Music Perception with the Double Electrode Mode in the Nucleus Freedom CI System

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Keywords: Cochlear implant, music perception, simultaneous stimulation

Introduction

The Nucleus Freedom CI System offers the possibility to stimulate two adjacent electrodes simultaneously, resulting in 22 real and 21 virtual electrodes, and a total of 43 channels. In Figure 1, the current fields of single and dual electrode stimulation are shown schematically. It was shown by Busby and Plant (2005) that the stimulation of the virtual electrodes evokes a different pitch perception than the stimulation of the corresponding single electrodes alone. However, it was not clear if a processing strategy that is based on virtual channels will give better representation of the signal, especially in terms of pitch perception. The aim of the present study was therefore to test music perception of a 43 channel versus the standard 22 channel map.

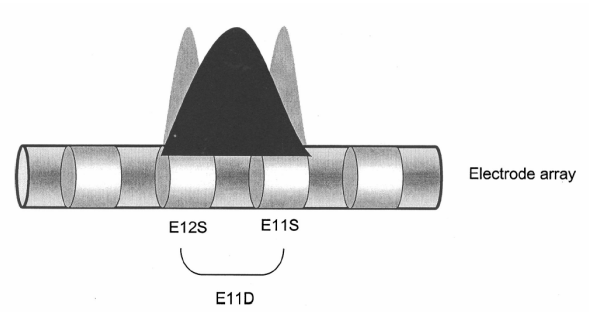


Figure 1. Schematic illustrating single and dual electrode stimulation. The dual electrode in this example, E11D, is produced by electrically coupling the two single electrodes, E12S and E11S. The two gray areas from single bands represent the hypothesized current field from single electrode stimulation and the single black area represents the hypothesized current field from dual electrode stimulation. Figure courtesy Peter Busby.

Method

First, the procedure after Busby and Plant (2005) was carried out, that is, pitch ranking tasks were done on electrode level. The goal of this was to identify subjects who were able to perceive a different pitch in correct order through virtual stimulation. Next, a 43 channel map was programmed on a research processor, and the subjects had to listen to this map at home for one to two weeks, to compare the quality of music to the quality when using the standard map. After this, pitch ranking of complex tones, an instrument recognition test, and a spectral resolution test were carried out in the lab for the 43 channel and the standard maps.

Subjects

Four adult CI users took part in the study. They had all suffered from a progressive severe hearing loss before implantation. The table below gives an overview.

No	Year of Birth	Sex	Implanted at Test Time Since [months]	Standard Map at Test Time		Musical Education
				Maxima/Rate (ACE)	IIDR [dB]	
01	1931	F	42	10/1200	30-65	4
02	1964	M	13	10/720	30-70	4
03	1968	M	25	10/1200	25-65	6
04	1959	F	44	10/1200	35-65	4-5

Musical Education:
1 Active professional musician before deafness
2 Professional training, but infrequent performing before deafness
3 Non-professional training, frequent playing before deafness
4 Non-professional training, occasional playing before deafness
5 Moderate training, no practice, basic knowledge of musical terms
6 Little training, no practice, little experience in listening to music
7 No training, no practice, no experience in listening to music

Experiment I: Pitch ranking on electrode level

Single and double electrodes were stimulated, and stimulus parameters such as comfort levels and stimulation rate were taken from subject's standard map. The Nucleus Implant Communicator (NIC) tool was used for this, and the testing procedure was implemented in Matlab. Pitch ranking was always done using three electrodes at a time (two real and the virtual electrode in between); each pair was presented 20 times. Before the test, loudness was balanced for all electrode triplets. The following electrodes were tested: 21-20, 18-17, 15-14, 12-11, 9-8, 6-5, 3-2 (or 4-3 for those subjects were electrode 2 was switched off).

Figure 2 shows that all subjects were able to rank most electrodes correctly; only on the basal side, some (real and virtual) electrodes could not be resolved for two of the subjects.

