Evaluation of different phone solutions in CI, hearing aid and bimodal users

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Introduction

For people with hearing loss, everyday activities like talking on the phone can be challenging. Factors contributing to this are the lack of visual cues (lipreading), the lack of binaural abilities, the presence of (loud) background noise in a variety of listening situations, a modified speech signal due to reduced frequency bandwidth or difficulties coupling the phone to the CI. As a result, hearing impaired people tend to avoid these kind of telephone situations or delegate the task to their significant others or relatives.

Various products have been developed to improve speech intelligibility during phone calls. One example is the binaural algorithm DuoPhone by means of which the phone signal received on one ear is streamed to the contralateral ear. Furthermore, the Phonak DECT phone streams the signal directly into both ears simultaneously. Improved speech intelligibility for HA- and bimodal users has already been shown with this hearing assistance technology. The current comparative study includes hearing aid as well as CI and bimodal users to evaluate this technology for a broader range of people with hearing loss.

Material and Method

Study participants were invited for two appointments. All tests were performed in the lab (lab measurements).

Depending on the individual hearing loss (moderate to severe) the hearing aid groups were provided with Phonak Audéo V13 or Naida V hearing aids, respectively. CI and bimodal users used Advanced Bionics Naida CI Q90 speech processors. In addition to the speech processor bimodal users were also provided with Naida Link hearing aids.

All groups of participants used a standard landline phone, a Phonak DECT phone and a Motorola Moto G mobile phone during the measurements. In addition, the bilateral groups (bilateral HA, bimodal) performed measurements using the DuoPhone algorithm.

<u>General setup</u>

Measurements were performed in a loudspeaker setup (Figure 1) consisting of 12 loudspeakers arranged in a circle with a distance of 1.5 m from the center to the speakers. Participants faced the loudspeaker at 0°. Speech material was generated on a personal computer. The PC was coupled to the receiver handset input port of a landline phone (calling phone). This phone was used to call the measurement phone, i.e. either another standard landline phone, the Phonak DECT phone or a mobile phone. The speech material was then presented via the measurement phone to the participant.

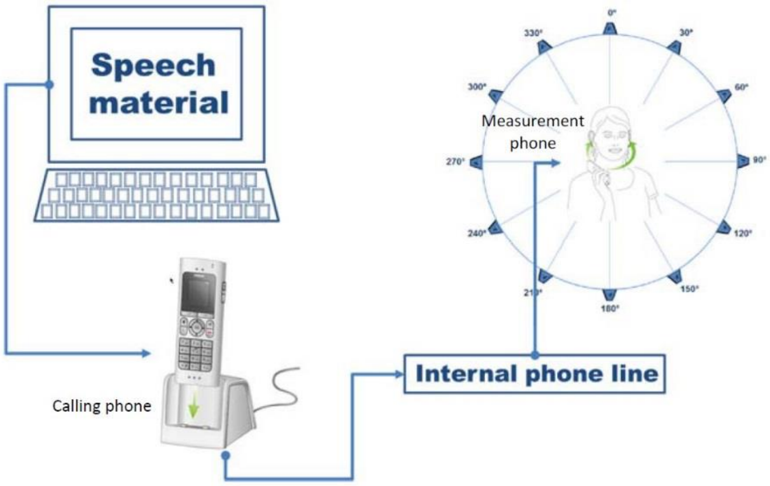


Figure 1: Test setup for speech intelligibility measurements

Assessment of **primary** outcome

Speech intelligibility

Speech intelligibility on the phone in background noise was measured with the Oldenburg sentence test (OlSa). The speech level was adapted to yield the speech reception threshold (SRT), which represented the speech level required for 50% correct word understanding, while the noise level was kept constant at 65 dB SPL. Two OlSa lists (20 sentences each) were used for each type of noise and phone condition. The presentation levels did not exceed 80dB SPL.

Prior to testing (once in each session), at least two practice lists were presented to the subject to avoid training effects during the test. The number of practice lists was adapted to the familiarity of the subject with the OlSa material during a phone call.

