



Combining Acoustic and Electric Stimulation in Cochlear Implant Recipients with Aidable Low-Frequency Hearing

The Naída CI Q90 Sound Processor

Introduction

In recent years, with improvements in cochlear implant technology and the resulting speech perception outcomes, more and more candidates with significant hearing in both ears are considering cochlear implantation.¹⁻³ As a result, the implanted ears of these recipients may have residual low frequency hearing that could benefit from amplification. For these recipients, fitting a hearing aid ipsilateral to the cochlear implant may provide additional speech perception, localisation and subjective sound quality benefits.⁴⁻⁶

The Naída CI Q90 sound processor* combines electrical stimulation delivered by the implanted electrode with acoustic amplification of the lower frequencies within one device. The traditional cochlear implant system provides access to a frequency range of 200 Hz to 8kHz, with electrical stimulation not reaching the most apical region of the cochlea. A hearing aid can also provide standard acoustic amplification across the frequency range, but usually residual hearing in such cochlear implant recipients remains below 1.5 kHz. Thus the two devices can work in parallel to provide stimulation along the cochlea delivering acoustic amplification in the lower frequency range, where the inner hair cells are still receptive, and electrical stimulation in the higher frequency regions of the cochlea.

This white paper reports some of the outcomes collected through a clinical study, which assessed speech understanding and subjective benefit, in a group of existing cochlear implant adult users who had some residual hearing in the implanted ear.

Subjects

Ten subjects who were for the majority of them implanted with the HiFocus™ Mid-Scala electrode were included: one unilateral cochlear implant user, five subjects using a contralateral hearing aid (which was removed for all testing) and four bilateral cochlear implants users. Among the bilateral recipients, two had preserved hearing in both ears; therefore in total, 12 ears were upgraded to electric acoustic stimulation with the Naída CI Q90 sound processor and acoustic earhook. Age at time of testing ranged from 38 to 80 years old with a median age of 60 years old and the duration of cochlear implant use ranged from 3 to 48 months with a median duration of 5 months. Unaided thresholds are depicted in figure 1.

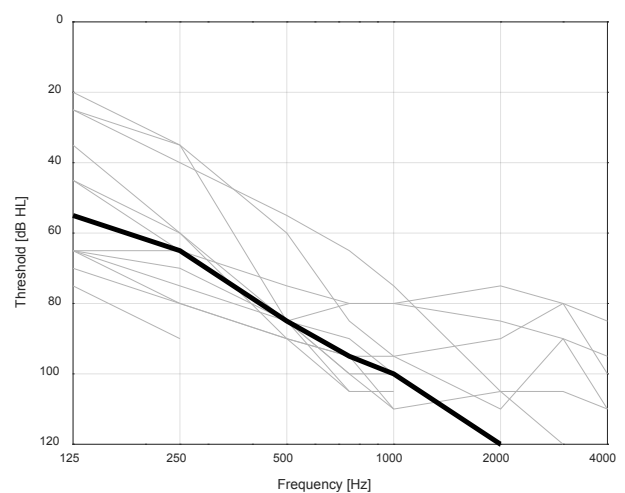


Figure 1: Individual hearing thresholds at time of first study appointment (in light grey) and median hearing thresholds (in bold black).

STUDY METHODS

Subjects' performances with two electro-acoustic fitting configurations with the new processor were compared to that obtained with their previous clinical program, which was uploaded on the new processor and evaluated at the first visit. There were three appointments at the centre with two take-home chronic phases in between. During the first visit, subjects were upgraded to electric acoustic stimulation with the Naída CI Q90 sound processor and acoustic earhook. The processor was fitted using Advanced Bionics custom fitting software, SoundWave™. All clinical settings from the previous processor were transferred into the new processor and the microphone was set to omnidirectional for all subjects. The subjects' audiograms were entered into SoundWave and the acoustic stimulation was fitted according to the AB-Phonak fitting formula, in which the automatic gain control and the input/output function of the electric and acoustic stimulations were matched.^{7,8} Fittings were generated so that the frequency ranges of the acoustic stimulation and electric stimulation did not overlap. The cutoff frequency for the acoustic amplification was set at the frequency where the hearing loss exceeded 85 dB HL (Cutoff 85 dB) at the first visit and 70 dB HL (Cutoff 70 dB) at the second visit. This frequency was then used as the starting frequency for the most apical electrode contact. Centre frequencies of the remaining electrodes were logarithmically interpolated to cover the full range between crossover frequency and the standard centre frequency for the most basal electrode. About three weeks experience was given before assessment with the first 'Cutoff 85 dB' fitting configuration (Visit 2) and then another three weeks with the second 'Cutoff 70 dB' fitting configuration (Visit 3) (Figure 2).

