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

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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 electroencephalographic 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, an 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.

Simulations I

Fig. 1 Simulated EFR level-growth functions for the mild-HI group in Encina-Llamas et al. (2016).

Synaptopathy:

- 60% of Med- and Low-SR loss
- EFRs are dominated by the responses from Med- and Low-SR fibers
- The off-frequency problem
- Complete dominance of on-frequency and at high stimulus levels

Mild hearing-impaired:

- NH = 2000 Hz 60 dB (as in Encina-Llamas et al. (2016)).
- Levels:
  - EFR level-growth: 5 to 100 dB SPL, 5 dB steps.
  - Stimuli: 2000 Hz (1/3 octave band at 20 kHz).
- Methods:
  - Full m = 85%, Shalene m = 25%.

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)?

Research Question

- EFR 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 (See poster P9 by Aravind Parthasarathy et al.).

Fig. 2 Simulated EFR level-growth functions with a 60% of loss of medium- and low-sensitivity fibers (SR) AN.

Fig. 3 Simulated EFR level-growth functions with the same ANF loss as in Fernandez et al. (2015) adapted from the mouse to the human cochlea.

Fig. 4 Simulated EFR level-growth functions to match the response from the NH group in Encina-Llamas et al. (2016).

Simulations II

Fig. 5 Simulated EFR level-growth functions for the mild-HI group in Encina-Llamas et al. (2016). The group-averaged audiogram is fitted assuming 2/3 of OHC dysfunction and 1/3 of IHC dysfunction.

Fig. 6 BVR tuning curves simulated with a high-intensity 500 Hz tone. Difference between NH and mild HI due to OHC dysfunction.

Fig. 7 Simulated EFR level-growth functions to match the response from the mild-HI 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 (See poster P9 by Aravind Parthasarathy et al.).

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REFERENCES

Bharadwaj et al. (2015). Comparison between the NH versus the synaptopathic simulation to match the NH group in Encina-Llamas et al. (2016) as in Fig. 4.


