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

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

Publication date:
2015

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

Citation (APA):
Bianchi, F., Santurette, S., Fereczkowski, M., & Dau, T. (2015). *Relation between temporal envelope coding, pitch discrimination, and compression estimates in listeners with sensorineural hearing loss*. Poster session presented at 169th Meeting of the Acoustical Society of America, Pittsburgh, Pennsylvania, United States.

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

Federica Bianchi[1*], Sébastien Santurette[1], Michal Fereczkowski[1], Torsten Dau[1]

[1] Hearing Systems, Technical University of Denmark, Ørsteds Plads Building 352, 2800 Kongens Lyngby, Denmark

*fbia@elektro.dtu.dk

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 coding 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 compression ratios (experiment 3).

Method

- Participants: 14 NH listeners, 10 HI listeners with SNHL.

Experiment I: Pitch discrimination

- Pitch discrimination of complex tones was measured via difference limens for fundamental frequency (F_0DLs).
- Stimuli: **Sine-phase** and **random-phase** complex tones filtered in either a **low** (LF: 0.3-1.5 kHz) or a **high** (HF: 1.5-3.5 kHz) frequency region to vary the resolvability of the harmonics [3].
- 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?"

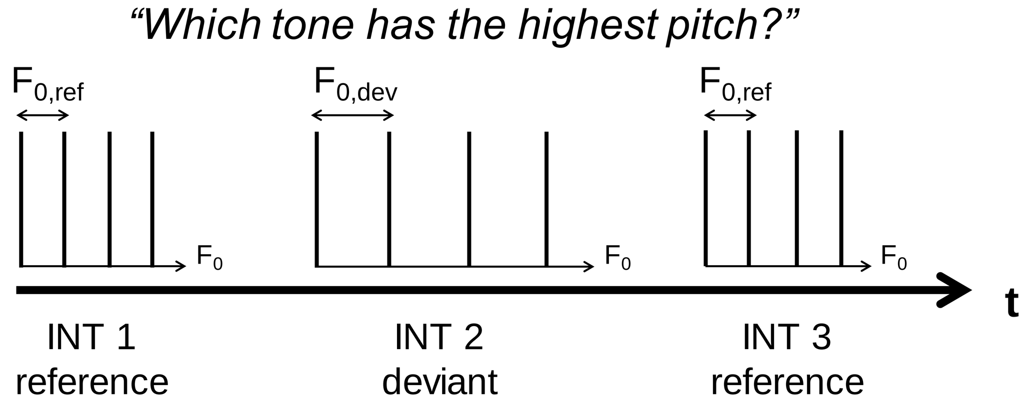


Figure 1 Stimulus presentation for the pitch discrimination experiment in a 3 AFC task. Listeners were asked to press a response button after stimulus presentation.

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 (m) 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 1.2 kHz.
- Measure masker level where probe is just audible as a function of gap duration.

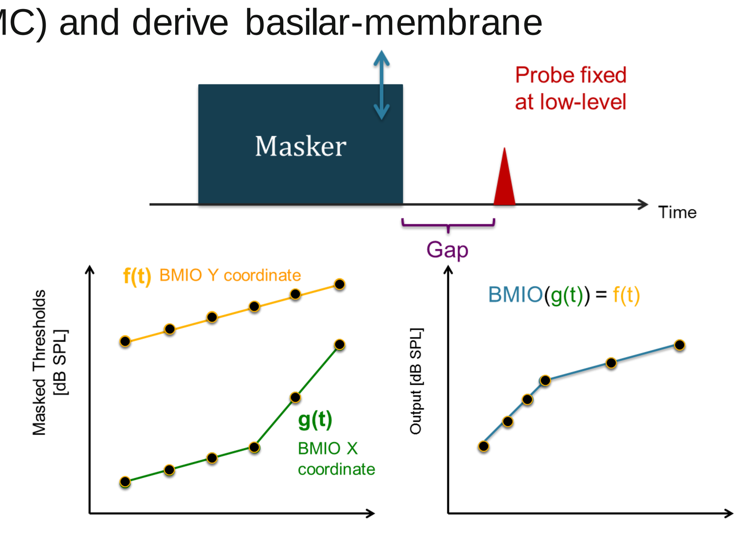


Figure 2 Stimulus presentation for TMC experiment (top panel). Schematics of the TMC (bottom left panel) and derived BMIO (bottom right panel).

