WIDEXPRESS

NO.30

JANUARY 2012

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USING THE WIDEXLINK TECHNOLOGY TO IMPROVE SPEECH PERCEPTION

Background

For most hearing aid users, the primary motivation for using hearing aids is to improve speech intelligibility. However, some listening situations continue to be difficult, even with amplification. Among those situations are speech perception while watching TV and talking on the telephone. According to MarkeTrak data (Kochkin 2005), hearing aid users are often dissatisfied with the performance of their hearing aids in those situations.

Manufacturers typically try to solve the problem of hearing television sound by means of a dedicated listening program optimised for that specific situation, or by offering an assistive listening device that wirelessly transmits TV sound to the hearing aids.

A special telephone for hearing aid users is often recommended when users have difficulties with telephone conversations. One of the drawbacks of having such a telephone installed is that users are restricted to making calls from their homes. Another drawback is the additional cost of acquiring a special device. An alternative approach is to utilize wireless transmission technology to transmit the telephone signal between the hearing aids, so that the user can hear the signal in both hearing aids. With the latter approach, users are spared the extra cost and trouble of having to acquire an extra device, and are no longer restricted to making calls from their homes.

A number of important considerations apply when developing new technologies to help improve hearing aid users' speech perception. The success of any given wireless transmission technology will depend on at least three key issues when applied to hearing aids: sound quality, transmission robustness, and power consumption.

At present, Bluetooth is the most commonly used technology for data and digital audio transmission. However, Bluetooth technology has some drawbacks, including a high codec delay and a high battery consumption, which make the technology less suitable for use in hearing aids. A decision was therefore made to develop a proprietary digital RF transmission technology, WidexLink, custom-designed for the exchange of audio and data between hearing aids, and between hearing aids and assistive listening devices (DEX devices).

Several factors were considered to be essential during the development of the wireless WidexLink technology. First of all, the highest possible audio quality must be achieved. Designing a very robust audio codec and RF transmission system to ensure stable, trouble-free transmission of sound and data during normal use was also a top priority.

WidexLink offers new possibilities for extended frequency range audio transmission (from 100Hz to 11kHz) when transmitting the telephone sound from the hearing aid to which the telephone handset is held to the hearing aid on the other ear (the Phone+ program). The same extended frequency range audio transmission is available when transmitting sound from external devices (the TV-DEX and M-DEX) to the hearing aids.

An important factor in maintaining a high audio quality is a low audio delay in the wireless transmission system. The WidexLink has been designed in such a way that a delay of less than 10ms was achieved.

Thanks to the unparalleled low latency during audio transmission, transparent sound, with an audio quality free of distortion and echoes, is achieved when the hearing aid microphones are used together with direct audio streaming to the hearing aids (e.g., in a TV situation).

This article summarises two studies that investigated the potential of the WidexLink technology to improve speech perception when listening to the sound from a television or talking on the telephone, respectively.

IMPROVED SPEECH PERCEPTION WITH THE TV-DEX

Introduction

As mentioned earlier, perceiving speech from the television is a problem for many hearing aid users, and this is one of the reasons why some hearing aid users are dissatisfied with their hearing aids (Kochkin, 2005). One way of solving this problem is to purchase an assistive listening device that can transmit sound from the television directly to the hearing aid, for example a TV-DEX.

The TV-DEX provides hearing aid users with echo-free stereo sound from televisions or stereos. The direct transmission of the television sound from the TV-DEX to the hearing aids can potentially shut out noise from the environment, resulting in a better signal-to noise ratio than when using hearing aids alone.

Tibbs, Crose, Lau, Keenan, and Schumacher (2011) conducted the study described in the following section to see whether TV-DEX would improve speech intelligibility in challenging listening situations, and whether users would prefer the sound quality of the transmitted audio signal, using hearing aids with the TV-DEX, rather than the hearing aid microphone sound.

Methods

10 hearing impaired subjects were recruited for the study. They all had good cognitive function, American English as their native language, and at least six months of experience with hearing aid use. Their selection was contingent upon auditory thresholds ≥ 20 dB HL at the 500Hz – 8,000 Hz range.

Participants were fitted binaurally with CLEAR440-9 BTE hearing aids with size 13 tubing and temporary instant fit foam tips. In-situ (Sensogram) thresholds were measured at 250Hz 500Hz, 1kHz, 2kHz, and 4 kHz with gain and features set at their default settings. A feedback test was also performed. The TV-DEX controller was placed around the neck of the participant and the TV-DEX base station was placed on top of the speaker in front of the participant (the 0° speaker, see Figure 1).

