Advanced Bionics™
A New Era of Innovation
Recent Research Summaries

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European Adult Multi-Centre HiRes™ 120 Study – an Update on 65 Subjects

Ambrosch P, Aschendorff A, Boermans PP, Boyle P, Büchner A, Cooper H, Eklöf M, Fielden C, Filipo R, Frachet B, Freijd A, Frijns J, Gallego S, Helbig S, Jeffs E, Kienast B, Lenarz Th, Lombaard S, Mancini P, Marco J, Meerton L, Meyer B, Morant A, Müller-Deile J, Pickerill M, Sterkers O, Truy E, Vanat Z, Wesarg Th

Cochlear Implants International (2010), 11(s1):406-411

The HiRes Fidelity 120™ sound coding strategy from Advanced Bionics™ implements "virtual" channels by steering current between adjacent electrodes. In this way the number of stimulation sites is no longer limited to the number of electrode contacts, but may be extended to 120 locations corresponding to 120 spectral bands. Recent research has shown that subjects can benefit from the current steering technique and so improve their performance.

The main objectives of this study were to verify this theory in adults, comparing performance with the previous coding strategy HiRes™ and also to determine the benefit of the Harmony™ sound processor compared to earlier processor models.

Data from 65 subjects are presented, including subjects with experience of HiRes 120 (N = 37) and subjects with no previous cochlear implant experience (N = 28). Speech tests in noise (at +10 dB signal-to-noise ratio) were conducted with both strategies and in both groups to assess performance in real life listening situations, and subjective benefits were assessed by a questionnaire. Each subject was his/her own control. A significant number of subjects improved with HiRes 120. The switch-over to the new strategy was uneventful and no problems were reported when upgrading subjects from previous sound processors to the Harmony. Subjects rated the sound quality of the HiRes 120 strategy as "clear", "pleasant", and "high quality". A significant improvement in sound quality and pleasantness of music was also reported with this strategy. The Harmony processor was found to be reliable, comfortable and to offer an increased battery life compared to the previous generation Auria™ (75% increase in battery life).

This report shows that the HiRes 120 sound coding strategy provides benefit to users in real life situations and that the combination of this strategy and the Harmony processor was preferred by 86.4% of the subjects.

Development of a Paediatric Audio-Visual Speech Test in Noise

Arnold L, Canning D, Boyle P

Cochlear Implants International (2010), 11(s1):244-248

It is important to be able to describe the auditory needs of children with impaired hearing in order to select appropriate school placement and rehabilitation. For example, signal to noise ratio and lip-reading abilities are significant factors in classroom listening and should be taken into account. This report describes a paediatric audio-visual speech test in noise (PAVT) which was developed to 1) evaluate the benefit obtained from adding lip-reading information to the auditory signal; 2) provide a valid and reliable test to inform education services as to the provision required for cochlear implant (CI) children.

Materials from two existing tests (McCormick and “English as a Second Language” toy tests) were selected and recorded from one male and one female speaker. Multi-talker babble noise was presented together with the speech signal. A monitor was available to display the corresponding video track to make lip-reading possible when required. Words were randomly presented to the subject whose task was to indicate the corresponding picture or toy, from a selection placed in front of him/her. Testing can be conducted with or without lip-reading, with an adaptive signal to noise ratio.

Pilot testing was performed on twelve paediatric CI users from Mary Hare School for the Deaf, UK. Audio-visual and audio alone PAVT thresholds were measured. In all but one case, the audio-visual condition led to better results; the subjects were able to understand more words when lip-reading information was used together with the audio signal. On average, the signal-to-noise ratio gain by using lip-reading was 8.3 dB.

The feasibility of using recorded audio-visual material to assess lip-reading abilities was confirmed by this pilot study. Benefit from lip reading can be measured very rapidly using the PAVT system, which may therefore provide a useful tool to assist in the choice of rehabilitation options for CI children. The option to test in noise provides a better representation of real-life conditions.

Electrical Field Imaging as a Means to Predict the Loudness of Monopolar and Tripolar Stimuli in Cochlear Implant Patients

Berenstein C, Vanpoucke F, Mulder J, Mens L

Hearing Research (2010), 270(1-2):28-38

The Advanced Bionics™ (AB) HiRes 90K™ electronic platform contains 16 current sources that can be programmed independently and stimulated simultaneously. Every contact generates an electrical field which is unique to each ear, as it depends on the detailed anatomy, the electrode type and location and the tissue conductivities.

