Towards a clinically viable spectro-temporal modulation test

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Introduction

The Spectral-Modulation Temporal (STM) test has shown good predictive power for speech-in-noise outcomes beyond the audiogram in several studies [1-5]. Thus, the STM test has gained increasing diagnostic value for hearing-aid fitting.

In the STM test, the depth of spectral-modulation patterns 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 2.

Thus far, 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 way as even the modulations set to maximum levels could not reliably 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 for hearing loss.

To extend the earlier experiments towards more realistic speech-in-noise scenarios. Previous tests typically used headband presentation of target and maskers that were either co-located steady-state noise (HFA), modulated noise (SSN), or babble noise (BT) presented at high levels but without frequency-specific compensation for audibility [3].

Method and material

Participants

N = 14, age 61–83 years, hearing-loss configurations with modeled age-corrections. Audiograms in terms of left/right mean of Hearing Threshold Levels (HTLs) 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 assess performance properly.

- Wide carrier bandwidth, 354 – 5655 Hz (except one condition with 354 – 2000 Hz bandwidth).
- Loudspeaker output levels at 1 kHz were: 75 dB sound-pressure-level (SPL) in all relevant 1/3-octave bands, according to the individual left/right-mean audiogram (8).
- 3-AFC test paradigm with 1 s stimulus duration, no level roving, and static presentation.
- In addition to using a noise carrier [1,2], two conditions with a tone-complex carrier (100 Hz spacing) were included.

The 6 conditions selected are reflected in Figure 4 and table 1. All reported STM thresholds were averaged across 3 test runs.

Speech-in-noise test

The speech-in-noise test was set up in an ISO chamber (B, 0 ± 4 dBth), with a male talker, presented at a nominal level of 70 dB-SPL. The four talkers presented from 2200 and 4400 Hz (see Figure 3) were running male talkers with speech signal with spectral steady-state noise (SSN) mixed in 0 dB below each speaker. 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) the talker, ear aids, or hearing aids.

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 valid STM threshold. The results for the two speech-in-noise conditions are shown in Figure 5.

Fig. 2. left/right mean audiograms of all participants

Fig. 3. Sketch of the speech-in-noise test loudspeaker layout, showing 3 talkers in front and four maskers (Mi-M4).

Analisys

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

- APVT: mean of left and right HTL values across 500, 1000, 2000, and 4000 Hz.
- LAF: mean across 250, 500, 1000 and 2000 Hz as in [5].
- HFA: mean across 2000, 3000, 4000, and 6000 Hz as in [5].

All correlations are summarized in Table 1. For the Spatial SRTs, the preferred predictor was the tone4co2kHz, whereas for the Speech SRTs, the SSN was preferred for the STM thresholds. In both cases, the HFA hearing loss descriptors was also preferred. The correlations with Age were small and counter-intuitive, hence this variable was disregarded from further analysis.

Table 1. Individual predictor-outcome correlations. N = 15. Preferred predictors are highlighted (p < 0.05).

Discussion

The hearing-loss descriptors

The higher correlations observed for SRT compared with SRTA and SRTD, with results from [7] obtained with similar speech-in-noise setups. In contrast, no evidence was found that the best hearing-loss descriptor in a much larger dataset [8], beyond Figure 4. Note that by AKP and G7 showed preference to the CIAP predictor for both spatially and temporally separated and co-located maskers and voices.

Given the weighty evidence from [5], multiple regression analysis was applied to the variables listed in Table 2, three outcomes were studied.

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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 [5].
- The preferred STM thresholds on their own have considerable predictive power for the SRT outcomes, and can explain additional variability in SRT outcomes beyond the hearing-loss descriptors. The actual amount depends on the degree to which the hearing-loss descriptor is tailored to the dataset.

- As an additional observation it was found that:

Note on future clinical use

Data from the STM test was used here to match the time hearing loss was compensated for speech-in- noise testing, i.e. not ear-specific. In potential future clinical applications, where the two ears usually are aided independently, ear-specific audibility compensation in the STM test should be considered.

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References


Fig. 4. STM thresholds for all six test conditions. On the ordinate, 0 dB corresponds to full modulation (upper bound); 1D: standard deviation; n- : noisy; t- : tone.

Fig. 5. SRTs for the two speech-in-noise conditions.

Fig. 6. This study: amount of SRT variance explained by the hearing-loss (HTL) descriptors and the preferred STM predictor. Whole-model significance (α < 0.05) is indicated by *.

Fig. 7. Bernstein et al. (2016): amount of speech-in-noise outcome variance explained by individual HTL values, N = 154.