Relation between temporal envelope coding, pitch discrimination, and compression estimates in listeners with sensorineural hearing loss

Bianchi, Federica; Santurette, Sébastien; Fereczkowski, Michal; Dau, Torsten

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Introduction
Recent physiological studies in animals showed that noise-induced sensorineural hearing loss (SNHL) increased the amplitude of envelope coding in single auditory-nerve fibers [1, 2]. As pitch detection of unresolved complex tones is assumed to rely on temporal envelope coding mechanisms, the present study investigated pitch-discrimination performance in listeners with SNHL. Additionally, peripheral loss of compression was considered as a potential factor in envelope coding enhancement. In experiment 1, pitch discrimination was investigated in normal-hearing (NH) and hearing-impaired (HI) listeners for complex tones of varying harmonic resolvability. Envelope processing was assessed in the same listeners in a behavioral amplitude-modulation detection task (experiment 2). Basilar-membrane input/output functions were estimated to assess individual contribution ratios (experiment 3).

Method

- **Participants:** 14 NH listeners, 10 HI listeners
- **Experiment I: Pitch discrimination**
  - **Stimuli:** Sinusoidal carrier at 2 kHz, amplitude modulated at the modulation frequencies (\( f_M \)) of 25, 50, 100, 150, 200, 300, 400, 500, 800, 1000, 1500 Hz.
  - **Paradigm:** 3 AFC, two intervals contained a reference complex tone with a fixed \( f_0 \), and one interval contained a deviant complex tone with a larger \( f_0 \). “Which tone has the highest pitch?”

Experiment II: Amplitude-modulation detection

- **Stimuli:** Sinusoidal carrier at 2 kHz, amplitude modulated at the modulation frequencies (\( f_M \)) of 25, 50, 100, 150, 200, 300, 400, 500, 800, 1000, 1500 Hz.
- **Paradigm:** 3 AFC, two intervals contained a pure tone and one interval contained the amplitude modulated tone. The smallest detectable modulation depth (\( d \)) was measured as a function of \( f_M \) (i.e., temporal modulation transfer function, TMTF).

Experiment III: Cochlear compression estimates

- **Measure temporal masking curves (TMC) and derive basilar-membrane input/output function (BMIO) [4].**
- **Stimuli:** Sinusoidal probe at 2 kHz.
  - **On-frequency masker:** tone at 2 kHz.
  - **Off-frequency masker:** tone at 1 kHz.
  - **Measure masker level where probe is just audible as a function of gap duration.

Results

**Experiment I: Pitch discrimination**

- **NH listeners (sine phase)**
  - 6 musicians
  - 8 non-musicians
- **HI listeners (deviant phase)**
  - 4 musicians
  - 6 non-musicians

**Discussion**
As pitch-discrimination thresholds were found to depend on musical training, the ratio between random-phase and sine-phase thresholds (F0DL ratio in Fig. 6) of unresolved complex tones was used as an indicator of envelope processing, independent of musical training. Nine HI listeners showed F0DL rates larger than NH listeners, suggesting that changes in envelope coding play a role in pitch-discrimination of unresolved complex tones. Figure 8 shows that there is a trend for the increase of auditory filters bandwidth and loss of cochlear compression to consistently vary with the increase of F0DL ratios (panels A) and decrease of modulation thresholds (panels B).

Conclusions and perspectives
Overall, these findings suggest that changes in temporal envelope coding ID listeners affect pitch discrimination of unresolved complex tones. Such changes seem to be partly ascribed to auditory filters broadening and loss of cochlear compression. Future modeling work will consider the effects of degraded frequency selectivity and loss of compression on the modulation power at the output of the auditory filters to clarify how each factor contributes to pitch-discrimination performance in HI listeners.

References