A new tool for subjective assessment of hearing aid performance: Analyses of Interpersonal Communication

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The performance of two different adaptive beamformer approaches in environments close to reality were investigated. They were subjectively evaluated via questionnaires and focus group discussions. Additionally, a new tool was tested, to assess how well video analyses with external rating of subjects' communication behavior, related to the grounded theory approach, generate new measures to describe the communication behavior using the different hearing aid algorithms. With this methodology, the results show different behavior of the participants between the algorithms in loud environments only. The new assessment tool was found to be a valuable method for obtaining a deeper insight into subjects' behavior and a new promising outcome tool for audiology.

INTRODUCTION

Directional microphone systems in hearing devices improve the speech intelligibility in complex listening situations. This has been confirmed in various studies in defined situations in the laboratory (e.g., Ricketts and Mueller, 1999; Ricketts and Henry, 2002; Bentler, 2005; Picou *et al.*, 2014). However, the question remains as to how relevant these results are for real life. Common measuring tools (e.g., questionnaires) used during clinical field trails are not sensitive enough and produce results with high variability, depending on the prudence of the subjects while filling in the questionnaire and on the situations occurring during the field trial. Research systems for evaluation in real life (e.g., Hasan *et al.*, 2013) are able to verify the situation by collecting physical data of the environment. They turned out to be a step forward but there are still the subjects' uncertainties which cannot be avoided/controlled by such systems.

Another approach is the simulation of real talking and listening situations in a laboratory and the use of head trackers, to get an objective measure of the influence of the systems by monitoring head movements (Cohen *et al.*, 2014). To overcome this uncertainty, it is necessary to use methodologies which do not make use of the subject's ratings of the test systems itself, but instead, provide measures demonstrating the effect of the test systems on the subjects' behavior objectively. This would then lead to conclusions regarding the performance of the test systems.

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Two studies comparing the same directional microphone systems show contradictive results in the laboratory and home trial (Appleton-Huber and König, 2014; Latzel, 2015). In the lab, the system with the binaural beamformer showed favorable results compared to the system with the monaural beamformer, particularly in the areas of objective and subjective speech understanding. In contrast, in the home trial, where subjective results were obtained via questionnaires, the results were the opposite, especially for the situation "speech in (loud) noise".

To improve interpretation of the data, a new methodology was transferred for the use with hearing aids in order to compensate for the disadvantages of a field test and the limited clinical relevance of lab measurements. This methodology has been used previously with a stronger focus on ethnographic field observation to analyse if and how social robots are experienced as social actors (Lindemann and Matsuzaki, 2014). Therefore a meaningful combination of the advantages of home and laboratory trials was set up.

Our study had two main objectives:

1. To investigate how two different adaptive beamformer approaches perform in environments close to reality when they are subjectively evaluated with questionnaires and focus group discussions.
2. To assess how well video analyses with external rating of the subjects' communication behavior related to the grounded theory approach, generate new measures to describe the hearing performance of different hearing aid algorithms.

METHOD

A subgroup of the subjects from the beamformer study described in Latzel (2015) was invited to a moderated group discussion session. All participants were present at the same session. The subjects consisted of five experienced and two inexperienced hearing aid users. Six of them were male and three were female. All subjects had a moderate to severe hearing loss: better ear (4HFA), 43.8 dB HL (SD: 6.5 dB); worse ear (4HFA), 49.0 dB HL (SD: 6.4 dB). The mean age was 76.0 years (range 56-78 years). During the former beamformer studies, subjects had perceived differences of at least two scale points between the different beamformer approaches in daily life.

During the testing, subjects wore Phonak Audeo V90 312 hearing aids which were fitted according to the Phonak Adaptive Digital fitting formula (Latzel, 2013). The hearing aids were set with two programs:

- Program 1: Adaptive Monaural Beamformer: adaptive UltraZoom (aUZ)
- Program 2: Adaptive Binaural Beamformer: adaptive StereoZoom (aSZ)

Two difficult listening situations were simulated with the use of CAS (Communication Acoustic Simulator) at the Hörzentrum Oldenburg.

The first one was a laboratory scenario (S1) simulating a coffee house with an average sound level of 55 dB (LA_{eq}).

The second one was a loud laboratory scenario (S2) simulating a supermarket with an average sound level of 67 dB (LA_{eq}).