Multipolar stimulation can combine these base fields to form a new stimulation field which can drive the auditory nerve in unique ways. This feature can be used to address some fundamental limitations in the electrical coupling to the auditory nerve. One application of multipolar stimulation is current steering, in which two fields are added with the same polarity in order to shift the field focus. When carefully controlled, a continuously varying electrical tonotopy can be produced. This feature underlies the HiRes™ 120 strategy. A second promising application, still in research phase, is current focussing, by which adjacent fields are combined with opposite polarity, e.g. a tripolar stimulation pattern. The aim is thus to limit the spatial extent of the neural excitation and improve channel independence.

One major challenge of the use of such complex fields is adequate loudness control. When the intracochlear base fields combine, the resulting field typically differs in density. The perceived loudness therefore also changes dramatically, complicating the fitting process.

This paper investigates the hypothesis that loudness changes can be predicted by calculating the resultant field from the individual base fields and assuming that its loudness will be similar if the peak of the complex field is scaled back to the original voltage level. If this holds, then the programming levels of complex strategies can be derived from monopolar programming levels and an objective measurement of the monopolar base fields, a technique known as electrical field imaging or EFI. The AB implant can measure these fields accurately, except in the vicinity of the stimulating contact. Therefore a free parameter α must be introduced.

The paper concentrates on the evaluation of partially tripolar fields. Loudness balancing experiments were performed and electrical fields measured in a group of ten AB users using different device generations and electrode types.

Overall, the results support the hypothesis that multipolar fields and perceived loudness can be predicted accurately. Optimization of the α coefficient is necessary. Interesting differences were observed between electrode types.

Evidence of Technology Impact

Boyle P

Cochlear Implants International (2010), 11(s2):43–47

Performance of cochlear implant (CI) users has steadily improved over the years. This improvement is mainly due to an evolution in the technology, such as in the electronics, the electrode array design and sound coding strategies. This report reviews some of these developments, focussing on Advanced Bionics™ devices.

Sound processing strategies. The Advanced Bionics sound processors have been continuously refined in many ways, but arguably the largest impact on speech understanding has been through the coding strategies. Over the last ten years we have seen progression from “standard resolution” strategies (e.g. CIS and SAS) to HiRes™ offering improved temporal detail and, more recently, enhancement of spectral detail through the current steering implemented in HiRes Fidelity 120™.

Music perception. As well as providing better speech understanding, appreciation and discrimination of music has been demonstrated in subjects using the HiRes Fidelity 120 strategy, presumably because pitch perception is particularly critical to music perception.

Front end processing. A dual time constant automatic gain control has been implemented and shown to enhance speech understanding in noise, though subjective benefits are not so clear. An additional pre-processing algorithm, “ClearVoice™”, has also been shown to provide large improvements in speech understanding in noise, particularly for constant noise sources such as produced by machinery or airplanes.

Assessment tools. A new speech recognition test is described which aims to assess understanding in realistic listening conditions. This test delivers sentences at three different levels (50, 65 and 80 dB SPL) and by a female and a male speaker. These options are changed randomly during the test in order to simulate normal conversational speech more closely.

Results with the Harmony™ Speech Processor in Combination with the First Generation of Advanced Bionics™ Implant System

Brendel M, Rottmann T, Büchner A, Frohne-Büchner C, Lenarz Th

DGA Proceedings (2010), CD ISBN 978-3-9813141-0-6

At the Medical University of Hannover (MHH) there are more than 450 users of the Advanced Bionics™ first generation "C1" implant (Clarion™ 1.0 and 1.2). These implants are driven by previous-generation processors including the body-worn and Platinum BTE™ sound processors and the Clarion 1.0, 1.2 and S-Series processors. These all supported the CIS, SAS and MPS/PPS coding strategies. To date, the Harmony™ BTE, supporting the HiResolution™ strategies, has been approved for use only with the CII and HiRes 90K™ implants. To give users of the first generation implant system access to the advantages of this new processor a new Digital Signal Processing (DSP) code was developed. The combination of the Harmony with the new DSP code is called the C1 Harmony and allows programming of the SAS, CIS and PPS coding strategies. The objective of this study was to confirm both the safety and efficacy of the C1 Harmony prior to commercial distribution.

A group of 29 C1 users participated in the study. All were postlingually deafened, with a mean age of 56.5 years, a mean duration of implant use of 12.2 years and a mean duration of deafness of 4.9 years. Speech perception tests (Freiburger monosyllables, HSM sentence tests in quiet and noise) were performed with the original clinical processor at a baseline appointment and with the Harmony after a one month take-home period. Subjective reports were collected via questionnaires and from an interview.

Speech perception tests showed an improvement with the C1 Harmony compared to the previously used processor. For the group the results in both tests in quiet were significantly better with the Harmony. The subjective rating from a sound quality questionnaire showed a trend for a better overall quality and a significant improvement for hearing in background noise with the C1 Harmony compared to the previous processor, though more problems with an echo were reported. Subjects were interviewed regarding their preference for one or the other processor on a scale from 1 to 10. In total, 80% of the subjects preferred the C1 Harmony, 3% had no preference and 17% preferred their original processor.

