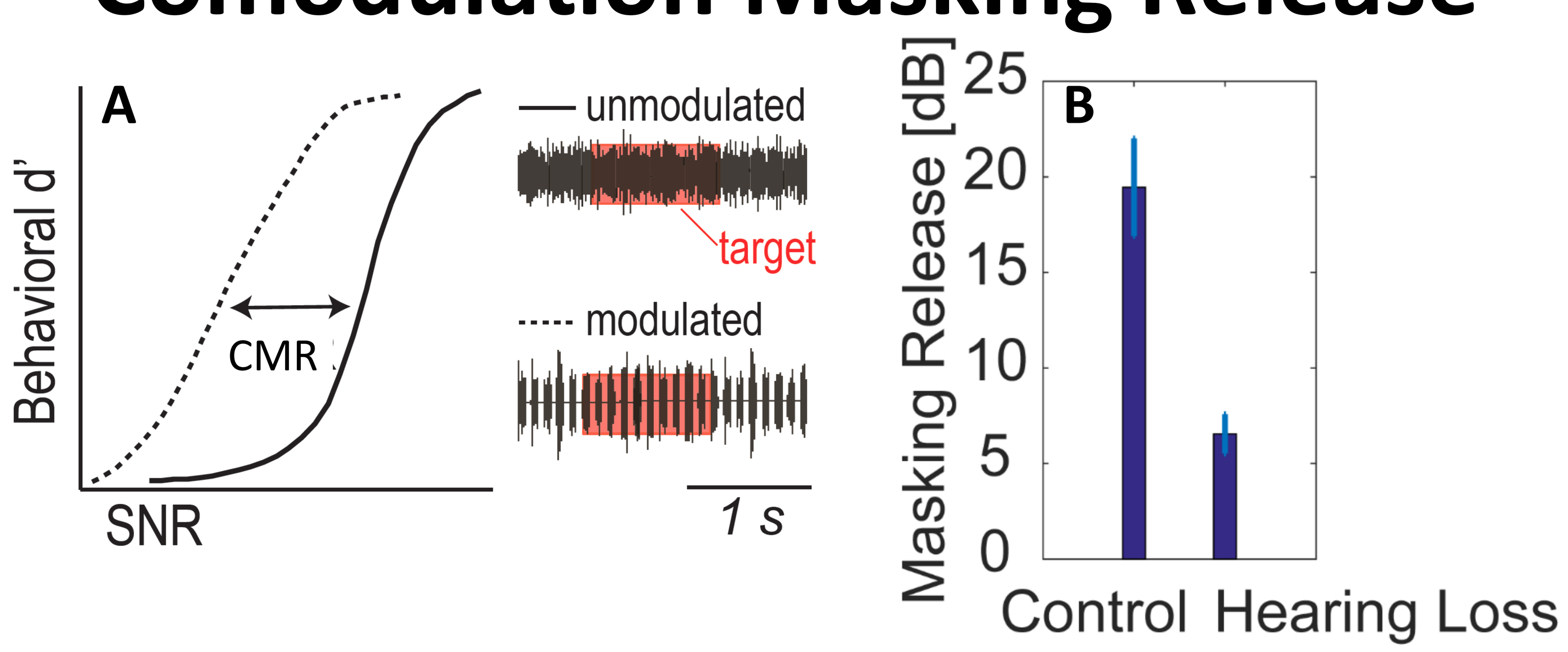

Figure 1. A: Class Comodulation Masking Release Paradigm. **B:** Recent behavioral findings in a rodent model of hearing loss (Ihlefeld *et al.*, 2016).

Hypothesis

Hearing loss weakens inhibitory strength throughout the auditory central nervous system and this could contribute to a reduced ability to listen in situations with background sound.

Prediction

2 key features of neural network are needed to properly segregate sound sources: **feedforward inhibition** and **short-term depression**.

By weakening the parameters for both, we examine how would this particular neural network responds to sound under hearing loss.