The first outcome measure was named Analyses of Interpersonal Communication in Realistic Acoustical Experimental Settings (AICRAS©) and consisted of a questionnaire and focus group discussion. The participants were encouraged to discuss the following topics, assuming a general interest of all participants, so that all would be both active (talking) and passive (listening) participants at the discussions:

- Topic 1: "Important hearing situations" (in the quieter lab scenario)
- Topic 2: "Experiences with hearing aids" (in the quieter lab scenario)
- Topic 3: "Communication in noise" (in the louder lab scenario)
- Topic 4: "Needs for future hearing aids" (in the louder lab scenario)

Subjects were firstly asked to fill out a questionnaire individually, rating different dimensions of hearing aid performance on a scale of 1-7 or −4 (too soft) to +4 (too loud). During discussion topics 1 and 3, they tested aUZ and during topic 2 and 4, they tested aSZ. They were not allowed to change the program to receive absolute ratings. Following this, subjects filled in one questionnaire as a group, where each of them judged aUZ in comparison to aSZ with regards to several different hearing aid performance dimensions (loudness of speech, speech intelligibility, listening effort, sound, loudness of the environment, and overall satisfaction) for both quieter and louder scenarios. Hearing aid performance dimensions and scales, from −5 (aUZ is better) to +5(aSZ is better), were shown or a board and participants were asked to give their ratings by placing stickers on the board.

In addition a second outcome measure was used named Video-based Analyses of Interpersonal Communication in Realistic Acoustical Experimental Settings (VIB-AICRAS©): An external rater watched a video of the focus group of subjects and rated their communication behavior based on the grounded theory approach by Glaser and Strauss (1967).

An example of the coding process for the grounded theory approach based on the video of the study can be seen in Fig. 1.

Recording	Phenomena	Indicators	Concepts
	Two persons are situated side by side. The left one leans his head slightly to the side and the right one moves his lips. Both of them are wearing glasses.	The left person listen closely to what the other person had said. The right person leans forward, to be better understood.	A verbal interaction.
			Face-to-face.
			loud environment.

Fig. 1: Example of the grounded theory approach for a certain section of the video from the study.

The external rater judged the communication behavior of the subjects according to two theoretical aspects indicated in Glaser and Strauss (1967) and Strauss (1987) respectively. The first aspect was ‘forms of interaction’, where the raters judged the amount of symbolic gestures (e.g., waving hands, “blocking behaviour”) being used versus the amount of verbal communication. The second aspect was ‘interdependence’, where the rater judged the amount of face-to-face communication compared to group interaction. Both aspects were judged for aSZ and aUZ in both S1 and S2 lab scenarios. The rater identified, in total, 286 scenes and the analyses of the two hours of video material took approximately two weeks.

RESULTS

All box plots which follow show minimum, maximum, median, 25th and 75th quartiles. Results of the AICRAS© outcome measure can be seen in Figs. 2-4. As a general remark, all users reported noticing clear differences between aUZ and aSZ especially in the louder lab scenario (S2). Inexperienced users preferred aSZ in S2, due to more of the loud background sound being suppressed.

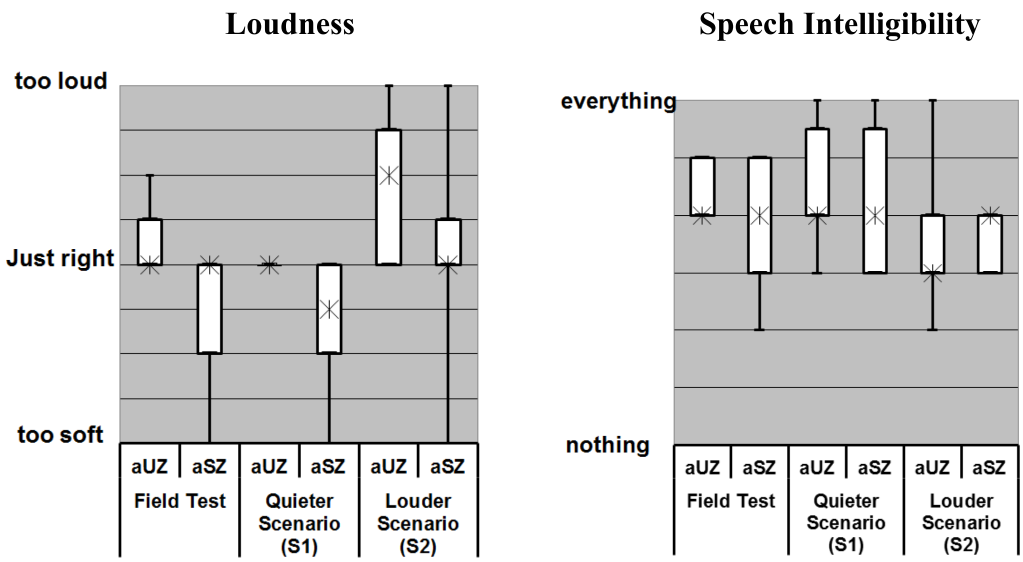

Fig. 2: Results of questionnaires completed individually. Comparison of results from the home trial with results in quieter and louder lab scenarios. Loudness was measured on a 9-point scale (−4 to +4). Speech Intelligibility was measured on a 7-point scale.