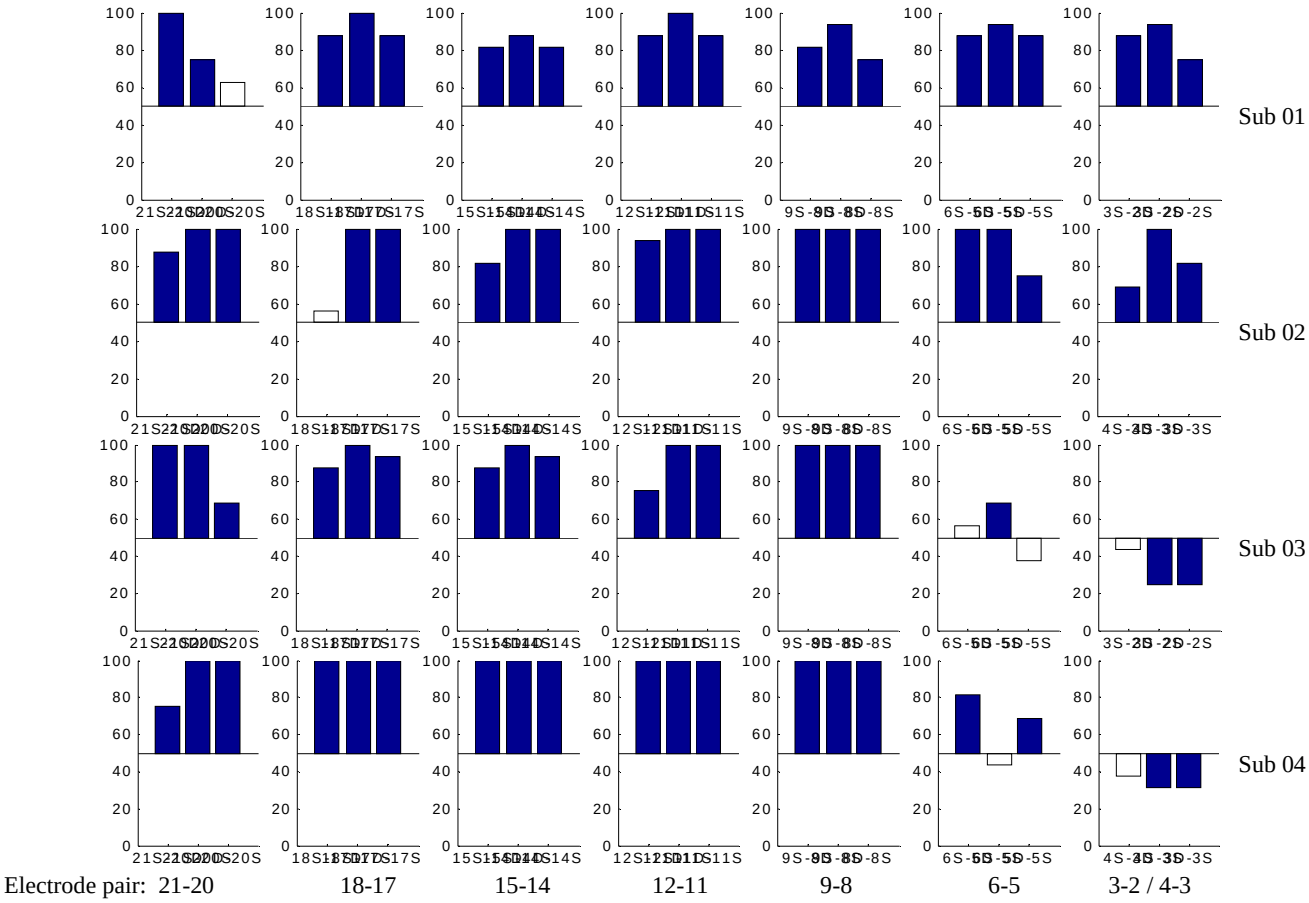


Figure 2: Pitch ranking results for the four subjects. Each row of graphs represents a different subject. The three bars in each graph show the percent pitch ranking for the three comparisons in each set of electrodes. The electrode pairs (in expected order of higher pitch over lower) are shown on the lower axis. Bars above the 50% line show that the pitch ranking was in the expected order and bars below the 50% line show a pitch reversal. Pitch ranks above 65% or below 35% were significantly above chance and are shown as filled bars. Unfilled bars indicate a nonsignificant pitch rank.

