IMPROVING HEARING PERFORMANCE IN COCHLEAR™ NUCLEUS® 6 USERS WITH TRUE WIRELESS ACCESSORIES

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Cochlear Ltd. and the GN Resound hearing aid company recently formed a technology partnership that enables true wireless connectivity between Cochlear™ Wireless Nucleus® 6 and Cochlear Baha® 4 Sound Processors and a range of audio sources. This portfolio of wireless accessories includes a remote microphone (Cochlear Wireless Mini Microphone), a Bluetooth® audio streaming accessory (Cochlear Wireless Phone Clip) that may be used with mobile smart telephones or other Bluetooth-enabled personal electronics, and a television accessory (Cochlear Wireless TV Streamer).

Each of these accessories aims to enhance speech recognition, sound quality, and the overall listening experience in situations that are known to provide the most difficulty for persons with hearing loss. They deliver the audio signal of interest from the accessory directly to the user's hearing instrument via digital radio frequency transmission on the 2.4 GHz globally license-free ISM (Industry, Science, Medical) band. This is the same band used by Bluetooth and many other commercial applications that use digital UHF (Ultra High Frequency) radio transmission. After digitising the audio signal, these wireless accessories utilise a proprietary protocol/ language to deliver the signal of interest to the receiver located within the hearing instrument. Use of a proprietary protocol reduces the delay in signal transmission, which prevents audio and visual signals from being out of synch with one another, a fact that is of particular importance for the Mini Microphone and TV Streamer. Additionally, the use of the proprietary protocol reduces the power consumption of the wireless accessories, allowing for reasonable battery current drain when used with a hearing aid or cochlear implant. Use of traditional Bluetooth audio streaming directly to a hearing aid or cochlear implant sound processor has not been feasible because the relatively high power consumption of the traditional universal Bluetooth protocol would result in unreasonably low battery life.

An ongoing research study at the Hearts for Hearing Foundation in Oklahoma City, Oklahoma is investigating the benefit that Nucleus 6 users receive from the use of each of these wireless accessories. This paper describes preliminary results of the first six subjects who have participated in this study.

METHODS

Participants

The first six subjects who participated in this study all used Nucleus Freedom® (CI24RE) Cochlear Implants. Three were unilateral recipients, and three were bilateral recipients. The unilateral recipients did not use a hearing aid on their opposite ear because they felt they did not benefit from bimodal use.

Equipment

All participants used the Nucleus 6 Sound Processor while participating in this study. Their speech recognition was evaluated while they used the Nucleus 6 Sound Processor alone and while they used the Nucleus 6 Sound Processor with each of three different wireless accessories (see Figure 1).

Cochlear Wireless Mini Microphone

The Cochlear Wireless Mini Microphone is a miniature remote microphone that delivers the audio signal captured at the microphone directly to the recipient's Nucleus 6 Sound Processor via the proprietary digital radio frequency transmission protocol on the 2.4 GHz band. The Mini Microphone possesses a clip so that it may be attached to the talker's clothing about six inches below his/her mouth. The Mini Microphone also possesses a 3.5 mm audio phone port to allow the user to connect via an auxiliary cable to the headphone port of consumer audio electronics. It may be paired to each Nucleus 6 Sound Processor for bilateral recipients.

Cochlear Wireless Phone Clip

The Cochlear Wireless Phone Clip may be paired with any Bluetooth-enabled consumer electronics device (e.g., smart mobile telephone, laptop computer, tablet, etc.). Once the pairing is complete, the Phone Clip receives the audio signal from the mobile telephone (or other Bluetooth-enabled personal device) via Bluetooth and streams it directly to the Nucleus 6 Sound Processor via the proprietary digital radio frequency transmission protocol on the 2.4 GHz band. When used with a mobile telephone, the speech of the Nucleus 6 user is picked up by a microphone in the Phone Clip and delivered back to the user's mobile telephone via Bluetooth so that it may be heard by the person with whom the Nucleus 6 user is conversing. This approach allows for hands-free, wireless use of the mobile telephone. Bilateral Nucleus 6 users may receive the audio signal bilaterally from the Phone Clip.

