Template based CI artifact attenuation to measure Electrically Evoked Auditory Steady State Responses

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Electrically evoked auditory steady-state responses (EASSRs) are currently being investigated for objective cochlear implant fitting. EASSRs can be detected in the electro-encephalogram (EEG) in response to periodic (modulated) pulse trains presented through the cochlear implant. However, the EEG is obscured by electrical artifacts caused by (1) the implant's radiofrequency link, and (2) the electrical stimulation pulses. These CI artifacts can also be present at the response frequency. Their characteristics are subject and stimulus dependent, and vary depending on the stimulation mode. In monopolar mode, the CI artifacts are larger in amplitude and longer in duration than in bipolar mode.

CI artifacts can be removed by blanking which applies a linear interpolation over the duration of CI artifact. This method only works if the CI artifact duration is shorter than the interpulse interval, which is the case for low-rate (<<500 pulses per second, pps) pulse trains, or stimulation in bipolar mode. We recently showed that the CI artifact can also be removed at contralateral recording electrodes for stimulation at 500 pps in monopolar mode. At ipsilateral recording electrodes or for stimulation at higher pulse rates, a different method is needed to remove the CI artifacts. We therefore developed a new method based on template subtraction.

EASSRs were measured in eight subjects at subthreshold stimulation intensities and for stimulation at 500 pps in monopolar mode. Based on these recordings we constructed CI artifact templates for each subject in each recording electrode.

We evaluated the method in two steps, by first verifying that the CI artifacts can be removed in the absence of a neural response and second verifying that artificially generated responses can be reliably reconstructed. (1) We subtracted a template, constructed based on a subthreshold recording, from the same recording. If the CI artifacts are correctly removed, we expect the detection rate to be about 5%, which is the significance level of the response detection test. With blanking, the obtained median false alarm rate was 69% (IQR=47%) which reduced to 4%(IQR=11%) after template subtraction. (2) We added a simulated response, with varying amplitude and phase, to the subthreshold recordings used above. The same template as in (1) was subtracted from the data. If the CI artifacts were correctly removed, we expect to obtain the correct amplitude and phase. The percentage of channels with correct amplitudes (POCA) was calculated for each subject. The median POCA over all subjects was 29% (IQR=44%) with blanking, and increased to 94% (IQR=12%) after template subtraction.

Based on artificially generated data with recorded CI artifacts and simulated neural responses, we conclude that template subtraction is a promising method for CI artifact attenuation.

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