Auditory evoked potentials from deaf individuals using cochlear implants

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Abstract
Auditory evoked potentials (AEPs) provide an objective measure of auditory cortical function. However AEPs from cochlear implant (CI) users are contaminated by the electrical artefact produced by the device. Independent component analysis (ICA) has been reported to attenuate the CI artefact and recover the AEPs. Here the effects of CI artefact attenuation on the quality of the AEPs were systematically investigated. Electroencephalography data were recorded from 10 adult CI users presented with auditory and visual stimuli. The CI artefact attenuation rate was calculated to investigate the ICA sensitivity and AEP quality was determined based on a signal-to-noise ratio (SNR) measure. ICA specificity was evaluated with a hybrid simulation approach and by comparing visual evoked potentials (VEPs) from CI users with and without CI artefact attenuation. The results showed that AEPs could be recovered from all CI users, indicating high specificity. Moreover, AEP amplitudes were highly correlated with age, demonstrating that individual differences were well preserved. CI users with a high AEP SNR were characterised by a significantly shorter duration of deafness compared to low AEP SNR individuals. The results confirm that ICA is a valid tool to attenuate CI artefact, allowing the objective, non-invasive study of auditory cortex rehabilitation in CI users.

Method
Eighteen post-lingually deafened cochlear implant (CI) users (16 females, mean age 59.8±13.9 years) and 18 age and gender matched normal hearing (NH) participants (20 females, mean age 55.2±12.9 years) took part in the study. All CI users were implanted unilaterally except one. All participants were right-handed and had no history of neurological or psychiatric disorders and normal or corrected to normal vision.

Stimuli
Auditory stimuli were taken from a pool of 270 environmental sounds of natural objects previously rated in a norming study (Schneider, R. et al. 2009). Sounds (24 kHZ, 16-bit) were played for 800 ms via loudspeakers positioned at an azimuth of 45° in front of the participant. Sounds were presented at a comfortable level. Visual stimuli were taken from a pool of 52039 depicted images of natural objects from the same norming study. The stimuli were presented centrally for 800 ms, with the visual stimulus being an angle of 5° vertically and horizontally. In visual trials (see Experimental design and Task) stimuli included a grey square which was presented centrally for 800 ms, enabling a contrast of at least 20%. Stimuli were presented using a 23 inch monitor and screen background was black at all times. All stimuli were presented using Presentation 6.0 software (Neurobehavioral Systems).

Experimental design and Task
An audio-visual semantic priming paradigm (Schneider, D., Debener, S., Rapp, W., Tholen, D. (2007)).

Participants were seated in an electrically shielded, sound attenuated and dimly lit booth. EEG data were recorded from 68 channels using a high-input impedance amplifier system (Neuroscan, Compumedics, El Paso, USA) and a customized electrode cap (Easycap, Herrsching, Germany). (Hine & Debener, S. 2009, Hin, Thornton, Davis & Debener, 2008) The cap was fitted with 66 AC/NC electrode sites in an equidistant layout. Two additional electrodes were placed below the eyes. EEGs from some electrodes (mean 3±3 electrodes, range 2–6 electrodes) could not be recorded due to the location of parts of the CI device (i.e., transmitter-receiver coil, cable to processor). Data were recorded with a sampling rate of 1000 Hz using the nose-tip as reference, and were analogue filtered between 0.1 and 300 Hz. Electrode impedances were maintained below 50 kΩ prior to data acquisition.

Data Processing
EEG data were processed using custom scripts and EEGLAB (https://sccn.ucsd.edu/eeglab). Data reduction using the MNEKIT (Mleinik, MA) environment. Independent components (ICs) representing eye-blinks and electrocorticography (EG) artefacts were semi-automatically identified using OVARMAP (Vida, et al., 2000) and were removed by back projection of the remaining ICs. These ICs are labelled as conventional artefacts. The properties of the remaining ICs were visually inspected to identify those representing the CI artefact.

The AEPs were obtained by time-domain averaging. AEP amplitude and latency analyses were performed for a frontal central electrode where the grand average amplitudes were largest for both groups (approximately FCz). AEP peak amplitudes and latencies were determined using a semi-automatic procedure as implemented in peaksdet.net (www.hilker.cc/peaksdet.html).

Results
ICA sensitivity — there was not a single CI user dataset where AEPs were not buried by large electrical CI artefact.

ICA Specificity: CI artefact attenuation rate — substantial individual differences were observed in the amount of attenuation, largely reflecting strong individual differences in the magnitude of the artefact.

Conclusion
These results complement previous studies showing that ICA can successfully attenuate the electrical CI artefact in EEG data from CI users, thus allowing the recovery of reliable AEPs. ICA has demonstrated good sensitivity and specificity. In addition, the recovered AEPs from CI users reflected the expected correlations with aging and clinical parameters. The development of tools to automatically identify and select components representing electrical artefact remains an important goal for the future. Overcoming this limitation would help to establish multiple-channel AEPs in response to speech and natural sounds for the objective monitoring of auditory cortical rehabilitation after implantation. The complementary use of objective measurements of auditory cortex function may help to shape rehabilitation programs and thus improve the quality of life from CI users.

References

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