Validation of a spatial speech-in-speech test that takes Signal-to-Noise Ratio (SNR) confounds into account

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Introduction

Adaptive Speech-Perception Threshold (SPT) measures are popular for good reasons. However, the unbound nature of the SNR at which the SPT is achieved often leads to wide spread in SPT [1], certainly for aided hearing-impaired listeners. Thus, hearing aids are under test they will be subjected to very different SNRs among listeners. This has the possibility of causing SNR confounds which may lead to faulty conclusions [2,3]. Furthermore, the SRT is often much lower than the SNR found in realistic listening situations [4,5], particularly when testing normal-hearing listeners. This may compromise the ecological validity of the test procedures.

To address these problems, the SFS [Spatial Fixed-SNR] speech-in-speech intelligibility test was proposed, which uses a fixed-SNR paradigm. Percent-correct scores within the informative 20-90% range are obtained for the individuals by selecting among four test conditions with different test difficulty [6]. Thus, the SFS test is aimed at within-subjects comparisons. As an option, Target Location Uncertainty (TGLU) can be added to the test [7].

Aim of the study

To validate the SFS test with emphasis on:
1. Do the four SFS conditions change test difficulty as expected?
2. Can the SFS test measure an expected contrast?
3. Does TGLU provide any added insight?

Method and material

Target speech was the Danish HINT corpus [8], played at 70 dB SPL (C). The masker speech signals were recordings of speakers reading from a fairy tale: two females and two males, used in pairs arranged symmetrically around the listener, see Figure 1. Target and masker speech signals were matched to a female reference spectrum and masker speech pauses were cut down to 65 ms. The four SFS test conditions are outlined in Table 1, in all non-TGLU conditions the target came from O°. All reported SNR values are referenced to the centre of the loudspeaker ring with the listener absent. The test protocol is outlined in Table 2.

Listeners

A total of 26 hearing-impaired listeners with sensorineural and mixed hearing loss took part (21 females and 5 males). Their mean age was 65 years (range 51-91 years). Their average SNR thresholds at 0.5, 1, 2, and 4 kHz were ranged from 29 to 66 dB, with a mean value of 46 dB. Subjects were listening binurally through Oticon Ago Pro miniRITE (Receiver In The Ear) hearing aids, fitted with closed power domes. Directionality and noise management were disabled.

Experimental contrast

A comparison was made between an individually prescribed linear compression aid setting (LIN), and a setting with dB additional gain and fast-acting compression limiting (CLM). Frequency-specific SNR thresholds were individually set to the expected output from the LIN setting with a representative SFS test input signal. A fast-acting compression changes the SNR at the output, depending on input SNR and signal characteristics [3]. The difference in the SFS results between the masker and the speech signal is the compression effect. A 2 dB increase in the input SNR makes a 2 dB decrease in the output SNR, which is the information that is available to the listeners.

Results

The Effect of the SFS Conditions

The measured SRTs for listening to the TGLU fixed-SNR paradigm were subjected to a repeated measures ANOVA with factors hearing aid setting (LIN, CLM), and target location [8]. The results are shown in Table 3. All SRTs were corrected for the effects of TGLU and TGLU interactions in the LIN/CLM conditions. The overall mean SRT for all listeners was 2.5 dB. The SRTs in the LIN setting were lower than the SRTs in the CLM setting by 2.5 dB (p < 0.001). The SRTs were significantly higher in the left ear target condition than in the right ear target condition by 2.5 dB (p < 0.001). The SRTs were significantly higher in the right ear target condition than in the left ear target condition by 2.5 dB (p < 0.001).

Discussion

The SFS test is validated. With regard to the study’s aims it was shown that:
1. The four SFS conditions change test difficulty as expected.
2. The SFS test is able to detect relevant differences between the tested LIN and CLM hearing-aid settings with high statistical significance.
3. Target location uncertainty (TGLU) appears to offer additional insights (at the cost of extra testing time).

Recommendations

The Spatial Fixed-SNR (SFS) test was validated. With regard to the study’s aims it was shown that:
1. The four SFS conditions change test difficulty as expected, such that informative % correct data could be measured for all listeners in the target SNR range.
2. The reliability of the SFS test was found to be on par with the standard HINT test, and possibly even better when used with the fixed-SNR paradigm (compare Figures 3 and 4).

Conclusion

The proposed Spatial Fixed-SNR (SFS) test was used to compare a linear hearing-aid setting to a setting with aggressive compression limitation. Two sub-groups of listeners were tested in a fixed-SNR paradigm at -5 and +5 dB SNR, respectively.