Figure 2 shows the results of the questionnaires which the subjects filled in individually. The home trial results were obtained in a prior study (Latzel, 2015). Loudness was perceived as “too loud” with aUZ and “adequate” with aSZ in S2. aSZ was perceived as slightly “too soft” in the quieter scenario (S1). Speech intelligibility was rated better with aSZ in contrast to aUZ in S2 but the speech intelligibility was rated lower in S2 than in the home trial.

Interestingly, participants rated the algorithms the same as they had in the home trial, when tested in the quieter lab situation, S1. This suggests that, during the home trial, the participants were mainly only in quieter situations because they deliberately avoided louder ones. They had been instructed to test the hearing aids also in louder situations. Nevertheless, they apparently did not. This would explain why the laboratory and home trial results from Appleton-Huber and König (2014) and Latzel (2015) were contradictory.

Figures 3 and 4 show the results of the questionnaires which subjects filled out as a group. There was a preference for aUZ in the quieter scenario for all dimensions with a general shift towards a preference of aSZ for the louder lab scenario. That is a second indication that the system is doing what it is intended to do (aUZ in softer noise environments, aSZ in louder environments) and that participants may have avoided louder situations during the home trial, so that that the advantages of aSZ could not be perceived.

Remark: The low rating of speech intelligibility in the louder lab scenario for aSZ may be due to the more “frontal” communication with the tester during the group assessment. The tester was standing quite far away and was therefore out of the radius so that the directional microphone was no longer effective anymore.

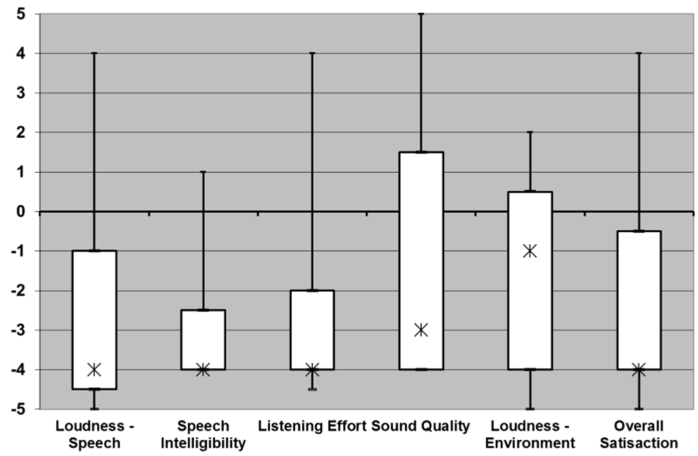

Fig. 3: Results of the questionnaire completed as a group for the quieter scenario (S1). Subjects rated preference of aUZ or aSZ for each dimension using a scale of -5 to +5.

Results of the VIB-AICRAS© outcome measure can be seen in Figs. 5 and 6.

In the quieter scenario, the behavior of the participants was very similar for both algorithms. This indicates that in quieter situations, the performance difference between the two algorithms is too small to make a difference in the behavior of the participants.

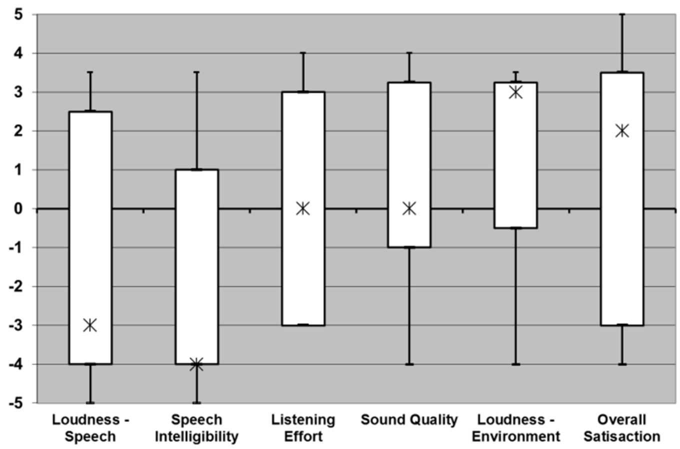

Fig. 4: Results of the questionnaire completed as a group for the louder scenario (S2). Subjects rated preference of aUZ or aSZ for each dimension using a scale from −5 to +5.