The C1 Harmony provided significantly better speech perception than the previous processor. The majority of subjects preferred the Harmony and rated the sound quality better than that of their previous processor. The C1 Harmony has recently been released in Europe.

Results of a Pilot Study with a Signal Enhancement Algorithm for HiRes™ 120 Cochlear Implant Users

Büchner A, Brendel M, Saalfeld H, Litvak L, Frohne-Büchner C, Lenarz Th

Otology & Neurotology (2010), 31(9):1386-1390

Even though there is no doubt about the benefit of cochlear implantation in cases of severe to profound sensorineural deafness, cochlear implant (CI) users still experience severe limitations regarding sound quality, music appreciation and speech perception in adverse listening situations such as in reverberant or noisy environments.

To improve hearing in noise, the incorporation of a noise reduction algorithm to the HiRes™ 120 coding strategy was initiated. This study investigated this signal enhancement algorithm “ClearVoice™”.

Thirteen participants implanted with either the CII or HiRes 90K™ implant and using HiRes 120 in everyday life were enrolled in the study. The subjects had a mean age of 58.4 years. The mean duration of deafness was 3.3 years and mean duration of CI use was 1.7 years. During one acute session the participants were tested with the clinical HiRes 120 program, as well as two different ClearVoice settings. The HSM sentence test in speech shaped noise (55 dB SPL; SNR adjusted individually to produce a score of around 50% correct) was administered for all three program settings. During a subsequent take-home phase the participants were asked to use all three programs in their everyday listening situations and to give a subjective rating of sound quality and speech perception via a questionnaire (APHAB).

Twelve out of 13 participants showed improved scores on the HSM for both ClearVoice conditions. Performance with both ClearVoice conditions was highly significantly better than with the baseline condition, but there was no difference between the ClearVoice conditions themselves. The individual APHAB questionnaire results showed at least one of the ClearVoice conditions to be better in six of twelve participants. The group mean scores for the subjective rating of sound quality were not significantly different from each other. The majority preferred one of the ClearVoice conditions, four participants preferring the strong and three preferring the moderate setting.

Individual scores of speech perception showed improvements for all 13 participants. Group mean speech perception scores were highly significantly better for the ClearVoice settings compared to the clinical baseline program score. Subjective preference for the moderate versus strong ClearVoice was evenly distributed across the group.

Evaluation of the Built-in T-Coil of the Behind-The-Ear Sound Processor Harmony™

Frohne-Büchner C, Brendel M, Saalfeld H, Büchner A, Lenarz Th

Cochlear Implants International (2010), 11(s1):412-415

The Harmony™ is the current Advanced Bionics™ Behind-The-Ear (BTE) sound processor, which offers a built-in T-Coil to access external signal sources. In an acute test session four different options for using the telephone were evaluated: the built-in T-Coil, the built-in microphone of the processor, the T-Mic™ pinna microphone and the external telecoil originally developed for the Auria™ BTE processor.

Harmony users were tested on the Freiburger monosyllables test which was administered via telephone. Testing was performed using the four different input options. Additionally, the subjects completed a questionnaire concerning their telephone habits in everyday life. The study group consisted of 14 adult cochlear implant (CI) users with HiRes 90K™ or CII implant systems, with a mean age of 52 years (32 to 72 years) and a mean duration of deafness of 48 years (24 to 67 years).

The best result, of 66.4%, was achieved using the modular external T-Coil, which was significantly different from the other three options. There were no significant differences among the other three options (between 53 and 55%). The majority of the subjects had a subjective preference for either the external T-Coil or the T-Mic.

While the results using the T-Mic and built-in T-Coil were similar on this test in a quiet background, the T-Coil would be expected to have an advantage for use of the telephone in background noise. It is likely that the T-Mic was preferred by the subjects in this study because it is the standard option in everyday life for most users.

The built-in T-Coil provides a similar hearing quality to the T-Mic and is recommended for using the telephone in background noise. For CI users who regularly use an induction system the modular external T-Coil should be considered.

Understanding in Everyday Life Situations; Results from Paediatric Cochlear Implant Users

Frohne-Büchner C, Büchner A, Kreibohm K, Brendel M, Rühl S, Lesinski-Schiedat A, Lenarz Th

Cochlear Implants International (2010), 11(s1):291-295

As implanted children reach secondary level the number of teenagers with cochlear implants (CI) is increasing. There is therefore considerable interest in understanding the everyday listening habits, use of accessories and subjective performance of children and adolescents. The reported study investigated these topics using a questionnaire.

