The Influence of Spectral and Temporal Acuities in Hearing on Speech Intelligibility

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1. INTRODUCTION

Hearing impaired listeners with cochlear hearing loss (HI) often complain about their abilities to understand speech, especially in the presence of concurrent background noise. Objective measurements underline their subjective findings: to obtain equal speech intelligibility HI need higher speech to noise ratios (S/N) than normal hearing persons (NH). In a model Plomp (1978) distinguishes two factors that account for HI's deteriorated speech intelligibility: attenuation and distortion.

Elevated hearing thresholds illustrate attenuation. If cochleae are less sensible, speech becomes inaudible. Mere amplification, as provided by hearing aids, restores audibility. But in general HI still perform less even when speech is presented well above their hearing thresholds, giving rise to the idea that impaired cochleae distort speech. Two possible sources of distortion are impairments of spectral resolution and temporal neural coding.

Models of speech intelligibility, like the Speech Intelligibility Index (ANSI, 1997) and the Speech Transmission Index (Steeneken & Houtgast, 1980), stress the transfer of speech modulations in different frequency bands. Reduced spectral or temporal acuities can impair this transfer. For HI with reduced spectral acuity, modulations mix over frequency bands, contaminating frequency-specific modulations. Reduced temporal acuity might diminish the modulation depth especially of higher modulation frequencies within a band.

Noordhoek et al. (2001) measured spectral and temporal acuities as well as speech intelligibility for a small group of HI. She found that in this group 1) spectral and temporal acuity scores are independent and 2) impaired spectral or temporal acuity is associated with reduced speech intelligibility. The current study tries to confirm these findings with a large group of naïve HI.

2. METHOD

Speech intelligibility is measured in two ways. 1) The Speech Reception Threshold test in speech fluctuating noise (SRT_{fluc}) estimates the S/N that gives 50 % intelligibility in speech-like modulated masking noise (Festen & Plomp 1990). We expect that the SRT_{fluc} test puts demands on listeners' temporal acuities in particular. 2) The Speech Reception *bandwidth* Threshold (SR*b*T) test measures the bandwidth needed for 50 % intelligibility employing band-pass filtered speech centered around 1 kHz in complementary band-stop filtered masking noise (Noordhoek et al. 2001). We anticipate poor SR*b*T scores to coincide especially with impaired spectral acuity.

A recently developed clinically applicable test measures spectral and temporal acuities of listeners at a specified frequency (Hilkhuysen et al., submitted). The current study focuses on acuities around 1 kHz. Listeners detect sweeps in spectrally or temporally modulated noise grids. Detection thresholds reveal the widths of auditory filters and time windows.

The long-term average spectrum of masking noises and signals at 0 dB S/N is placed halfway between the listener's hearing threshold and uncomfortable loudness level (UCL), that is in the middle of the listeners dynamic range. This eliminates in both SRT tests audibility effects on speech intelligibility. Spectral and temporal acuities vary with intensity. In order to acquire acuity estimates at levels present during the SRT tests, the masking noise in the spectral and temporal acuity test is also positioned in the middle of the listener's dynamic range.

Only HI participated who have at least 30 dB dynamic ranges and whose speech intelligibilities in quiet are 80 % or more. Local standard clinical audiometry provides this information. The study focuses on the ear with the highest intelligibility in quiet. A preliminary 46 HI, who visited the hearing center for hearing-aid adjustment, subsequently carried out all tests twice.

3. RESULTS

Final scores are means over double measurements: metric means for SRT_{fluc} scores and geometric means for the other tests. Statistical analyses employ logarithmically transformed SR*b*T and spectral and temporal acuity scores. Table 1 shows Pearson correlations, the corresponding scatterplot matrix (not included here) shows homogeneous clouds of points. Entries on the diagonal of Table 1 are

Table 1. Correlation between test scores (n=46). Diagonal entries represent reliability estimates. Test reliability influences ordinary off-diagonal correlations. Estimates of correlations that would be obtained with 100 % reliable tests are parenthesized. Numbers between brackets represent 95% confidence intervals for uncorrected correlations.

	SR*b*T	SRT_{fluc}	spectral	temporal
SR*b*T	.80 [.66-.89] (1.00)	.63 [.42:.80] (.73)	.59 [.36:.75] (.68)	.23 [-.06:.49] (.27)
SRT_{fluc}		0.92 [.85-.95] (1.00)	.42 [.25:.63] (.46)	.24 [-.05:.50] (.25)
spectral			.93 [.88-.96] (1.00)	.24 [-.06:.49] (.25)
temporal				.96 [.92-.98] (1.00)

reliability estimates based on correlations between test and retest scores using Spearman-Brown prophecy formula. Reduced reliabilities attenuate the off-diagonal correlations, corrected estimates are expressed by numbers in parentheses.

The two SRT tests correlate highest, both measure partly the same phenomenon. Spectral acuity correlates well with SR*b*T and moderately with SRT_{fluc}, but in neither case enough to account for all differences in speech intelligibility among HI. Correlations of temporal acuity with other tests are low.

4. DISCUSSION

The present study finds reliable differences in temporal acuities among HI, but these differences have no influence on speech intelligibility. Looking at speech intelligibility models one might theorize that reduced temporal acuity possibly causes distortion, but the current data find no evidence for this hypothesis. HI with reduced temporal acuities seem to have comparable access to those speech modulations that are essential for speech intelligibility as HI with normal temporal acuities. However, it is remarkable that temporal acuity varies independently from spectral acuity, implying impairments of different auditory mechanisms.

The current results confirm the findings of Noordhoek et al (2001) that reduction of spectral acuity distorts speech intelligibility. It deteriorates in particular SR*b*T scores, simply explained by spectral masking. Noise from lower frequencies masks the modulations in the enclosed band-passed filtered speech. At the same time energy from low-frequencies within the band of speech can mask speech modulations in the higher part of the band. Consequently HI with reduced spectral acuities need broader bands of speech to acquire equal intelligibility, that is to obtain an equal amount of speech modulations.

Reduction in spectral acuity appears to be one source of distortion but explains only part of the problems that HI experience while listening to speech in concurrent noise. Among the speech intelligibility tests SRT_{fluc} scores have the lowest proportion of explained variance, hence SRT_{fluc} scores seem more sensitive to this unknown distortion source.

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