Psychoacoustic Modeling for Hearing Aid Fitting

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Introduction

Prescription of gain for hearing aid fittings aims at recovering speech intelligibility (SI) and loudness perception. However, the resulting gain often fails to meet customers expectations in terms of sound quality (SQ). This is because changes of hearing aid fitting parameters for an improvement of SI results in a reduction of SQ and vice versa.

This study addresses the question whether psychoacoustic modeling of SQ can be used for improving the acceptance of the hearing aid fit. The second issue deals with the role of SI in users' acceptance of hearing aids.

The questions were investigated by the empirical evaluation of two different targets, which were chosen on the results of psychoacoustic modeling. One modeling strategy aimed at achieving a certain score for SI in a combination with best possible SQ (Target 1). The other aimed at the same score for SQ, whereas estimation of SI was ignored (Target 2).

For the investigation of hearing loss dependent perception differences, the empirical study was conducted with two groups of subjects with mild and moderate hearing losses, respectively.

Recursive modeling

A recursive modeling was implemented in Matlab (see Figure 1), which included a real-time model of a hearing aid signal processing and two psychoacoustic models for evaluation.

The SII model [1] was used for the estimation of SI and the MCHI-S model [3] for the estimation of SQ. Two different standard audiograms were used for the modeling part in order to simulate moderate (N4 audiogram) and mild (N2 audiogram) hearing losses [2]. International speech test signal (ISTS) [4] was used as the input for the hearing aid model. This allowed the simulation of hearing aid performance followed by analyzing its influence on the modified signal with SII and MCHI-S model. The fitting was recursively adapted until the results of the evaluation achieved the following constraints:

For Target 1, SI had to achieve at least 30% more word recognition than was predicted by SII model for the unaided hearing loss. Hence the SI prediction had to aim for 58% word recognition for the moderate and 84% for the mild audiogram. A linear reduction of the SQ value predicted by the MCHI-S model was applied, if the SI constraint was not met. The best possible SQ under this constraints resulted in a predicted score of about 70% for both audigrams.

The recursive modeling procedure for Target 2 had to achieve the same score for SQ as Target 1 (70%). Under this constraint the psychoacoustic modeling resulted in a SI score of 43% for the moderate and 81% for the mild audiogram.

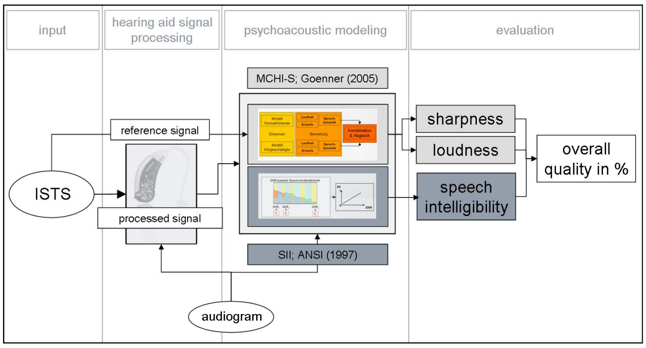

Figure 1: Block diagram of the recursive modeling.

The resulting targets were transformed in a hearing loss dependent fitting formula, which could be used for individual fitting of hearing aids in the following empirical study.

Empirical Study

Study 1 - Moderate hearing losses

10 subjects with bilaterally symmetric downward sloping moderate hearing loss took part in this investigation. Their audiograms were comparable to the standard hearing loss N4. Their age was between 32 and 81 years (Median = 72 years) and all were experienced hearing aid wearers. All participants were bilaterally fitted with premier behind-the-ear (BTE) hearing aids and both targets. Apart from a feedback reduction system, no adaptive parameters were active and no further adjustments after initial fitting were applied. All paticipants were fitted with custom earmolds and 2mm venting.

Study 2 - Mild hearing losses

11 subjects with bilaterally symmetric downward sloping mild hearing loss participated in Study 2. Their hearing losses were comparable to the standard hearing loss N2. Their age was between 20 and 74 years (Median = 67 years). Four of the participants were new to hearing aids, seven were experienced hearing aid wearers. For the participants of this study the BTE hearing aids were fitted with standard open domes.