Model

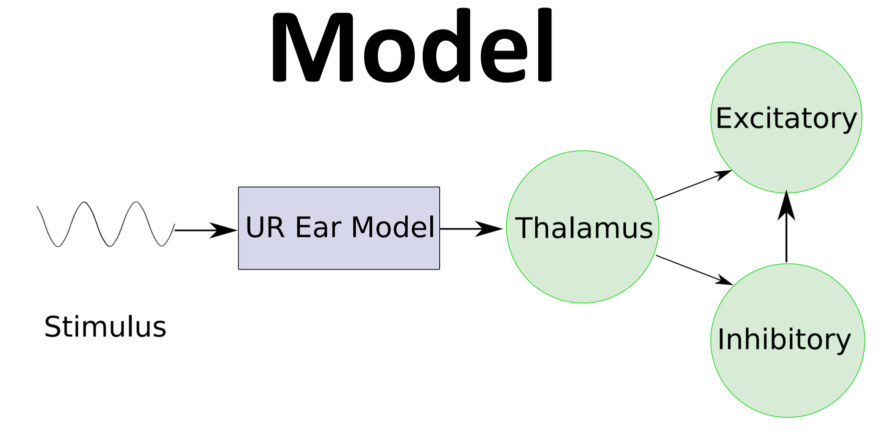

Figure 2. Computational model. The UR Ear Model simulates the output of the inferior colliculus (Carney 2016). The thalamus-cortical model is adapted from Schiff and Reyes (2012).

Acoustic Stimulus

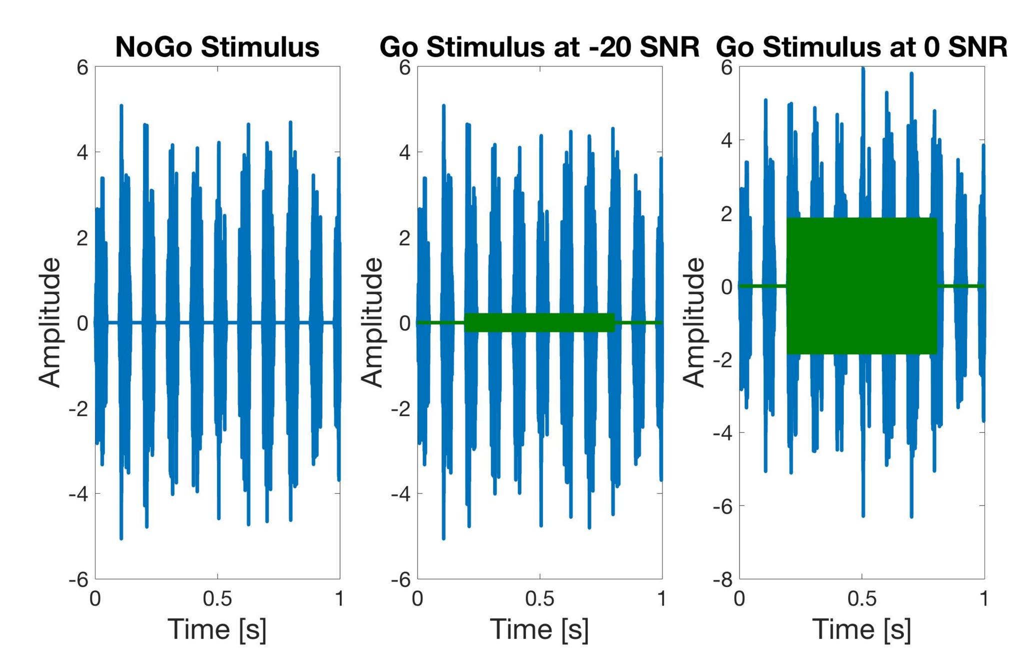

Figure 3. Left to Right: masker, tone at -20 dB SNR, tone at 0 dB SNR.

Result 1

Normal hearing (NH) Go vs. NoGo Trial. By comparing the neural activities at different SNR, we see that the neurons respond strongly to dips with additive spikes and suppress responses to masker bursts with subtractive spikes, a phenomenon known as envelope locking suppression (e.g. Las *et al.*, 2005).

