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Spectro-temporal modulation sensitivity and discrimination in normal hearing and hearing - impaired listeners

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Introduction

When a signal varies in its properties along the time and frequency, this is considered a modulation. Speech signals exhibit temporal and spectral modulations. The sensitivity to these modulations has been studied in normal-hearing (NH) listeners, yielding temporal, spectral and spectro-temporal modulation transfer functions (Dau et al. 1997, Eddins & Bero 2007, Chi et al. 1999). Recently, Mehraei et al. (2014) showed significant differences between normal-hearing and hearing-impaired (HI) listeners in spectro-temporal modulation (STM) *detection* and also the relation between STM sensitivity to speech intelligibility in noise. Moreover, Henry et al. (2005) showed large differences in STM *discriminations tasks*. The present study attempted to establish the limits of STM perception in NH listeners and two groups of HI (with either good or poor speech intelligibility).

Motivation

The reduced STM sensitivity in HI listeners has been ascribed to temporal fine structure processing deficits and a loss of frequency selectivity (Bernstein et al. 2013, Mehraei et al. 2014) . The main assumption of this study is that the individual differences in STM sensitivity can be related to the **existence of supra-threshold distortions** (Plomp, 1986).

Research Questions

Q1: Where are the limits of STM perception in NH listeners for narrow-band noise carriers?

Q2: Can supra-threshold distortions be characterized by STM detection thresholds?

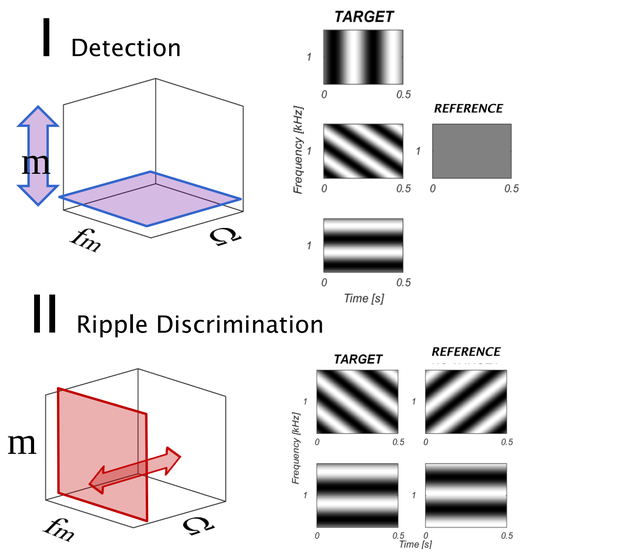


Fig. 1: STM are defined by modulation depth (amount of modulation), modulation frequency (f_m, cycles per second) and spectral density (Ω, cycles per octave). The tasks performed here are **I Detection:** minimun amount of modulation, **II Discrimination:** maximun spectral density for fully modulated ripples.

Experiment I: Limitations in STM sensitivity and discrimination in NH listeners

Method

Subjects:
15 Young NH listeners

Procedure:
3AFC, 1-up 2-down

Stimuli:
Level: 35 dB SL
Modulated 1 octave noise:

- F_c = 1kHz
  f_m = 4 Hz , Ω = 2 c/o
- F_c = 4kHz
  f_m = 4 Hz, Ω = 4 c/o

Results

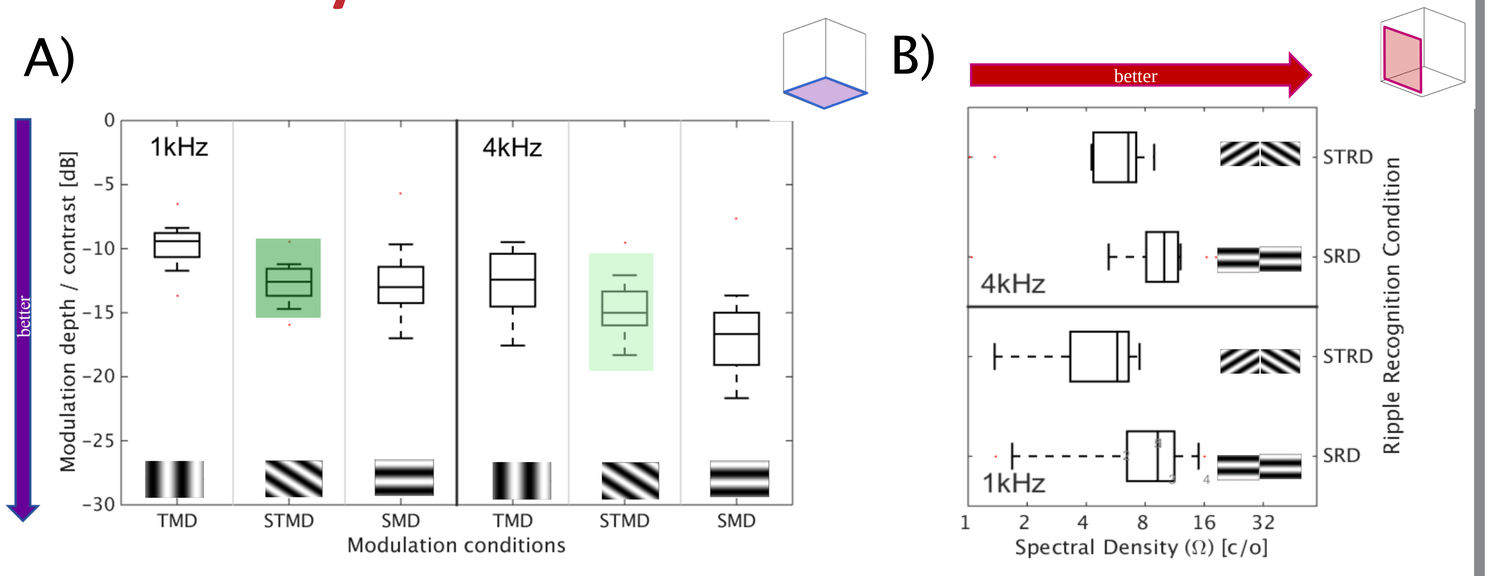
Fig. 2: A) Detection thresholds for temporal (TMD), spectral (SMD) and spectro-temporal modulations (STMD).

⇨ The STMD thresholds were lower (better) than only TMD

B) Spectro-temporal ripple discrimination (STRD) and Spectral (SRD) ripple discrimination for 1-octave band modulated noises.

⇨ There was not significant difference for the two frequency conditions.

⇨ STRD threshold was lower and was found less suitable for a clinical set-up.



Experiment II: Spectro-temporal modulation sensitivity and hearing deficits

Method

Subjects:
23 subjects were divided in three groups by means of the SSQ* questionnaire for Speech:
5 NH , 9 HI_A , 9 HI_B

STM detection:

- 2 conditions:
  - 1 Khz, f_m = 4 Hz, Ω = 2 c/o
  - 4 Khz, f_m = 4 Hz, Ω = 4 c/o
- Level: SRT_q ** + 30 dB + SRT_N ***
- 3 IFC, 1-up 3-down procedure

TM detection:

- Same frequencies (1 and 4 kHz) and f_m (4Hz)

Hearing Profiles

Profile A:

- ❑ Speech Spatial Quality hearing scale (SSQ) higher than the average (4.4) (Gatehouse & Noble, 2004)
- ❑ Hearing loss and communication handicap is captured by the audiogram

Profile B:

- ❑ SSQ lower than average
- ❑ A speech communication handicap is expected
- ❑ Worse frequency and temporal resolution may lead to supra-threshold distortions

* SSQ : Speech, Spatial and Quality
** SRT_q : Speech reception threshold in quiet
*** SRT_N : Speech reception threshold in noise