Speech perception was tested by means of the 32-Item ORCA Nonsense Syllable Test (Kuk et al., 2010) that uses nonsense consonant-vowel-consonant-vowel-consonant syllables as test stimuli, and includes items containing energy in an extended bandwidth region. The test was presented in a counter-balanced order in quiet and in noise for the following conditions:

i. Unaided

ii. Aided

iii. Aided with TV-DEX (Room On)

iv. Aided with TV-DEX (Room Off)

Evaluation was carried out in a quiet room. Test signals were played at 68 dB SPL from the 0° loudspeaker located three metres away from the participant. The noise source, when activated, originated from three loudspeakers located at 90°, 180°, and 270°, 1 metre away from the participant. The test setup is shown in Figure 1 below.

Location of loudspeakers in test

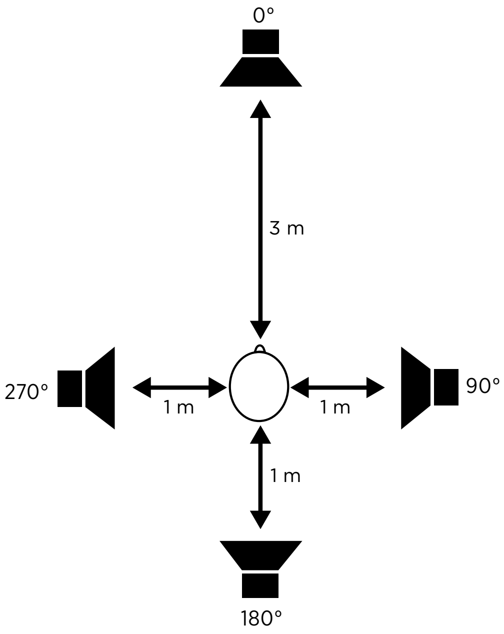

Figure 1: Location of the loudspeakers in the test setup: Loudspeakers were placed in front of the subject (0°), at the rear (180°), to the right (90°) and to the left (270°) at a distance of one and three metres, respectively.

The noise stimulus, an 8-person babble uncorrelated noise, was presented at levels sufficient to obtain a 0 dB SNR.

Finally, one-way and two-way repeated-measures ANOVA tests were performed to see whether the measured differences were significant ($p < 0.05$).

Results

Figure 2 shows the correct identification scores for all phonemes in quiet, measured across the four test conditions. The statistical tests revealed that the effect of test condition was significant ($p = 0.001$). Post hoc analysis showed that significantly more phonemes were identified correctly in the Aided, DEX Room On, and DEX Room Off conditions than in the Unaided condition ($p<0.05$). The tests also revealed a significantly higher correct identification score in the DEX Room On condition than in the Aided condition ($p <0.05$).

Correct identification scores for all phonemes, quiet condition

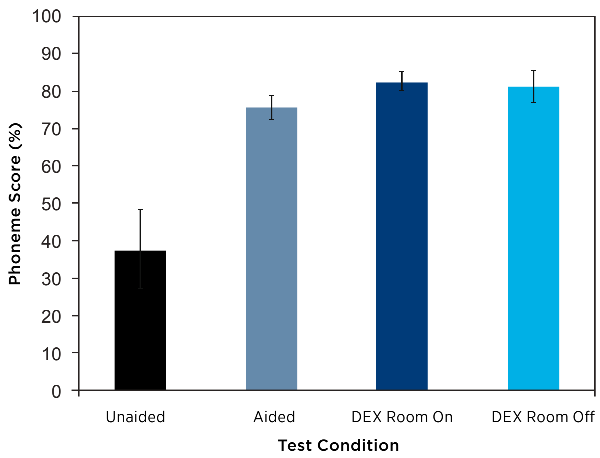

Figure 2. Correct identification score for all phonemes in quiet across the four test conditions of unaided, aided, DEX with Room On, and DEX with Room Off.

Figure 3 shows the correct identification scores for all phonemes in noise (0 dB SNR) for the four test conditions. The statistical tests revealed a significant effect of test condition ($p < 0.001$) in this case also. Post hoc analysis indicated that significantly more phonemes were identified correctly in the Aided, DEX Room On, and DEX Room Off conditions than in the Unaided condition ($p <0.05$). The tests also showed that significantly more correct phoneme identifications were obtained in the DEX Room Off vs. DEX Room On and Aided conditions ($p<0.05$), and in the DEX Room On vs. Aided conditions ($p<0.05$).

