Speech audiometric hearing aid fitting based on modern speech tests

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Introduction

Calculation of gain for hearing aid amplification is usually based on the pure tone audiogram, while verification of the hearing aid benefit is based on speech tests. Even for individuals with identical pure tone audiograms, and consequently identical prescribed gain, speech intelligibility scores often strongly differ. The reason for this is that speech intelligibility (SI) is only partially correlated with audibility, and depends on additional factors, such as the extent of damage to the inner hair cells.

A model that takes these effects on average into account is the effective audibility [1]. Another approach directly derives the functionality of the cochlea from the speech audiogram [2]. Both approaches suggest decreasing the gain provided by the hearing aid, if the individual speech audiogram is worse than the prediction of the Speech Intelligibility Index (SII). This idea is driven by the hypothesis that, in such cases, gain (which would otherwise normally be prescribed) further compromises speech intelligibility by adding distortion and increased masking.

A previous work [3] calculated effective audibility for individual subjects and uses this data to modify the gain setting of a cohort of hearing impaired subjects. This combined approach calculated the prescribed gain as a function of the individual speech audiogram measured with the Freiburger test and a modification of the SII [4].

The purpose of the current study was to investigate the efficacy of two modern speech tests in quiet (Oldenburger sentence test (OLSA) and monosyllabic rhyme test (WAKO)) for deriving measurements of effective audibility from individual subjects. The methodology for this investigation utilized a wide range of speech presentation levels, a variable range of audible frequencies and an almost complete speech discrimination function.

Method

For 16 hearing impaired subjects a pure tone and speech audiogram of the unaided worse ear was measured. The mean hearing threshold with minimum and maximum is shown in figure 1. The subjects were between 61 and 78 years old, on average 71 years. Audiograms were measured on seven left and nine right ears.

In order to obtain an almost complete speech discrimination function, intelligibility measurements for each subject were conducted from low to the maximum possible SI. The upper limit of speech presentation level was defined as 10 dB below uncomfortable level. For OLSA in quiet the SRT was measured for 50% and 80% intelligibility. One additional measurement was conducted at a fixed level between the 80% SRT and the upper limit.

WAKO in quiet was measured twice (test-retest measurement) with consonant lists at 65 dB, at the upper limit as defined above and one additional level.

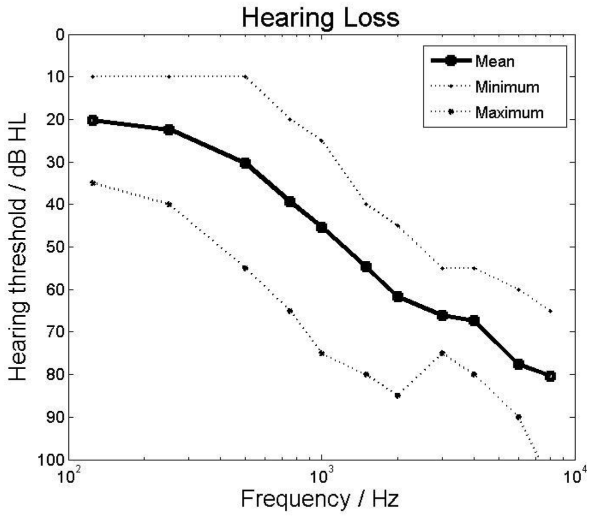

Figure 1: Mean hearing threshold (solid line) with the range of mininum and maximum values (dashed lines) for all 16 subjects.

Results

In figure 2 and 3 exemplary results are shown for one subject. The top graph of each figure displays the measured SI vs. the SII calculated with the individual hearing threshold. The bottom graph shows the individual threshold, the speech spectrum at different levels and the audibility function calculated from the SII for three different speech presentation levels. For each subject the relation between audibility and measured SI can be assessed.

In figure 2 the results of a generic subject with OLSA in quiet are shown. It can be seen that the presentation levels of speech are overall low, with values ranging from 45 to 65 dB. The SII calculation for the individual hearing threshold results in an audibility function that exists only for lower frequencies up to 1kHz.

In figure 3 the results for an exemplary subject with WAKO in quiet are shown. The SI is measured over a wide range of presentation levels from 30 to 95 dB. In the bottom graph, an overestimation of SI at higher presentations levels can be observed. Taking the individual hearing threshold into account, the audibility function across frequencies increases in proportion to the speech presentation level. In this case the absolute values of the audibility in the lower frequencies are lower for the maximum speech presentation level. This is caused by the level distortion factor defined in the SII, that reflects the reduction of SI for very high levels.

