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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, Edin & 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 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
• : f = 4 kHz, f0 = 2 f0/3
• : f = 4 kHz, f0 = 4 f0/3

STM detection:
• 2 conditions:
 1 kHz, f0 = 4 Hz
 4 kHz, f0 = 4 Hz

TM detection:
• Same frequencies (1 and 4 kHz) and f0 (4kHz)

Results

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

1) The STM thresholds were lower (better) than only TMD
2) Spectro-temporal ripple discrimination (STRD) and Spectral (SRD) ripple discrimination for 1-octave band modulated noises.

There was no significant difference for the frequency conditions.

STM threshold was lowered 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 SISI questionnaire for Speech:
5 NH, 9 HIa, 9 HIb

STM detection:
• 2 conditions:
 1 kHz, f0 = 4 Hz
 4 kHz, f0 = 4 Hz

TM detection:
• Same frequencies (1 and 4 kHz) and f0 (4kHz)

Hearing Profiles

Profile A:
• Speech Spatial Quality (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 expected
• Worse frequency and temporal resolution may lead to supra-threshold distortions

Results

Fig. 3: STM sensitivity individual results (ears) for the NH, HIa, and HIb groups. Results at 9 dB show the subjects which were not able to perform the test.

No condition at 4 kHz, HI presented reduced STM thresholds. HI showed a difference with NH of 9 dB and HIb 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.

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 audiogram. The results from the present study suggest that spectro-temporal modulation detection might be a good candidate for characterizing hearing deficits towards a clinical profiling.

References


Fig. 1: STM are defined by modulation depth (amount of modulation), modulation frequency (f0 cycles per second) and spectral density (Q, cycles per octave). The tasks performed here are: (I) Detection: minimum amount of modulation, (II) Discrimination: maximum spectral density for fully modulated ripples.

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

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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 (HIa, and HIb) and two with profile B (HIa and HIb). 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 (HIa: +13 dB) or reduced (HIb: -6 dB).

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