Investigating SRT 'manipulators' for a spatial speech-in-speech test

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Four ways of shifting the speech reception threshold (SRT) for five-word sentences were investigated: Changing the target-masker spatial separation, changing the number af maskers, changing the adaption target, and changing the masker-talker gender.

Background

Adaptive SRT procedures are popular for good reasons, but they have drawbacks related to the unbounded nature of the Signal-to-Noise Ratio (SNR) at which the SRT is achieved [1].

(Lack of) ecological validity

Often the SRT is much lower than the SNR found in realistic listening conditions. If the test involves aided listening, the hearing aid may therefore be subjected to conditions for which it was never intended. This has the potential to cause misleading results.

SNR confounds

Aided hearing-impaired listeners often show a wide spread in SRT. Therefore, the hearing aids under test will be subjected to very different SNRs among different listeners. These differences in SNR can affect hearing-aid signal processing and can in turn potentially confound the test results [2,3].

Aim of the study

The long-term goal is to devise a spatial speech-in-speech test with means of addressing ecological validity and SNR confounds. This will be achieved by selecting appropriate test conditions so as to shift the individual listener's SRT towards a common desired SNR. This particular study examined four candidate SRT 'manipulators':

- Change the spatial separation between target and maskers.
- Change the number of maskers between two, four, and six.
- Change the adaptation target between 50% words and 50% sentences correct.
- Change the masker talker gender between female and male.

Methods

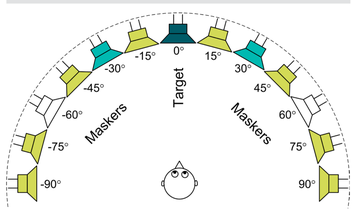
Target speech: Danish HINT sentences [2], all consisting of five words, presented from 0°.

Masker speech: Running speech (reading from a fairytale), speech pauses cut down to 65 ms. Two female talkers or two male talkers, used in pairs arranged symmetrically around the listener, see Figure 1.

Presentation levels: The target level was fixed at 70 dB SPL (C). The masker level was varied adaptively. The SRTs, i.e. SNRs corresponding to 50% correct words or sentences, were found by a maximum likelihood approach, based on lists of 20 sentences. All levels refer to the point between the listener's ears, without the listener present.

Spectral matching: In most test conditions, target and maskers were spectrally matched to a female speech spectrum. In three conditions, they were matched to the original male target.

Figure 1. Loudspeaker set-up for experiment. Configurations used can be read off Table 1. The configuration with two maskers at ±30° served as a reference condition.



Methods, continued

Protocol: 20 SRTs were determined for each listener, see Table 1. The test conditions were divided across two visits and the order was balanced across listeners. Both visits started with two training lists.

Table 1. Overview of included test conditions (A-T).

Spectral shape	Masker gender	Adapt. target	Masker configuration						
			2 maskers				4 maskers		6 maskers
			±15°	±30°	±45°	±75°	±30/90°	±15/45°	±15/45/75°
Female	Male	Word	A	B	C	D	E	F	G
		Sentence	H	I	J	---	K	L	---
	Female	Word	M	N	O	---	P	Q	---
Male	Male	Word	R	---	S	---	T	---	---

Listeners: *N* = 20 hearing-impaired listeners with sensorineural hearing loss participated. Pure Tone Average (PTA) hearing loss across 0.5, 1, 2, and 4 kHz ranged from 29 dB HL to 69 dB HL, with a mean of 51 dB HL and a standard deviation of 11dB HL. Subjects were listening binaurally aided using their own hearing aids, which had directionality and noise management disabled during testing.

Results

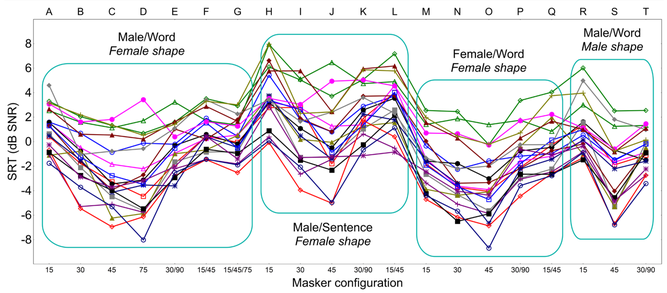
The raw SRT data were analysed with a mixed-model main-effects ANOVA, see Table 2. The results showed significant effects of the main manipulator variables, Masker configuration, Adaptation target, and Masker Gender. Spectral shape had no significant effect. The significant effect of Listener corroborates the considerable spread in individual SRTs, see Figure 2.

There were significant within- and between-visit training effects. These effects were corrected for in the data presented and analysed below, including the plot of the individual SRTs in Figure 2.

Table 2. ANOVA main-effect results.

Effect	*F*-value	*p*-value
Masker configuration	$F_{6,369}$ = 90.4	< .00001
Adaptation target	$F_{1,369}$ = 277	< .00001
Masker gender	$F_{1,369}$ = 70.8	< .00001
Spectral shape	$F_{1,369}$ = .043	.83
Listener (random)	$F_{19,369}$ = 66.7	< .00001
Within-visit	$F_{1,369}$ = 7.17	.0077
Between-visit	$F_{1,369}$ = 7.75	.0056

Figure 2. Individual SRTs for 20 test subjects in 20 test conditions labelled A-T according to Table 1.

