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Connecting a Biophysical Auditory Periphery Model to Perceptual Back-ends for Psychoacoustic Performance Prediction across Tasks

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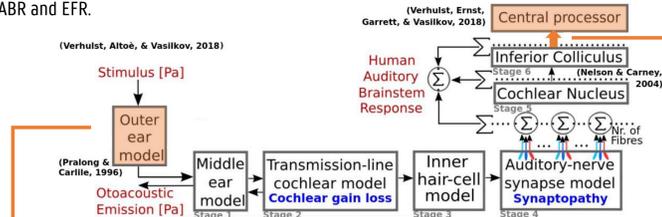
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Motivation

Biophysical models of the human auditory periphery can simulate objective markers of peripheral hearing such as auditory brainstem responses (ABRs), and envelope-following responses (EFRs), and can be used to simulate how hearing loss affects these responses. Here we show how perceptual back-ends can be attached to a model to predict behavioral detection thresholds in 3-AFC psychoacoustic tasks. Our objective is to better understand how the simulated detection cues are affected (1) by intrinsic changes in the test stimuli, and (2) as a function of outer-hair-cell deficits or synaptopathy.

Auditory Periphery Model

The Verhulst, Altoè, & Vasilkov, (2018) model was primarily validated (1) to capture broadband and level dependent cochlear filter tuning derived from human OAEs, Single-unit AN adaptation and EFR properties, and (2) it can be used to study the impact of OHC and AN fiber/synapse loss have on ABR and EFR.

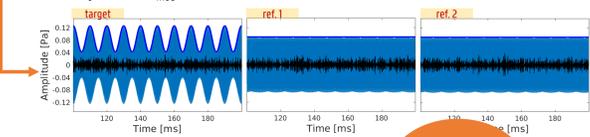


Approach

- Two back-ends (central processors) were added to study their robustness to predict behavioral performance across task conditions within and across listeners.
- We designed the simulation procedure to mimic as realistically as possible the actual listening task
- Objective: Investigate how well can these perceptual models predict absolute psychoacoustic performance and between-subject variability and how they relate to stimulus-driven changes and sensorineural hearing loss, namely OHC damage and synaptopathy.

Psychoacoustic Task: 3-AFC AM detection

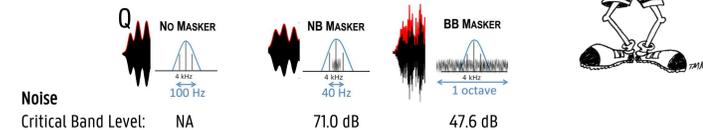
Stimulus: $f_c = 4 \text{ kHz}$, $f_{mod} = 100 \text{ Hz}$, $dur = 500 \text{ ms}$, 70 dB SPL



Independent variable: Modulation depth m [dB]

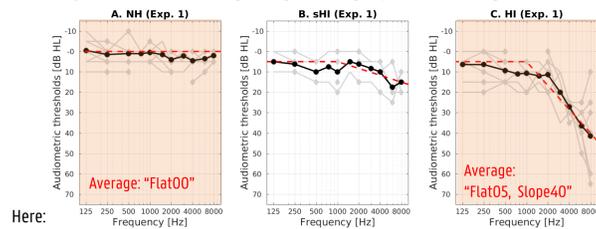
Test outcome: Modulation detection threshold [dB]

Three background noise conditions:



Experimental data

34 Participants: 14 Normal Hearing, 10 slight Hearing Impaired, 10 Hearing Impaired



Here: Simulations using average Hearing Profiles of the NH and HI groups (Flat00 and Flat05-Slope40)
For each cochlear gain profile two synaptopathy conditions were simulated: 13-3-3 and 7-0-0

Simulations

Independent variable: Modulation depth m [dB].
Fixed steps at -30, -24, -18, -12, -6, and 0 dB

Trials: Each condition was repeated 20 times

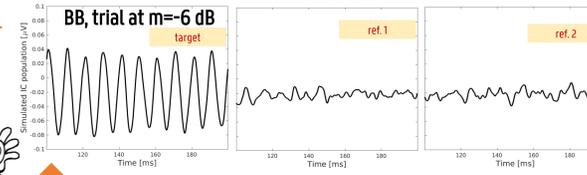
Hearing Impaired profiles:

- Flat00 + 13-3-3
- Flat00 + 7-0-0
- Flat05, Slope40 + 13-3-3
- Flat05, Slope40 + 7-0-0



Back-end Processor

Input to the back-end of the model: IC output (401 channels)

