Influences of syllabic compression on speech evoked potentials in Cochlear Implant users.

Torsten Wohlberedt[(1)], Frank Digeser[(1)], Horst Hessel[(2)], Ulrich Hoppe[(1)]
[(1)] ENT Clinic University of Erlangen
[(2)] Cochlear GmbH, Hanover

Background

Fitting of Cochlear Implants is usually based upon subjective statements of the patients about their auditory perception. Cortical Auditory Evoked Potentials (CAEP) are a well known method to get information about auditory perception without any cooperation of the subject. (Agung et al., 2006; Hyde, 1997; Jones et al., 1998; Korczak et al., 2005; Näätänen and Picton, 1987) In the past several studies have shown, that it is possible to elicit CAEP in cochlear implant users (Hoppe et al., 2001; Hoth 1998; Groenen et al., 2001). This paper describes speech evoked CAEP in cochlear implant listeners in association with a used acoustic pre-processing, the syllabic compression. (McDermott 2002) In particular, the influence of syllabic compression was investigated for two consonant-vowel-syllables differing in the voicing of the consonant.

Methods

CAEP were recorded from ten cochlear implant listeners provided with a nucleus freedom implant. A sine burst and the natural syllables /ta/ and /da/ were used as stimuli for the CI implanted group, without and with activated syllabic compression. Additionally, CAEP to the same speech and tone stimuli were derived in five normal hearing subjects serving as a reference group. All stimuli were presented at 60 dB SPL.

Results

The following significances are listed in Table 1. Figure 1 and 2 illustrate the findings as box-whisker charts. Therefore the left side shows the results for the CI implanted group and the right side shows the results for the normal hearing group. The middle line of each box shows the median of the pooled data and the lower and upper lines indicates the lower and upper quartile. Figure 1 shows the latencies of the N1 waves (upper plot) and of the P2 waves (lower plot). Figure 2 displays the belonging amplitudes.

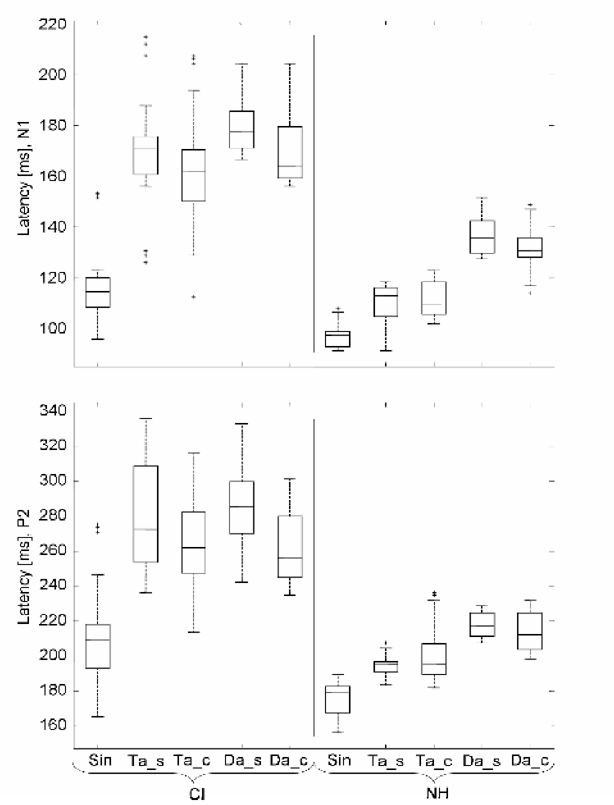

Figure 1. Shown are the N1 latencies (upper plot) and the P2 latencies (lower plot) of the potentials obtained from CI implanted listeners and from normal hearing subjects (NH).

Result 1) In all subjects CAEP could be reliably recorded and a clear N1-P2 complex was observed. In the CI group N1 and P2 latencies are significantly longer than those of the normal hearing group. While N1 amplitudes differ not significantly between the two groups, P2 amplitude is decreased in the cochlear implant group.

Result 2) In all subjects the sine burst elicits earlier N1 and P2 components and larger N1 amplitudes than the spoken syllables.

Result 3) The speech stimulus /ta/ elicits earlier N1 and P2 waves than the stimulus /da/ in both groups.

Result 4) When a syllabic compression is used latencies of both N1 and P2 and N1 – P2 interpeak amplitude decrease.