To date, 23 children and adolescents between the ages of eight and 21 years have participated in the survey, approximately half of them with prelingual onset of deafness. All subjects used an Advanced Bionics™ implant system, with a range of different sound processors (Clarion™ S-Series, Platinum Speech Processor, C1 behind-the-ear processor, CII behind-the-ear processor, Auria™, Harmony™). The questionnaire started with questions on the subject's demographics and personal profile; then it covered four everyday listening topics: 1) telephone, 2) music, 3) at school or university, 4) in other social environments. An additional mini-questionnaire included more detailed questions about the situation at school and whether a change of educational setting had occurred following implantation.

Subjective ratings and objectively measured speech perception were not significantly different between the pupils attending mainstream schools and those attending schools for the hearing impaired. The only significant differences between the groups were for unknown speakers on the phone and unknown teachers at school. To what degree this is influenced by habits requires further investigation.

Many users of a behind-the-ear processor used the T-Mic™. It can be used in every situation and improves speech perception in background noise. The comfortable handling is certainly a feature that leads to frequent use.

Other assistive listening devices were used only rarely and their use was unrelated to the type of school. Even FM systems were not used widely. Reasons for limited use may be that early implantation leads to high levels of performance not necessitating assistive listening devices or that stigma leads to rejection. FM systems were mainly used by younger children.

Evaluation of Music Perception in Adult Users of HiRes™ 120 and Previous Generations of Advanced Bionics™ Sound Coding Strategies

Gazibegovic D, Arnold L, Rocca C, Boyle P

Cochlear Implants International (2010), 11(s1):296-301

In 2007 Advanced Bionics™ launched the novel sound coding strategy HiRes™ 120. This strategy incorporates the concept of current steering and provides up to 120 stimulation sites using only 16 electrodes. Early clinical results showed improved speech understanding in noisy environments. Also, the naturalness of speech and music and the overall sound quality were shown to be improved.

The aim of this evaluation was to assess whether there is any difference in music perception, listening frequency, enjoyment and ability to differentiate special musical features between three groups of subjects using different generations of strategies:

- "C1" (a combination of CIS, SAS and MPS strategies)
- HiRes
- HiRes 120

The evaluation was based on a questionnaire. One of the sections assessed the subjects' ability to identify specific musical features. A group of 25 normal hearing (NH) subjects and 20 cochlear implant users have completed the questionnaire so far.

Preliminary results suggest that the NH subjects outperform the C1 group. Nevertheless, the HiRes 120 group scored close to the NH group and in many tasks up to two points (1-10 scale) above the HiRes group.

Based on the data obtained from NH subjects, the questionnaire seems to be able to collect a large amount of data within a short time frame. Preliminary results indicate that the evaluation material is a suitable measure for identifying musical experience and the ability to recognize specific musical features in users implanted with the Advanced Bionics system. The users of HiRes 120 sound processing appear to benefit from the more precise delivery of the spectral content of sound when listening to music.

Development of a Software Tool Using Deterministic Logic for the Optimization of Cochlear Implant Processor Programming

Govaerts PJ, Vaerenberg B, De Ceulaer G, Daemers K, De Beukelaer C, Schauwers K

Otology & Neurotology (2010), 31(6):908-918

This article describes the rationale, development and features of FOX® (Fitting to Outcomes eXpert). Fitting of the cochlear implant processor is a time-consuming procedure aimed at defining the values of a subset of the available electric parameters, based primarily on behavioural responses. This "traditional" fitting approach is comfort-driven with high intra-individual and inter-individual variability, both with respect to the user and to the clinician. Its validity in terms of process control can be questioned. Good clinical practice would require an outcome-driven approach. An intelligent agent may help solve the complexity of addressing more programming parameters based on a range of outcome measures.

We have developed a software application consisting of deterministic rules which analyze the program settings in the processor together with psychoacoustic test results obtained with that program. These rules are based on correlations between fitting parameter settings and performance measures taken from everyday clinical practice. The data transfer to and from FOX may be either manual or through seamless digital communication with the cochlear implant (CI) fitting software and the psychoacoustic test suite. It recommends and executes modifications to the program settings to improve outcomes.

The development and modes of operation are outlined in this paper, and a case example is provided. FOX has been used for more than a year now and appears to be able to improve measured outcomes. It is argued that this novel tool allows a systematic approach focusing on outcomes, reduces the fitting time, and improves the quality of fitting. It introduces principles of artificial intelligence into the process of CI fitting.

