The Acoustic Change Complex in Cochlear Implant Listeners

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1. Introduction

Cochlear implant (CI) users have a wide range of speech perception performance. Currently, there is no clear understanding on exactly how auditory, cognitive and perceptual abilities contribute to this variation. The Acoustic Change Complex (ACC) is a potential tool for measuring these abilities at the level of the auditory cortex.

1.1. The Acoustic Change Complex (ACC)

The ACC is a cortical evoked potential that consists of a P1-N1-P2 response that occurs after a change within an auditory stimulus and is measured using Electroencephalography (EEG). It can be used to help understand how auditory detection and speech processing occurs in the auditory cortex and has been successfully measured in CI listeners using a narrow range of speech/speech-like stimuli[1-3].

The aim of this study is to see if the ACC can be recorded in CI users with a broad range of stimuli, and whether or not it can be used to predict their speech processing abilities.

2. Methods

2.1. Stimuli

Four fricatives (/s/, /sh/, /v/, /z/) and four vowels (/a/, /aw/, /u/, /ii/) were recorded by a female native English speaker. Portions of each sound and a portion of silence, 300-400 ms long, were then concatenated into sequences including every possible pair (56 pairs in both orders). These concatenated sequences were then processed to be flat in terms of pitch and amplitude. The random order of pair is used to avoid any N1 suppression from a repetition effect. This stimulus design means that the ACC response can be looked at as an average for all possible pairs, for individual pairs (e.g. s-z, or aw-v, etc.) or for pair types (e.g. fricative-fricative, vowel-fricative, silence-sound, etc.).

2.2. Participants

Thirteen post-lingually deafened CI adults (age range 23-72) took part. Participants had either one or two CIs.

2.3. Procedure

The ACC at each change of stimuli was recorded using EEG with 64 cap electrodes and 7 external electrodes. The nose was used as a reference. Participants listened to the stimuli via a loudspeaker with their CIs kept on their normal comfortable setting, whilst watching a cartoon without audio to keep them entertained. Each participant also completed an IEEE sentence task, a consonant identification task and a vowel identification task.

3. Results

When the ACC response is viewed as a grand mean across all participants and stimuli pairs it is clearly contaminated with implant artefact (Figure 2, A). However, when the trials from silence to sound are removed the effect of the artefact is greatly reduced. Furthermore, when we look at the mean of the remaining trials for each individual, subject 8 has a clear artefact contamination (Figure 4). When looking at pair types separately, subject 3 also shows artefact contamination for vowel-fricative and fricative-vowel trials. When we remove these two subjects and all trials involving silence, the grand mean is much cleaner (Figure 2, B).
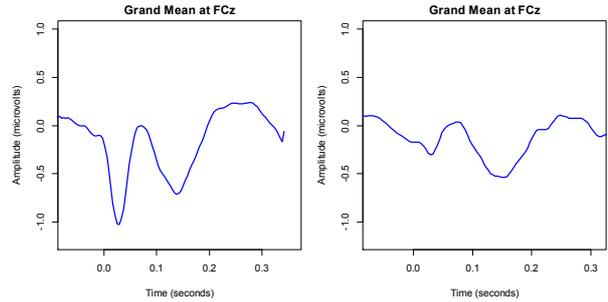

Figure 1: *Grand mean of all trials and participants at FCz (A) minus participants with a large CI artefact and all trials from silence to sound and sound to silence (B).*
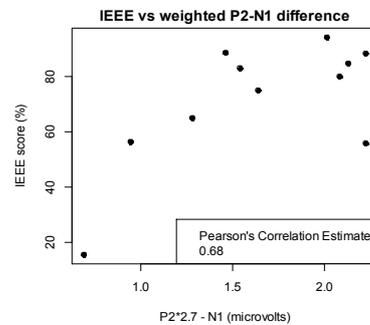

Figure 4: *Scatter plot of IEEE score vs. weighted P2-N1 magnitude.*

The behavioural results show a wide range of performance across the group; particularly for the IEEE sentence task (mean = 75.2 %, range = 78.80 %), and all three tasks were highly correlated (lowest correlation = 0.915). For these reasons, we used the IEEE scores as the measure of speech perception performance for further analysis.