Results

Experiment I: Pitch discrimination

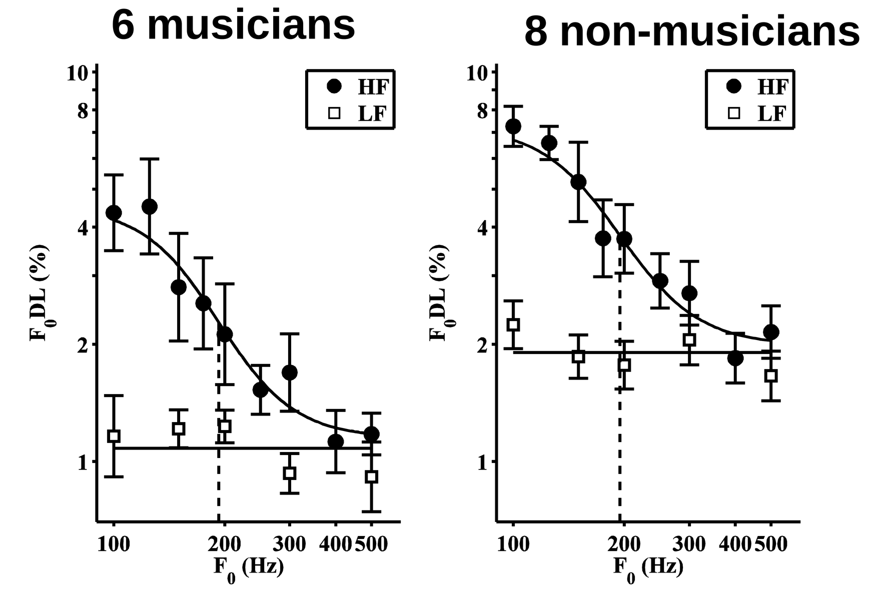


Figure 3 Pitch discrimination thresholds as a function of F_0 for complex tones filtered either in a low (white squares) or high (black circles) frequency region. Left panel: Musicians, right panel: Non-musicians.

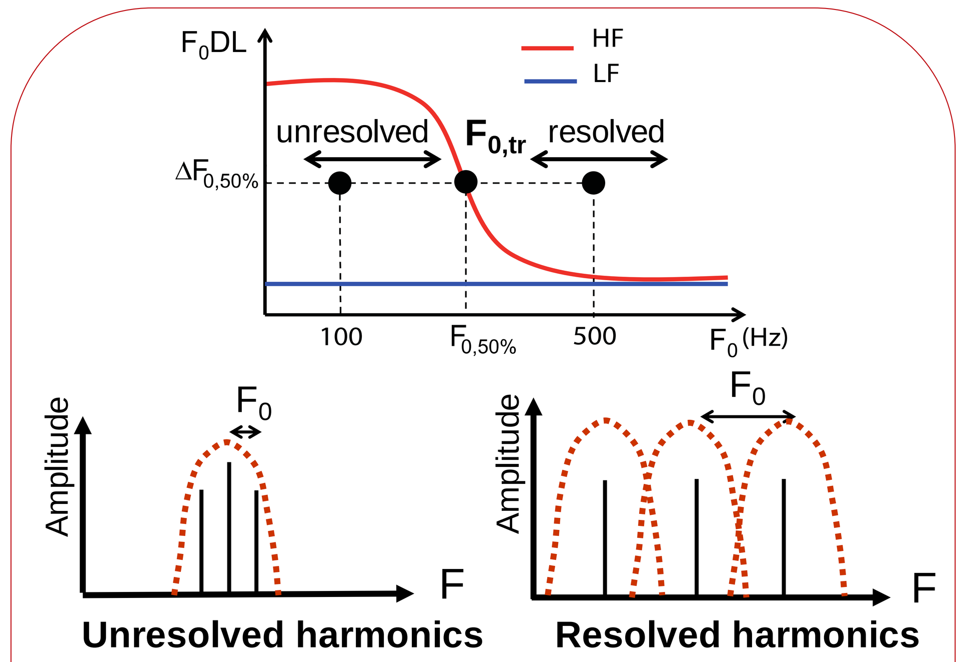


Figure 4 The transition point ($F_{0,tr}$) depicts the point on the fitted sigmoid for which the harmonics start to get resolved.