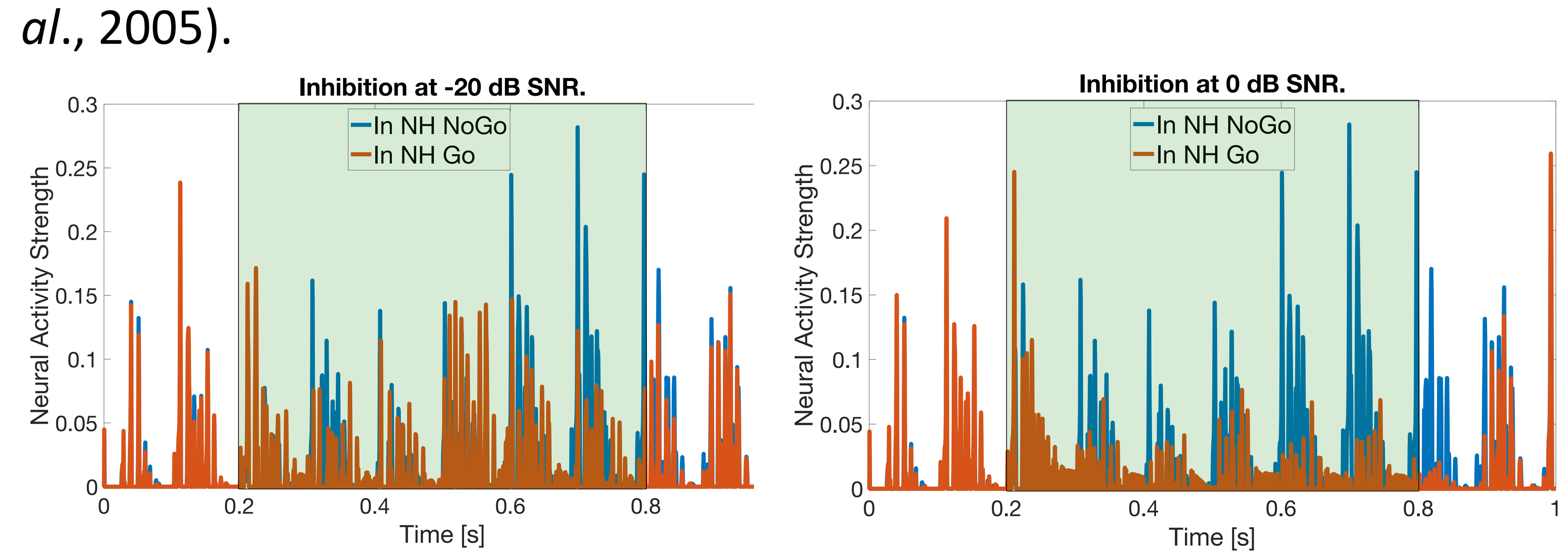

Figure 4. NH Go vs. NoGo Trial. Left: Inhibitory response at -20 dB SNR. Right: Inhibitory response at 0 dB SNR.

Result 2

NH vs. Conductive Hearing Loss (CHL). The model predicts weakened envelope locking suppression and lower neural activity.

