

# 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.

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**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<sup>®</sup> 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

Table 1  
Subject demographics by group.

Nucleus 5 Group	Hybrid group
4 sites	9 sites
40 traditional CI recipients	42 Hybrid CI recipients
Mean age = 47 yrs (13.2 yrs - 81.2 yrs)	Mean age = 67 yrs (27.5 yrs - 90.1 yrs)
CI24RE, CI512, CI422 implants	Hybrid L24 implants
Nucleus 5 sound processor	Freedom Hybrid sound processor

positioned in front of the listener at 60 dBA with competing speech-weighted noise at 55 dBA (+5 dB SNR) from a speaker positioned at 90° on the side of the implant. If subjects scored >60% on AzBio sentences in noise (+5 dB SNR) with the Nucleus 6 sound processor during initial testing, all remaining tests were conducted at 0 dB SNR to reduce the risk of ceiling effects. The Hybrid group subjects were tested at 65 dBA with a +5 dB SNR.

Subjective data were obtained via the Speech, Spatial and Qualities of Hearing Scale - Comparative (SSQ-C), a validated self-assessment tool commonly used in hearing aid and cochlear implant research (Gatehouse and Noble, 2004). The comparative version was used in order to compare the two sound processor models in each group. It consists of 49 probes encompassing the three specific hearing domains of speech hearing, spatial hearing, and qualities of hearing.

### 2.3. Study schedule

The subjects were evaluated at two different visits. At the first visit, speech recognition scores were obtained under three conditions: using the subject's own processor (Nucleus 5 or Freedom Hybrid) with the default programming setting of ASC + ADRO, a comparative program using a Nucleus 6 processor with ASC + ADRO, and the Nucleus 6 processor default program setting with SCAN. After 4 weeks of take home experience, the subjects repeated testing for the Nucleus 6 processor default programming setting with SCAN (Table 2).

## 3. Results

### 3.1. Objective data

#### 3.1.1. Nucleus 5 group

At the first visit, the forty Nucleus 5 group participants demonstrated a mean score of 21.2% on the AzBio test using

their Nucleus 5 processor with ASC + ADRO, a mean score of 24.3% using the new Nucleus 6 processor with ASC + ADRO, and a mean score of 53.1% using the Nucleus 6 with default SCAN setting. At the second visit, after four weeks of practice at home, the subjects demonstrated a mean score of 56.4% using the Nucleus 6 with SCAN. Furthermore, when performance between the Nucleus 5 with ASC + ADRO setting and the Nucleus 6 SCAN setting was examined on an individual basis via paired t-tests with a one-sided 0.025 alpha level, findings yielded significant results indicating statistical evidence of superiority. Using a non-inferiority NI margin of 10%, results showed that 75% of participants demonstrated an improvement in performance, 23% stayed the same, and only 1% showed a decrement (Fig. 1).

#### 3.1.2. Hybrid group

At the initial visit, the forty-two Hybrid subjects demonstrated a mean score of 40.75% on the AzBio test using their Freedom Hybrid processor with ASC + ADRO, a mean score of 38.0% using the Nucleus 6 processor with ASC + ADRO, and a mean score of 64.3% using the Nucleus 6 with default SCAN setting. After the four week home practice interval, the subjects demonstrated a mean score of 68.0% using the Nucleus 6 SCAN setting. A binomial comparison of individual subject results between the Nucleus 5 ASC + ADRO setting and the Nucleus 6 SCAN setting showed that 66% of participants showed an improvement in performance, 29% stayed the same, and 5% showed a decrease in performance (Fig. 1).

### 3.2. Subjective data (SSQ-C)

The comparative version of the Speech, Spatial and Qualities of Hearing Scale (SSQ-C) was used to compare performance between the Nucleus 6 processor and the participant's own processor. The SSQ-C is divided into 3 subscales designed to analyze auditory ability in real word environments. The Speech Hearing Scale examines speech in quiet and in noise, one-on-one conversation, and in groups/meetings. The Spatial Hearing Scale judges ability to hear where sounds are coming from, distance, movement, and sound segregation. The Sound Qualities Rating Scale assesses ease of listening, naturalness, clarity, identification of different speakers, musical pieces and instruments, as well as everyday sounds. The participants scored each item using a scale of –5

Table 2  
Study schedule and test conditions by group.