The difference in speech reception threshold (SRT) on the phone in the presence of background noise was calculated between the overall SRT for the Phonak DECT phone and the overall SRT for the standard landline phone.

Background noise

Another background scenario (Cafeteria noise) was used additionally to the Oldenburg noise for the Oldenburg Sentence Test.

This noise was recorded with a multichannel surround sound microphone and provided via twelve loudspeakers with room impulse responses to get the best realistic scenario in the lab.

Assessment of **secondary** outcome

The difference in speech reception threshold (SRT) on the phone in the presence of background noise was calculated between the overall SRT's of the respective phone solutions:

- Phonak DECT phone – standard landline phone + DuoPhone algorithm
- Standard mobile phone – standard mobile phone + DuoPhone algorithm

Participants

26 hearing impaired participants participated in the study: 6 participants in the HA-group with unilateral moderate or severe hearing loss, 12 participants in the HA-group with bilateral moderate or severe hearing loss, 3 participants in the unilateral CI-group (two of them being bimodal and also tested in the CI+HA group) and 7 participants in the CI+HA-group. They all had hearing aids or a Naida CIQ70/Q90 processor and at least one-year experience with their hearing devices.

Results

The following section shows all average SRT-results for OLSA and Cafeteria-noise, separately shown and discussed for the bilateral HI-users and bimodal users. The unilateral HI- and CI-users are included in the results from **all** participants and will not be discussed individually.

The non-parametric Wilcoxon Rank Test was used to reveal potential differences between our different telephone conditions. The reasons for using this statistical test are the small number of participants (<30) and the observation that the data are not normally distributed.

All participants

The following graphs show results for all measured phone conditions for both background noises (OlSa: olnoise in grey, cafeteria in green) from all participants.

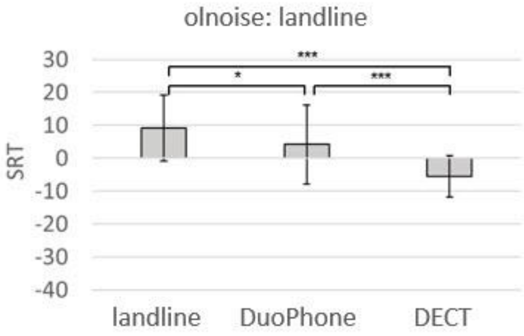


Figure 2: SRT in landline conditions in olnoise

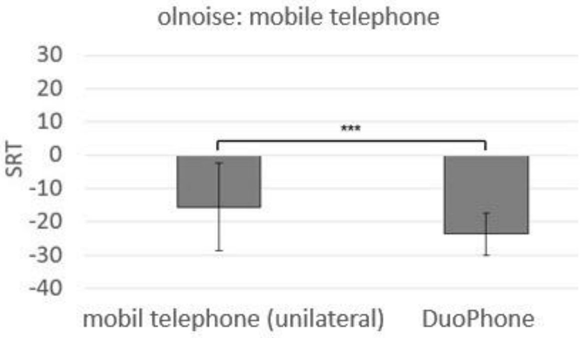


Figure 3: SRT in mobile phone conditions in olnoise

Figure 2 shows the relationship between the SRT's in the unilateral landline-, the binaural DuoPhone- and the binaural DECT-condition in olnoise. Significant differences between all conditions were found. The DECT-telephone showed the best result in comparison to the other telephone conditions for all participants. The average improvement from unilateral landline to DuoPhone was 5dB ($Z=-2.154$, $p<0.05$), from DuoPhone to DECT 10 dB ($Z=-3.462$, $p<0.05$) and from unilateral landline to DECT 15 dB ($Z=-4.281$, $p<0.05$).

Figure 3 shows the SRT in dB for the unilateral mobile telephone and the binaural DuoPhone-mobile telephone-condition for all participants. The average improvement was 8 dB; this corresponds also to a significant difference between both conditions ($Z=-3.621$, $p<0.05$).

