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Improved hearing in noise using new signal processing algorithms with the Cochlear™ Nucleus® 6 sound processor

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Abstract

Objective: To demonstrate the performance benefit of the Automatic Scene Classifier (SCAN) algorithm available in the Nucleus® 6 (CP900 series) sound processor over the default processing algorithms of the previous generation Nucleus 5 (CP810) and Freedom® Hybrid™ sound processors.
Methods: Eighty-two cochlear implant recipients (40 Nucleus 5 processor users and 42 Freedom Hybrid processor users) listened to and repeated AzBio sentences in noise with their current processor and with the Nucleus 6 processor.
Results: The SCAN algorithm when enabled yielded statistically significant non-inferior and superior performance when compared to the Nucleus 5 and Freedom Hybrid sound processors programmed with ASC + ADRO®.
Conclusion: The results of these studies demonstrate the superior performance and clinical utility of the SCAN algorithm in the Nucleus 6 processor over the Nucleus 5 and Freedom Hybrid processors.

Keywords: Cochlear implant; Speech perception; Nucleus 6; Automatic scene classifier (SCAN); SmartSound iQ

1. Introduction

Cochlear's Nucleus 6 external sound processor offers enhanced signal processing features for improved listening in noisy environments. Its predecessors, Nucleus Freedom® and Nucleus 5 used automatic sensitivity control (ASC) and adaptive dynamic range optimization (ADRO®) via the SmartSound® and SmartSound® 2 sound management systems to enhance speech signals in background noise. These signal processing technologies were successful in increasing speech understanding (James et al., 2002; Wolfe et al., 2009) but varying microphone directionality between Standard, Fixed (zoom), or Adaptive (Beam) was dependent on manual program changes by the user. Recipient and professional feedback indicated that many recipients were reluctant to make program changes because it was inconvenient, drew attention to the device, and caused them concern that the wrong program could be chosen for a specific listening environment. Cochlear responded to this valuable user feedback by developing a fully automated environmental analyzer for its newest sound processor model. The advanced Nucleus 6 system uses Cochlear's next generation SmartSound technology, SmartSound®iQ, to pair Cochlear's suite of input processing algorithms including Signal-to-Noise Ratio - Noise Reduction (SNR-NR), Wind Noise Reduction (WNR), and the industry's first automatic scene classifier (SCAN) for a seamless listening experience. This article reports a subset of the data collected from two multi-center investigations.

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There are two default input processing algorithms in the Nucleus 5 and Nucleus Freedom sound processor programs that are designed to maximize sound comfort and speech intelligibility: automatic sensitivity control and adaptive dynamic range optimization. Automatic sensitivity control (ASC) reduces the sensitivity of the processor's microphones based on the level of detected background noise (Seligman and Whitford, 1995; Patrick et al., 2006). With the addition of adaptive dynamic range optimization (ADRO) which regulates individual channel gains, speech signal inputs remain comfortable and audible for the listener (James et al., 2002; Dawson et al., 2004). In the Nucleus 6 processor, ASC, ADRO, SNR-NR and WNR algorithms are available at all times when chosen by the programming clinician. By default, Cochlear Custom Sound® programming software creates a SCAN program as well as a non-SCAN program using standard directionality.

Adjustable microphone activation and directionality improve speech detection and enhancement in the presence of background noise (Amlani, 2001; Bentler, 2005). The Freedom processor utilized two microphones that were hard wired and a voice activity detector (VAD) to distinguish speech from noise (Spriet et al., 2007). The Nucleus 5 and the Nucleus 6 processors use two precisely calibrated and matched omni-directional microphones to digitally create different directional response patterns (Wolfe et al., 2012). In the Fixed directional mode there is a static null point (120° or 240° depending upon the side of the cochlear implant) where sound is constantly and maximally attenuated by about 15–20 dB (Wolfe et al., 2012). With Adaptive directionality, that null point is dynamic and can move if the largest noise source moves, continually reducing unwanted noise from the sides and rear. Fixed directionality is optimal for environments where the desired signal is located in front of the user and intrusive noise remains to the sides or behind or is diffuse in nature, and Adaptive directionality is the best choice when the signals may be shifting location such as in a group setting or when the user is moving. When the microphones are using Standard directionality, they are sensitive to sounds all around the user, with slight attenuation of sounds (about 5 dB) at the sides and back, similar to normal hearing.

Signal-to-Noise Ratio Based Noise Reduction (SNR-NR) is designed to attenuate steady-state background noises irrespective of the direction. It detects the background noise level in individual frequency channels, estimates the signal-to-noise-ratio (SNR) in each channel for each time sample, and attenuates those channels with a poor SNR. The result is an instantaneous reduction of background noise levels while retaining speech and other important signals for the user (See Mauger et al., 2014 and Wolfe et al., 2015 for further explanation).

Wind Noise Reduction (WNR) is a new algorithm that, upon the detection of wind, quickly changes microphone directionality settings and uses multichannel compressors to reduce the low frequency noise from wind (Mauger et al., 2014). This algorithm is designed to retain the target signal while reducing much of the distortion that users may encounter during outdoor activities, such as riding a bicycle, and thus increasing comfort.

Environmental scene classifiers have been available in some hearing aids; however, SCAN is the first application of such digital technology for individuals using electrical and electrical-acoustic stimulation. The SCAN setting continuously analyzes the acoustic signal, extracting fundamental elements such as variations in signal level, modulation, pitch, rhythm and tone and then uses these features to classify the listening environment into one of six scenes: Quiet, Noise, Speech, Speech in Noise, Wind, or Music (see Mauger et al., 2014 for a more in depth description of algorithm properties and interactions). Once the scene is identified, SCAN directs the Nucleus 6 to combine the microphone outputs and provide different directional response patterns: Fixed directional (zoom), Adaptive directional (Beam), or Standard directional (Wolfe et al., 2015). This automation reduces the need for additional sound processor programs and manual program selection by the user who may avoid changing programs due to uncertainty regarding when to make a change. Furthermore, previous generation sound processors provided a maximum of four preset programs for active users to choose from, whereas the Nucleus 6 can automatically transition between six scenes based on its analysis of environmental signals. The intelligent classification algorithms of SmartSound iQ take the decision-making burden off the user so that people of all ages and lifestyles can enjoy the benefits.

The purpose of this study was to compare the innovative Nucleus 6 automatic signal processing algorithm SCAN to the previous generation strategies available in the Nucleus 5 and Freedom Hybrid processors.

2. Methods and materials

2.1. Subjects

Two study groups were evaluated for effects of the Nucleus 6 technology. Forty participants (aged 13.2 yrs–81.2 yrs, mean age = 47 yrs) who were recipients of a CI24RE, CI512, or CI422 series implant and current users of the Nucleus 5 sound processor were enrolled in the Nucleus 5 group, and forty-two participants (aged 27.5 yrs–90.1 yrs, mean age = 67 yrs) who were Hybrid L24 series implant recipients and current users of the Freedom Hybrid sound processor were enrolled in the Hybrid group. Each participant was a unilateral implant recipient, with a minimum of three months' experience with their current sound processor, and prior documentation of sentence recognition testing in noise at a difficulty of +10 dB SNR or poorer (Table 1).

2.2. Measures

Objective speech recognition data were collected using the commercially available AzBio Sentence Test which is comprised of 15 lists; each list contains 20 sentences of low contextual information (Spahr et al., 2012). For the Nucleus 5 group, the AzBio sentences were presented from a speaker