Correct identification scores for all phonemes, noise condition

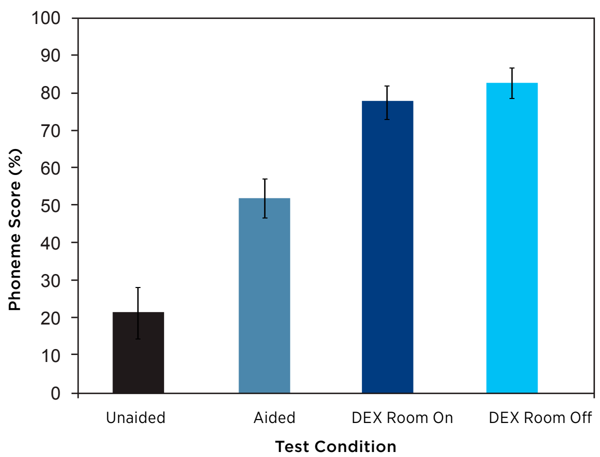

Figure 3. Correct identification score for all phonemes in noise across the four test conditions of unaided, aided, DEX with Room On, and DEX with Room Off.

The participants' phoneme identification scores were also analysed in terms of manner of articulation. The results showed that the subjects performed significantly better in the two DEX conditions than in the Aided condition in both quiet and noise. However, as may be observed in figures 4 and 5, there was a much greater gap between their performances in the Aided vs. DEX conditions in noise than in quiet. This applies across phonemes – those with primarily low-frequency content (e.g., nasals) as well as those with primarily high-frequency content (e.g., fricatives).

Identification scores by manner of articulation, quiet condition

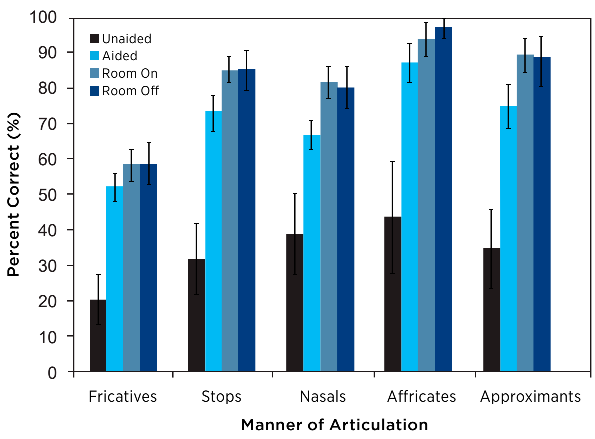

Fig 4: Identification scores by manner of articulation: fricatives, stops, nasals, africates and approximants in the four different settings in quiet.

Identification scores by manner of articulation, noise condition

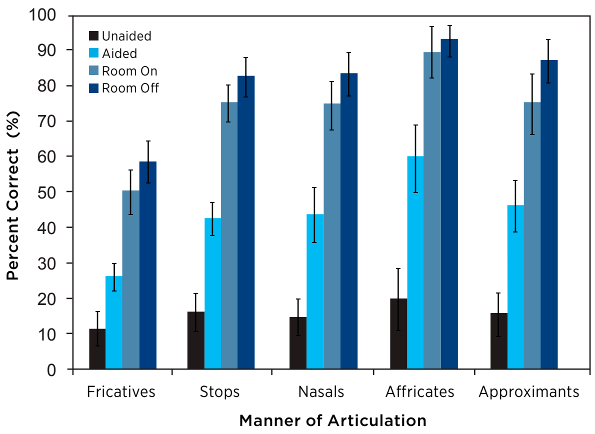

Fig 5: Identification scores by manner of articulation: fricatives, stops, nasals, africates and approximants in the four different settings in noise.

Performance on two of the fricatives with the highest amount of high-frequency content was examined in detail (Boothroyd et al. 1994). The results showed that the effect of test condition was significant for /s/ ('s') and /ʃ/ ('sh') in quiet ($p = 0.002$ and $p = 0.003$, respectively) and in noise ($p < 0.001$ and $p < 0.001$, respectively).

As may be observed in figures 6 and 7, the subjects' performance on /s/ and /ʃ/ was notably worse in the Aided than in the DEX Room On and DEX Room Off conditions in noise than it was in quiet.