VISIT 1

- Upgrade to the Naída CI Q90 sound processor and acoustic earhook
- Upload and evaluation of **clinical program**
- Fitting with cutoff frequency at **85 dB**

~3 weeks

VISIT 2

- Evaluation of cutoff frequency at **85 dB**
- Fitting with cutoff frequency at **70 dB**

~3 weeks

VISIT 3

- Evaluation of cutoff frequency at **70 dB**

Figure 2: Schedule of the study.

Outcome Measures

Speech Reception Thresholds (SRT) for 50% speech intelligibility were measured using the adaptive Oldenburg sentences test (OLSA).⁹ Stationary noise was presented at a fixed level of 65 dB(A) from a loudspeaker in front of the subjects. Two lists of 20 sentences each were administered in each fitting configuration. Speech was coming from the front facing loudspeaker at a varying presentation level. Subjective performances were assessed using part 1 - Speech hearing and part 3 - Qualities of hearing of the Speech Spatial Qualities questionnaire (SSQ) with a 10 point Likert scale.¹⁰

Results

Due to the changed frequency to electrode allocation during the initial fitting, some subjects did not like the sound quality so the lower frequency boundary of the electrical stimulation was adjusted until an acceptable sound quality was achieved and this fitting configuration was used for the testing. Ten complete datasets were collected for speech understanding. After about three weeks of acclimatisation, there was an improvement in median speech reception thresholds of 1.3 dB for the 'Cutoff 70 dB' configuration and 1.4 dB for the 'Cutoff 85 dB' compared to the clinical program (Figure 3). This was statistically significant for the 'Cutoff 70 dB' fitting setting (Wilcoxon Matched Pairs test with a corrected alpha value; $p=0.016$). There was no significant difference between the two electro-acoustic fitting configurations.

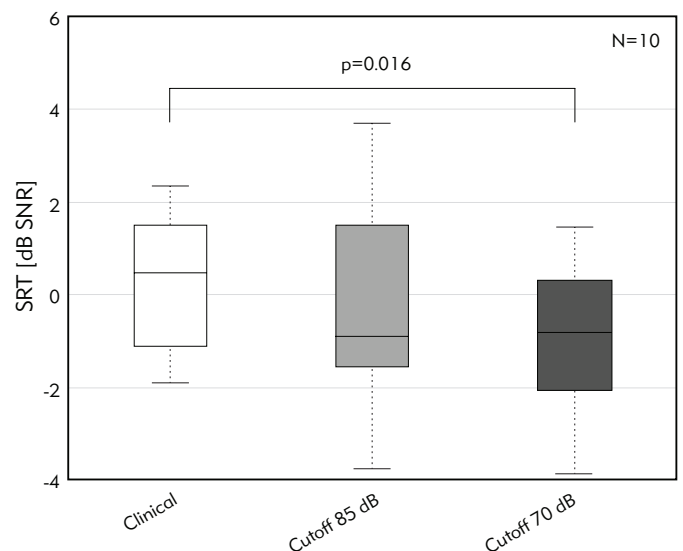


Figure 3: Boxplots showing quartiles and median values for OLSA speech perception results for the original clinical program compared to the two electro-acoustic fitting configurations with the Naída CI Q90 sound processor. The whiskers show the maximum and minimum values. If there was significant residual hearing in the contralateral ear, this was plugged to ensure performance of the ipsilateral ear alone was measured.

Six out of ten subjects provided subjective reports for all three conditions through the SSQ questionnaire. There was an improvement in median scores for speech intelligibility and sound quality for both the electro-acoustic fitting configurations with the Naída CI Q90 processor (Figure 4). Subjects also provided verbal comments through the study which are shown in table 1. Only one subject, G, indicated that he was unhappy with the sound quality of the electro-acoustic fitting configuration, and decided to revert back to his clinical program. Comments from all other individual subjects indicated that hearing was improved.