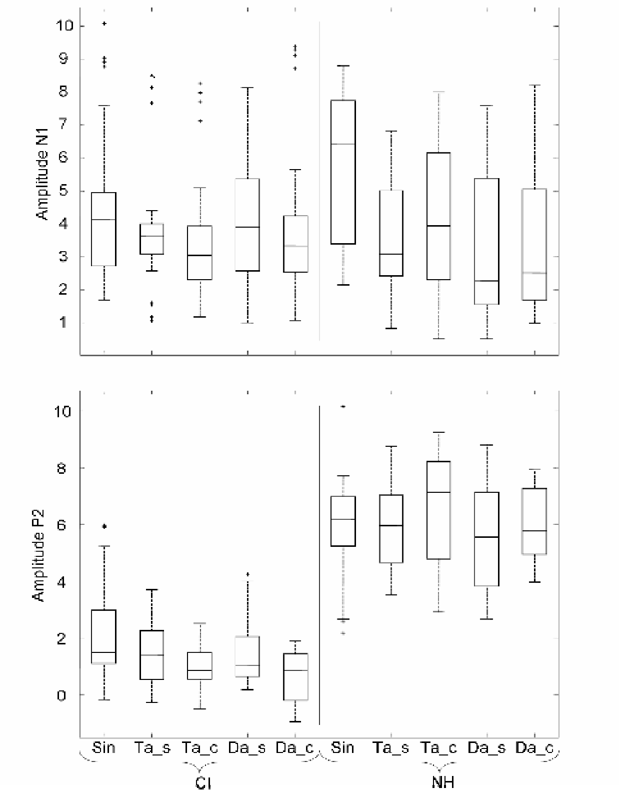

Figure 2. Shown are the N1 amplitudes (upper plot) and the P2 amplitudes (lower plot) of the potentials obtained from CI implanted listeners and from normal hearing subjects (NH).

Discussion

Result 1) An observation of occurring activation artefacts showed that the delay caused by the processors processing time lies in the range between 11ms to 13 ms. This delay correlates with the longer latencies observed by the responses evoked by the sine burst, but it can't explain the much bigger differences found when the syllabic stimuli were presented. Furthermore the reason for this could be an effect of different perceived loudness, caused by the difference of how the nerve is stimulated. Maybe the presented stimuli were perceived on different gages even though the presented level was the same. But because of the small differences in N1 amplitude between the two groups, this is an unlikely explanation. Furthermore the reason can be a missing activation during the consonant part of the syllables, resulting from a stimulus level, which is lower than activation thresholds defined as map parameters. This can be examined by simulating the implant activation in respect to specific parameter of the map, used by the subject during stimulation. The results of such simulations are electrodograms, which for one subject are shown in figures 3, the simulation without syllabic compression and figure 4, the simulation with used syllabic compression. In these figures the whole activation for all 22 electrodes of the electrode array is shown. Electrode 22 is the electrode which represents the lowest frequency band and electrode 1 is the electrode for the frequency band including the highest possible frequencies. The length of each line indicates the energy of activation.

In both figures it can be seen, that the consonant yields to an activation, so the differences in N1 and P2 latency between the two groups can not be an effect of missing stimulation.

We assume that cortical processes are responsible for the found delay.

