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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, Edmins & 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 modulations (STM). STM detection and also the relation between STM sensitivity to speech intelligibility in noise. Moreover, Henly et al. (2005) showed large differences in STM discrimination 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?

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 band

• f = fth
f th = 4 kHz, f tc = 2 kHz
f = fth
f th = 4 kHz, f tc = 4 kHz

A) Detection thresholds for temporal (TMD), spectral (SM) and spectro-temporal modulations (STMD): The STM thresholds were lower (better) than only TMD
B) Spectro-temporal ripple discrimination (SRD) and Spectral (SRD) ripple discrimination for 1-octave band modulated noises.

Results

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

C) No temporal ripple distortion was shown for all the listeners.

D) The STM thresholds showed a smaller difference than the frequency conditions.

E) SRD threshold was lower and was found less suitable for a clinical set-up.

Experiment II: Spectro-temporal modulation sensitivity and discrimination in HI listeners

Method

Subjects: 23 subjects were divided in three groups by means of the SSQ* questionnaire for Speech:
5 NH, 9 HI1, 9 HI2

STM detection:
• 2 conditions:
1 kHz, f th = 4 kHz Ω = 2 kHz
4 kHz, f th = 4 kHz Ω = 4 kHz

• Level: SSQf th = 30 dB + 2 SRD**
• 3 IFC, 1 up 3 down procedure

TM detection:
• Same frequencies (1 and 4 kHz) f th (4 kHz)

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

Results

Fig. 4: STM and TM detection thresholds for 2 subjects with profile A (HI1) and HI2 groups and two with profile B (HI1 and HI2). 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 (HI1 < 15 dB) or reduced (HI2 > 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 STM. Overall, these results suggested that the two groups may be affected by different impairments. Within the Better hiAring Rehabilitation (BEAR) project, a new battery test will provide information about the hearing deficits beyond the audiological. 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.

References