Identification scores of /s/ and /ʃ/, quiet condition

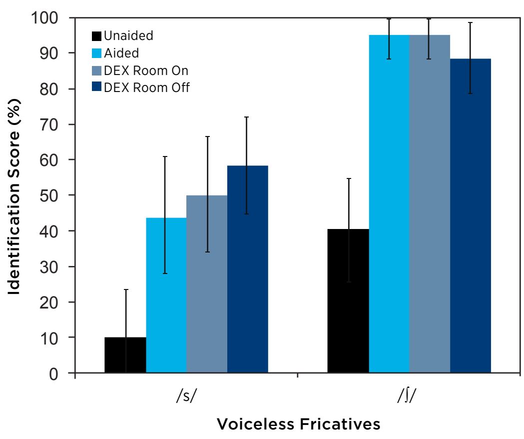

Fig 6: Identification scores of the fricatives /s/ and /ʃ/ in the four different settings in quiet.

Identification scores of /s/ and /ʃ/, noise condition

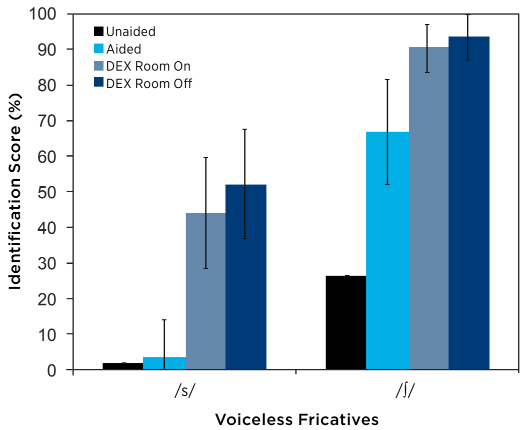

Fig 7: Identification scores of the fricatives /s/ and /ʃ/ in the four different settings in noise.

Summary

The results of this study showed an improvement in intelligibility when using the TV-DEX. An improvement was observed in both quiet and noise; however, the improvement was greater when the streaming device was used in noise.

A considerable difference in performance in quiet vs. noise was observed in connection with the identification of the /s/ and / / phonemes. While the subjects obtained higher identification scores with the TV-DEX than in the Unaided and Aided conditions in both quiet and noise, there was a considerably gap between their correct identification scores in noise. No problems with drop outs or artefacts were reported.

These findings support the value of using the TV-DEX to improve intelligibility when listening to TV sound.

SPEECH INTELLIGIBILITY AND PHONE+ PROGRAM

Introduction

Understanding speech on the telephone is another difficulty experienced by many hearing aid users (Yanz, 2005). According to Picou and Ricketts (2011), there are at least three reasons for this: the absence of visual cues when talking over the phone, difficulties associated with telephone coupling, and background noise.

Widex has developed the Phone+ program with the aim of improving speech perception in this specific situation. In addition to being optimized to provide the best possible frequency response for telephone sound, the Phone+ program permits the user to hear the telephone signal in both ears by using real-time audio transmission of the signal from one hearing aid to the other. The microphones are turned off on the receiving side to shut out environmental noise. By receiving the signal in both ears, the hearing aid user may be able to benefit from binaural squelch (Dillon 2001, Picou and Ricketts 2011)

Korhonen et al. (2011) conducted a study on the Phone+ program to determine whether the program was able to improve speech perception, compared to a traditional acoustic telephone program (the Phone program). The main details of the study are presented in the following.

Methods

12 adults with bilateral sensorineural hearing loss participated in the study (5 males, 7 females). Their ages ranged from 65 to 83 years with a mean age of 74 years. Pure-tone averages at frequencies 500 Hz, 1 kHz, and 2 kHz were 51.1 dB HL. Korhonen et al. measured the speech identification performance using the ORCA-Nonsense Syllable Test (Kuk et al., 2010) through a telephone handset using different hearing aid programs, including the Phone and Phone+ programs.

The test was administered in quiet using two presentation levels: a normal input level (68 dB SPL) and a soft input level (43 dB SPL). The test conditions were counterbalanced and the study was carried out as a double-blind experiment. To calculate levels of significance, one-way or two-way repeated-measures ANOVA were conducted. Results with $p<0.05$ were defined as significant.

RESULTS

Consonants

The average consonant identification performance on the ORCA-NST showed that at a normal input level (68 dB SPL) the consonant identification scores were 65.5% for Phone+ and 63.2% for Phone. No statistically significant difference was found in comparisons between the two programs.