Speech Perception with Cochlear Implants as Measured Using a Roving-Level Adaptive Test Method

Haumann S, Lenarz Th, Büchner A

ORL Journal for Oto-Rhino-Laryngology and its Related Specialties (2010), 72(6):312-318

While early cochlear implant (CI) systems could only provide help with lip-reading, today candidates can expect speech understanding even in challenging listening situations. The most widely used performance measures are speech recognition tests. The most common method is where speech and noise signals are presented at a fixed Signal-to-Noise Ratio (SNR) and performance expressed as percent correct. A common problem with this approach, however, is floor and ceiling effects. In order to remedy this problem, adaptive tests can be used where the SNR is varied in order to assess the Speech Reception Threshold (SRT), which is usually taken as the SNR resulting in a 50% score. In this paper, a new method was assessed which aims to combine the advantages of an adaptive regime with the goal of testing CI users in a more realistic situation.

The study population consisted of 55 postlingually deafened adults. At the time of testing, mean subject age was 55 years, mean duration of CI use was 3.0 years and mean duration of deafness prior to surgery was 1.8 years. Subjects used CI systems by Cochlear Corporation (Freedom or Esprit 3G speech processor, ACE speech coding strategy), Advanced Bionics™ (Auria™ or Harmony™ speech processor, HiRes™ or HiRes 120 speech coding strategy) and MED-EL (Opus 2 speech processor, FSP speech coding strategy). In the first experiment the speech signal was presented at randomly roving levels of 55, 65 and 75 dB SPL and in the second experiment the levels were roved at 50, 65 and 80 dB SPL. In both experiments the noise level was adjusted adaptively to obtain 50% speech understanding.

In the first experiment the overall mean SRT was 2.3 dB and SRTs for the individual processor groups were Harmony: 1.2 dB, Auria: 2.0 dB, Freedom: 4.6 dB, Esprit 3G: 3.9 dB and Opus: 0.1 dB. In the second experiment the overall mean SRT was 3.0 dB, with individual processor group SRTs of Harmony: 1.3 dB, Auria: 2.6 dB, Freedom: 5.8 dB, Esprit 3G: 6.4 dB and Opus: -1.0 dB.

The test method used in this study, which aims to test CI users under more realistic conditions, allows modification of the test difficulty by changing the amount of level roving. In this way the method is able to assess the effects of various subject-specific and technical parameters on everyday speech perception with CIs. Processing parameters such as automatic gain control and input dynamic range are known to influence speech understanding at different loudness levels and in noise (i.e. everyday listening situations) and it is suggested that this roving level test provides a more realistic measure of performance and assessments of these parameters than traditional methods.

STARR Validation Working Group: Cochlear Implant Users' Everyday-life Performance Assessed in Clinical Practice

Joffo LM, Boyle P

Cochlear Implants International (2010), 11(s2):52–56

The STARR (Sentence Test with Adaptive Randomised Roving levels) aims to make an assessment of speech understanding that more closely relates to real-life listening situations. Sentences are each delivered by either a male or a female speaker, at one of three different presentation levels and with adaptively varying background noise. The presentation order is randomized for both the level and the speaker. Sound processor functionality is thus more fully challenged than in traditional speech tests. The objectives of this work were to propose clinical adoption of a test better reflecting everyday-life listening conditions and to collect data for validating the test.

Within this project STARR data are being collected from adult cochlear implant (CI) users in seven UK centres as part of their clinical routine. To collect normative data, list equivalence, learning effects and test-retest variation, each participant is tested on five lists of 30 sentences. There are 25 sentence lists in the STARR test, so that each sentence list is tested on five different participants. If more than two keywords are incorrectly repeated from one sentence, then the Signal to Noise Ratio (SNR) is increased for the following sentence. If less than three keywords are incorrectly repeated, the SNR for the next sentence is reduced. The SNR step size reduces from 10, to 5 and finally to 2.5 dB to allow a rapid convergence towards an estimate of Speech Reception Threshold (SRT).

As a preliminary step a data set from 25 normal hearing individuals was collected. The overall SRT obtained from these individuals was around -6 dB. The participants performed slightly worse with the female voice (higher SRT) than with the male voice, probably due to the female speaker having a faster delivery rate than the male speaker. There was a low inter-list variability, with only one list (№2) having a deviation of more than 1 dB. Participant recruitment is ongoing for CI and hearing aid users.

The methodology behind STARR makes it a more difficult test which better represents real-life listening conditions. The data obtained from normal hearing individuals showed little variation between the male and female speakers and low inter-list variability amongst the 25 sentence lists.