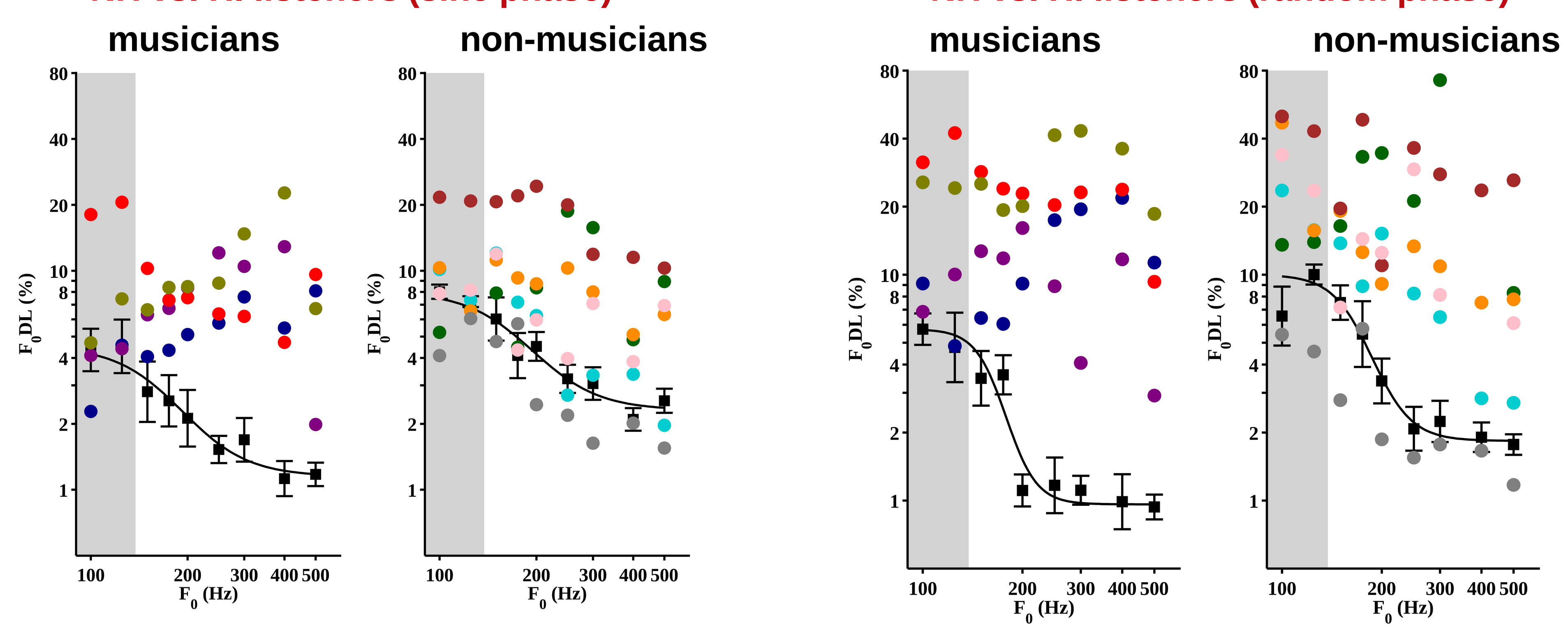


Figure 5 Pitch discrimination thresholds as a function of F_0 for HF-filtered complex tones. Black squares: Mean of NH listeners; colored circles: Individual HI thresholds. The gray-shaded region depicts the region where the complex tones are unresolved for both NH and HI.

- Pitch-discrimination thresholds were dependent on musical training (see Fig.3) [5, 6, 7].
- Unresolved conditions (gray-shaded region in Fig.5):
  - 8 HI performed **as well as NH** for **sine-phase** complexes
  - 6 HI performed significantly **worse than NH** for **random-phase** complexes.
- The ratio between the random-phase and the sine-phase threshold for unresolved complex-tone can be considered as an indicator of envelope processing that is independent of musical training (see Fig.6).