Procedure

For all participants the following subjective tests were conducted:

- speech test with monosyllables in quiet (Freiburger Speech Test, 65dB SPL),
- adaptive speech in noise test with sentences (SRT = 50% intelligibility for OLSA sentences in noise, condition S_0N_0),
- ratings for an Acceptance questionnaire, while presenting several sound files (speech in quiet, speech in noise, music and noise),
- preference rating of both fittings.

Results

SI for monosyllabels in quiet and SRT for sentences in noise

Study 1 - Moderate hearing losses

As mentioned before, the SII model predicted 15% higher intelligibility for Target 1 than for Target 2. In accordance with the above model prediction, subjects achieved a significantly better SRT ($t_{[1,9]} = -3,313; p \leq .01$) for the OLSA test with Target 1 (SNR = -1dB) than Target 2 (SNR = 0dB). The subjects, however, had on average a slightly higher mean ($t_{[1,9]} = -1,009; n.s.$) for SI in quiet for Target 2 (64%) than Target 1 (59%).

Study 2 - Mild hearing losses

For audiograms used in Study 2 the SII model predicted almost identical speech intelligibility for both targets. This was also reflected in the empirical data, in which the subjects showed non-significant differences for SI in quiet (Target 1: 86% / Target 2: 81%), and noise (Target 1 and Target 2: SRT = -3dB).

Acceptance questionnaire

Figure 2 shows the results for the ratings regarding the Acceptance questionnaire. For Study 1 there was a significant better rating ($t_{[1,9]} = 2,674; p \leq .05$) for sound quality for Target 1 than Target 2. The other ratings showed the same tendency, but the differences were not significant.

In Study 2 there was a general tendency for better ratings of Target 2, however the differences were not significant.

Preference test

While there was a clear preference for Target 1 by 80% of the subjects with moderate hearing losses (Study 1), Target 2 was prefered by 66% of the subjects with mild hearing losses (Study 2).

Conclusion and future work

For mild hearing losses with open fittings, the modeling procedure as well as the questionnaire data did not reveal significant differences for fitting targets optimized

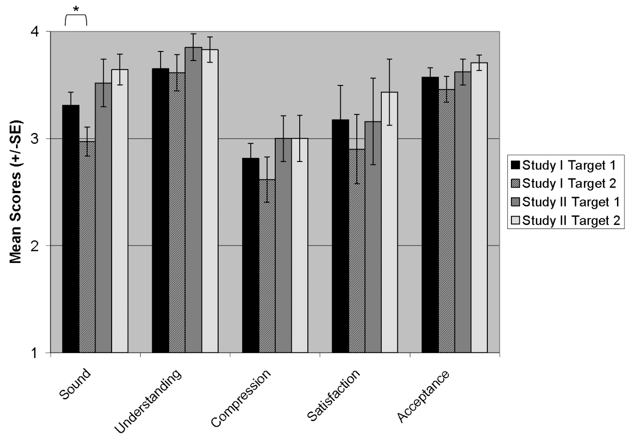

Figure 2: Mean scores for Acceptance questionnaire ratings with error bars indicating standard error. * indicating statistically significant differences ($p \leq .05$) between Target 1 and 2 revealed by paired t-Tests.

for speech intelligibility and sound quality, or those optimized for sound quality alone. This is possibly, because of unclear ratings, which is typical for unexperienced listeners. This could especially be the case, since when subjects were asked to designate a preferred target, the clear winner was the fitting target optimized for sound quality alone. Overall these results support the assumption that there is no need to focus on modeling speech intelligibility for fitting targets for mild hearing losses.

In contrast, for subjects with closed fitted moderate hearing losses, there is a special need for modeling both intelligibility and speech quality. Obviously, they preferred fitting targets which aimed at the best balance between speech intelligibility and sound quality.

In this study, however, there was a linear reduction of sound quality if the desired intelligibility was not reached. It is possible that there is a better fitting target with another weighting of intelligibility and sound quality. This should be a matter of further research.

Bibliography

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