Experiment II: Music tests on coding strategy level

The Nucleus research processor L34 was programmed with three maps. The current standard served as a baseline. The number of maxima was limited by the maximal total rate, 14400 Hz. Three subjects had a rate per electrode of 1200 Hz. For those subjects, a 43 channel map with the same rate as the standard map would only allow 12 maxima. To be able to use more maxima, a second 43 channel map was created at a rate of 720 Hz for these subjects, and 20 maxima were used. The table below gives a summary for the three maps:

Map	Rate per Electrode	Maxima	Total Rate
Standard Map	Standard Rate	from Map	from Map
43 channel A	Standard Rate	12	12 x Standard Rate
43 channel B	Standard ≤ 720 Hz: Standard Rate Standard > 720 Hz: 720 Hz	20 20	20 x Standard Rate 14400

For the home test, a music CD with 13 music pieces was supplied to the CI user. The CD consisted of music pieces from each of 5 musical styles (classic, pop, jazz, vocal, solo instrument). The subjects had to indicate on a response sheet which of the three maps they liked best for which piece of music, and which the liked least. The subjects were allowed to set the music playback system at home in any way they like. A side effect of the home test was that the subjects were trained a little to the new maps, which was a good basis for the music tests in the lab.

With the three maps (for some subjects only with two maps, standard against 43 channels with 20 maxima), the following music tests were carried out in the lab:

1. Complex pitch ranking test with semisynthetic clarinet tones. The tone pairs had a distance of 1, 3 or 6 semitones, in 3 frequency ranges (octaves 3/4/5). Stimuli were presented randomly, and levels were roved. Each pair was repeated 8 times, and the question was, which tone is higher in pitch.

2. Instrument (timbre) recognition test. 8 instruments had to be identified by pictures, all playing the same melody in their corresponding frequency range. Each instrument was repeated 3 times.

3. Spectral resolution test after Henry et al. (2005). Rippled noise stimuli were presented in a 3AFC task, and the number of ripples per octave was adapted.

The results of the home test are shown in Figure 3; the standard map was clearly preferred

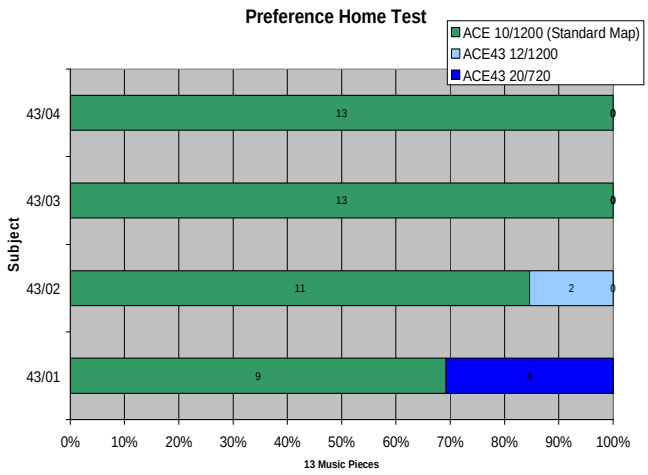


Figure 3: Preference of music pieces in the home test. It is shown for each subject how many pieces were liked best with which map. The standard map was subjectively preferred for most music pieces. Subjects 01 and 02 commented that the difference between the maps was quite small for some music pieces.

The results of the lab music tests are shown in Figures 4 to 6. Overall, no clear advantage of the 43 channel maps was observed.