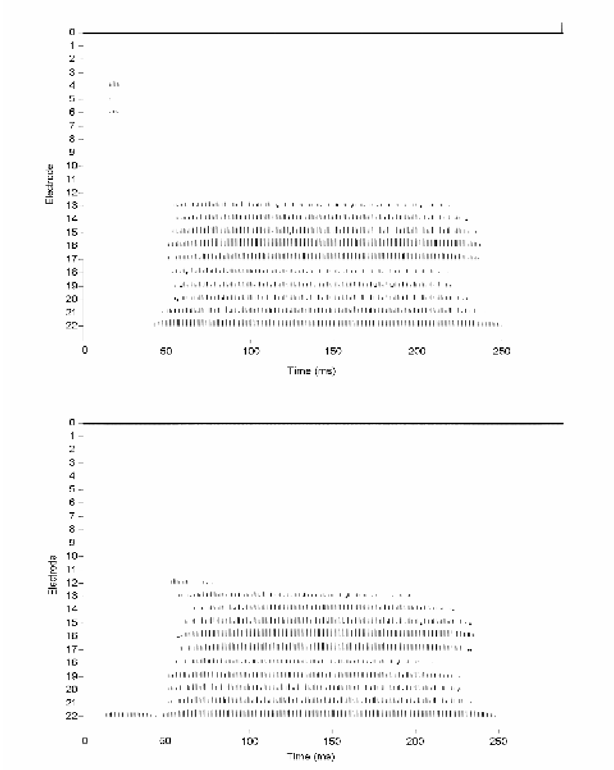

Figure 3. Shown are the electrodograms of subject S4 evoked by the syllable /ta/ (upper plot) and by the syllyble /da/ (lower plot) while the standard setting was used.

Result 2) The sine burst was on the onset and offset manipulated with a cosine ramp, to avoid spectral splatter. But anyhow the electrodograms showed spread activation over eleven electrodes, while after a few milliseconds only three electrodes were active. This spread activation yields to the earlier waves and the bigger amplitudes.

Result 3) The shorter N1 and P2 latencies in this case can be explained by the different time-frequency properties of the voiced and unvoiced consonants of the two stimuli, respectively. These differences yield to different CI activation patterns, shown in figure 3. The consonant part of the stimuli /da/ only activates one electrode nearest the apex. The consonant of the syllable /ta/ activates 3 electrodes more basal instead. The amount of activated electrodes and the place of activation yields to the observed shorter latencies.

Result 4) This finding can again be explained with the electrodograms in figure 4. A syllabic compression yields to an activation of additional electrodes and it raises the energy of each activated electrode. This again yields to summation effects and to shorter N1 and P2 latencies.

Conclusions

In summary it can be said that CAEP can be reliably recorded on CI users and a syllabic compression yields to significant changes in CAEP. These changes can be explained by a more spread activation along the electrode array as a result of the enhanced perceived level. The study demonstrates that speech evoked CAEP are a good candidate for objective evaluation of acoustic pre-processing algorithms. Furthermore, the study indicates different speech processing in CI listeners and in normal hearing listeners.

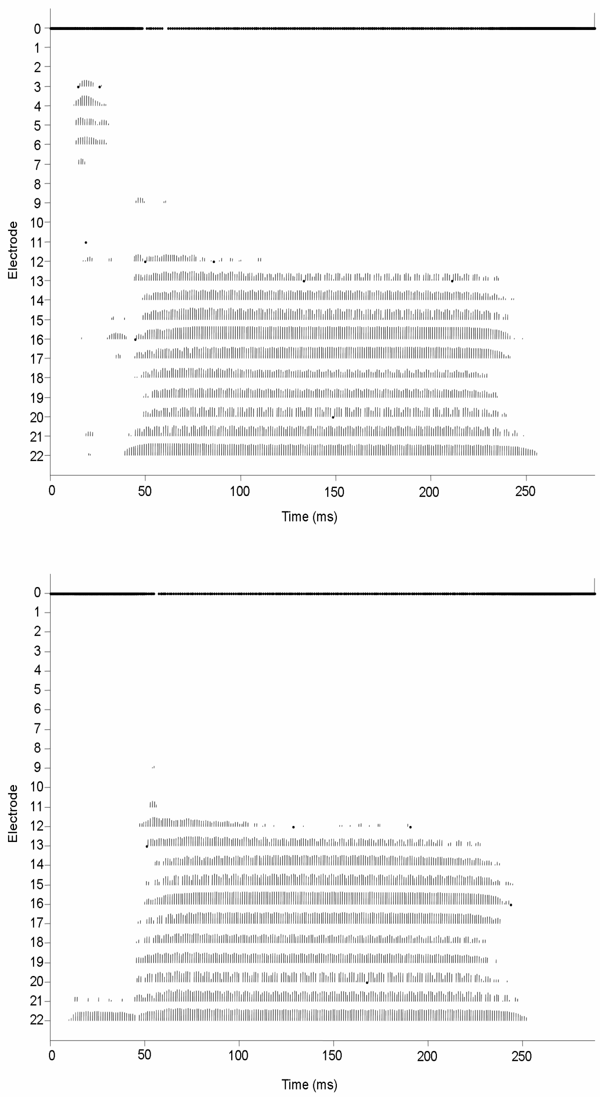

Figure 4. Shown are the electrodograms of subject S4 evoked by the stimulus /ta/ (upper plot) and by the stimulus /da/ (lower plot) while the syllabic compression was active