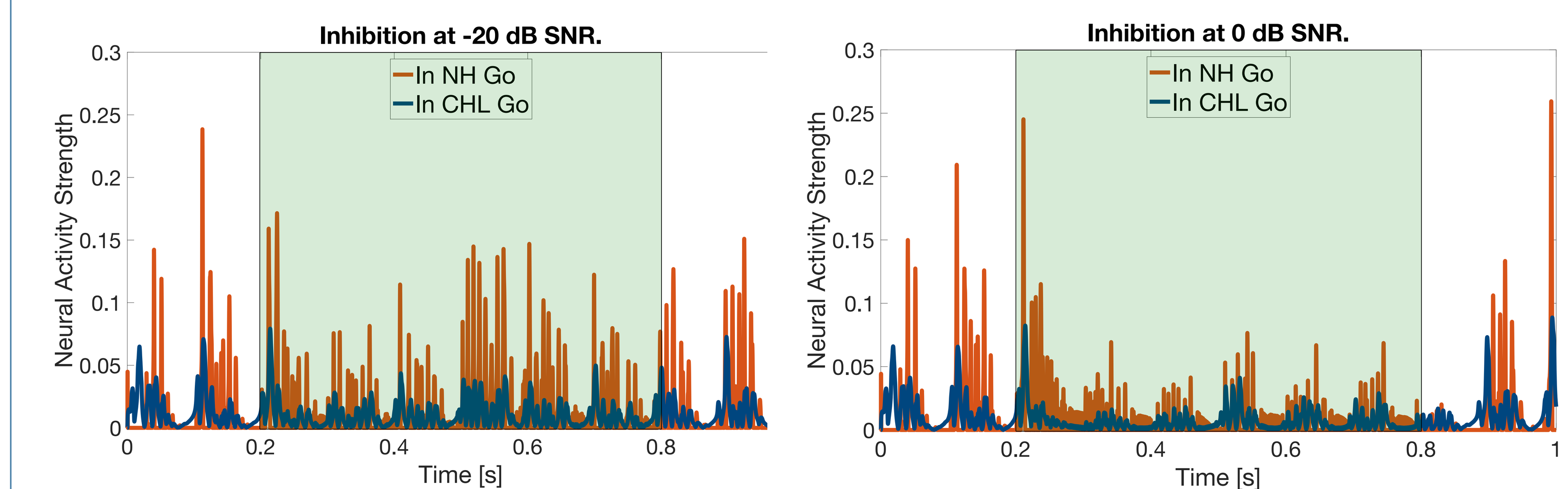

Figure 5. Go Trial normal hearing vs. conductive hearing loss. Left: Inhibitory response at -20 dB SNR. Right: Inhibitory response at 0 dB SNR.

Result 3

CHL Go vs. NoGo Trial. Despite reduced overall neural activity, differences in firing pattern between Go and NoGo trials persist, albeit at much reduced magnitude. Thus, hearing loss individuals may be able to recover background listening.

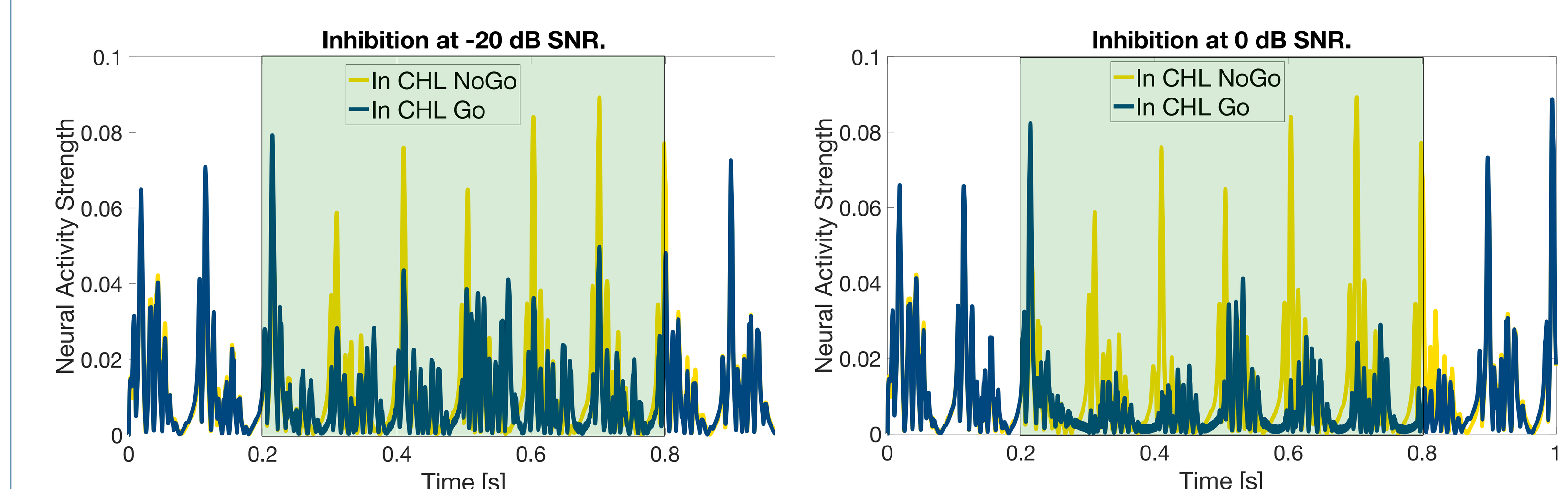

Figure 6. CHL Go vs. NoGo Trial. Left: Inhibitory response at -20 dB SNR. Right: Inhibitory response at 0 dB SNR.

Discussion

We observe reduction in overall neural activity under simulated hearing loss. However, using realistic parameters of weakened inhibition, this reduction in activity affects both conditions with and without the target tone. Envelope locking suppression persists, albeit at reduced strength.

References

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Las, L., Stern, E.A. and Nelken, I., 2005. Representation of tone in fluctuating maskers in the ascending auditory system. Journal of Neuroscience, 25(6), pp.1503-1513.

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Schiff, M.L. and Reyes, A.D., 2012. Characterization of thalamocortical responses of regular-spiking and fast-spiking neurons of the mouse auditory cortex in vitro and in silico. Journal of neurophysiology, 107(5), pp.1476-1488.

Acknowledgement

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