Towards a clinically viable spectro-temporal modulation test

Zaar, Johannes; Simonsen, Lisbeth Birkelund; Behrens, Thomas; Laugesen, Søren

Publication date:
2018

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

Link back to DTU Orbit

Citation (APA):
Introduction

The Spectro-Temporal Modulation (STM) test has shown good predictive power for speech-in-noise outcomes beyond the audiogram in several studies [1-3]. Thus, the STM test is a potential diagnostic value for hearing-aid fitting.

In the STM test, the depth of spectro-temporal modulations applied to a wide-band carrier is varied, and a threshold is determined at which the test subject can just detect the difference between the STM stimulus and a reference without modulations. A schematic example of an STM stimulus is shown in Figure 1.

In a recent study in a large clinical population [5], a substantial sub-group of the participants reached the test’s upper bound, in the same manner as the modulations set to maximum, they could not discriminate the target stimulus from the reference.

Aims of this study

To modify the STM test in terms of stimulus parameters and procedure to make it sensitive within the target population of people with hearing impairment. In particular, to carry out the STM test with full compensation from 20 Hz to 20 kHz.

To extend the earlier experiments towards more realistic speech-in-noise scenarios. Previous tests typically used headphones presentation of target and maskers that were either co-located steady-state noise (SSN), modulated noise (t1co or t2co) or babble noise (n1co) presented at high levels but without frequency-specific compensation for audiometry.

Method and material

Participants

N = 12, age 61-02 years, hearing-loss configurations with modulated audiograms. Audiograms in terms of left/right mean of Hearing Threshold Levels (HTL) are shown in Figure 2.

STM conditions

STM stimulus parameters were chosen to make the test easier, so as to avoid the upper-bound issue, and to ensure the modulations set to maximum were relevant to real-world listening situations. Figure 3 shows the spectro-temporal modulations applied to the wide-band carrier.

To extend the earlier experiments towards more realistic speech-in-noise scenarios. Previous tests typically used headphones presentation of target and maskers that were either co-located steady-state noise (SSN), modulated noise (t1co or t2co) or babble noise (n1co) presented at high levels but without frequency-specific compensation for audiometry.

Speech-in-noise test

The speech-in-noise test was set up in an IC hearing booth (RT2 = 0.4 s). Targets were 20-item lists of Danish sentences, all spoken by a male talker, presented at a normal level of 70 dB SPL. The four maskers presented from 20 Hz to 20 kHz (see Figure 3) were different running male speech signals with speech-shaped steady-state noise (SSN) mixed in 0 dB below each speech masker. All speech signals and the SSN were shaped to have the same long-term spectrum. Compensation for hearing loss was achieved by raising [where necessary] all 1/3 octave band levels of the target to 15 dB (A), with a roll-off starting at 5 kHz down to 48 dB (A) 8 kHz to protect the loudspeakers.

Results

The STM thresholds for each of the 6 different conditions are shown in Figure 4. Note that in all runs, including the training runs, all participants managed to produce a STM threshold. The results for the two-speech-in-noise conditions are shown in Figure 5.

Analysis

First, the potential predictor variables were individually correlated with the STM to select the preferred ones. The considered predictors were the 6 STM variants, Age, and three hearing-loss descriptors:

- **4PTA**: mean of left and right HTL values across 500, 1000, 2000, and 4000 Hz.
- **LFA**: mean across 1250, 2500, 5000 and 10000 Hz, in dB.

Table 1 presents the individual predictor-outcome correlations.

Secondly, a multi-variate linear regression was conducted for each STM outcome. This was done in a manual stepwise fashion, considering first the preferred hearing-loss descriptor, then adding the STM predictor. The results are illustrated in Figure 6, left most columns.

Discussion

The higher correlations observed for PTA compared with HTL in table 1 are in good agreement with results from [7].

Protocol

Visit 1: Otoscope, audiogram, and speech-in-noise testing. Order of visit (Spatial, then STM) was the same for all tests, while the use of test lists was balanced across conditions.

Visit 2: STM, training and 3 test conditions: n1co, n2co, and t1co, in balanced order.

Visit 3: STM, reference and 3 test conditions: n4co, n2co, and t1co, in balanced order.

All experiments were done under ethical approval from the Scientific Ethical Committee of the Capital Region of Denmark.

Conclusions

Referring back to the study’s aims it can be concluded that:

- The proposed modifications to the STM test appear to have solved the upper-bound issue reported in [3].

- The preferred STM thresholds on their own have considerable predictive power for the SRT outcomes, and can explain additional variance beyond the hearing-loss descriptors. The actual amount depends on the degree to which the hearing-loss descriptor is tailored to the dataset.

- The Speech-in-noise outcome should greater individual variation and allowed more variance to be explained by the hearing-loss and STM predictors, compared with the co-located steady-state-noise (SSN) condition.

As an additional observation it was found that:

- From the 4PTA test, a considerable amount of variance for audiometry applied in this study, the hearing-loss descriptors have considerable predictive power for the supra-threshold SRT outcomes.

Acknowledgements

The authors wish to acknowledge the support from the Oticon foundation, as well as the contributors to this study from Lund University, Thomas Lennar, Angel G., Alejandro Lopez Valdes, Gary Jones, Nicolas Le Goff, Paul Sanchez Lopez, and James Harte.

References


Figure 1: Schematic of an STM test stimulus. Grey-scale indicate modulation (mg): (2) cycles per octave.

Figure 2: Left: mean audiograms of all participants. Right: Mean±SD of the training data.

Figure 3: Sketch of the speech-in-noise test loudspeaker layout, showing [1] in front and four maskers (M1–M4).