SPAN: Improved Current Steering on the Advanced Bionics™ CII and HiRes 90K™ Systems

Litvak L, Saoji A, Boyle P

Cochlear Implants International (2010), 11(s1):465-468

The Harmony™ sound processor offers HiRes Fidelity 120™ (HiRes™ 120) sound processing to recipients of the Advanced Bionics™ CII or HiRes 90K™ implants. With HiRes 120, simultaneous delivery of current to pairs of adjacent electrodes results in effective stimulation at sites of the cochlea between the physical contacts, thereby providing up to 120 spectral bands. Studies have already shown that Harmony recipients gain benefit from using this strategy in hearing in noise and listening to music, compared to the HiRes strategy. Following the same concept, the SPAN algorithm was designed. It is able to effectively replace deactivated or faulty physical electrodes using current steering.

The aim of the study was to determine if this algorithm provides benefits in speech perception and subjective preference. Nine adult subjects, using the Harmony processor were tested with several programs: (i) standard HiRes 120 program, (ii) HiRes 120 programs with disabled electrodes replaced by “virtual” electrodes (SPAN algorithm) and (iii) HiRes 120 programs with electrodes turned off but not replaced by virtual electrodes.

The group mean results showed that speech recognition in quiet and noise, as well as subjective sound quality, are equivalent with the standard HiRes 120 program and programs where disabled electrodes were replaced by virtual electrodes. Thus, virtual electrodes generated by simultaneous stimulation of non-adjacent electrodes can compensate for disabled electrodes. On the other hand, a clear decrease in performance, and subjective preference, was observed with programs with disabled electrodes, which were not replaced.

The SPAN algorithm has the potential to replace, or substitute for, physical electrode contacts which are not viable or produce undesirable sensations and provide comparable performance to the HiRes 120 strategy.

Encoding Pitch Contours Using Current Steering

Luo X, Landsberger DM, Padilla M, Srinivasan AG

The Journal of the Acoustical Society of America (2010), 128(3):1215-1223

Accurate pitch perception is important for both speech understanding and music appreciation. In normal hearing listeners pitch perception is generally described by temporal and place theories. Cochlear implant (CI) users rely on both mechanisms for pitch perception, but only with limited success, as their spectral resolution is limited by the number of implanted electrodes. Current steering is one way to increase the number of pitch percepts beyond the number of physical electrodes. With this technique current is delivered simultaneously to two adjacent electrodes with an adjustable weighting. The weighting applied to each electrode steers the peak of excitation between the two contacts. Preliminary studies have shown that most CI users can perceive such intermediate "virtual" channels (VCs) elicited by current steering. This study investigated CI users' ability to perceive pitch cues from time-varying VCs to identify pitch contours.

Seven adult users of the Advanced Bionics™ CII or HiRes 90K™ devices were studied. They were tested on apical, medial, and basal electrode pairs with stimulus durations from 100 to 1000 ms. In one stimulus set, nine pitch contours were created by steering current between the physical electrodes and the VC halfway between the contacts. Another stimulus set contained only three pitch contours (flat, falling, rising). VC discrimination was also tested on the same electrodes. The results showed that pitch contour identification (PCI) scores were similar across electrode locations, and significantly improved with longer durations. For durations longer than 300 ms, two subjects had nearly perfect identification of the nine contours, and five subjects perfectly identified the three basic contours. Both PCI and VC discrimination varied greatly across subjects. There was a significant correlation between cumulative d' values for VC discrimination and 100-, 200-, and 500-ms PCI scores. These results verify the feasibility of encoding pitch contours using current steering, and suggest that identification of such contours strongly relies on CI users' sensitivity to VCs.

These results were obtained through the unique combination of multiple current sources and specific electrode spacing available with the Advanced Bionics CII and HiRes 90K devices. It is unknown how users would benefit from intermediate place pitches elicited with the Nucleus or MED-EL systems (having respectively a single current source or larger electrode spacing).

Signal Processing Strategies for Cochlear Implants Using Current Steering

Nogueira W, Litvak LM, Edler B, Ostermann J, Büchner A

EURASIP Journal on Advances in Signal Processing (2009), Volume 2009, Article ID 531213, 20 pages doi:10.1155/2009/531213

In contemporary cochlear implant (CI) systems, the audio signal is decomposed into different frequency bands, each assigned to one electrode. Thus, pitch perception is limited by the number of physical electrodes implanted into the cochlea and by the bandwidth assigned to each electrode. The Advanced Bionics™ HiRes 90K™ implant, in conjunction with the Harmony™ processor, has the capability of creating "virtual" channels by simultaneous delivery of current to pairs of adjacent electrodes. By steering the locus of stimulation to sites between the electrodes, additional pitch percepts can be generated.

