Speech perception and subjective benefit in paediatric C40+ users after the upgrade to Fine Structure Processing (FSP)

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Introduction

The amount of speech information available to patients with cochlear implants (CIs) is reduced by the limitations of current CI systems, which are characterised by (a) an insufficient number of effective channels imposed by the design and placement of the electrode, leading to poor frequency resolution; (b) a deficiency in the representation of the fine structure of the input signals and (c) too coarse a representation of the fundamental frequencies that are required to interpret complex sounds (Wilson et al, 2008). Recent advances in developments with cochlear implant systems have opened new listening possibilities for cochlear implant users. One of the advances is combined Electric Acoustic Stimulation (EAS) of the auditory system for persons with functional hearing in low frequencies. Using EAS, fine structure information is presented without modification in the low-frequency range (thus compensating for limitation (b)) and this fine structure information is likely to include F0 (thus compensating for limitation (c)). There are numerous studies which proved the benefit of EAS (Lorens et al. 2008; Skarzynski et al 2009)

In order to transfer the benefits of EAS to patients without low frequency hearing, the Fine Structure Coding Strategy (FSP) was developed by MED-EL. The FSP strategy therefore is designed to provide improved frequency coding in the apical channels of the cochlear implant. This is achieved by providing a temporal code for frequency which is derived from zero-crossings in the band-pass filter output signals on these channels. Details on the FSP strategy can be found in Arnoldner et al. (2007). The recent release of the MAESTRO 3.0 fitting software allowed for backward compatibility, which allows users of COMBI 40+ previous generation implant utilising the CIS+ coding strategy, to be fitted with the new generation audio processor – OPUS 2, using FSP or HDCIS strategies. The CIS+ strategy is a further development of the CIS strategy (Wilson et al, 1991) in that it uses the Hilbert transform for envelope detection. The HDCIS strategy is similar in concept to the CIS+ strategy and it is available in the OPUS 2 behind-the-ear speech processor. Currently, there are no published papers reporting outcomes with FSP when implemented using the COMBI 40+ cochlear implant, probably because the MAESTRO 3 software allowing for backwards compatibility has only recently been released. Also, there are no papers outlining outcomes in children. As the number of children implanted with COMBI 40+ worldwide is substantial, it is important to investigate whether they, too, are able to take advantage of the new technology. This study aimed to assess the objective and subjective performance of children with long-term experience with the C40+ cochlear implant system, who have now received an upgrade to the OPUS 2 using FSP and HDCIS.

Methods

Sixty children, who had more than 3.5 years device experience with the TEMPO+ speech processor using CIS+ coding, were upgraded to the OPUS 2 audio processor and were fitted and tested with the HDCIS strategy (Interval I). After 3 months, they were fitted with the FSP coding strategy (Interval II) and tested with all strategies (FSP, HDCIS, CIS+). After a further 3 months, they were further assessed on all three strategies and chose their take-home strategy (Interval III). The children were all prelingually deafened: 51 were congenitally deaf and the other 9 had an onset of hearing loss during the prelingual period. Aetiologies were as follows: unknown (25), genetic (17), maternal rubella (5), toxoplasmosis (2), prematurity (2), Ototoxic medication (2), anoxia (1), septicaemia (1), meningitis (1), diabetes mellitus (1), head injury (1), Usher's syndrome (1) and Waardenburg's syndrome (1). The average age at cochlear implantation was 3.8 years (1.5 – 9.5), the average time of device use was 6.3 years (3.9 – 8.4) and the average at age at upgrade was 10.0 years (5.9 – 15.7).

The children were tested using the AAST (Adaptive Auditory Speech Test) in quiet and in noise at each test interval. The Adaptive Auditory Speech Test (AAST) was developed by Frans Coninx (iFAP, Sölingen, Germany) for speech recognition threshold estimation in children over 3 years of age. The test is based on an adaptive, close set procedure implemented as an interactive PC game in multiple choice format with 6 alternatives. During the “HearingTreat” Remediation of Hearing Loss - MARIE CURIE ACTIONS project, the test was adapted into Polish and age-dependent normative data for speech in quiet and in noise were collected.

The children also completed visual analogue scales questioning satisfaction, when listening to speech and to a pop song. The VAS scale for satisfaction required the child to mark on a 20 cm scale whether the strategy was “bad”, “average” or “good”, with smiley faces to assist the child in decision making.