When looking at the individual responses for the different pair types, the responses are not clean enough to measure a reliable P1, N1 or P2 magnitude. Therefore, for these data, we used the responses averaged across all pairs (not including trials with silence) for each individual to see how the ACC relates to the behavioural results. We used multiple regression as a guide, and it showed that the N1 and the P2 magnitude are predictive of the IEEE scores. In particular the P2 magnitude was almost three times as large as the N1. In order to take into account the small P2 magnitude and the large observed N1, the P2 was weighted and the difference between this and the N1 was used to view the relationship between the ACC and IEEE scores. This shows a significant correlation (Pearson's Correlation Estimate = 0.68, p = 0.02) between the weighted P2-N1 difference and the IEEE scores (Figure 4).

4. Discussion and Conclusions

1. The ACC can be elicited with fricatives and vowels in CI users.

2. A continuous chain of stimuli reduces the effect of the CI artefact for ACC measurement for most CI users.

3. The difference between the N1 and P2 magnitude, with the P2 magnitude carrying more weight,

predicts speech perception abilities in CI users when using these stimuli.

These results are indicating the ACC as a potential objective measure of speech perception. This could prove useful for assessing the abilities of children and other patients who are not able to perform behavioural testing. Furthermore, by using this technique (concatenated chains) many trials can be measured in a short period of time, which is very important for ERP measurement in this population.

A larger group of CI users would give more power to multiple regression models and in particular, more low performing CI users would give us a fuller picture of the pattern seen in these data. However, these results are promising for the use of the ACC as a predictive measure of speech perception.

5. References

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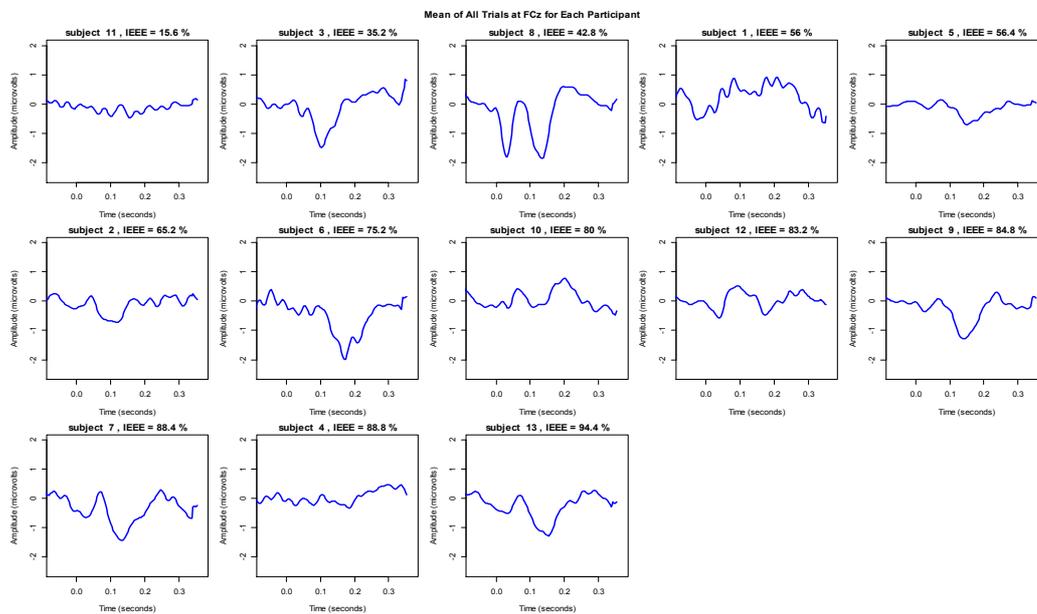
Figure 3: *Mean responses for all trials apart from silence to sounds and sound to silence for all participants in order of IEEE score.*