Hearing Impairment: Benefit of Optimized Beamforming obtained with Hearing Glasses in a Multi-Source Noise Field

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Introduction

One of the obstacles complained by persons suffering from hearing impairment is their highly degraded speech perception under adverse listing conditions. Even high end hearing aids with multi channel beamforming do not restore this ability sufficiently in complex diffuse noise situations. A recently introduced hearing aid embodied in a pair of glasses frame offers advanced directivity by means of four microphones mounted in line in each temple (c.f. Figure 1) in order to obtain sophisticated beamforming (directivity index DI 9 dB, [1]). The recently introduced "multi-source noise field" speech in noise test allows the presentation of a realistic multi-talker noise environment and enables the measurement of binaural interaction regarding the separation of signal and noise arriving from different directions [2].

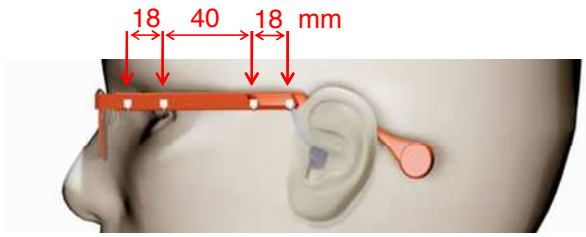

Figure 1: hearing glasses microphone mounting

Material and Methods

Subjects

10 subjects participated in the study. Average subject age was 74 years (standard dev. 8 years) and average duration of hearing aid experience was 6 years. All but one of the subjects were users of behind the ear devices. Most of the subjects had sensorineural hearing losses, without middle ear component. One subject showed an air-bone gap exceeding 10 dB at some test frequencies. Seven subjects had symmetric losses (difference for the average pure tone thresholds of 500, 1000 and 2000 Hz smaller than 15 dB), three subjects showed larger differences with 21 dB at maximum. Subjects did not complain about tinnitus or suffered from recent sudden deafness. Every subject signed a letter of informed consent before inclusion and received an allowance for participation.

Method

Speech intelligibility experiments and data collection were conducted by a personal computer with a high quality 24-bit 8-channel AD-DA converter (RME Digiface). The multi-source noise field was presented by means of a a four-loudspeaker array (details in [2]).

Aim of the study was the assessment of benefit and efficacy of directional microphones of three different hearing aid devices in terms of speech recognition in a multi source noise field:

1) subjects own hearing aid with directional microphone setup,
2) low cost hearing aid with omnidirectional microphone setup,
3) hearing glasses with high end directional microphone setup,
4) hearing glasses with low budget directional microphone setup.

Test devices were a) Hearing Glasses (Varibel, Netherlands) b) subject's own hearing aid and c) low cost hearing aid (Solo T, Phonak, Switzerland).

Figure 2: hearing glasses (Varibel, Netherlands)

Procedure

Prior to the tests, otoscopy ensured open ear channels and absence of middle ear infection.

The sequence of testing the four test conditions was randomized.

Fitting of the low cost hearing aid: The device was equipped with digital trimmers. The setting of the trimmers was carried out according to the individual audiogram and the prescriptions given by the manufacturer. The present amplification was measured by means of a 2 ccm coupler and a Maico MH 20 device and adjusted if necessary. After first fit, an aided threshold measurement was performed. The subject was also interviewed about his own impression of the hearing aid fitting. Based on these comments, a fine-tuning was performed with slight variation of the trimmer setting. After having accomplished the fine tuning, the subjects listened to four sound examples (brass music, traffic noise, conversation in noise, conversation in quiet) and filled out a questionnaire regarding loudness, sound quality, perception of own voice, speech intelligibility and personal satisfaction

with the fitting. An experienced hearing aid acoustician was in charge for fitting of the devices.

Fitting of hearing glasses: The hearing glasses were fitted by means of software provided by the manufacturer. The default prescription rule was applied. After first fit, an aided threshold test was performed. If necessary, a fine-tuning was performed based on comments from the subject with tools provided by the fitting software. After having accomplished the fine tuning, the subjects had to listen to sound examples and to answer questionnaires regarding sound quality. A representative of the manufacturer was in charge of the fitting of the hearing glasses.