Summary

- As shown in previous studies, combining acoustic and electric stimulation in the same ear for recipients with usable low frequency residual hearing can provide additional listening benefits.
- Eleven out of the 12 upgrade cases (92%) continue to use the Naída CI Q90 sound processors with electric acoustic stimulation.
- The upgrades to electric acoustic stimulation with the Naída CI Q90 sound processor resulted in a median improvement in speech reception threshold of up to 1.4 dB after an acclimatisation period.
- Subjectively, there were also improvements in the domains of sound quality and speech understanding on the SSQ questionnaire and subjects reported improvements in hearing speech, their own voice, music and overall sound quality.
- Six out of the ten ears were also tested with an overlapping fitting configuration (where acoustic amplification reached a hearing loss of up to 85 dB HL and electric transmission already started at a hearing loss of 70 dB HL). Two of these subjects had distinctly better results with this fitting configuration than with the non-overlapping fitting configurations.
- This study highlights the fact that individual preferences for fitting configuration differed among subjects and underlines the importance of having access to fitting parameters in order to be able to optimise programs according to individual needs.
- The Advanced Bionics' fitting software, together with the Naída CI Q90 sound processor and acoustic earhook, allowed easy fitting of the acoustic and electric stimulation and therefore amplification of any remaining hearing in the implanted ear.

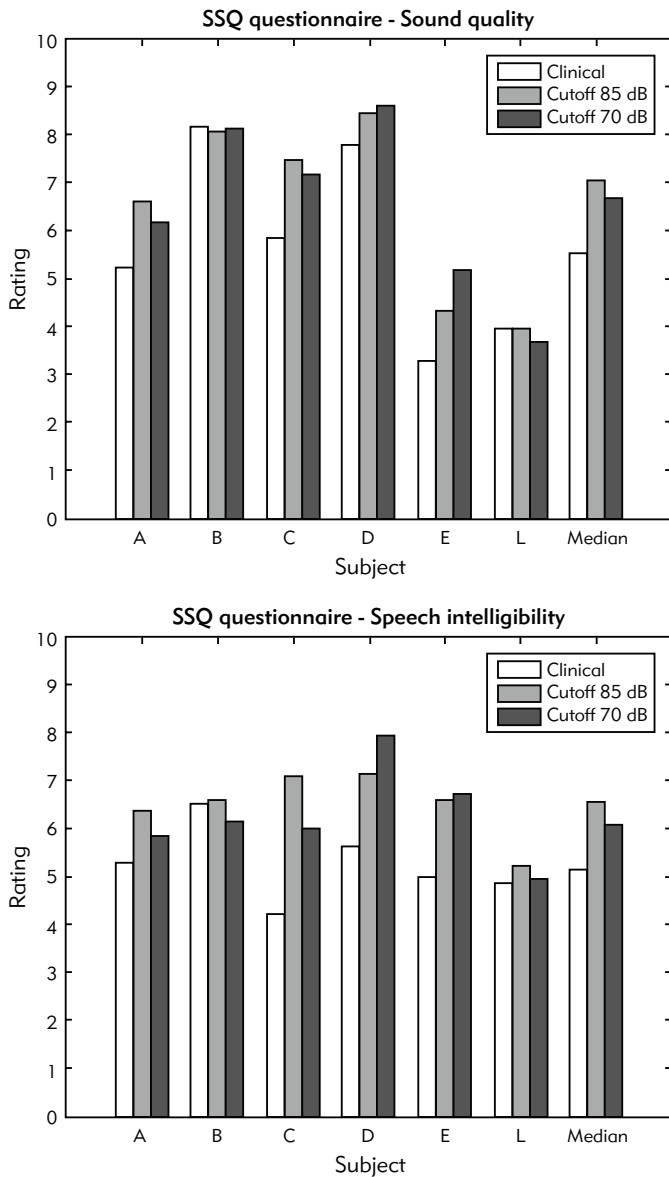


Figure 4: Individual and median speech intelligibility and sound quality ratings from the SSQ questionnaire for six subjects. Bars show scores for the original clinical program and the two electro-acoustic fitting configurations with the Naída CI Q90 sound processor.

A - spontaneously pleasant hearing sensation, everything more distinct	B - better speech understanding in noise and self-perception while singing
C - more distinct, low frequency voices clearer	D - speech understanding better, more natural hearing (music)
E - more natural, spatial sound	F - speech understanding in noise better
G - not better, hears additional crackling and rustling	H - spontaneously distinct better speech understanding
K - own voice more natural, the high pitched sound is gone	L - better, more rounded sound

Table 1: Individual verbal subjects reports.

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*The electric acoustic stimulation with the Naida CI Q90 sound processor and acoustic earhook is not yet available in all regions. Please contact your Sales Representative for approval status in your region.