Cochlear Wireless TV Streamer

The Cochlear TV Streamer may be connected to the audio output ports of a television using either stereo RCA cables or a digital optical cable. Once connected, the audio signal from the television is streamed directly to the Nucleus 6 Sound Processor via the proprietary digital radio frequency transmission protocol on the 2.4 GHz band.

Cochlear Wireless Mini Microphone

Portable clip-on microphone that transmits speech or sound

Cochlear Wireless Phone Clip

Hands-free audio connection to Bluetooth devices

Cochlear Wireless TV Streamer

Stereo audio streaming from the television and other consumer electronics

Figure 1: Cochlear Wireless Accessories

Test conditions

Speech recognition in quiet and in noise was evaluated with and without each of the wireless audio accessories in a 7.7 m x 7.5 m x 2.8 m room that had an ambient noise level of 44 dBA. Figure 2 shows the positions of the test equipment and the participant in the room. In conditions in which speech recognition was evaluated in noise, uncorrelated classroom noise[1] was presented from four Genelec 8020B loudspeakers located at approximately 30, 135, 225 and 330 degrees azimuth relative to the participant.

Assessment of performance with the Cochlear Wireless Mini Microphone

Sentence recognition in quiet and in noise was assessed with and without the use of the Mini Microphone. The Mini Microphone was positioned 6 inches directly below a Genelec 8020B loudspeaker that was used to present target sentences. The participant was seated 2.6 m from the Cochlear Mini Microphone. Sentence recognition in noise was evaluated at competing noise levels ranging from 50 to 75 dBA in 5 dB increments. Sentence recognition was evaluated with one full list of AzBio sentences (20 sentences) per condition.[2] The intensity of the test sentences was 85 dBA at the position of the Cochlear Mini Microphone and 65 dBA at the location of the participant. Sentence recognition was assessed across 14 conditions:

Nucleus 6: Quiet and Competing Noise at 50, 55, 60, 65, 70 and 75 dBA

Nucleus 6 and Mini Microphone: Quiet and Noise at 50, 55, 60, 65, 70 and 75 dBA

The order of test conditions and AzBio sentence lists were randomised across participants.

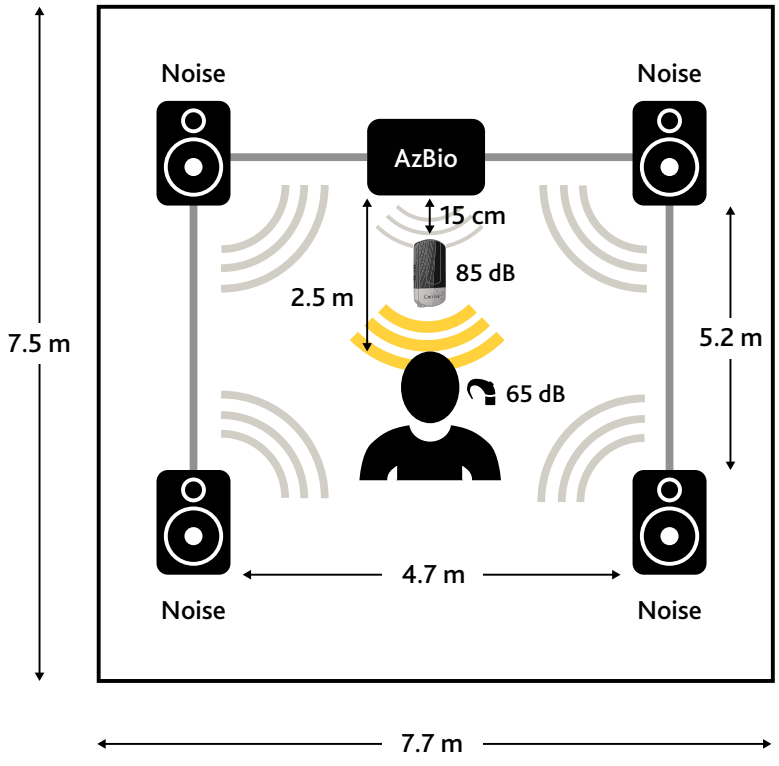

Figure 2: Mini Microphone test setup

Assessment of speech recognition over the telephone with the Cochlear Wireless Phone Clip