Speech Audiometry

a) Freiburger Monosyllables: subjects had to perform the Freiburger monosyllable speech test in quiet at 65 dB SPL for all aided conditions. Stimuli were presented by loudspeaker at 1.20 m distance in a sound isolated room. Two randomly selected lists of 20 monosyllables each were presented. Displayed results are averages of these two measurements.

b) Speech perception in a multi source noise field (MSNF): The Oldenburger Sentence test (OLSA) test was performed in closed set condition. Subjects provided their answer by means of a touch screen. Speech was presented in frontal position. Speech level was controlled by an adaptive procedure implemented in the OLSA-application software. Noise level was fixed at 65 dB SPL. Noise was presented simultaneously from four directions: 45, 135, 225, 315 degrees. Noise type was speech simulating noise (singe speaker, average amplitude modulation at 4 Hz) according to Fastl [3], details in [1]. As has been showed by Wagener et al. for application of the OLSA sentence test, a period of training is necessary to overcome learning effects caused by repeated presentation. Therefore, a list consisting of 30 sentences was presented before start of the measurements without noise at 70 dB speech level with the own hearing aid condition. All subjects performed in this condition better than 70% correct. To complete the training session, a 20 sentence test list was presented in MSNF condition with adaptive speech level. Start speech level was set to 70 dB SPL. After finishing the training session, the test with different hearing aids/conditions was conducted. Test lists comprising 30 sentences were selected by the experimenter according to a predefined sequence for each condition.

c) Final judgment: at the end of the test, each subject did perform a ranking of each hearing device in terms of his preference.

All individual results except the results of the standard audiometry were averaged as median with the 25% and 75% quantiles. The significance of test results and the difference between results were checked by means of a paired samples t-Test. A significance level below 0.05 was set. Statistical calculations were carried out with SPSS version 13.0.

Results

The pure tone audiogram averaged over all subjects and ears shows a mild sloping characteristic as was expected (Figure 3). Median threshold is 37 dB/500 Hz, 65 dB/4 kHz and 77 dB/8 kHz.

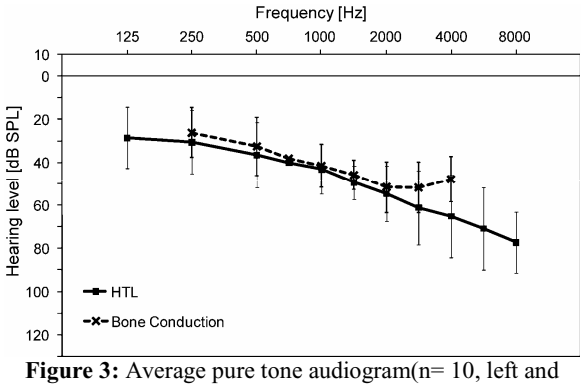

Figure 3: Average pure tone audiogram(n= 10, left and right data collapsed, air and bone conduction)

Without hearing aid, at 65 dB speech level, performance in the Freiburger Monosyllable test was 40% correct on average. Average recognition rate was highest for the own hearing aid condition (77%). The poorest results are visible for the low cost hearing aid condition (63.8%). Both hearing glasses (low cost and high) showed comparable performance (average 71% and 69.5%, $p > 0.28$) but results reached not the level of the own hearing aid (Figure 4).

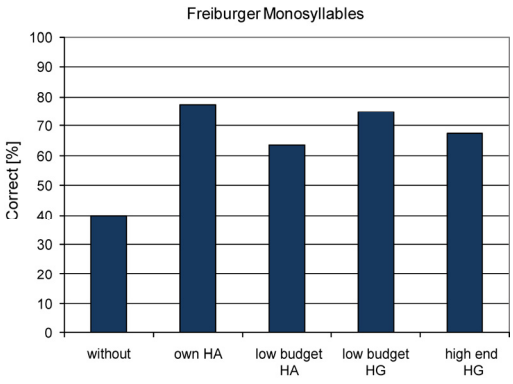

Figure 4: Results of the Freiburger Monosyllable test (65 dB speech level) in the different aided conditions compared to unaided situation.

Speech perception in the MSNF condition (65 dB SPL noise level) showed a slightly better performance with the own hearing aid compared to the low cost hearing aid condition but this small difference was not statistically significant ($p > 0.49$, Figure 5). Both types of hearing glasses showed significantly higher signal to noise ratios compared to the own BTE device condition ($p < 0.027$, low budget, and $p < 0.044$, high end). Comparing low budget and high end hearing glasses condition, the impact of the high end directional microphone setup is visible in terms of a median higher SNR, however, due to largely scattering results this difference is not statistically significant ($p > 0.28$). With the high end hearing glasses, some subjects were able to discriminate speech even at an SNR of -15 dB.

