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 [3, 7]. Thus, the STM test becomes an additional 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 3.

**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 elderly people with hearing impairment. In particular, to carry out the STM test with full compensation for audibility in the presence of hearing aids. To extend the earlier studies towards more realistic speech-in-noise scenarios. Previous tests typically used head-room presentation of target and maskers that were either co-located steady-state noise (SSN), modulated noise (LFA), or babble noise (M) presented at high levels but without frequency-specific compensation for audibility.

**Method and material**

**Participants**

N = 12, age 61-82 years, hearing-loss configurations with modulated asymmetries. Audiograms in terms of left/right-mean means 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 in such a way that the testing was located in a region of moderate-to-severe hearing loss.

- **Wide carrier bandwidth**, 50 – 5000 Hz (except one condition with 354 – 2000 Hz bandwidth).
- Low-frequency ripple distorted noise, 1-2 kHz, and 4 kHz upward-moving temporal ripple (low mean modulation frequency).
- Frequency-specific hearing loss compensation scheme, starting at 65 dB broadband SNR and then leveling at least 15 dB SNR (Carrier level) in all relevant 1/3 octave bands, according to the individual left/right-mean audiograms.
- 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 (100Hz spacing) were included.

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

**Speech-in-noise test**

The speech-in-noise test was set up in an IEC environment (RT0.4 ± 0.6). Targets were 20-item lists of Danish speech, and to achieve speech material for the male talker, presented at a normal level of 70 dB SPL. The four maskers presented from 100° and 315° (see figure 3) were different running male speech signals with speech-shaped steady-state noise (SSN) mixed in 8 dB below each speech signal. All speech signals and the SSN were shaped to have the same long-term spectrum.

**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.

**Analysis**

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

- **APTS**: mean of left and right HTL values across 500, 1000, 2000, and 4000 Hz.
- **LMA**: mean across 125, 250, 500, and 1000 Hz in [dB].
- **HFA**: mean across 2000, 3000, 4000, and 6000 Hz in [dB].

All correlations are summarized in table 2. For the Spatial SRTs, the preferred predictor was the tona2co2kHz, whereas for the 4PTAs and LFA, the preferred predictor was the SSN. In both cases, the ARA hearing loss descriptors were discarded. The correlations with Age were small and counter-intuitive (i.e., this variable was disregarded from further analysis).

**Discussion**

**The hearing-loss descriptors**

The higher correlations observed for ARA compared with HTL in table 1 are in good agreement with the results from [7] obtained with similar speech-in-noise setups. In contrast, (3) found HTL to be the best hearing-loss descriptor in a much larger dataset (N = 124) based on figure 7. Note that table 1 and (7) gave preference to the ARA predictor for both spatially separated and co-located stimuli, indicating that the different result found in [3] may be due to the difference between spatially separated and co-located maskers and test stimuli.

**Spatial versus SSN SRTs**

Figure 5 shows that the Spatial SRTs in average were higher than the HTL and that the spread was wider. The higher mean SRT makes the Spatial condition more ecologically relevant (9) and the higher separate co-located SRT outcomes, indicating that the different result found in [3] may be due to the difference between spatially separated and co-located maskers.

Note on future clinical use

Douglas' presentation of the STM was shown here to match the way hearing loss was compensated for the speech-in-noise testing, i.e. not ear-specific. In potential future clinical applications, where the two ears usually are aided independently, ear-specific audiometry compensation in the STM test should be considered.

**Conclusions**

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

- The modified presentations 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 outcome variance beyond the hearing-loss descriptors. The actual amount depends on the degree to which the hearing-loss descriptor is tailored to the database.
- The Spatial speech-in-noise outcome showed 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 expected to observed outcome correlations 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 contributions to this study from Laurel Carney, Thomas Lunner, Elaine Ng, Alejandro Lopez Valdes, Gary Jones, Nicolas Le Goff, Raul Sanchez Lopez, and James Harte.