Towards closed-loop transcranial Electrical Stimulation

DOI:

[10.1016/j.brs.2017.01.370](https://doi.org/10.1016/j.brs.2017.01.370)

Document Version

Accepted author manuscript

[Link to publication record in Manchester Research Explorer](#)

Citation for published version (APA):

Kohli, S., Krachunov, S., & Casson, A. (2017). *Towards closed-loop transcranial Electrical Stimulation: a comparison of methods for real time tES-EEG artefact removal using a phantom head model*. 467–468. Abstract from 2nd International Brain Stimulation Conference, Barcelona, Spain. <https://doi.org/10.1016/j.brs.2017.01.370>

Citing this paper

Please note that where the full-text provided on Manchester Research Explorer is the Author Accepted Manuscript or Proof version this may differ from the final Published version. If citing, it is advised that you check and use the publisher's definitive version.

General rights

Copyright and moral rights for the publications made accessible in the Research Explorer are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Takedown policy

If you believe that this document breaches copyright please refer to the University of Manchester's Takedown Procedures [<http://man.ac.uk/04Y6Bo>] or contact uml.scholarlycommunications@manchester.ac.uk providing relevant details, so we can investigate your claim.

Important notes:

Do **NOT** write outside the grey boxes. Any text or images outside the boxes **will** be deleted.

Do **NOT** alter the structure of this form. Simply enter your information into the boxes. The form will be automatically processed – if you alter its structure your submission will not be processed correctly.

Do not include keywords – you can add them when you submit the abstract online.

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

Methods: Describe your selection of observations or experimental subjects clearly

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.

Important notes:

Do **NOT** write outside the grey boxes. Any text or images outside the boxes **will** be deleted.

Do **NOT** alter the structure of this form. Simply enter your information into the boxes. The form will be automatically processed – if you alter its structure your submission will not be processed correctly.

Do not include keywords – you can add them when you submit the abstract online.

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).

Important notes:

Do **NOT** write outside the grey boxes. Any text or images outside the boxes **will** be deleted.

Do **NOT** alter the structure of this form. Simply enter your information into the boxes. The form will be automatically processed – if you alter its structure your submission will not be processed correctly.

Do not include keywords – you can add them when you submit the abstract online.

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

- [1] S. Kohli and A. Casson, "Removal of transcranial a.c. current stimulation artifact from simultaneous EEG recordings by superposition of moving averages," in *37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Milan, 2015.

Acknowledgements

The authors would like to thank Rogue Resolutions Ltd for providing equipment (the Neuroconn DC stimulator plus and the NeuroPrax) and support for this study.