Performance Outcomes of Nucleus® 6 SmartSound® iQ Technology with the First Cochlear Implant Scene Classifier

Introduction

Almost all listening environments contain some level of background noise, originating from a variety of sources with a range of spectral characteristics. Stationary or diffuse noise tends to have relatively low amplitude modulations which typically fall outside the speech spectrum (Plomp, 1983; Rosen, 1992) such as noise from traffic or room ventilation systems. In contrast, competing speech noise often has acoustic properties very similar to those of the target speech, producing a more challenging listening situation (Festen & Plomp, 1990). Background noise can also be generated from environmental sources such as wind, which has a typically intense low-frequency spectrum that is particularly annoying to individuals using hearing devices.

Given the many different existing noise types, and that combinations of these may be unique to every cochlear implant (CI) recipient’s listening environments, no single input processing or sound coding technology is sufficient to provide maximum performance benefits and comfort. A multifaceted approach involving a range of technologies specifically designed to target different noise situations is required.

Nucleus SmartSound and SmartSound 2 technology

Cochlear™ has actively researched solutions to overcome the challenges of listening in noise, culminating in the introduction of Nucleus® SmartSound® technology in 2005. SmartSound encompassed a variety of input processing technologies including Automatic Sensitivity Control (ASC), channel-specific Adaptive Dynamic Range Optimisation (ADRO®), together with a range of microphone directionality (Patrick et al., 2006). ASC is a slow acting algorithm designed to automatically reduce the level of noise in a noisy environment (Seligman & Whitford, 1995: Patrick et al., 2006), while ADRO is a pre-processing technology that continuously adjusts the gain in each channel to place the signal optimally within the electrical hearing dynamic range (Blamey, 2005).

The use of directional microphones has proven to be very effective in reducing the interference of noise in hearing aid recipients (Killion, 2004; Bentler, 2005), and were first introduced into Nucleus sound processors in the mid 1980’s.
SmartSound iQ with SCAN

The recent release of the Nucleus 6 (CP900 series) sound processor delivers the newest generation of SmartSound technology called SmartSound iQ (SSiQ), with an industry first automatic scene classifier termed SCAN. SmartSound iQ delivers several new options for improved hearing performance and listening comfort in noise, including an advanced background noise reduction algorithm (SNR-NR) and a wind noise detection and reduction algorithm (WNR).

SmartSound iQ noise reduction (SNR-NR) is designed specifically for CI sound processor requirements to attenuate constant background noises irrespective of their direction. This technology detects the background noise level in each frequency channel, estimates the signal-to-noise ratio (SNR) in each channel for each time sample and attenuates those channels having low SNRs which are indicative of background noise. SNR-NR acts instantaneously to reduce background noise levels while retaining speech and other important signals (Hersbach et al., 2012; Mauger et al., 2012).

Annoyance from wind noise is a common complaint from hearing aid and cochlear implant recipients. Wind noise is even more problematic with directional microphone systems due to greater low frequency noise from wind (Chung et al., 2009; Chung & McKibben, 2011) and distortions to microphone directionality (Chung, 2012). With SmartSound iQ, when wind noise is detected, the microphone directionality is optimised for use in wind. Specifically designed multi-channel compressors are then activated to reduce the low frequency wind noise while retaining other sounds. A pilot study evaluating wind noise reduction in the Nucleus cochlear implant sound processors indicated positive speech understanding and listening quality results (Goorevich et al., 2012b).

Until now, SmartSound technologies were typically provided to recipients via a number of different listening programs, manually switched using a remote assistant or via the processor buttons. In this format, a number of factors may prevent many cochlear implant recipients from achieving their best hearing performance at all times including, dexterity issues, the need to manually change programs, uncertainty as to when to change programs, and the possibility of selecting the ‘wrong’ program in specific listening environments. To address this, the Nucleus 6 sound processor offers a scene classifier (SCAN), providing automatic detection of a user’s listening environment, and automatic selection of appropriate settings without the need for multiple processor programs or manual program changes.

