Minimum bandwidth required for speech reception by normal-hearing and hearing-impaired listeners

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Abstract: The bandwidth of speech (with a center frequency of 1 kHz) required for 50% sentence intelligibility was measured for 10 normal-hearing and 29 hearing-impaired listeners. The average speech-reception bandwidth threshold (SRBT) of normal-hearing listeners is 1.4 octave. Most hearing-impaired listeners need a wider bandwidth to reach 50% intelligibility. It is assumed that a wider-than-normal SRBT points to a deterioration in suprathreshold sound processing in the 1-kHz frequency region.

INTRODUCTION

Listenem with a sensorineural hearing impairment often have difficulties in understanding speech in noise, even if the speech is presented well above the hearing threshold. Several studies have suggested that these difficulties are due to suprathreshold impairments that distort the perception of sounds (1, 2, 3). However, clear correlations between an elevated speech-reception threshold (SRT) in noise and a deterioration in specific auditory functions (e.g., temporal or spectral resolution) have not been found. A possible reason for this is that such aspects of suprathreshold signal processing are usually measured at only one or two frequencies, while a broad range of frequencies contributes to the understanding of everyday speech.

An adaptive test was developed that might be useful in locating the deteriorated suprathreshold abilities underlyng impaired speech perception. This test determines the bandwidth of speech with a center-frequency of 1 kHz required for 50% intelligibility (speech-reception bandwidth threshold or SRBT). For the SRBT, only a limited frequency region is important. Therefore, correlations between the SRBT and suprathreshold abilities at 1 kHz may be more evident than correlations between the SRT for wide-band speech in noise and suprathreshold abilities at one or two frequencies.

In this study, the SRBT was measured for 29 listeners with sensorineural hearing impairment. Ten normal-hearing listeners participated in the experiment as a reference group.

METHOD

For all listeners (normal-hearing and hearing-impaired), hearing threshold and uncomfortable loudness level (UCL) were measured at octave frequencies from 250 to 4000 Hz. The UCL was also measured for a broadband noise with a spectral shape equal to the individual's UCL shape over the octave frequencies.

The SRBT was measured with a list of 13 sentences. In the SRBT test, the speech bandwidth was changed according to an adaptive up-down procedure. The speech was filtered with a bandpass filter, centered at 1 kHz. Complementary bandstop noise was added to the speech. To keep the signal above hearing threshold at all frequencies, speech and noise spectra were shaped to fit in the dynamic range of the individual listeners. For each listener, the spectrum was positioned halfway the dynamic range. Each listener performed two SRBT tests. The mean result of the two tests was considered as the SRBT for that listener.

RESULTS

Figure 1 shows the SRBT as a function of hearing threshold at 1 kHz, for the two groups of listeners. The average SRBT of the normal-hearing listeners is 1.4 octave. The SRBT of the hearing-impaired listeners ranges from 1.4 to 4.0 octave. The standard deviation of the individual SRBT, representing a reliability measure of the test, is 0.25 octave. The upper limit of the one-tailed 95% confidence interval of the SRBT for the group of normal-hearing listeners is chosen as the border between a normal and wider-than-normal SRBT. This limit is indicated in Fig. 1 with a horizontal line at 1.7 octave. When this criterion is used, 6 hearing-impaired listeners have a normal SRBT, whereas 23 listeners have a wider-than-normal SRBT.
The long-term average speech spectrum was brought halfway the dynamic range of each listener, to keep the speech above threshold for all frequencies. Unfortunately, for some hearing-impaired listeners the difference between hearing threshold and UCL was smaller than the dynamic variations in speech at one or more octave frequencies. In these situations, a part of the relevant dynamic range of the speech may have been presented below the hearing threshold. This could be an explanation for some wider-than-normal thresholds. The SII model [Speech Intelligibility Index (4)] can be used to estimate the effect of the inaudibility of a part of the speech on the SRBT. According to the SII model, the relevant dynamic range of the speech is 30 dB. Thus, if the dynamic range of a listener is smaller than 30 dB at a given frequency, a part of the speech will be presented below threshold in the SRBT test. The SII model appears to be able to predict the wider-than-normal SRBT for three hearing-impaired listeners (triangles in Fig. 1) from their narrow dynamic range. The remaining differences between the performance of normal-hearing and hearing-impaired listeners are most probably caused by a degradation of supra-threshold sound processing in the 1-kHz frequency region.

Figure 1 shows a clear correlation between SRBT and hearing threshold at 1 kHz (R=0.78), although the relevant dynamic range of the speech was above the hearing threshold for most listeners. A sensorineural hearing-impairment involves an elevation of the hearing threshold and various supra-threshold impairments. Several auditory functions deteriorate with increasing hearing loss (5, 6). These relations between hearing threshold and supra-threshold signal processing may cause the observed correlation between SRBT and hearing threshold at 1 kHz.

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**REFERENCES**