Implementation of Perceptual Channels in Children implanted with a HiRes90K device: Preliminary Report

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Background

Modern cochlear implant sound processing strategies such as HiRes [Frijns, 2003] and HiRes120 [Litvak, 2007], claim to provide more fine structure and place pitch information that earlier sound coding methods. Where such benefits exist they should be particularly visible in cases with better neural survival. This work focuses on children who are naturally well placed, through a shorter duration of deafness and residual neural plasticity, to benefit from any enhanced information available in the sound coding strategy. Comparisons are made between three groups of children: a group using: HiRes, a group crossed over from HiRes to HiRes120 and a group first fitted in HiRes120.

Sound may be considered in terms of three types of information: intensity, temporal and spectral. The HiRes sound coding strategy represents intensity well by processing a large acoustic dynamic range, typically 60 dB, something that has shown to be important for real life listening [Spar, 2007]. In HiRes stimulation rates of up to 5,100 pulses per second per channel (pps/ch) are fast enough to follow the fine temporal structure variations in speech [Buechner, 2006]. Excellent results with HiRes have been demonstrated for both adults [Koch, 2004] and children [Bosco, 2004]. However, HiRes provides only 16 channels, limiting the available spectral information.

The HiRes90K implant contains 16 independent current sources, each which is normally stimulated one at a time to deliver spectral information for one channel. Since the current sources are truly independent they may also be stimulated so that two adjacent electrodes are stimulated simultaneously as depicted in figure 1. The resulting electrical field now shows a maximum somewhere between the two physical electrode contacts. By varying the proportion of current which is split between the electrode contacts the centroid of the electrical field may be "steered", in the space between the two contacts. Hence, it is possible to address neural populations lying along the cochlea which are smaller than the 1 mm physical electrode contact spacing. Previous psychophysical work has shown that implant users typically detect five distinct pitch-precepts between a pair of adjacent electrode contacts [Advanced Bionics, 2006]. This finding led to development of HiRes120: eight spectral channels processed between each of the 16 electrodes (15 gaps times 8 spectral channels giving 120 stimulation sites, hence HiRes120).

Method

Three groups of children were studied, one fitted from the beginning in HiRes, one converted from HiRes to HiRes120 (Switch-over) and one fitted from the beginning with HiRes120 (switch-on). The ages and duration of implant use are shown in table 1. While the HiRes and HiRes120 s-over groups are very similar the HiRes120 s-on group was a little younger and hence that much less mature in terms of ability to undertake testing. All children were fitted on the basis of Neural Response Imaging thresholds [Firzst, 2005]; the responses confirmed by careful behavioural assessment and verified using free-field audiometry. Clinical SoundWave® software was used for all fittings. The automatic T-level option was used where thresholds were set at 10% of the most comfortable, M-level. In s.over group no changes were made to either hardware or psychophysical levels when changing from Hires to Hires120. All subjects used the same PSP [Advanced Bionics, 200x], body worn processor and T and M-levels.

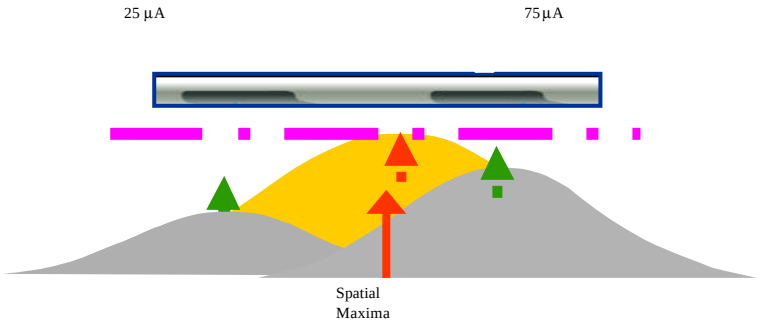

Figure 1: The basis of HiRes120. Current is delivered simultaneously on adjacent electrode contacts. The electrical fields combine, the centroid being steered in the space between the contacts depending on the proportion of current applied to either contact.