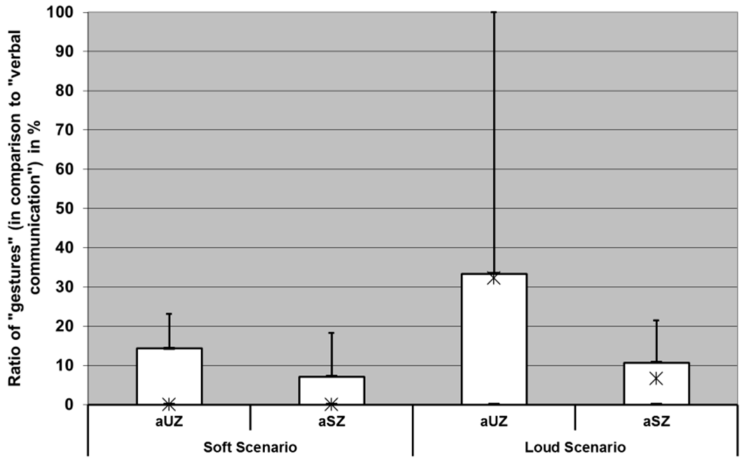

Fig. 5: VIB-AICRAS© 'Forms of interaction'. Ratio of symbolic gestures (compared to verbal communication) for aSZ and aUZ in both lab scenarios.

The external rater noticed a higher ratio of non-verbal communication (ratio of symbolic gestures to spoken words) for aUZ (mean = 28.4%) in comparison to aSZ (7.1%) in the louder lab scenario (p = 0.11, Wilcoxon, see Fig. 5), indicating more difficulty communicating in this situation. However, analyses also showed side-effects to using aSZ: The subject had to turn himself significantly more often towards his neighbor, in order to understand better. (p = 0.02, Wilcoxon, statistically significant).

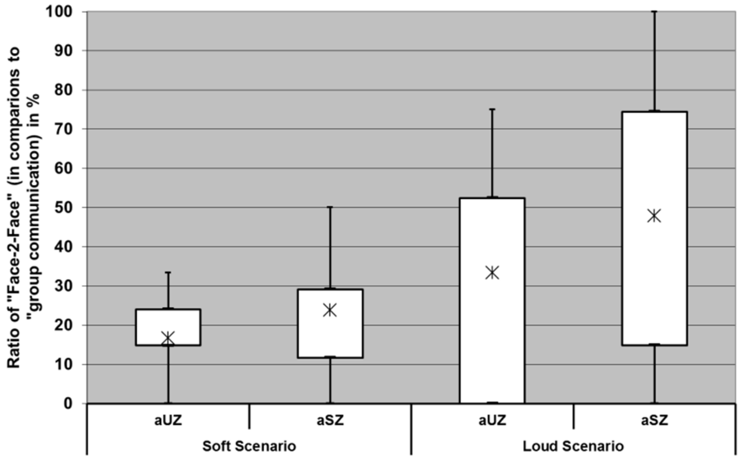

Fig. 6: VIB-AICRAS© 'Interdependence'. Median of face-to-face communication ratio (compared to group interaction) for aSZ and aUZ in both lab scenarios.

The external rater also noticed that the ratio of face-to-face communication in comparison to group interactions increases with increasing noise level. There was a higher ratio of face-to-face communication with aSZ (mean = 46.6%) than with aUZ (mean = 30.4%) with $p = 0.17$ (Wilcoxon, see Fig. 6), which leads to the side-effect described above.

Consequently, in the louder scenario, the difference between the algorithms is apparently larger and therefore can be seen in differences in participant behaviour. This indicates that the use of a narrower beamformer results in less group communication and more communication with the person sitting opposite.

CONCLUSIONS

Based on the questionnaire data, a slight overall preference in loud situations for aSZ was observed. This preference was based on subjects perceiving the environmental sound as smoother.

The home trial results for the dimension "situation with loud noise" is more highly correlated with the results of the quieter than of the louder lab scenarios. Subjects did not experience (were avoiding) loud situations during the home trial which explains the contradictive results.

In quieter situations there is preference for aUZ in all dimensions, whereas aSZ was preferred more in louder situations. This was observed especially for inexperienced hearing aid users.

The results lead to the conclusion that focusing only on maximum speech intelligibility by a narrower beamformer is not always favorable. It depends on the situation and the subjects' individual experiences/preferences and this should be something to consider during the hearing aid fitting procedure.

In general, the questionnaire tool AICRAS© and, especially the video tool VIB-AICRAS©, can be seen as valuable tools to obtain new outcome measurements in audiology.

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