Many state-of-the-art hearing aids currently use ‘environmental classification’, whereby the audio input signal is categorised into one or more ‘scenes’ to determine appropriate characteristics for automatic program selection (Allegro et al., 2001; Büchler et al., 2005). Recent pilot research has indicated that this type of automatic scene classification and program selection can benefit cochlear implant recipients as well (Case et al., 2011; Goorevich et al., 2012a).
The SCAN program analyses microphone input signals and classifies the sound environment into one of six scenes (Speech in Noise, Speech, Noise, Wind, Quiet and Music). For each scene, SCAN selects the most appropriate microphone directionality pattern (standard, fixed or adaptive) and activates the appropriate scene technology based on the determined environment. Changes in settings are transitioned smoothly to avoid any abrupt or disruptive listening percept for the recipient. In addition to controlling the input processing technologies for each scene, SCAN also stores the scene classification on the Nucleus 6 sound processor. Datalogging of scene information can be reviewed off-line by a clinician for troubleshooting, device counselling and/or program optimisation, offering objective insights.

This paper presents the performance outcomes of adults fitted with the Cochlear Nucleus 6 sound processor using SmartSound iQ with SCAN.

Materials and Methods

Subjects

Twenty-one Australian adults, using a mix of Nucleus CI500 Series and CI24RE cochlear implants, participated in the study. The mean age for this group was 67.8 years, with a range of 49 to 90 years. Average length of cochlear implant use was 5.6 years, ranging from one to 15 years.

Study design

The study used a repeated-measures, single-subject design, in which each subject served as his or her own control. Subjects were evaluated using their existing Nucleus 5 (CP810) sound processor and the new Nucleus 6 (CP900) sound processor with SmartSound iQ. Sentence perception in noise with different listening programs was compared for each subject across five test sessions, and the order in which the programs were tested was counter-balanced to control for order effects. Prior to testing, all recipients had a minimum of two weeks use of the Nucleus 6 sound processor to acclimatise to the default program.

Listening programs

Study participants used their preferred listening program in noise with their Nucleus 5 sound processor, with 57% of subjects choosing the Noise program (with zoom processing) and 24% choosing the Focus program (with Beam). The remaining 19% used a variety of other listening programs with standard microphone directionality.

Speech perception scores with their Nucleus 6 sound processor were obtained using a variety of programs with differing combinations of input processing options including the default automatic SCAN program. The programs tested are listed in Table 1.
Speech perception

All testing in noise was conducted using the Australian sentence test in noise (AuSTIN), which is an adaptive SRT sentence test using either speech weighted noise (SWN) or 4-talker babble (4TB) as the noise source (Dawson et al., 2013). This test determines the signal-to-noise ratio (SNR) for 50% sentence intelligibility with each listening program. The target speech signal was presented at a fixed 65 dB SPL (RMS) level from a speaker positioned in front of the subject. Testing was conducted using both SWN and 4-talker babble noise which was increased or decreased based on the subjects’ response. Both noise types were tested in two different spatial configurations, S0N0 (signal at 0 degrees, noise at 0 degrees) and S0N3 (signal at 0 degrees, noise at 90, 180 and 270 degrees). All speech and noise configurations had the speaker locations at 1.2m from the listening position. Each test run comprised 20 sentences from which individual SRTs were calculated. Two SRTs for the same test condition were then averaged to determine each subject’s mean SRT score.

Results were analysed using a repeated measures one-way analysis of variance (ANOVA) with post-hoc Newman-Keuls comparisons to determine the effect of program.
Results

1. Significant directional microphone benefit shown in 4 talker babble

Figure 1 shows the group mean SRTs at 65 dB SPL in spatially separated (S0N90,180,270) 4TB noise with the Nucleus 6 sound processor. A lower SRT (dB SNR) value indicates an improved speech perception outcome. The SCAN program automatically selected adaptive directionality (Beam) in this condition and achieved a group mean SRT of -3.9 dB which was significantly better than the ‘No SmartSound’ and ‘Everyday’ conditions with SRT’s of 0.0 and -0.4 dB, respectively, using standard microphone directionality (p<0.001). The average SRT benefit of SCAN over the ‘No SmartSound’ and ‘Everyday’ conditions was 3.9 and 3.5 dB, respectively.

Results reinforce that adaptive microphone directionality such as Beam, is valuable for listening to speech in noise where the noise source is to the rear and sides of the recipient.
2. Noise reduction (SNR-NR) benefit in speech weighted noise

Figure 2 shows the group mean SRTs at 65 dB SPL in SWN with speech and noise coincident (S0N0) using the Nucleus 6 sound processor. In this challenging listening condition where both speech and noise are delivered from a speaker in front of the listener, a lower SRT value indicates an improved speech perception outcome. The SCAN program using SNR-NR in this speech and noise condition resulted in a group mean SRT of -2.9 dB, significantly better (p<0.001) than the ‘No SmartSound’ and ‘Everyday’ SRTs of -0.58 and -1.3 dB. No significant difference in SRT was shown between the ‘No SmartSound’ and ‘Everyday’ conditions. The average SRT benefit offered by SCAN over the ‘No SmartSound’ and ‘Everyday’ conditions was 2.3 and 1.6 dB, respectively.