Recorded word recognition was assessed as the participants listened to one full list (50 words) of monosyllabic CNC words.[3] CNC words were delivered from a Sony CFDZW755 compact disc player and then delivered to a NEC DSX 34B BL Display Tel landline phone by way of an RCA component cable that was plugged into the THAT-2 telephone interface. Next, the landline telephone was used to make a telephone call to an Apple iPhone 4S mobile telephone from which the recorded CNC words were presented (see Figure 3). Previous measurements made with the Apple iPhone indicated that the CNC words were at 65 dB SPL when leaving the iPhone receiver. The subject set the volume control of the Apple iPhone mobile telephone to his/her most comfortable listening level (MCL) as would be done in daily life, while listening to the words in quiet and left the volume control at the setting for the remainder of the study. In the condition in which telephone performance was evaluated without the use of the Phone Clip, the recipient held the mobile telephone next to the microphone of the Nucleus 6 Sound Processor on the preferred ear for telephone use. In the condition where telephone performance was evaluated with use of the Phone Clip with the Nucleus 6 Sound Processor, the Phone Clip was used to wirelessly deliver the speech stimuli from the mobile telephone directly to the sound processor. The audio signal was streamed to each sound processor for bilaterally implanted participants. Monosyllabic word recognition was assessed across four conditions:

Nucleus 6: In quiet and in competing noise set to 65 dBA at the iPhone receiver with volume control of phone adjusted to individual MCL.

Nucleus 6 and Cochlear Phone Clip: In quiet and in competing noise set to 65 dBA at the iPhone receiver with volume control of phone adjusted to individual MCL.

The order of test conditions and CNC word recognition lists were randomised across participants.

Figure 3: Phone Clip test setup

Evaluation of speech recognition over a television with the Cochlear Wireless TV Streamer

Sentence recognition in quiet and in noise was evaluated with use of the Computer-Assisted Speech Perception Testing and Training CasperSent program, version 3.7, which serves to assess the participant's ability to recognise audio and visual cues because the target sentences are spoken by a woman whose face is displayed on a monitor.[4] CasperSent sentences were presented from an Element ELEFW328 81 cm LED Television (HD 720p resolution) located 4.1 m directly in front of the participant (see Figure 4). Audio-visual sentence recognition was assessed in quiet at 65 dBA but with the TV volume control adjusted to individual MCL as in daily life, and in the presence of 65 dBA of competing noise both with and without the use of the TV Streamer, which was coupled to the audio output port of the television by way of a digital optical audio cable.

The subject adjusted the volume control of the television to his/her most comfortable listening level while listening to the target stimuli in quiet without the use of the TV Streamer. Then, audio-visual sentence recognition was assessed in the following four conditions:

Nucleus 6: In quiet and in competing noise set to 65 dBA and TV volume set to MCL.

Nucleus 6 and Cochlear TV Streamer: In quiet and in competing noise set to 65 dBA and TV volume set to MCL.

The order of test conditions and CasperSent sentence recognition lists were randomised across participants.

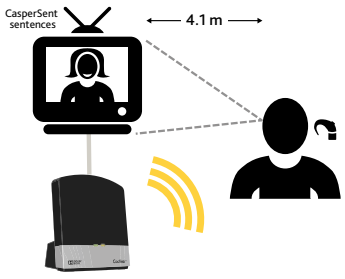

Figure 4: TV Streamer test setup

RESULTS

Cochlear Wireless Mini Microphone

Average speech recognition in quiet and across the noise conditions with the Nucleus 6 alone and with the Nucleus 6 and Mini Microphone is shown in Figure 5. Data from the two quiet conditions were analysed using a one-way repeated measures analysis of variance (ANOVA), and results revealed significantly better speech recognition in quiet with the Mini Microphone over the Nucleus 6 alone (F [1, 12] = 32.7, p = 0.002). To examine significant differences across noise conditions, a two-way repeated measures ANOVA was conducted, showing a significant main effect of device condition (F [1, 72] = 94.1, p = 0.0002), a significant main effect of listening condition (F [5, 72] = 88.6, p < 0.000001), and significant interaction effect between device and listening condition (F [5, 72] = 11.5, p < 0.00001).