For AAST data analysis two-way repeated measures ANOVA was used to look for an interaction effect between strategy and interval. As there were only 10 subjects with complete VAS data sets, analysis for an interaction effect across strategies and intervals could not be performed. Instead, a one-way ANOVA was performed (for subjects who had complete data sets) to uncover any relationships between the coding strategies when presented with speech and music stimuli at Intervals II and III. Post-hoc pairwise comparisons between strategies were performed with the Holm-Sidak Test.

Results

Results for the AAST test in quiet and in noise are shown in Figures 1a and 1b. Across all three strategies at Intervals II and III, results for speech in quiet showed significance for interval (p=0.037) and strategy (p<0.001). Analysis for an effect of strategy shows significant differences across strategies: CIS versus FSP (p<0.001), CIS versus HDCIS (p<0.001), and HDCIS versus FSP (p=0.033). Results for speech in noise showed significance for strategy (p=0.005). Post-hoc analyses showed a statistically significant difference for CIS versus FSP (p=0.005), and CIS versus HDCIS (p=0.005).

Results for the VAS Satisfaction rating are found in Figure 2. No significant differences between strategies (p=0.653) were found for speech stimuli at Interval II, but a significant effect was found for Interval III (p<0.001). Post-hoc analyses showed significant differences in speech stimuli at Interval III for all pairwise strategy comparisons i.e., FSP versus CIS+ (p<0.001), HDCIS versus CIS+ (p<0.001), and FSP versus HDCIS (p=0.048). For music stimuli at Interval II revealed significant differences between strategies (p=0.016). Post-hoc tests found significant differences for HDCIS versus CIS+ (p=0.010), and FSP versus CIS+ (p=0.023). Results for music stimuli at Interval III are also significant for strategy (p<0.001). Post-hoc testing showed significant differences for HDCIS versus CIS+ (p=0.002), and FSP versus CIS+ (p<0.001)

Discussion

Our results demonstrate a significant improvement in speech perception with the FSP and the HDCIS strategy in the OPUS 2 processor when compared with the CIS+ strategy in the TEMPO + processor. In addition, speech recognition results obtained in quiet show a significant advantage for FSP over HDCIS. VAS for satisfaction with the speech stimuli did not show a significant strategy effect at Interval II. However, at Interval III there was a significant benefit for FSP over both HDCIS and CIS+ and for HDCIS over CIS+. Using the music stimuli, there was a significant advantage for FSP and HDCIS over CIS+. Finally, all children chose to go home with the FSP strategy, which in our opinion further demonstrates the benefit children perceive with this strategy.

What is particularly encouraging is the consistency of our results with previous FSP study in adults (Arnoldner et al. 2007, Riss et al. 2008), considering our sample consisted of children, as children tend to be particularly difficult to assess using objective and subjective measures. Despite these challenges, we selected an appropriate speech test measure that was able to replicate speech tests scores and benefit for FSP, as found in adults.

Conclusions

Development of new technologies especially in the field of speech processors and coding strategies has proved to be not only beneficial for new cochlear implant candidates but also for users of the previous generation of implants.

Acknowledgements

The authors would like to thank Ms. Ilona Anderson, Dr. Peter Nopp and Dr. Edda Amann for assistance with writing this paper.

References

Arnoldner C., Riss, D., Brunner, M., et al. (2007). Speech and music perception with the new fine structure speech coding strategy: preliminary results. *Acta Oto-Laryngol*, 127(12), 1298-303.

Lorens A, Polak, M, Piotrowska A, Skarzyński H: Outcomes of Treatment of Partial Deafness with Cochlear Implantation: A DUET Study. *The Laryngoscope* 2008;11892):288-294.

Riss, D., Arnoldner C., Reiß, S., et al. (2008). 1-year results using the Opus speech processor with the fine structure speech coding strategy. *Acta Oto-Laryngol*, DOI: 10.1080/00016480802552485