Results

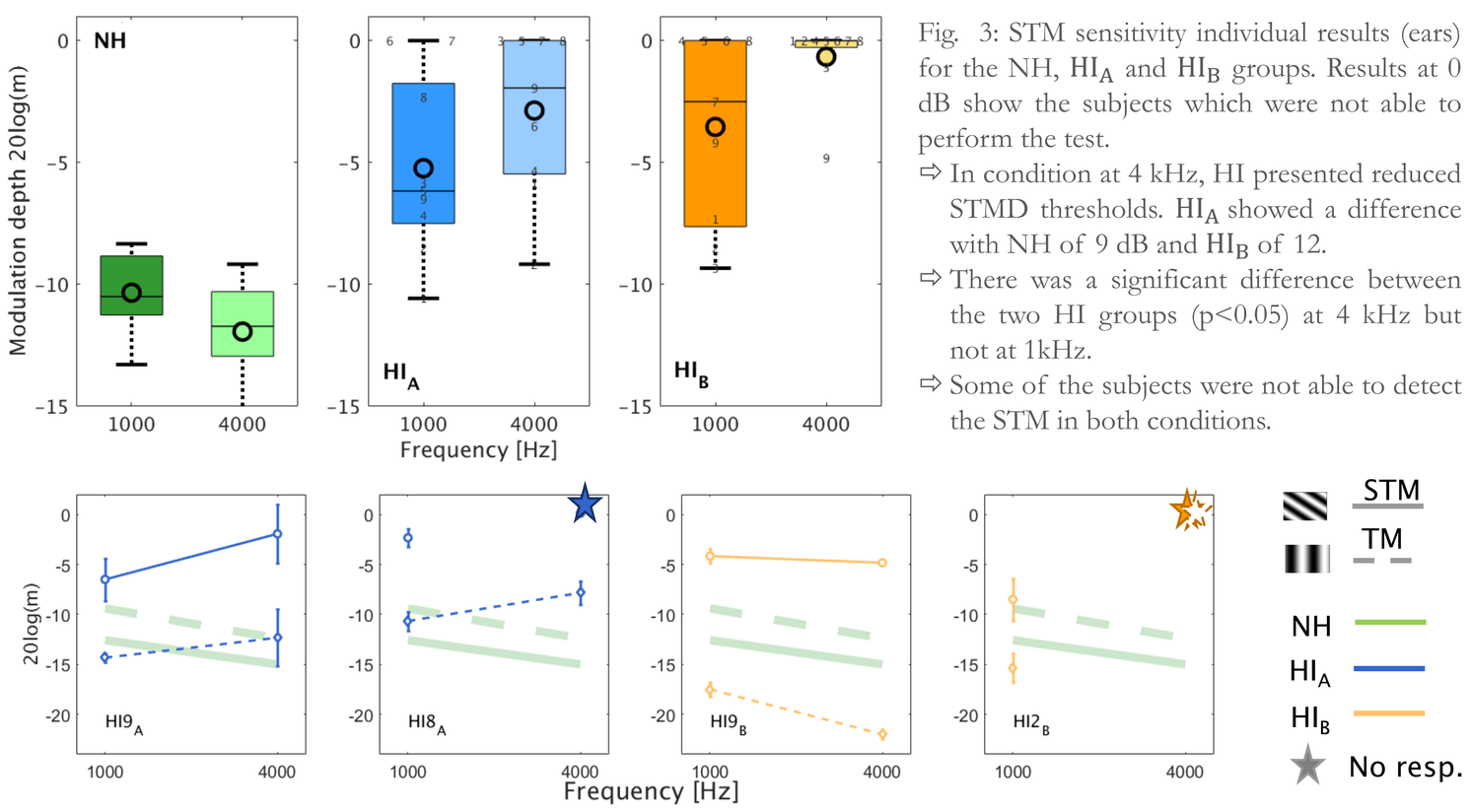


Fig. 3: STM sensitivity individual results (ears) for the NH, HI_A and HI_B groups. Results at 0 dB show the subjects which were not able to perform the test.

⇨ In condition at 4 kHz, HI presented reduced STMD thresholds. HI_A showed a difference with NH of 9 dB and HI_B of 12.

⇨ There was a significant difference between the two HI groups ($p<0.05$) at 4 kHz but not at 1kHz.

⇨ Some of the subjects were not able to detect the STM in both conditions.

Fig. 4: STM and TM detection thresholds for 2 subjects with profile A ($HI8_A$ and $HI9_A$) and two with profile B ($HI9_B$ and $HI2_B$) . The symbol (★) represents a threshold that was not measured. **Profile A** showed a difference between TM-STM thresholds of 9 dB. **Profile B** showed either an increased TM-STM ($HI9_B$ ~13 dB) or reduced ($HI2_B$ ~0 dB).

Conclusion and Outlook

In the present study the HI listeners were divided in two groups by means of the SSQ questionnaire. Significant differences were observed between the two groups in STMD. Overall, these results suggested that the two groups may be affected by different impairments. Within the Better hEAring Rehabilitation (BEAR) project, a new battery test will provide information about the hearing deficits beyond the audiogram. The results from the present study suggests that spectro-temporal modulation detection might be a good candidate for characterizing hearing deficits towards a clinical profiling.

- NH listeners were more sensitive to STM than to purely temporal modulations.
- Some HI listeners were not able to performe the STMD task, especially profile B (with poorer self-reported speech understanding).
- STMD or the threshold difference between STMD and TMD could be part of a clinical test for hearing profiling.

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