Nucleus 5 group	Hybrid group
<b>Visit 1:</b>	<b>Visit 1:</b>
<ul style="list-style-type: none"> <li>• Test Nucleus 5 (ASC + ADRO)</li> <li>• Test Nucleus 6 Custom (ASC + ADRO)</li> <li>• Test Nucleus 6 Default (SCAN)</li> </ul>	<ul style="list-style-type: none"> <li>• Test Freedom Hybrid (ASC + ADRO)</li> <li>• Test Nucleus 6 Custom (ASC + ADRO)</li> <li>• Test Nucleus 6 Default (SCAN)</li> </ul>
<b>Visit 2:</b>	<b>Visit 2:</b>
<ul style="list-style-type: none"> <li>• Test Nucleus 6 Default (SCAN)</li> </ul>	<ul style="list-style-type: none"> <li>• Test Nucleus 6 Default (SCAN)</li> </ul>
<b>Test measures:</b>	<b>Test measures:</b>
AzBio in noise (60 dBA at +5/0 dB SNR)	AzBio in noise (65 dBA +5 dB SNR)

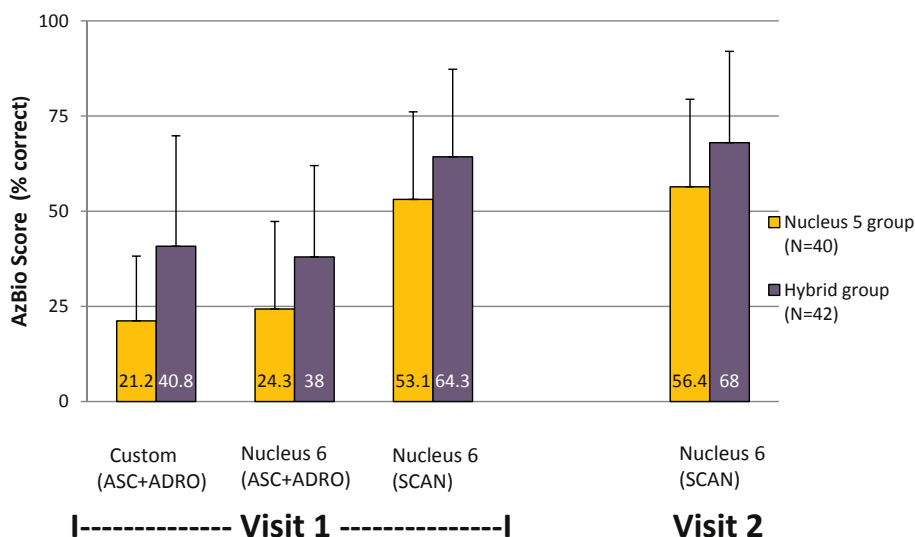


Fig. 1. AzBio scores by group at Visit 1 and Visit 2.

to +5 where −5 corresponds to performance much worse, 0 corresponds to no change, and +5 corresponds to performance much better.

### 3.2.1. Nucleus 5 group

After 4 weeks of take home experience with the Nucleus 6 sound processor, most subjects (36/40; 90%) reported benefit on the Speech Hearing Scale of the Nucleus 6 processor over their Nucleus 5 processor. A few subjects (3/40; 7.5%) rated the Nucleus 6 sound processor to be no different than the Nucleus 5 sound processor, and one subject (2.5%) reported a negative rating.

For the Spatial Hearing Rating Scale, most subjects (32/40; 80%) reported benefit with the Nucleus 6 sound processor compared with their Nucleus 5 sound processor. A few subjects (5/40; 12.5%) rated the Nucleus 6 processor to be no

different than the Nucleus 5 processor, and three subjects (7.5%) reported a negative rating.

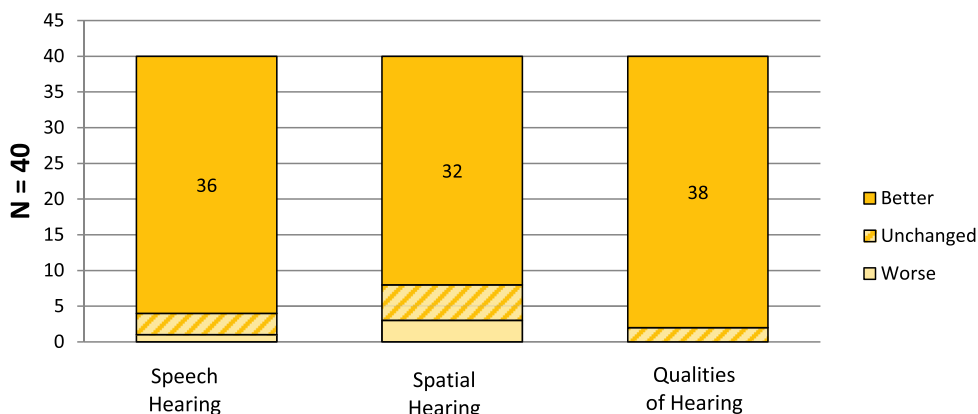
On the Sound Qualities Scale most subjects (38/40; 95%) rated the Nucleus 6 processor as better than the Nucleus 5 processor. Two subjects (5%) rated the Nucleus 6 processor as no different, and no subject (0%) rated it as worse (Fig. 2).

### 3.2.2. Hybrid group

After four weeks of take home use, most subjects (34/42; 81%) reported benefit on the Speech Hearing Scale with the Nucleus 6 processor compared with the Freedom Hybrid processor. A few subjects (8/42; 19%) reported a negative rating.

