Towards closed-loop transcranial Electrical Stimulation

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Title:

Towards closed-loop transcranial Electrical Stimulation: a comparison of methods for real time tES-EEG artefact removal using a phantom head model

Authors & affiliations:

Siddharth Kohli, School of Electrical and Electronic Engineering, University of Manchester, siddharth.kohli@postgrad.manchester.ac.uk
Sammy Krachunov, Department of Chemical Engineering and Biotechnology, University of Cambridge, sm2205@cam.ac.uk
Alexander J. Casson, School of Electrical and Electronic Engineering, University of Manchester, alex.casson@manchester.ac.uk

Abstract: (Your abstract must use Normal style and must fit in this box. Your abstract should be no longer than 300 words. The box will ‘expand’ over 2 pages as you add text/diagrams into it.)

Preparation of Your Abstract
1. The title should be as brief as possible but long enough to indicate clearly the nature of the study. Capitalise the first letter of the first word ONLY (place names excluded). No full stop at the end.
2. Abstracts should state briefly and clearly the purpose, methods, results and conclusions of the work.

Introduction: Clearly state the purpose of the abstract
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Results: Present your results in a logical sequence in text, tables and illustrations
Discussion: Emphasize new and important aspects of the study and conclusions that are drawn from them

Introduction:

To date most studies investigating electroencephalogram (EEG) with transcranial alternating current stimulation (tACS) have been limited to comparing EEG before/after stimulation. Although methods are now available for tACS-artefact removal, to develop closed-loop stimulation protocols these algorithms need to be reformed to operate in real-time. We present a comparison of existing artefact removal procedures implemented in real-time to determine their suitability for use in closed-loop stimulations, adjusting the stimulation parameters to match ongoing EEG activity.

Methods:

A head phantom model was created using gelatine and moulded into a scalp shape (Fig. 1). Inside this electrodes were placed to input EEG data which simulates EEG activity to electrodes placed on its surface. EEG data during an alpha-task (eyes open/close) and a visual ERP-task (face/non-face) was simulated during tACS stimulation. This provides known EEG components under the tACS-artefact allowing verification of the performance of artefact-removal algorithms. The tACS-artefact was removed using NeuroPrax’s built-in algorithm and using 2 other methods: Superposition using Moving Averages (SMA) [1] and Adaptive-Filtering (AF).

Results:

All methods successfully reconstructed EEG, alpha-bursts/ERPs were easily identified (Fig. 2). The NeuroPrax has the highest accuracy with correlation coefficient of 0.99, whereas SMA and AF have coefficients of 0.91 and 0.81 respectively.
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**Figure 1** - Left: System Design. Right: Model with EEG/tACS electrodes.

**Figure 2** – Left: Alpha test results sham and tACS. Right: Average ERPs for face/non-face stimuli.

SMA has the longest convergence time before true EEG is observed. NeuroPrax has no delay/convergence at the start of stimulation, but it requires training prior to recording. All of the methods present artefacts at the end of the stimulation, these are shortest for AF (Fig 3).
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**Figure 3 – Convergence/filter artefacts at the start/end of stimulation.**

**Conclusion:**
Though NeuroPrax provides the best results, when considering closed-loop stimulation it is suboptimal since it requires training each time stimulation settings are changed. Both AF/SMA are independent to stimulation parameters overcoming this. AF has a smaller convergence time to collect valid EEG, but SMA has better performance after the start-up transient has finished.

**References**


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