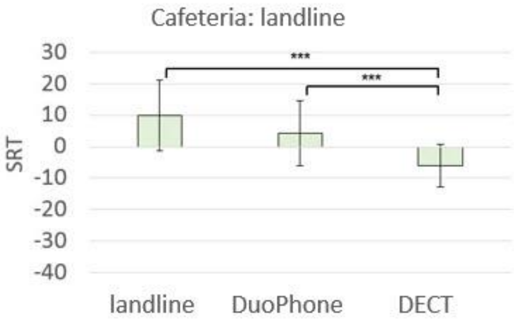


Figure 4: SRT in landline conditions in Cafeteria noise

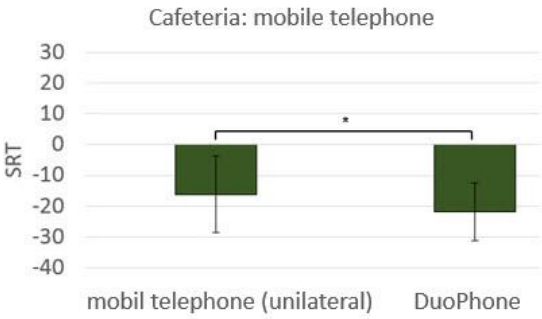
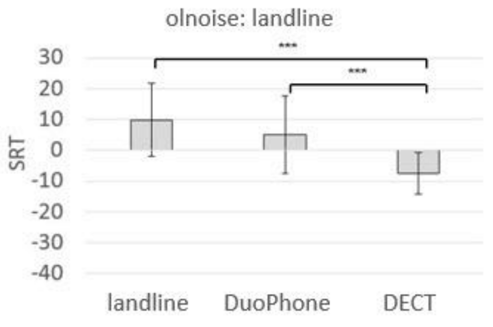


Figure 5: SRT in mobile phone conditions in Cafeteria noise

Figure 4 shows the SRT in dB for the unilateral landline-, the binaural DuoPhone- and the binaural DECT-condition in Cafeteria-noise for all participants. The average improvement from unilateral landline to DuoPhone was 6 dB, from DuoPhone to DECT 10 dB ($Z=-3.549$, $p<0.05$) and from unilateral landline to DECT 16 dB ($Z=-4.464$, $p<0.05$). The relationships between unilateral landline to DECT and between DuoPhone- and DECT-condition showed significant differences. The difference between the monaural unilateral landline and the binaural DuoPhone-condition, however, was not significant.

Figure 5 shows the average improvement (6dB) from the unilateral mobile-telephone and the binaural DuoPhone-mobile telephone-condition for all participants in Cafeteria-noise. The difference was significant (Z=-2.343, $p<0.05$).

Bilateral HI participants
The following section shows all average SRT-results for OLSA and Cafeteria-noise, for all bilateral HI-users.



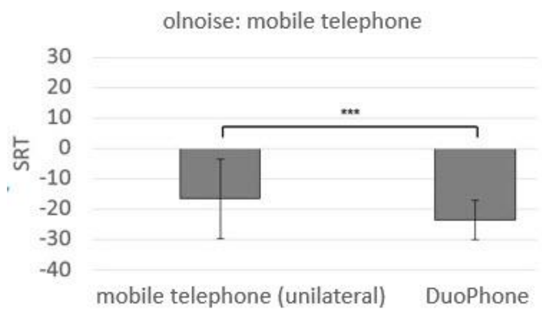
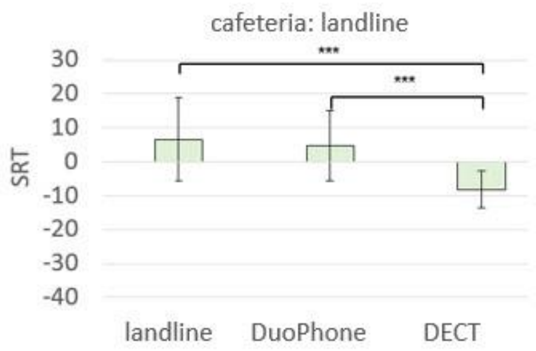


Figure 6: SRT in landline conditions in olnoise

Figure 7: SRT in mobile phone conditions in olnoise

Figure 6 shows the SRT in dB for the unilateral landline-, the binaural DuoPhone- and the binaural DECT-condition in olnoise for all bilateral HI-users. The average improvement from unilateral landline to DuoPhone was 5 dB, from DuoPhone to DECT was 13 dB (Z=-2.845, $p<0.05$) and from unilateral landline to DECT 18 dB (Z=-2.746, $p<0.05$). The differences were significant, except the improvement between unilateral landline and DuoPhone-condition.