	Group Size	Age months (yrs)	Device use months
HiRes	6	59.3 (3.4)	31.7

HiRes120 x-over	6	53.7 (4.5)	25.6
HiRes120 s-on	5	30.2 (2.5)	2.5

Table 1

The standard test battery used to monitor speech and language development at the University La Sapienza includes: Listening Progress Profile (LPP), Discrimination Bi-Trochee Polysyllabic (BTP) word Pest, Perceptive Ability Test (TAP), an Italian adaptation of GASP, Bisyllabic word recognition and phonetically balanced bisyllabic words in closed and open-set. These various test measures have been described in previous publications [Bosco, 2004]. Given that young children are being studied measures were presented by experienced clinicians using live-voice. Analysis has been focused on determining performance against a variety of levels: detection, identification, recognition and comprehension [Erber, 1982]. Additional measures of speech perception included the ASSE [Govaerts, 2006] where pairs of carefully processed consonants are presented in a sequence containing an odd one out. This method may be applied to very young children and reveal differences in spectral information processing. Spectral differences have been mapped to the bandpass filters comprising the 16 HiRes channels. To complement these measures structured interviews, MAIS (Robbins, 1991 and Prise (Kishon-Rabin, 2005) questionnaires were conducted with parents. The interviews addressed both sound perception and production and importantly for HiRes120 also considered musical abilities.

Results

In figure 2 the three groups are compared in terms of their performance across the categories of performance.

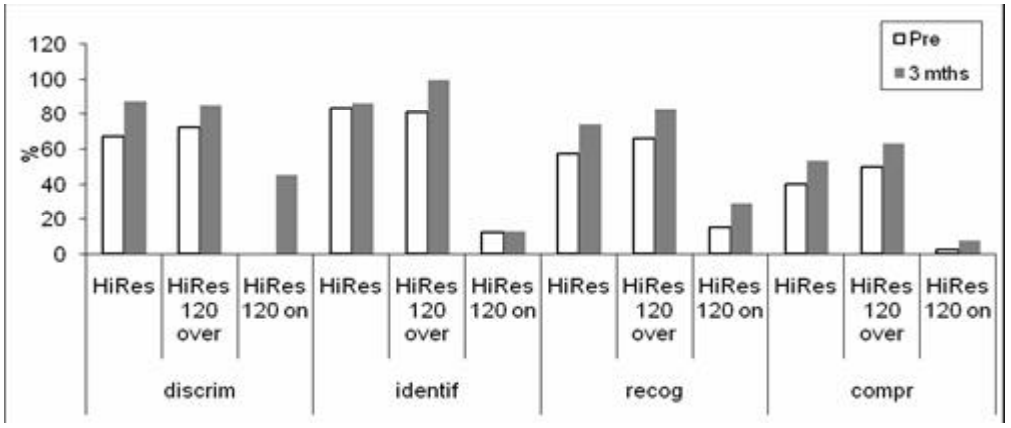

Figure 2: Comparisons of HiRes, HiRes120 x-over and HiRes120 s-on groups across the categories of discrimination, identification, recognition and comprehension. The HiRes and HiRes120 x-over groups are similar, the latter showing slightly stronger results. The HiRes120 s-on group is younger, shows lower scores but much stronger improvements than the other groups in the discrimination category.

The pairs of bars show performance for pre- and three months of use conditions. The HiRes and HiRes120 s-over groups are quire similar. However, group mean scores for HiRes120 s-over are higher for the identification, recognition and comprehension categories. It is worth noting that the baseline scores for the HiRes120 s-over group are a little higher than the HiRes group. The HiRes120 s-on group being less mature show substantially lower scores that the other two groups. This is true for both pre-implantation and after three months of HiRes120 use. However, highly encouraging improvements may already be seen, for example the discrimination score improvement from zero to 45% is much stronger than the corresponding changes seen for the other two groups.

In figure 3 ASSE identification scores for the HiRes120 x-over group are shown in comparison to the HiRes group. While group improvement on HiRes is not seen at three months there is a clear improvement with HiRes120.

Figure 3: ASSE identification scores at pre- and three months for the HiRes and HiRes120 x-over groups showing a much stronger improvement for the HiRes120 group

In the structured interviews HiRes120 was reported to be associated with a number of positive speech perception related factors. An increased attention span was found as well as improved ability to differentially perceive loudness and pitch. Better comprehension of speech was highlighted, particularly for noisy listening situations. Interestingly, a greater attention to rhythm and melody were also suggested. Complementing this observation was an improved intonation. Overall speech production quality and intelligibility were reported to be better with HiRes120, particularly for the production of synthetic sounds. These findings were complemented by reports of HiRes120 supporting incidental learning of nursery rhymes, short songs and poems.

Discussion and Conclusions

Theory suggests that HiRes120 should lead to improved spectral information and to this information being most useful in cases of high neural survival, i.e. children with short duration of auditory deprivation. While these three month results are only an early indication of performance, they are nonetheless quite positive. There are signs of improved discrimination suggesting better use of spectral information. Reports of improved comprehension in noise and music perception are also in line with the theory. Further work is required to monitor performance over time, particularly for the younger HiRes120 son group.

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