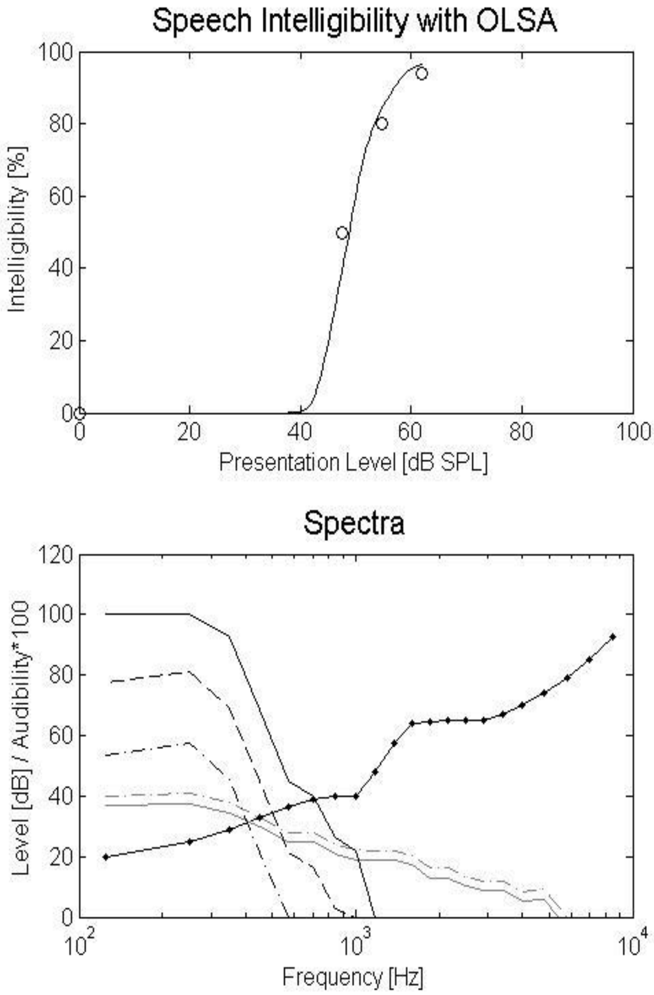

Figure 2: Results for one subject with OLSA in quiet. **Top:** SII (solid line) vs. measured SI with OLSA sentences in quiet (circles) as a function of the presentation level in dB SPL. **Bottom:** measured hearing threshold (black dotted line), OLnoise speech spectrum at 65 dB and maximum presentation level (grey dashed and solid lines) and the audibility*100 (black lines) for different presentation levels.

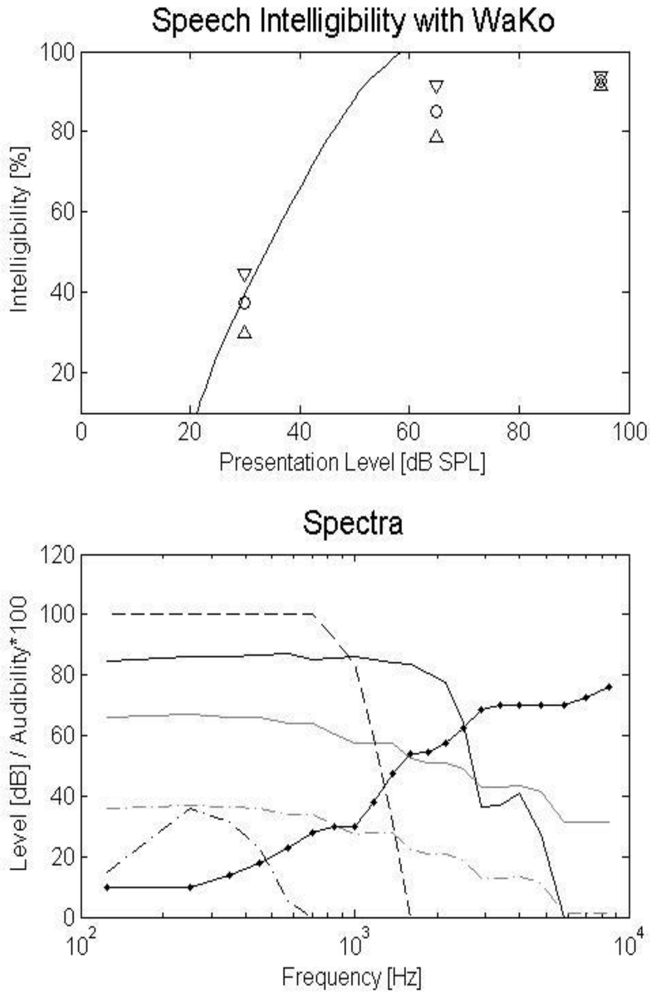

Figure 3: Results for one subject with WAKO in quiet. **Top:** SII (solid line) vs. measured SI with WAKO word correct in quiet with average value (circles), and single values for test and retest measurements (triangles) as a function of the presentation level in dB SPL. **Bottom:** measured hearing threshold (black dotted line), GoeNoise speech spectrum at 65 dB and maximum presentation level (grey dashed and solid lines) and the audibility*100 (black lines) for different presentation levels.

Conclusions

The purpose of the current study was to investigate the efficacy of the OLSA and WAKO speech tests in quiet for deriving measurements of effective audibility from individual subjects. The main results indicate that the WAKO is promising for this approach because of the increasing audibility across frequencies in proportion to the speech presentation level. In addition, the speech presentation levels are similar to those of conversational speech. The OLSA, however, seems to be not suitable for this approach mainly because of the low presentation levels and therefore limited audibility above 1 kHz.

Perspectives/Future work

Future work will focus on the quantification of individual effective audibility and implementating it in a speech audiometric based fitting formula. Furthermore, the benefit for the hearing impaired will be evaluated.

References/Acknowledgements

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