The main goal of this work was to improve speech and music perception in CI recipients through the development of new signal processing strategies that exploit the current-steering capabilities of the Advanced Bionics device. These new strategies were designed to improve the spectral analysis of the audio signal through current steering and to deliver the signal with greater place precision. The challenge was to implement the experimental strategies in commercial sound processors so that they can be evaluated by implant users. Thus, a significant effort was put into executing the real-time applications in commercial low power processors. Two new sound processing strategies based on current steering were investigated: "SpecRes", a research version of HiRes™ with Fidelity 120 and "SinEx", which incorporates a new high resolution frequency estimator and a model of spectral masking.

In a chronic trial, speech recognition, pitch perception, and subjective appreciation of sound were compared using the two new current steering strategies and the standard HiRes strategy in nine adult Harmony users. Results from this study showed potential benefits of current steering strategies with respect to standard strategies like HiRes. New modifications of the signal processing algorithms, together with further investigation on simultaneous stimulation of the electrodes, hold great promise for improving the hearing capabilities of CI users.

Music Benefits with HiRes™ 120 Sound Processing

Osberger MJ, Quick A, Arnold L, Boyle P

Cochlear Implants International (2010), 11(s1):351-354

Today's cochlear implant users can understand speech very well in quiet, but the ability to understand speech in noise and to enjoy music remains generally poor. Music perception requires better spectral resolution (more channels) than speech even in normal hearing listeners. With the HiRes™ 120 strategy, Harmony™ system users have now access to greater spectral resolution, with the potential to improve their music perception.

This study examined music enjoyment and appreciation in 52 adult subjects using Harmony/HiRes 120. Everyday experience (enjoyment and frequency of listening) was assessed using a ten point scale. Appreciation was assessed with the Appreciation of Music in Cochlear Implantees test battery (AMICI, Spitzer et al., 2008). The AMICI consists of four subtests of graded difficulty. One subtest (noise versus music discrimination) was not used due to previously reported ceiling effects. The other three subtests were used: instrument identification, styles identification and musical pieces.

Most of the subjects listened to music (87%) and enjoyed it to some extent (83%). Younger subjects and those with more implant experience enjoyed music the most. Scores on the AMICI styles and instruments subtests were similar, indicating moderately good performance, all subjects scoring above chance, with the range of performance extending to 100%. The score on the musical pieces subtest was lower, reflecting the greater difficulty of this task. Subjects with shorter duration of deafness obtained higher scores on the AMICI styles and those implanted at a younger age performed better on the more difficult open-set AMICI pieces. Self-report of music enjoyment was correlated with only one of the AMICI subtests (musical pieces), suggesting that subjects can enjoy music even if they perform poorly on music tests. Conversely, subjects may score high on music tests but not enjoy music.

Many subjects performed relatively well on the closed-test AMICI subtests. Those subtests may be helpful during early implant use to demonstrate music benefit to new users.

Use of Telemedicine in the Remote Programming of Cochlear Implants

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During cochlear implant (CI) programming sessions where clinical staff are relatively inexperienced, particularly demanding users are encountered or equipment problems are suspected it is often desirable to have a higher level of expertise available. This expertise is often provided by the technical support department of the implant manufacturer. However, this resource is limited and not always widely available. Moreover, certain practical issues are often encountered when CI users live in remote areas and when regular visits to the CI centre during the first month of system use are challenging. Telemedicine is a concept made possible by modern communication technologies. It can be applied to remotely program CIs, a concept which could potentially overcome the above challenges. This study aimed to evaluate the applicability and efficacy of telemedicine in CI programming by analyzing its technical aspects and by assessing its impact on users' speech recognition.

Five experienced HiRes 90K™ users, able to give feedback during programming, were recruited. The aim was to compare remote and standard programming methods. For each method, programming parameters were assessed (sound coding strategy, input dynamic range, most comfortable levels (M levels) and thresholds). Subjects' performance was assessed by free field tonal and speech audiometry (disyllabic open set word tests) after three months of remote programming. In addition, subjective hearing perception was assessed through a qualitative questionnaire.

In terms of fitting parameters, remote fitting did not show any significant difference compared to standard fitting, although a trend was observed suggesting slightly lower M levels with remote programming compared to standard fitting routine. Regarding user performance, it was observed that the mean free field thresholds after remote programming were 6.2 dB higher (poorer) than after standard programming, which was in accordance with the lower M levels. However, no significant difference in speech performance in quiet was observed and both methods provided the users with the same level of subjective hearing satisfaction. No technical equipment issues were encountered, although a short delay (about 0.5s) was always present between triggering actions on the remote equipment and the intended event on the local equipment; but this could be handled within the fitting session without adverse consequence.