Post-hoc analyses were conducted to examine the significant main and interaction effects using the Tukey-Kramer Multiple-Comparisons Test. The post-hoc analyses revealed significantly better speech recognition with the Cochlear Mini Microphone relative to the Nucleus 6 Sound Processor alone (p < 0.05) as well as significantly poorer speech recognition as the noise levels increased (p < 0.05). Post-hoc analyses on the two-way interaction revealed that use of the Cochlear Mini Microphone resulted in significantly better speech recognition in noise at the 50, 55, 60, 65 and 70 dBA noise levels when compared to the Nucleus 6 alone (p < 0.05). No significant benefit of the Cochlear Mini Microphone over Nucleus 6 alone was seen for the quiet condition or the 75 dBA noise condition.

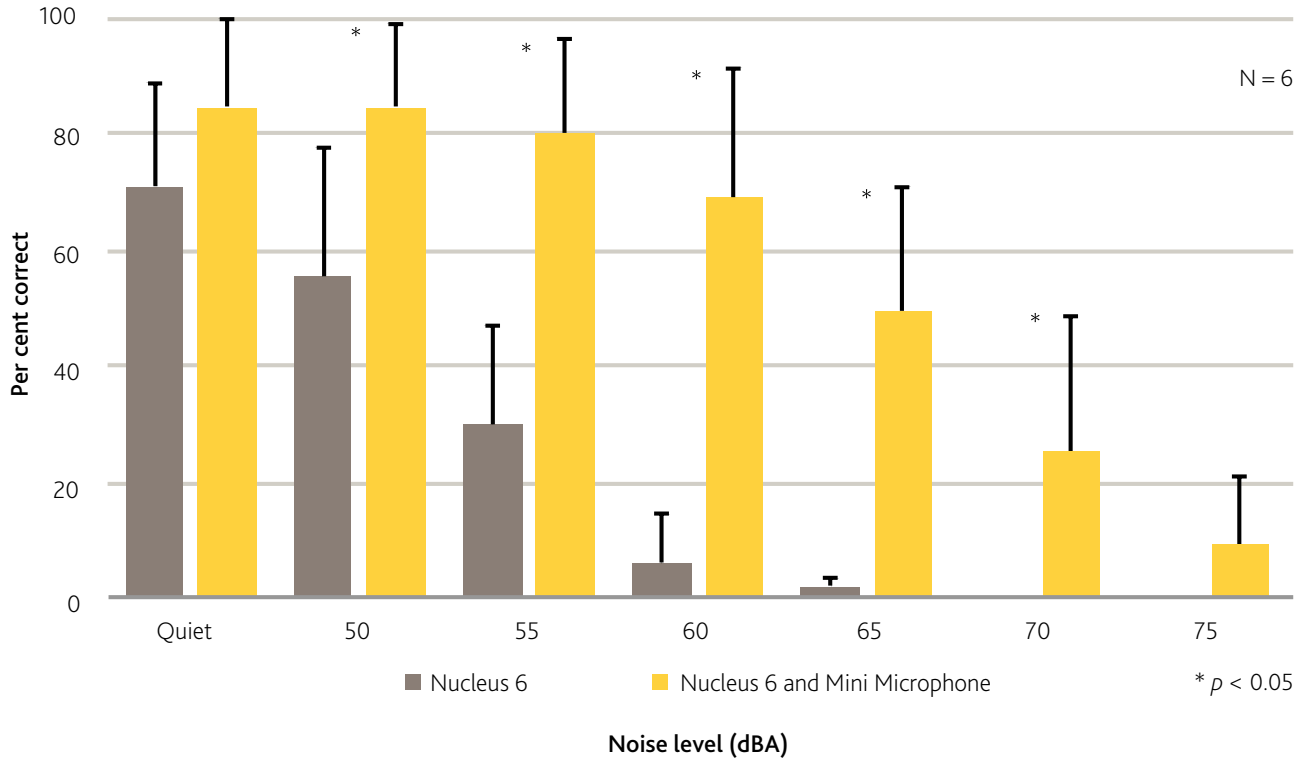

Figure 5: AzBio sentence recognition

Cochlear Wireless Phone Clip

Average speech recognition of the CNC words with and without the Phone Clip is shown in Figure 6. A two-way repeated-measures ANOVA to examine the effects of the device and listening conditions, indicated a significant main effect of device condition (F [1, 24] = 9.0, p = 0.03) and significant main effect of listening condition (F [1, 24] = 67.2, p = 0.0004). Post-hoc analyses on the main effects revealed significantly better speech recognition with the Phone Clip over the Nucleus 6 ($p < 0.05$) alone and significantly better speech recognition in the quiet condition over the noise condition ($p < 0.05$).