Correct identification of consonants in quiet

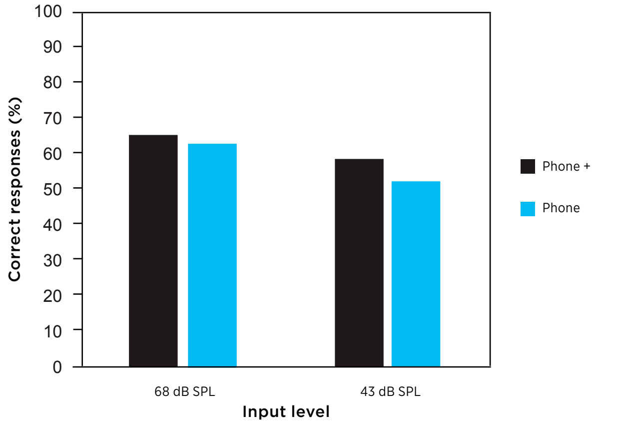

Fig 8: Average correct identification of consonants in the ORCA Nonsense Syllable Test at normal (68dB SPL) and soft (43 dB SPL) input level.

At a soft input level (43 dB SPL) the consonant identification scores were 58.9% for Phone+ and 52.4% for Phone. Post-hoc analysis showed that performance with the Phone+ program was significantly better than with the Phone program ($p < 0.05$).

Vowels

At a normal input level (68 dB SPL) no statistically significant difference was found in the vowel identification scores when the Phone and Phone+ programs were used. At a soft input level (43 dB SPL), the vowel identification scores were higher with the Phone+ program (91.0%) than with the Phone program (85.8%), but the difference was not statistically significant.

Program comparison

Even though the statistical tests only showed a significant difference between the consonant identification scores obtained with the programs in quiet, an examination of the individual performances of the participants revealed some interesting trends. As shown in the scatterplot of the scores with the Phone+ and the Phone in figure 9, at normal input levels (68dB SPL) seven participants performed better with Phone+ than Phone. Three had identical identification scores with Phone+ and the Phone program, and two performed better with Phone program than the Phone+ program.

At a soft input level, 10 participants performed better with the Phone+ program than with the Phone program. Closer inspection of the individual participants' results reveals that five of the poorest performers (those whose performance was below 50% when using the Phone program) improved 12.8% on average when using the Phone+ program compared to the Phone program.

Comparison of performance using Phone and Phone+

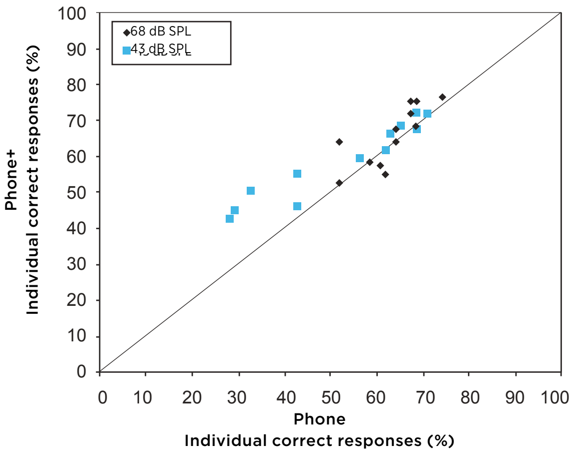

Fig 9: Individual consonant identification performance on the ORCA Nonsense Syllable Test with the Phone program (x-axis) and the Phone+ program (y-axis).

Summary

In summary, the results of this study showed that the Phone+ program with the bilateral presentation of the acoustic phone signal produced the best speech identification performance when speech was presented at a soft input level (43 dB SPL).

Results also showed that the Phone+ program improved consonant identification performance at a soft level (43 dB SPL). Consonant identification performance was 6.4% better with the Phone+ program than with the Phone program.

Vowels are typically higher in intensity than consonants, and are less problematic to hear for most hearing aid users (Boothroyd 1984). The identification performance was therefore, as anticipated, better with vowels than consonants with all four programs. No statistically significant differences were found in the four conditions. No problems with drop-outs or artefacts were reported.

Conclusion

The results of the TV-DEX study and the Phone+ study confirm that the WidexLink platform provides a wireless connection between hearing aids and between hearing aids and DEX devices that can improve speech perception for hearing aid users in two of the most difficult listening situations: when they are watching TV, and when they are talking on the phone.

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