This work showed the huge potential in using remote programming approaches to fit CI users. The continuous improvement in modern telecommunication systems should make it possible to further demonstrate feasibility and safety of remote programming. This technique opens the possibility for main centres to program CI devices remotely, thus reducing the need for local medical support, and to provide remote CI support to secondary centres, for example to assist in difficult fitting cases.

European Multi-Centre Paediatric Bilateral Study: Benefits of Bilateral Cochlear Implantation with HiRes™ 120

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Less information is available on the benefits of bilateral cochlear implantation in children than on unilateral implantation. The aim of this study was to assess the benefits that bilaterally implanted children receive from HiRes™ 120 in comparison to a unilaterally implanted control group. Children aged between 18 months and four years old were included and randomly assigned for either unilateral or bilateral implantation. The plan is to recruit 24 children in total and to assess speech recognition and sound localization through specific rating scales of speech production and communication, questionnaires to parents and performance testing. Children are to be evaluated at 3, 6, 12, 18, 24, 36, 48 and 60 months after the first fitting. In this report, preliminary data are presented for eleven subjects (four unilateral and seven bilateral users) up to the 18 month interval.

These early results are very promising. The Categories of Auditory Performance (CAP) showed that bilateral subjects developed speech production and communication faster than unilateral subjects. Indeed, most of the bilateral subjects were spread across category 3 (identification of environmental sounds) and category 4 (discrimination of some speech sounds without lip-reading) at three months whereas most unilateral subjects were only in category 1 (awareness of environmental sounds). Then, at six months, category 4 was reached by most bilateral children (85%) whereas half of the unilateral subjects were still in category 2 (response to speech sounds).

In addition, results obtained to date from the Speech Spatial Qualities questionnaire showed that bilateral implantation is helpful for sound localization. The difference in average score for the Spatial Rating Scale was significant between the two groups from twelve months onwards.

These preliminary results suggest a tendency towards the superiority of bilateral implantation over unilateral implantation.

Influence of Widening Electrode Separation on Current Steering Performance

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Current steering between adjacent electrodes makes it possible to create more spectral channels than the number of physical electrode contacts on an electrode array. With current steering on non-adjacent electrodes, termed "spanning," it might be possible to bridge a defective electrode contact or potentially reduce the number of electrode contacts for the same level of access to the auditory nerve. This study investigates the effectiveness of spanning.

Twelve adult users of the HiRes 90K™ cochlear implant with HiFocus™ 1j electrode were randomly selected to participate in this study. Electrode contacts were selected (from CT scans) at two locations in the cochlea: at 180° (basal) and 360° (apical) from the round window. For both locations, three psychophysical experiments were performed using simultaneous stimulation of electrode contacts. The number of intermediate pitches was assessed and the current weighting coefficient (α) was determined with loudness balancing. Finally, the pitch of a spanned channel was matched with the pitch of an intermediate physical electrode for assessing its effective location on the electrode array.

Spanning required significantly more current compensation to maintain equal loudness than current steering between adjacent electrode contacts. A significant decrease in discriminable intermediate pitches was observed with spanning compared with current steering between adjacent electrode contacts. No significant difference was found between the measured current steering coefficient and the theoretical coefficient and there was no significant difference between the apical and the basal locations.

Spanning over wider electrode distances is feasible. With increasing electrode spanning distance, greater current compensation is required to maintain equal loudness, and a gradual deterioration in the just noticeable difference for pitch is observed. However, the pitch progression is linear.

Experiences of the Use of FOX®, an Intelligent Agent, for Programming Cochlear Implant Sound Processors in New Users

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This report describes the application of the software tool "Fitting to Outcomes eXpert" (FOX®) in programming the cochlear implant (CI) processor in new users. FOX is an intelligent agent which may be used to modify CI programs on the basis of specific outcome measures. Decisions are made using heuristic logic and are based on a set of deterministic "rules" which were developed by linking these outcome measures to CI fitting parameters in a large number of CI users over several years.

A prospective study was conducted on eight consecutive adult CI users with a follow-up of three months. All subjects had postlingual deafness and were implanted with the Advanced Bionics™ HiRes 90K™ device. The processors were programmed using FOX, running a set of rules known as Eargroup's EG0910 advice, which includes a set of incremental "automaps" designed for the initial switch-on period. Following a loudness acclimatization period of one week with the automaps, optimization of the fitting was performed using FOX, based on a set of psycho-acoustic test results.

The three month median results showed acoustic thresholds of 25 dB HL, speech audiometry (phoneme) scores of 77% (55 dB SPL) and 71% (70 dB SPL) and loudness scaling at or close to the normal range at several frequencies.

It is concluded that this approach is feasible to start up CI fitting and yields good outcomes as measured by means of psychoacoustic tests. It is anticipated that this will standardize CI programming, reduce fitting times and optimize outcomes.

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