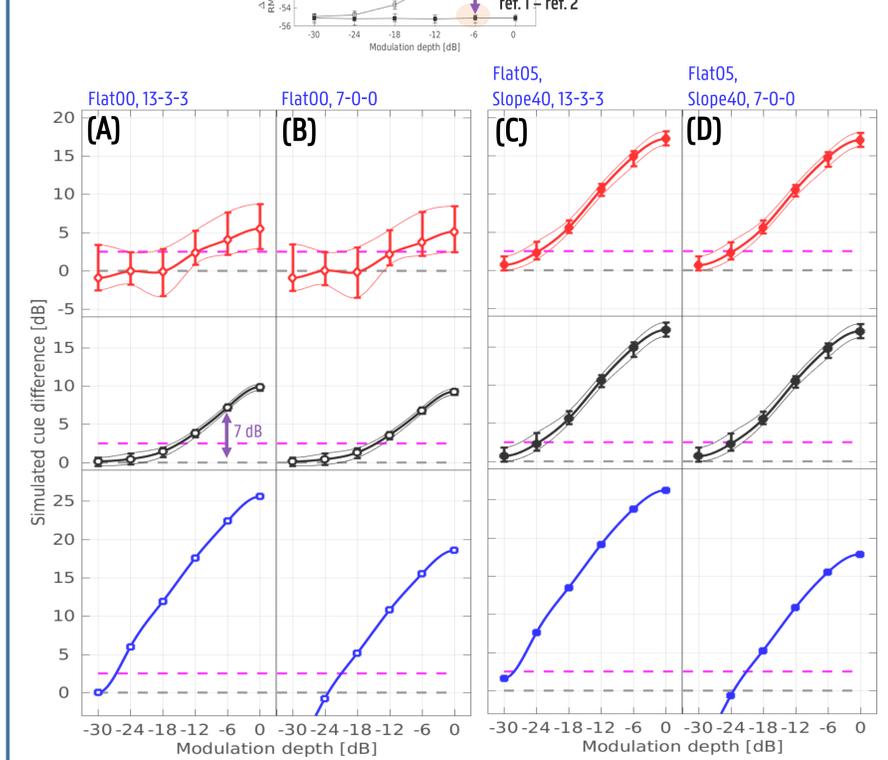


Decision type 1

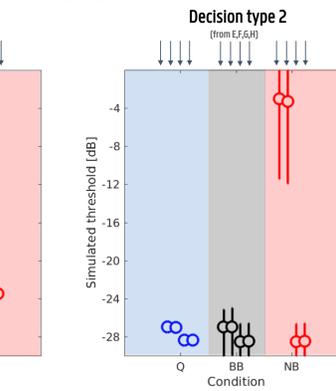
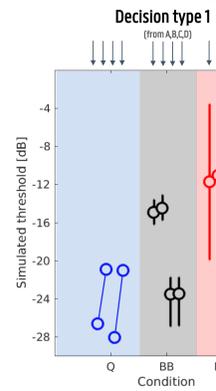
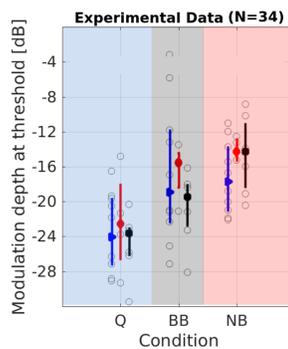
Within-trial RMS detector

Rationale:

Intervals target-ref.1-ref.2 directly compared to each other:



Results



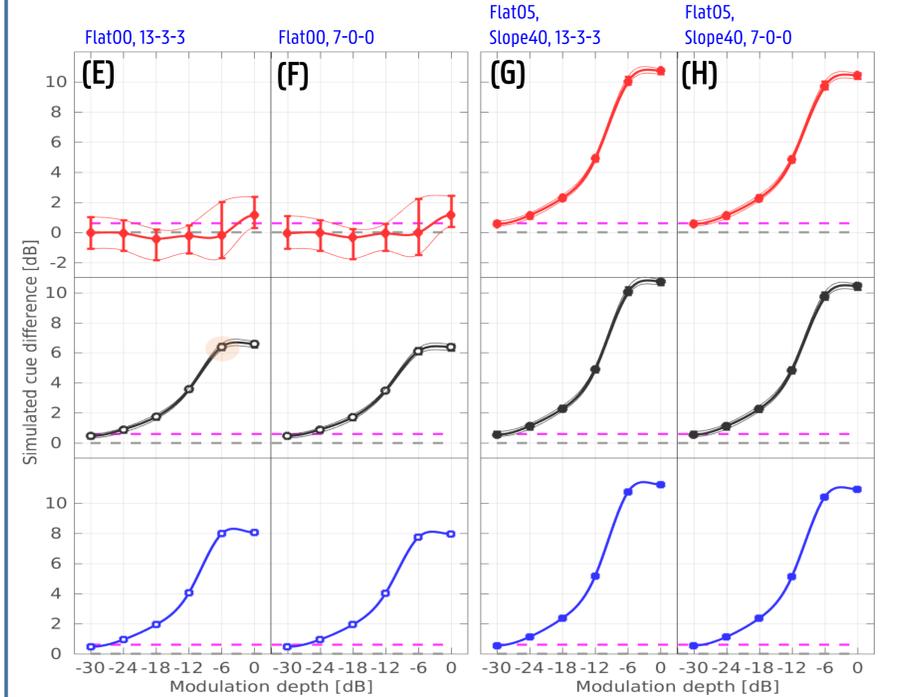
Decision type 2

Template-based RMS detector

Rationale:

Subjects can internalize the sounds they are listening to: they generate and use a "template" to perform the task.

The template is an average representation of a clearly detectable trial. Here we used $m = -3 \text{ dB}$



Discussion

In this work we examined to which extent two back-end processing stages attached to a biophysical auditory model can simulate a high-frequency AM detection task. We showed that:

- A psychoacoustic calibration is needed: The absolute sensitivity of the model depends on the attached back-end stage. It is relevant to establish a limit for the model resolution.
- The simulations using normal-hearing profiles were more affected by stimulus-driven variability, but the simulated variability is larger than in the experimental data.
- The detection cues in the BB condition increased when outer hair cell damage is accounted for.
- In this task, synaptopathy has the largest simulated effect on the quiet condition.
- Cochlear gain loss (Outer hair cell damage) has the largest effect on the BB condition

Acknowledgments

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