For the Spatial Hearing Rating Scale, most subjects (30/42; 71%) rated the Nucleus 6 processor as better than their Freedom Hybrid processor. A few subjects (5/42; 12%) rated

### SSQ-C results for Nucleus 5 group



**80% or more subjects reported better outcomes with Nucleus 6 on all three subtests**

Fig. 2. Results of the Speech, Spatial and Qualities of Hearing Scale (Comparative) by subtests for Nucleus 5 group.

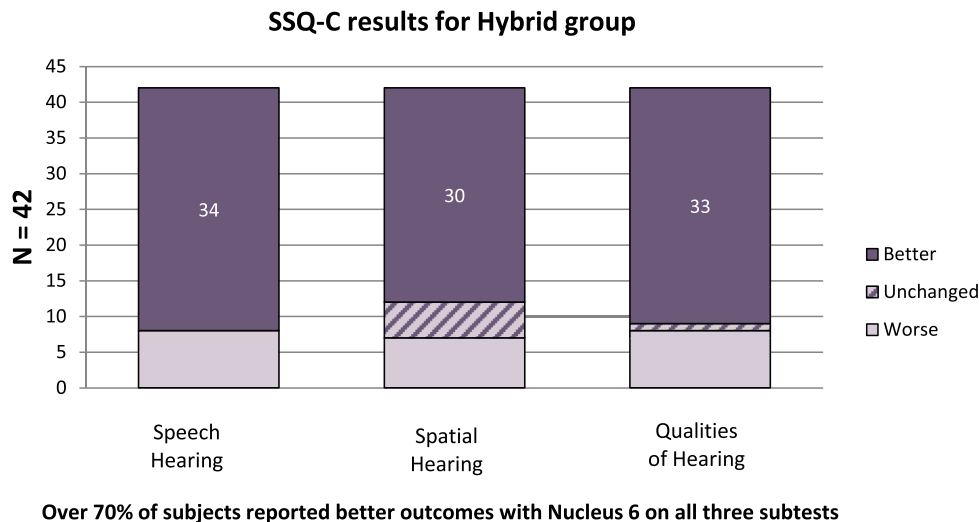


Fig. 3. Results of the Speech, Spatial and Qualities of Hearing Scale (Comparative) by subtests for Hybrid group.

the Nucleus 6 to be no different than the Freedom Hybrid, and a few subjects (7/42; 17%) rated it as worse.

On the Qualities of Hearing Scale most subjects (33/42; 79%) rated the Nucleus 6 as better than the Freedom Hybrid sound processor. One subject (1/42; 3%) rated the Nucleus 6 sound processor as no different, and a few subjects (8/42; 18%) rated it as worse (Fig. 3)

#### 4. Discussion

Results of both studies demonstrate superior performance with SCAN over Nucleus 5 and Freedom Hybrid processors when using ASC + ADRO. Over 70% of Hybrid subjects and 80% or more of traditional cochlear implant subjects reported subjectively better performance with Nucleus 6 on all SSQ-C subscales. One potential disadvantage of this study could be that recipients received only 4 weeks of listening experience prior to completing subjective questionnaires. Many subjects were long-term cochlear implant users and they may require additional listening experience to completely acclimate to changes in signal processing. Based on the data collected in these studies, the U.S. Food and Drug Administration (FDA) approved use of all SmartSound iQ features for individuals with both traditional and Hybrid L24 electrode arrays.\*

Including at least one SCAN program for new and existing recipients is recommended because this provides the best opportunity for the recipient to automatically use the most appropriate microphone directionality throughout the day, especially in difficult listening situations. It is also recommended that clinicians explain microphone directionality to recipients in order for the individual to take full advantage of signal orientation in noisy environments. In these studies, some subjects reported particular scenarios where they could not take advantage of SCAN because they were unable to face the signal of interest or because a noise source continually

entered and left the environment. In such cases, specific non-SCAN programs may be added to the sound processor with customizable signal processing features based on the user's preferences.

#### 5. Conclusions

The Cochlear Nucleus 6 is the first commercially available sound processor to implement an automatic scene classifying algorithm. This classifier comes standard in all Nucleus 6 processors and can effortlessly replace the tasks of environment analysis, decision-making, and manual program changing by the user. The new features of the Nucleus 6 sound processor have demonstrated clinical utility in this study and others (Mauger et al., 2014; Wolfe et al., 2015). Based on the objective results and positive recipient reports, it is reasonable to conclude that the Nucleus 6 feature SCAN is an improvement over the previous generation of sound processing algorithms, and is suitable for use by traditional cochlear implant and Hybrid L24 implant recipients.

Currently the FDA has approved SNR-NR, WNR, and SCAN for use with any recipient in the United States age 6 years and older who is able to (1) complete objective speech perception testing in quiet and in noise in order to determine and document performance and (2) report a preference for different program settings. This stipulation applies only to individuals in the United States. It does not apply in other countries; clinicians may use their clinical judgment and include these algorithms in programs for any Nucleus cochlear implant recipient.

#### Declaration of interest

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