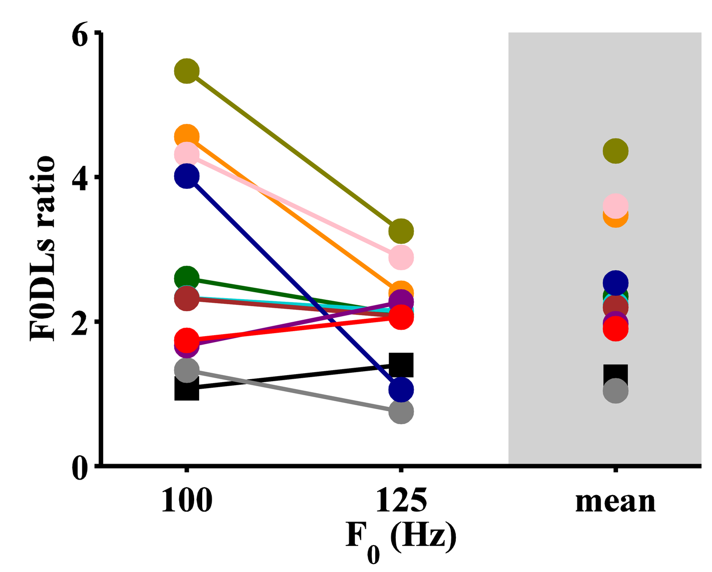
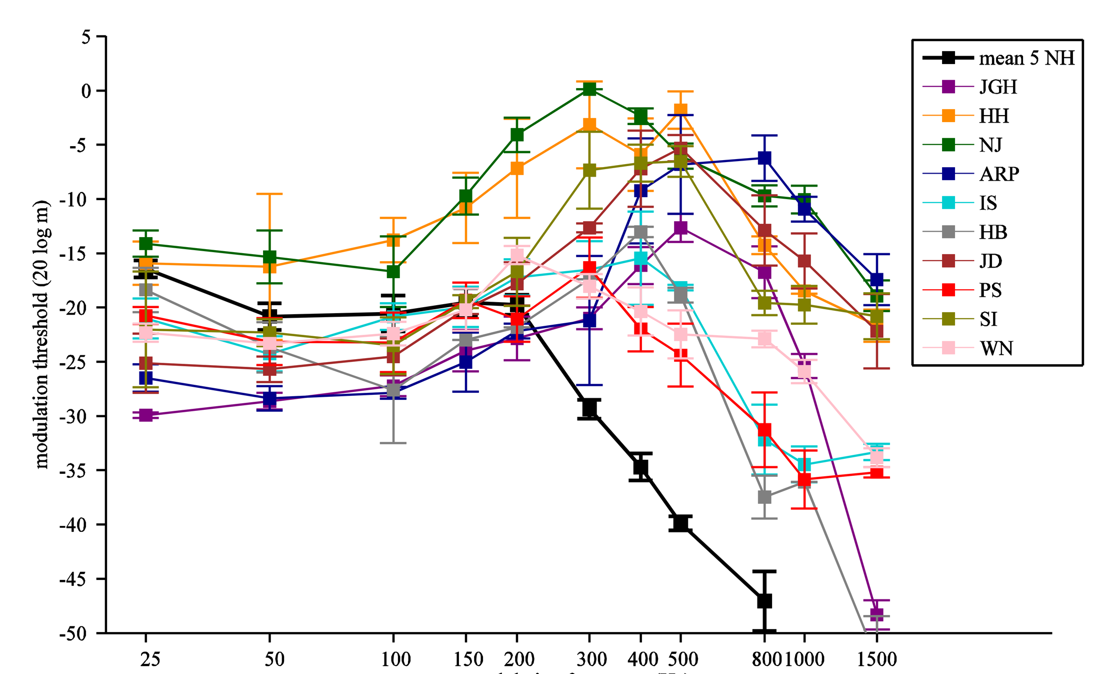


Figure 6 Ratio of random-phase and sine-phase pitch-discrimination thresholds for NH (black squares) and HI listeners (colored circles).

Experiment II: Amplitude-modulation detection



- 8 Hi listeners showed lower modulation thresholds than NH, when the sidebands were unresolved (i.e., for f_m < 200 Hz).
- Auditory filter bandwidth (BW) at 2 kHz was estimated from the TMTF curves (at the f_m corresponding to the 10-dB point re. the maximum threshold).

Figure 7 Amplitude-modulation thresholds for NH (black squares) and HI listeners (colored squares).

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 ratios 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 with the increase of F0DL ratios (panels A) and decrease of modulation thresholds (panels B).