Figure 7 shows the average improvement (7 dB) from the unilateral mobile telephone and the binaural DuoPhone-mobile in olnoise. The difference was significant (Z=-2.934, $p<0.05$) for all bilateral HI-users.



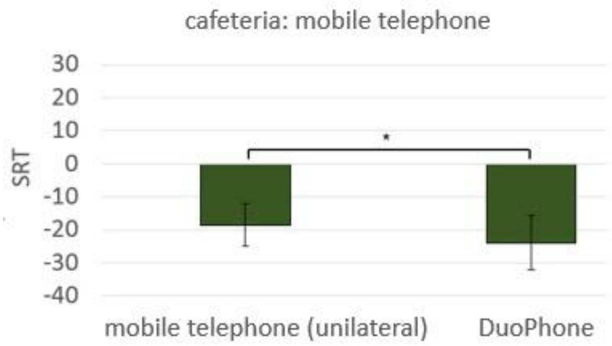


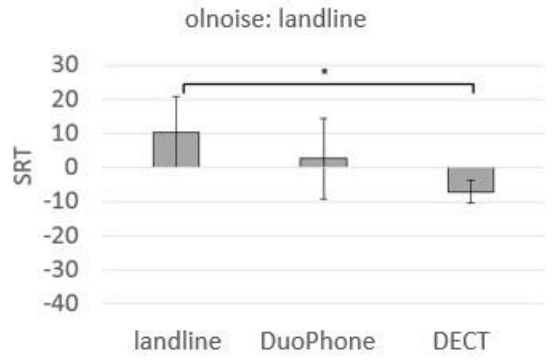
Figure 8: SRT in landline conditions in Cafeteria noise

Figure 9: SRT in mobile phone conditions in Cafeteria noise

Figure 8 shows the SRT in dB for the unilateral landline-, the binaural DuoPhone- and the binaural DECT-condition in Cafeteria-noise for all bilateral HI-users. The average improvement from unilateral landline to DuoPhone was 2 dB, from DuoPhone to DECT 13 dB (Z=-2.756, $p<0.05$) and from unilateral landline to DECT 15 dB (Z=-2.746, $p<0.05$). The differences were significant, except the improvement between unilateral landline to DuoPhone-condition.

Figure 9 shows the average improvement (5 dB) from the unilateral mobile phone and the binaural DuoPhone-mobile in Cafeteria noise. The difference was significant (Z=-2.223, $p<0.05$) for all bilateral HI-users.

Bimodal participants
The following section shows all average SRT-results for OLSA and Cafeteria-noise, separate shown for all bimodal users.



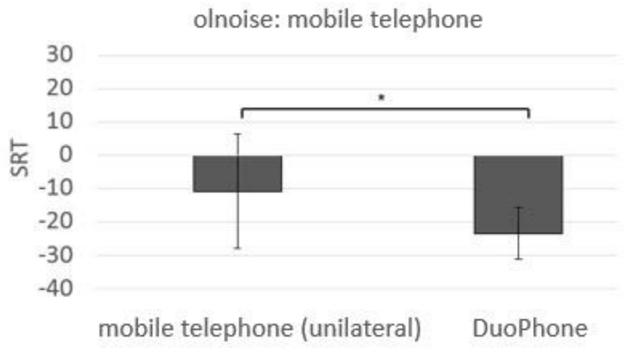
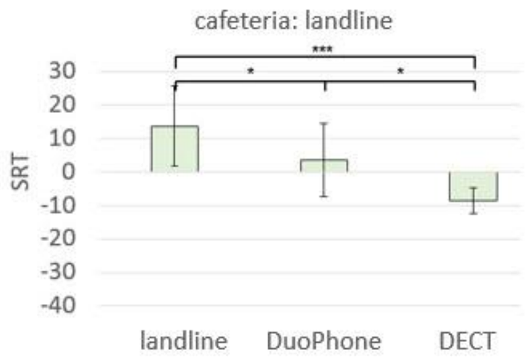