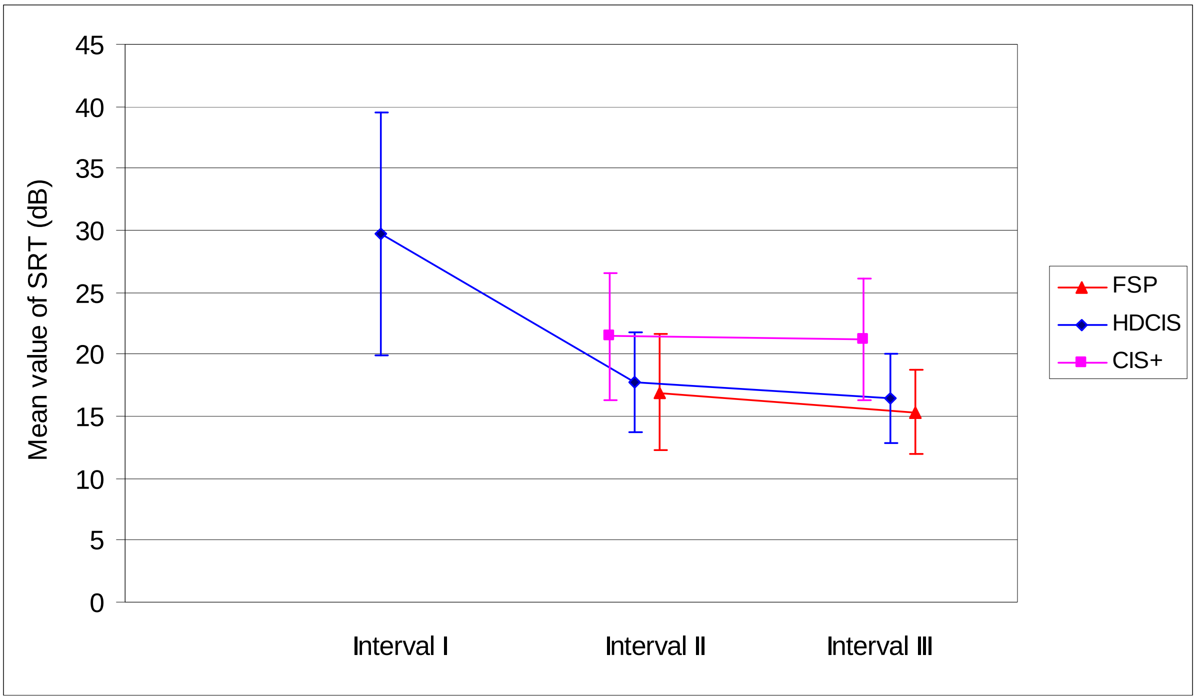
Skarzyński H., Lorens A., Piotrowska A., Podskarbi-Fayette R., Results of partial deafness cochlear implantation (PDCI) using various electrode designs. *Audiol Neurootol*. 2009;14 Suppl 1:39-45.

Wilson, B. S., Finley, C. C., Lawson, D. T., et al. (1991). Better speech recognition with cochlear implants. *Nature*, 352 (6332): 236-238.

Wilson BS, Dorman MF: Cochlear implants: a remarkable past and a brilliant future. *Hear Res* 2008; 242:3-21.

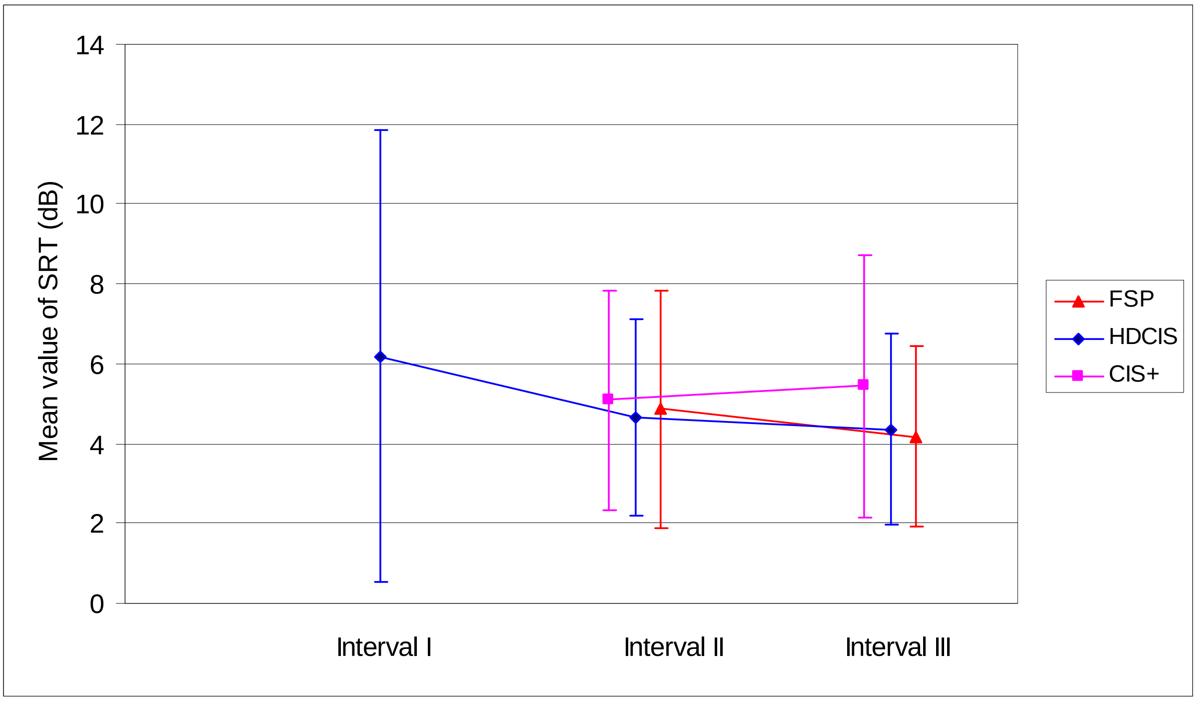
Figure 1: Results for the (a) AAST test in quiet and (b) the AAST test in noise, as a function of interval.