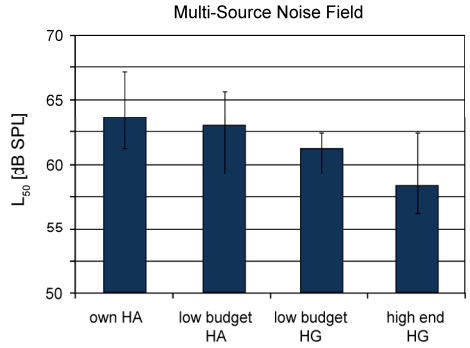

Figure 5: Speech reception threshold in a multi-source noise field in different aided conditions. Noise level at 65 dB SPL fixed, OLSA test method in closed set, see text.

Questionnaires (not displayed): Subjects had to rate their impression for the different sound examples on a range between 0 (worst) to 10 (best). Speech in quiet was perceived independently of device at a rather high level of quality, whereas the perception of traffic noise was judged nearly equally scattered and poorer with the different conditions. Speech in noise was rated poorer with the low cost hearing aid compared to all other conditions, whereas the own hearing aid was rated best. The sound quality of music was judged with medium ratings, except in the own hearing aid condition, where ratings were considerably higher. However, only the difference between own hearing aid and low cost hearing aid was statistically significant ($p < 0.003$).

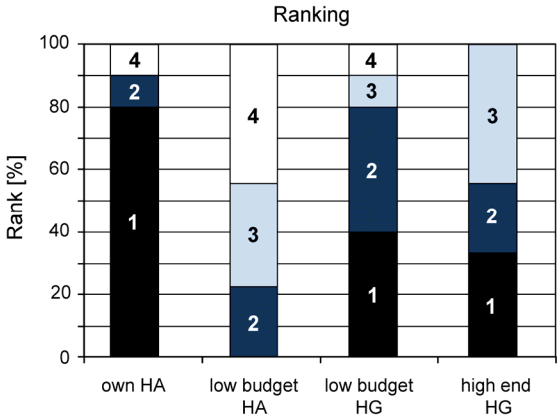

Figure 6: Ranking of the different conditions after end of the study. multiple ranking allowed.

At the end of the study, subjects were asked to rank the different conditions. Figure 6 displays ranking results for the four different aided conditions. Clearly visible, the majority of subjects preferred their own hearing aid as 80% voted for the first rank. A considerable number of subjects voted for the hearing glasses on first position; 40% preferred the low cost device (subjects were allowed to give a rank to multiple devices), 35% set the high end device to first position.

Discussion

The benefits of directional processing in hearing aids are well documented in laboratory settings. However, in environments with reverberation and higher amounts of diffuse sound field, the benefit of directional aids is quite limited and difficult to predict [4]. The main outcome of the study is that the directional microphone setup of the hearing glasses, especially with the high end version, is very effective even in complex noise environments with multiple noise sources from different angles of incident. It can be assumed that the advantage of a sophisticated directional microphone setup embodied in a glasses frame will also demonstrate a perceivable improvement for people hard of hearing with additional amblyopia in real life acoustic situations.

Further studies should investigate if acclimatization to the hearing glasses device can improve monosyllable comprehension. Since the present data show a small but statistically significant decrease after first fit (own hearing aid 77%, hearing glasses high end 69.5%), it remains open whether accommodation can improve monosyllable comprehension over time.

The ranking over all conditions gave no clear preference for the hearing glasses, however, a considerable number of subjects was in favor of the hearing glasses. A very recent comparison test between omni-directional and directional hearing aids had demonstrated also no clear preference, since subjective ratings for each of the three hearing aid responses (omni-directional, automatic-adaptive directional, and automatic-fixed directional) were similar as demonstrated by [5].

The observation that even the low budget hearing glasses can improve speech perception in noise considerably is remarkable, since this condition made use of the microphones located at the front of the device. Therefore, only limited effects of head shadow are expected. Maybe the reduced distance to the speech presenting loudspeaker had a small impact on the level of speech arriving from the front.

Conclusion

In a laboratory setting very similar to real life acoustic environments the directional microphone embodied in the hearing glasses device shows clear advantages compared to BTE hearing aids. Average improvement of signal to noise ratio with the high end version was 4.2 dB compared with data derived with the own hearing aids of the subjects.

Acknowledgements

Part of this work has been made possible in cooperation with the Varibel Company.

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