Figure 10: SRT in landline conditions in olnoise

Figure 11: SRT in mobile phone conditions in olnoise

Figure 10 shows the SRT in dB for the unilateral landline-, the binaural DuoPhone- and the binaural DECT-condition in olnoise for all bimodal users. The average improvement from unilateral landline to DuoPhone is 7 dB, from DuoPhone to DECT was 10 dB and from unilateral landline to DECT 17 dB ($Z=-3.582$, $p<0.05$). The latter difference was highly significant.

Figure 11 shows the average improvement (13 dB) from the unilateral mobile phone and the binaural DuoPhone-mobile in olnoise. The difference was significant ($Z=-3.261$, $p<0.05$) for all bimodal users.



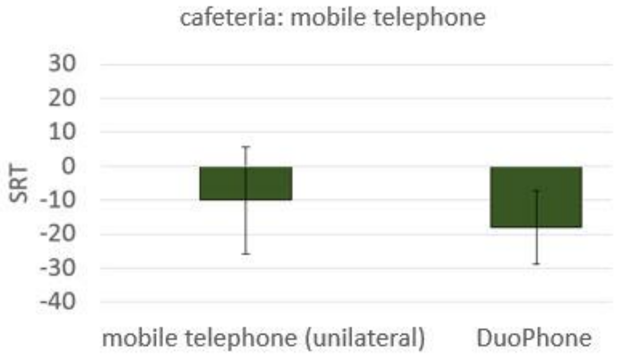


Figure 12: SRT in landline conditions in Cafeteria noise

Figure 13: SRT in mobile phone conditions in Cafeteria noise

Figure 12 shows the SRT in dB for the unilateral landline-, the binaural DuoPhone- and the binaural DECT-condition in Cafeteria noise for all bimodal users. The average improvement from Standard to DuoPhone was 10 dB ($Z=-2.223$, $p<0.05$) and from unilateral landline to DECT 23 dB ($Z=-3.622$, $p<0.05$). The differences between all conditions were significant.

Figure 13 shows the average improvement (8 dB) from the unilateral mobile telephone and the binaural DuoPhone-mobile in Cafeteria noise for bimodal users.

Conclusion

All participants could benefit from binaural presentation of the telephone signal in their hearing devices – independent of the surrounding noise.

The efficiency of a unilateral landline telephone to the binaural DuoPhone functionality increased distinctly by around 5 dB, from binaural DuoPhone to binaural DECT telephone by around 10 dB and from unilateral landline to binaural DECT telephone by around 15 dB.

Already reported improvements from binaural features for hearing aid users (Winneke et al., (2016), Appleton-Huber, Latzel (2013), Picou, Ricketts (2011, 2013), Nyffeler, (2010)) could be confirmed and were in the same range for bimodal users – independently of amplification prior to cochlear implantation and usable (aidable) hearing in the ear contralateral to the implant and of the surrounding noise. Bilateral telephone signals in addition to noise cancellation provide bimodal users with the possibility to use the telephone at all or with a substantial benefit for speech intelligibility in noise. Subjective comments were, that the participants mostly avoid such situations we presented to them in the lab. Therefore, the bilateral use of the telephone establishes more freedom of action and independency from circumstances for bimodal users.

The DECT-telephone provides a benefit for all users, regardless of being monaurally or binaurally aided.

Results were better with the unilateral mobile phone than with the unilateral landline phone for almost all participants. Efforts were made to examine the reason for these differences. The bandwidth of the mobile phone was compared to the bandwidth of the landline phone. This could not completely explain the rather big differences in speech intelligibility. In addition, the bandwidth of the mobile phone can also be subject to variations in the mobile network. The handling of both phones and how they were held against the ear/the microphone of the hearing device could have also played a role. Finally, the differences could not be fully clarified.

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