a)



45
40
35
30
25
20
15
10
5
0
Mean value of SRT (dB)
Interval I
Interval II
Interval III
FSP
HDCIS
CIS+

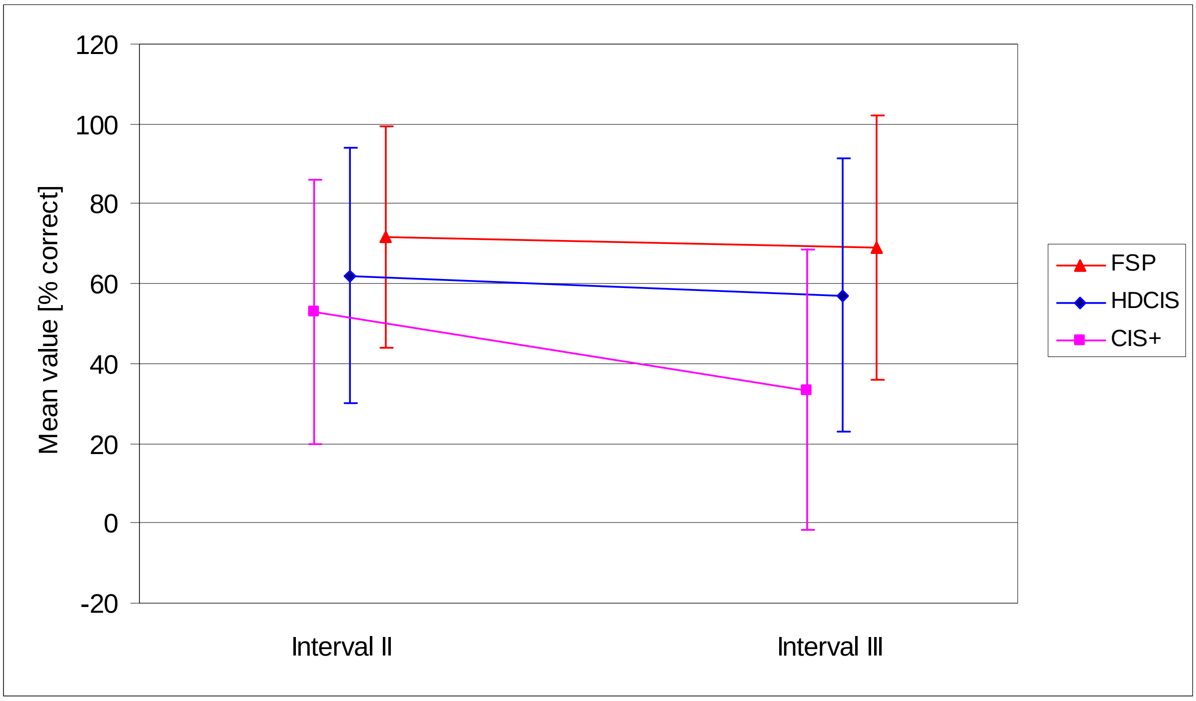
b)



14
12
10
8
6
4
2
0
Mean value of SRT (dB)
Interval I
Interval II
Interval III
FSP
HDCIS
CIS+

Figure 2: Results for the Satisfaction scaling using (a) the speech stimuli, and (b) the music stimuli.

a)



b)