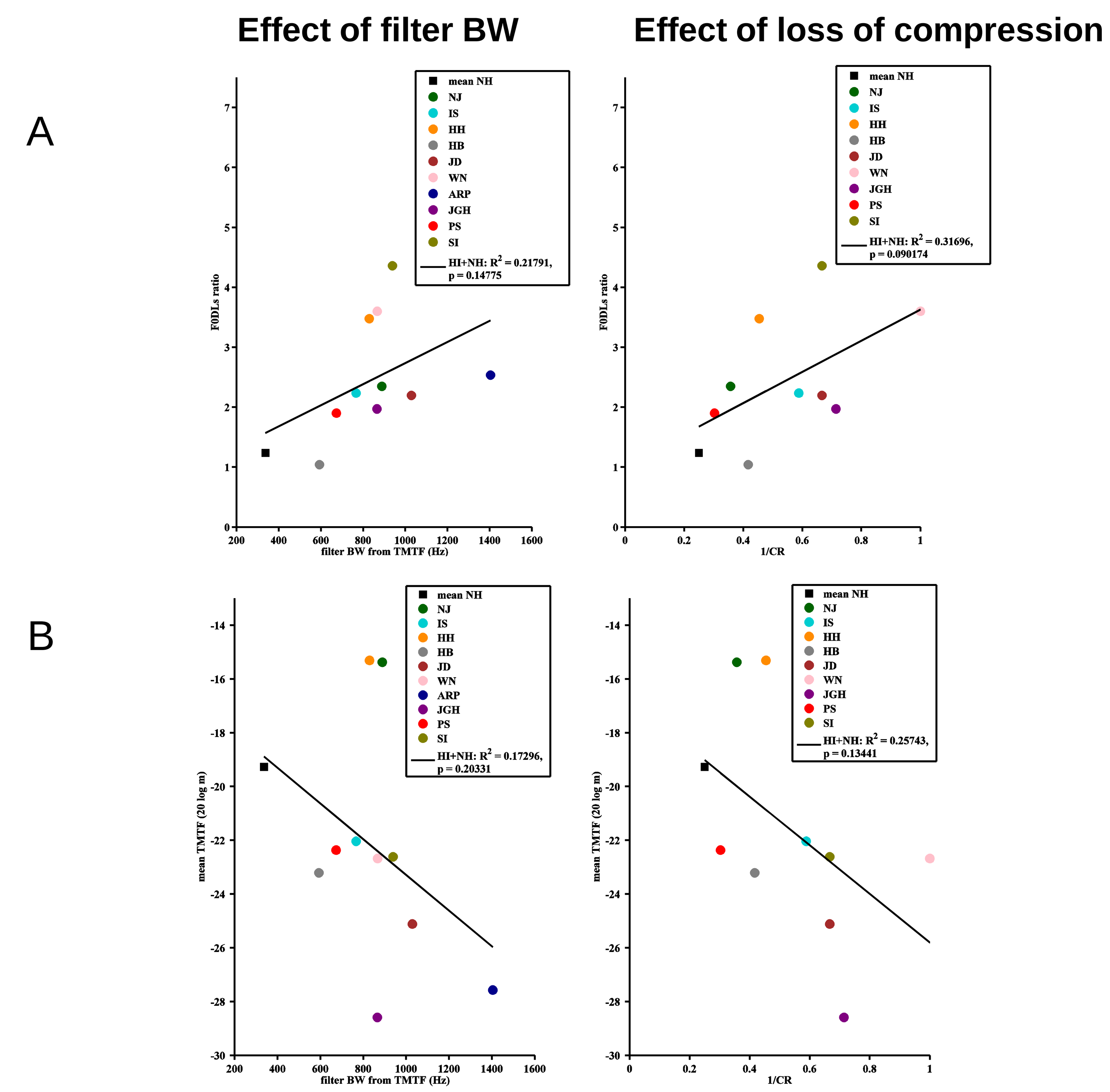


Figure 8 Correlation of F0DL ratios (A) and mean TMTF between 25 and 100 Hz (B) with auditory filter BW estimated from the TMTF curves (left panels) and loss of cochlear compression (right panels), for NH listeners (black square) and HI listeners (colored circles).

Conclusions and perspectives

Overall, these findings suggest that changes in temporal envelope coding in HI 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:

(1) Kale, S. and Heinz, M.G. (2010) "Envelope coding in auditory nerve fibers following noise-induced hearing loss". J. Assoc. Res. Otolaryngol. 11: 657–673.
(2) Henry, K.S., Kale, S. and Heinz, M.G. (2014) "Noise-induced hearing loss increases the temporal precision of complex envelope coding by auditory-nerve fibers". Frontiers in Systems Neurosci. 8 (20): 1-10.
(3) Bernstein, J.G.W. and Oxenham, A.J. (2006) "The relationship between frequency selectivity and pitch discrimination: Sensorineural hearing loss". J. Acoust. Soc. Am. 120 (6), 3929–3945.
(4) Fereczkowski, M. (2015) "Time-efficient behavioural estimates of cochlear compression", Contributions to Hearing Research, Volume 20 (PhD thesis).
(5) Micheyl, C., Delhommeau, K., Perrot, X., Oxenham, A. J. (2006). "Influence of musical and psychoacoustical training on pitch discrimination," Hear. Res. 219, 36–47.
(6) Spiegel, M.F., Watson, C.S. (1984). "Performance on frequency discrimination tasks by musicians and non-musicians". J. Acoust. Soc. Am. 76, 1690–1695.
(7) Kishon-Rabin, L., Amir, O., Vexler, Y., Zaltz, Y. (2001). "Pitch discrimination: are professional musicians better than non-musicians?" J. Basic Clin. Physiol. Pharmacol. 12 (2 Suppl), 125–143.