Significance values for differences in latencies and amplitudes inside of the four tested stimulus pairs

Stimulus pair	CI implanted subjects: N1 latency	N1 amplitude	P2 latency	P2 amplitude	N1 – P2 amplitude	Normal hearing subjects: N1 latency	N1 amplitude	P2 latency	P2 amplitude	N1 – P2 amplitude
Sin / Ta_s	$p < 1.7e-7$	$p < 4.5e-4$	$p < 8e-7$	$p < 7.6e-4$	$p < 8.6e-5$	$p < 2.9e-4$	$p < 1.9e-4$	$p < 8.8e-5$	$p < 0.88$	$p < 0.021$
Sin / Da_s	$p < 1.7e-7$	$p < 1.5e-4$	$p < 1.7e-7$	$p < 4.7e-5$	$p < 1.e-6$	$p < 8.8e-5$	$p < 1e-4$	$p < 8.8e-5$	$p < 0.85$	$p < 0.002$
Ta_c / Ta_s	$p < 0.007$	$p < 0.002$	$p < 0.018$	$p < 0.0015$	$p < 9.9e-4$	$p < 0.41$	$p < 9e-3$	$p < 0.17$	$p < 0.041$	$p < 0.019$
Da_c / Da_s	$p < 3.6e-7$	$p < 0.17$	$p < 1.7e-5$	$p < 0.003$	$p < 1.9e-5$	$p < 3.9e-4$	$p < 0.3$	$p < 2.9e-3$	$p < 0.12$	$p < 0.12$
Ta_s / Da_s	$p < 0.003$	$p < 0.38$	$p < 0.78$	$p < 0.37$	$p < 0.39$	$p < 8.8e-5$	$p < 0.66$	$p < 8.9e-5$	$p < 0.52$	$p < 0.83$
Ta_c / Da_c	$p < 0.046$	$p < 0.0042$	$p < 0.865$	$p < 0.28$	$p < 0.295$	$p < 8.6e-5$	$p < 0.08$	$p < 2.2e-4$	$p < 0.12$	$p < 0.044$

Table 1, shown are the significance values obtained via the paired both sided wilcoxon signed-rank test to show the differences in N1 and P2 latency and in N1, P2 and N1 – P2 inter peak amplitude, for both between the sine burst and the stimulus Ta_s and between the sine burst and the stimulus Da_s. Further for the pairs of stimuli Ta_c and Ta_s, Da_c and Da_s, Ta_s and Da_s and between Ta_c and Da_c

References

Agung K, Purdy SC, McMahon CM, Newall P (2006). The Use of Cortical Auditory Evoked Potentials to Evaluate Neural Encoding of Speech Sounds in Adults. J Am Acad Audiol, 17, 559 -572

Groenen PAP, Beynon AJB, Snik AFM, van den Broek P (2001). Speech-evoked cortical potentials and speech recognition in cochlear implant users. Scand Audiol, 30, 31 - 40

Hoppe U, Rosanowski F, Iro H, Eysholdt U (2001). Loudness perception and late auditory evoked potentials in adult cochlear implant users. Scand Audiol, 30, 119 – 125

Hoth S (1998). Die Messung später elektrischer evozierter Potentiale des auditorischen Systems bei CI-Patienten. HNO, 46, 739 – 747

Hyde M (1997). The N1 Response and Its Applications. Audiol Neurootol, 2, 281 – 307

Jones SJ, Longe O, Vaz Pato M (1998). Auditory evoked potentials to abrupt pitch and timbre change of complex tones: electrophysiological evidence of ‘streaming’? Electroencephalography and clinical Neurophysiology, 108, 131 - 142

Korczak PA, Kurtzberg D, Stappels DR (2005). Effects of Sensorineural Hearing Loss and Personal Hearing Aids on Cortical Event-Related Potential and Behavioral Measures of Speech-Sound Processing. Ear & Hearing, 26, 165 – 185

McDermott HJ, Henshall KR, McKay, CM (2002). Benefits of Syllabic Input Compression for Users of Coclear Implants. J Am Acad Audiol, 13, 14-24

Näätänen R, Picton T (1987). The N1 wave of the human electric and magnetic response to sound: A review and analysis of the component structure. Psychophysiology, 24, 375-425