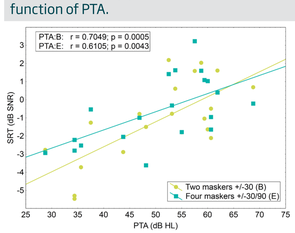


Individual and mean differences for 19 pairs of test conditions, constituting various SRT manipulator effects, are shown in Figure 4. The manipulator effects were further analysed in repeated measures ANOVAs performed on subsets of the SRT data. The listeners' gender, age, and PTA were included as predictor variables.

Effects of predictor variables

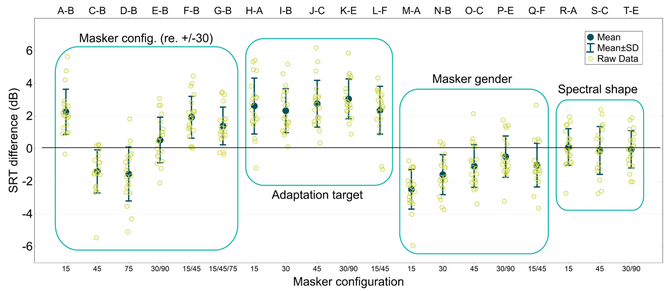
- No significant main effect of listener gender was observed, and listener gender did not interact with any of the SRT manipulators.
- A significant effect of PTA was observed, see example in Figure 3. The effect of age was also significant, but less pronounced. Age correlated mildly with PTA.
- While there was no significant interaction between PTA and Adaptation target, Masker gender, and Spectral shape, respectively, a slightly significant interaction between PTA and Masker configuration was observed, see example in Figure 3.

Figure 3. Individual SRTs in a two-masker (B) and four-masker (E) condition, plotted as a function of PTA.



Results, continued

Figure 4. Mean and individual SRT differences (manipulator effects) for 19 pairs of test conditions. The labelling of the pairs is according to Table 1.



Effects of SRT manipulators

- **MASKER CONFIGURATION**: While there was a significant effect of changing between the two-masker configurations, there was no additional effect of increasing the number of maskers to four or six.
- **ADAPTATION TARGET**: There was a significant main effect of changing between word and sentence scoring. There was no interaction with the masker configuration.
- **MASKER GENDER**: There was a significant main effect of changing between male and female masker talkers as well as a significant interaction between masker gender and masker configuration.
- Changing the spectral shape of the male target and maskers had no effect in any masker configuration.

Discussion

THE VARIATION IN MASKER CONFIGURATION, with the ±30° condition as reference, showed SRT shifts of +2.3 dB (±15°), -1.4 dB (±45°), and -1.5 dB (±75°) for the two-masker configurations. In all cases, the standard deviation (SD) was close to the expected minimal value (1.3 dB) of any SRT difference due to the HINT test-retest SD alone [4]. Thus, Cohen's effect size *d* (= mean/SD) was well above the 0.8 value required for a 'large' effect [5]. Using this as criterion, **changing spatial separation between target and maskers is an excellent SRT manipulator candidate**. Adding additional maskers to the ±15° and ±30° conditions changed SRT only marginally, and an interaction with PTA was observed. Thus, **changing the number of maskers is not a recommended SRT manipulator**; at least for the present hearing-impaired listeners. It should be noticed that changing the masker configuration, at a given SNR, will change the SNR measured at ear level (e.g., at the hearing-aid microphone position).

THE EFFECT OF CHANGING THE ADAPTATION TARGET from 50% words to 50% sentences was 2.6 dB on average across masker configurations. This is less than the 5.1 dB found with the Dantale II corpus (Danish Matrix test) in a previous study [6]. However, this was expected due to the HINT sentences' greater redundancy. As above, SDs were close to the 1.3-dB lower limit value. Using Cohen's *d* = 0.8 as criterion, **the Word/sentence SRT manipulator is an excellent candidate** for the conjectured test.

THE EFFECT OF MASKER GENDER depended on Masker configuration. In the ±30° condition, the magnitude was 1.6 dB, which is very close to the 1.7 dB found with the Dantale II corpus [6]. Again, SDs were close to 1.3 dB. The results in Figure 4 indicate that the benefit of having an opposite-gender masker is greatest when the spatial cues are least powerful (small target-masker separation). In the four-masker conditions, the combined masker signal is dominated by the 'wide' maskers due to the greater head-baffle effect at these angles of incidence. Using Cohen's *d* = 0.8 as criterion, **the Masker gender SRT manipulator is only relevant for the ±15° and ±30° two-masker configurations**.

Conclusion

Three useful SRT manipulators were identified that will allow the SRT of an individual listener to be shifted over approximately a 7-dB range. This holds considerable promise regarding developing a spatial speech-in-speech test that includes means of addressing SNR confounds and provides some control of the SNR at which testing takes place.

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