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Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
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. (2015) 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 electrophysiological 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.

Research Question
- 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)?

Methods
- **Model**:
  - Humanized AN model (Zilany et al., 2016).
  - 200 characteristic frequencies (CF), ranging from 0.2 to 20 kHz.
- **Simulations I**: 
  - Synapses per IHC are simulated by several independent computations of each AN CF (about 100 per CF). Synaptopathy is simulated by computing less of such independent computations.
- **Simulations II**: 
  - Simulated EFR level-growth functions from synaptopathic simulation to match the NH group in Encina-Llamas et al. (2016).

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 human listeners.

Acknowledgment
Research supported by the Division Center of Excellence for Hearing and Balance (NIDCD 5U54DC015653), through collaboration with Compeat BA, and by DOD W81XWH-15-1-0103 (S00 at NIH).

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