Cochlear Wireless TV Streamer

The average speech recognition on the CasperSent with and without the TV Streamer is shown in Figure 7. A two-way repeated-measures ANOVA was conducted to examine the effects of the device and listening condition. Results showed a significant main effect of device condition (F [1, 24] = 16.7, p = 0.009) and no significant main effect of listening condition (F [1, 24] = 2.9, p = 0.15). The post-hoc analysis on the main effect of device condition showed significantly better speech recognition across the quiet and noise conditions with the TV Streamer relative to performance with the Nucleus 6 alone. Also, an interaction existed. With use of the Nucleus 6 alone ($p < 0.05$), there was a significant reduction in speech recognition in noise relative to performance in quiet ($p < 0.05$). However, there was not a significant reduction in performance in the noise condition relative to quiet when the TV Streamer was used.

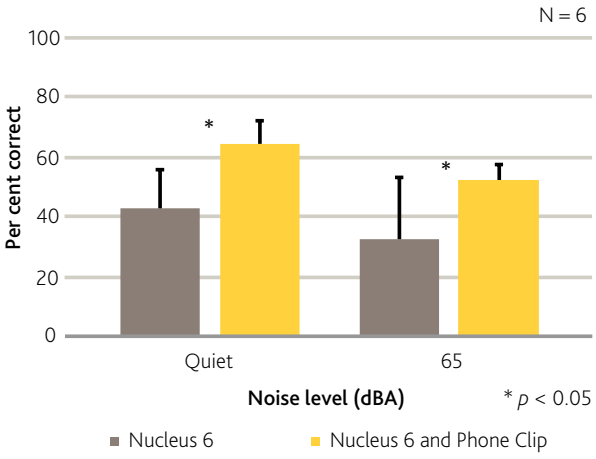

Figure 6: CNC word recognition

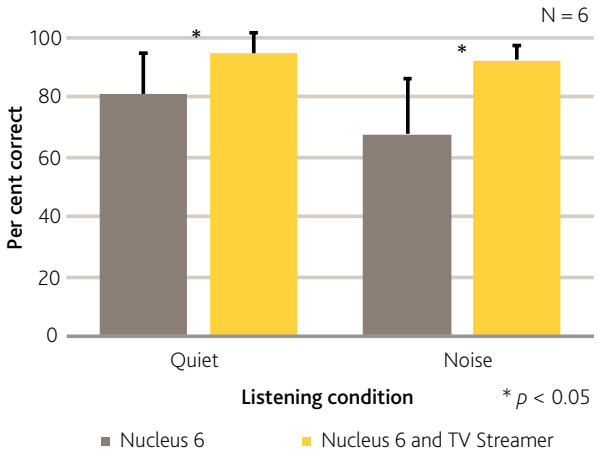

Figure 7: CasperSent sentence recognition

Discussion and conclusions

Cochlear Wireless Mini Microphone

- At nominal signal-to-noise ratios ranging from 0 to +10 dB, which are commonly encountered throughout day-to-day use, cochlear implant recipients frequently experience considerable difficulty with understanding speech in the presence of the noise.
- Use of the Mini Microphone with the Nucleus 6 Sound Processor significantly improved speech recognition in noise at 50, 55, 60, 65, and 70 dBA noise levels, which represents signal-to-noise ratios ranging from -5 to +15 dB depending upon the setting of the volume control to MCL.
- Use of the Mini Microphone may improve sentence recognition by as much as 50 to 60 percentage points.

Cochlear Wireless Phone Clip

- The Phone Clip allows hands-free use of Bluetooth-enabled mobile telephones and may also be used to stream audio from any other Bluetooth-enabled consumer electronic device (e.g., iPad tablet, laptop, Smart TV, etc.).
- The Phone Clip significantly improved word recognition in quiet and in noise over a mobile phone relative to using the phone with the Nucleus 6 Sound Processor alone.

Cochlear Wireless TV Streamer

- Use of the TV Streamer with the Nucleus 6 Sound Processor significantly improved recognition in speech over the television in quiet and in noise.

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D710887 ISS2 MAY15