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Hidden hearing loss with envelope following responses (EFR): The off-frequency problem

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Introduction

Recent animal studies have shown that noise over-exposure can cause the loss of auditory nerve (AN) fiber synapses without causing hair cell loss (see Kujawa and Liberman (2015) for a review). This AN fiber synapses loss has been termed “hidden hearing loss” or “synaptopathy”, since it is not reflected in the traditional pure-tone threshold. The envelope following response (EFR) has been proposed as a potential objective method to assess synaptopathy in humans (i.e., Bharadwaj et al., 2015), Encina-Llamas et al. (2016) reported different trends in EFR level-growth functions recorded using two modulation depths in normal-hearing (NH) and mild hearing-impaired (HI) listeners. The EFR is a gross cephalographic potential that represents the encoding of the envelope of the stimulus, arising from synchronized neural activity from all excited frequencies and fibers. In this study, a computational model of the AN was used to investigate the effects of off-frequency contributions (i.e. away from the characteristic place of the stimulus) and the differential loss of different AN fiber types on EFR level-growth functions.

Methods

- Can a phenomenological AN computational model explain the different trends observed in the EFR level-growth functions in NH and mild HI listeners reported in Encina-Llamas et al. (2016)?

**Model:**
- Humanized AN model (Zilany et al., 2014).
- 200 characteristic frequencies (CF), ranging from 0.2 to 20 kHz.
- Synapses per IHC are simulated by several independent computations of each AN CF (about 100 per CF). Synaptopathy is simulated by computing loss of such independent computations.

**Levels:**
- EFR level-growth: 5 to 100 dB SPL, 5 dB steps.
- EFR noise: -30 to 40 dB SNR, 5 dB steps. Low SAM at 70 dB SPL.
- EFR noise: -30 to 40 dB SNR, 5 dB steps. Low SAM at 70 dB SPL.
- Medium SAM at 70 dB SPL.

**Markers:**
- Blue markers denote the input level range that can be compared with the recorded EFR data in Encina-Llamas et al. (2016).
- EFR are gross cephalographic potentials, representing the sum of all electrical neural activity at the modulated frequency.

**Conclusion**

- EFRs at high stimulus levels are dominated by the off-frequency contributions.
- EFRs are dominated by the responses from high-SR fibers.
- EFR level-growth functions from synaptopathic frequencies in exposed mice show similar trends to EFR functions in some NH humans listeners (See poster P9 by Aravind Parthasarathy et al.).