The improvement shown is predominantly due to the SNR-NR algorithm rather than directional microphones since the speech and noise signals are co-located in this condition. These results suggest that existing recipients will gain significant performance benefits in noise by accessing new Smart Sound iQ noise reduction technology.
3. SCAN shows performance benefits for non-SmartSound recipients

Figure 3 shows the mean SRTs at 65 dB SPL in both 4TB and SWN using the Nucleus 6 sound processor with a spatially separated (S0N90,180,270) speaker setup. As in previous figures the ‘No SmartSound’ condition represents recipients who use only standard microphone directionality with all other technologies disabled. A lower SRT value indicated an improved speech perception outcome. The SCAN program using microphone directionality and SNR-NR, resulted in a group mean SRT of -3.9 dB in 4TB and -7.6 dB in SWN, significantly better than the ‘No SmartSound’ condition which resulted in SRTs of 0.0 and -2.8 dB, respectively (p<0.001).

The improvement shown results from directional microphone algorithms (zoom and Beam) and SNR-NR. These results suggest that use of SmartSound iQ technologies offer substantial hearing performance benefits, and that recipients who do not currently access them due to clinical fitting practices, choice of sound processor, or personal preference will gain significant hearing benefits with the SCAN program.
4. SCAN shows performance benefits for experienced SmartSound users

Figure 4 shows the mean SRTs at 65 dB SPL in SWN (S0N0 and S0N90,180,270) using Nucleus 5 and Nucleus 6 sound processors. Recipients in this study are experienced SmartSound users, more than 80% of whom routinely switch to a directional SmartSound 2 program for listening in noise. For the S0N0 configuration, Nucleus 6 with SCAN resulted in a group mean SRT of -2.9 dB which was significantly better than the Nucleus 5 condition which resulted in a mean SRT of -1.2 dB (p<0.001). For the S0N90,180,270 condition, a mean SRT of -7.6 dB was obtained with Nucleus 6, which was significantly better than the -6.3 dB SRT obtained for the Nucleus 5 condition (p<0.001).

Results suggest that even experienced users of a Nucleus 5 Sound Processor with SmartSound 2 are likely to gain improved speech understanding in noise (in addition to reduced inconvenience from manually switching sound processor settings) by upgrading to Nucleus 6 and accessing SNR-NR and the automated SCAN technology.
Conclusion

All recipients successfully upgraded to the Nucleus 6 system and preferred SCAN as their default listening program. SmartSound iQ and SCAN technologies produced significant benefits for listening in both steady-state and multi-talker babble noise when compared to 'No SmartSound' and 'Everyday' listening programs. The Nucleus 6 sound processor with SmartSound iQ provides significant performance improvements over a standard microphone configuration in spatially separated noise. The availability of a clinically relevant background noise reduction algorithm (SNR-NR) provides additional performance benefits for Nucleus 6 recipients, especially when tested in SWN.

For recipients with a Nucleus 5 sound processor converting to a Nucleus 6 sound processor, these study findings demonstrate the new SmartSound iQ technology will provide hearing benefits. With the automatic scene classifier (SCAN) in the Nucleus 6 system enabled for routine use, optimal and consistent scene selection is automatically achieved in each sound environment. Comprehension improved significantly over levels achieved with the Nucleus 5 system.

Cochlear continues to deliver performance benefits. The industry's first scene classifier (SCAN) will enable existing and newly implanted recipients to easily and automatically enhance their comprehension and listening experience.
References


As the leading global expert in implantable hearing solutions, Cochlear is dedicated to bringing the gift of sound to people all over the world. For thirty years, Cochlear has pioneered this technology, helping hundreds of thousands of people reconnect to their families and friends.

Along with the industry’s largest investment in research and development, we continue to partner with leading international researchers and hearing professionals, ensuring that we are at the forefront of hearing science.

For our customers, that means access to our latest technologies throughout their lives, and the ongoing support they need.

That is why seven out of ten people worldwide who choose a cochlear implant choose Cochlear as their hearing partner.

Acknowledgements

The authors would like to acknowledge the researchers, audiologists and recipients who contributed to the data and analysis reported in this paper.