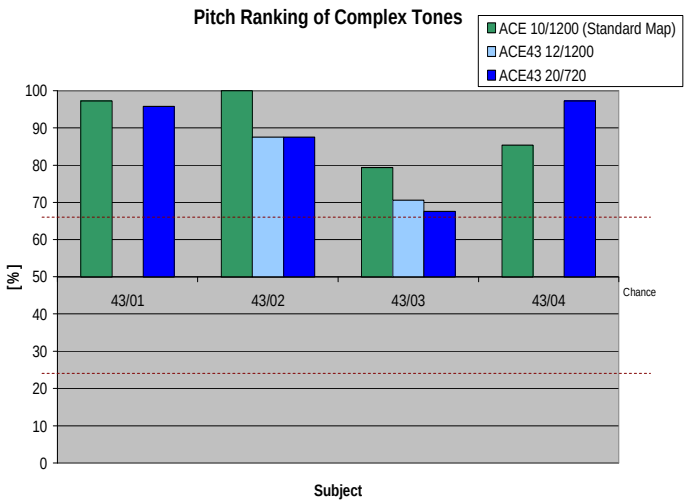


Figure 4: Pitch ranking of complex tones. Only for subject 04, the 43 channel map gave significant better results. For subjects 02 and 03, the results were significantly better with the standard map.

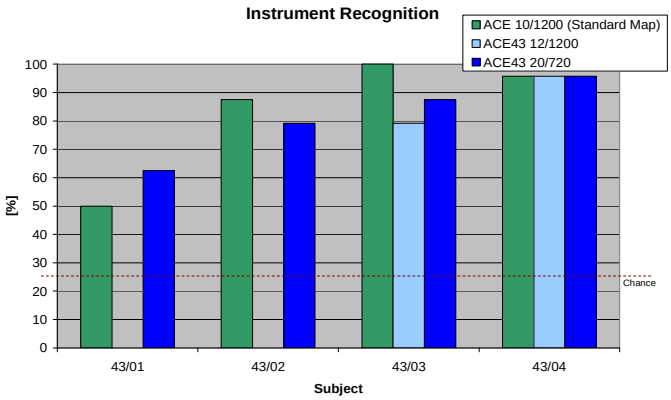
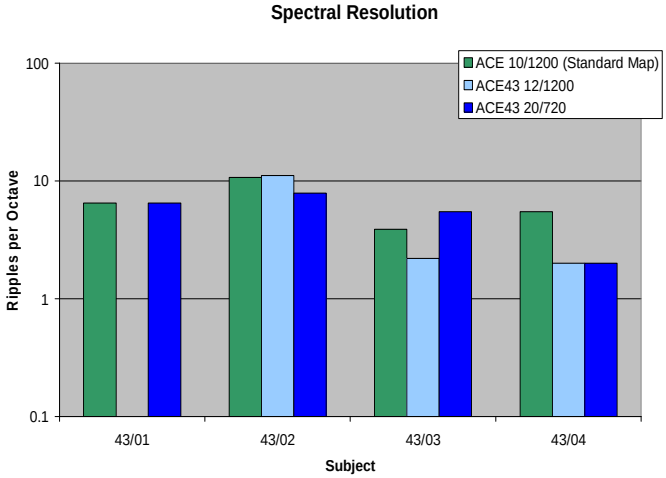


Figure 5: Instrument recognition test. For subject 01, recognition was slightly better with the 43 channel map, but subjects 02 and 03 performed worse with this map. Subject 04 reached the ceiling.



N:T. *N:T.: Not tested*

Figure 6: Spectral resolution test. The only significant difference could be observed with subject 04; the resolvable number of ripples per octave was lower with the 43 channel maps.

Conclusions

With the 43 channel map, pitch and timbre perception were not significantly improved, compared to the standard 22 channel map. Also, the standard map was subjectively preferred. Thus, even if pitch ranking on electrode level was mostly correct with virtual electrodes, a coding strategy based on this principle did not seem to give much benefit.

References

Busby, P. A., and Plant, K. L. (**2005**). "Dual electrode stimulation using the nucleus CI24RE cochlear implant: electrode impedance and pitch ranking studies," Ear & Hearing **26**(5), 504-511.

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This work was supported by research grant 320000-110043 from the Swiss National Science Foundation.