Unsupervised online self-calibration of error-related potentials for brain-machine interfaces

Dear Editors of PLoS One,

We recently finished a new study on the self-calibration of brain-computer interfaces for reaching tasks, and we would like the paper to be taken into consideration by your journal as a Research Article. We believe the proposed approach opens the door to more usable BCIs, and we hope that you will also appreciate its novelty for the community. We kindly suggest as academic Editors Dr. Mikhail A. Lebedev, and Dr. Gerwin Schalk. Please find below a referenced summary of the work.

The field of brain-computer interfaces (BCI) has witnessed largely successful applications in different contexts such as the control of assistive devices or communication restoration [1]. However, their impact has been limited to in-lab applications due to intrinsic limitations of the technology. Mainly, these systems rely on an initial calibration phase that needs to be frequently repeated due to the changing nature of the brain signals.

Despite their successful results, these methods aim at reducing the calibration phase rather than completely removing it. On the other hand, free-calibration BCIs remain scarce as they need to achieve BCI control together with a real-time, transparent, and unsupervised calibration executed in parallel. For these approaches, the main idea is to exploit redundancy or task constraints to limit the possible space of brain signals decoders to a tractable one. In non-invasive BCI, Kindermans et al. have thoroughly shown that such kind of BCI is feasible for P300 spellers [2,3]. In this approach, the self-calibration speller exploits the multiple repetitions of P300 stimuli and context information of the task, namely word constraints and grammar rules. Similarly, Orsborn et al. have also achieved a control from scratch for reaching tasks in an invasive brain-machine interface [4,5]. They initialized the decoder to a random behavior and updated it during online control using the assumption that the targets should only be reached following a straight line.

This paper presents a self-calibration BCI framework for reaching tasks, exemplified using error-related potentials. The proposed method exploits task constraints to simultaneously calibrate the decoder and control the device, by using a robust likelihood function and an ad-hoc planner to cope with the large uncertainty resulting from the unknown task and decoder. The method has been evaluated in closed-loop online experiments with 8 users using a previously proposed BCI protocol for reaching tasks over a grid. The results show that it is possible to have a usable BCI control from the beginning of the experiment without any prior calibration. Furthermore, comparisons with simulations and previous results obtained using standard calibration hint that both the quality of recorded signals and the performance of the system were comparable to those obtained with a standard calibration approach.

Yours faithfully,

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References

[1] Millan JdR, Rupp R, Muller-Putz GR, Murray-Smith R, Giugliemma C, et al. (2010) Combining brain-computer interfaces and assistive technologies: state-of-the-art and challenges. Front Neurosci 4.

[2] Kindermans PJ, Verstraeten D, Schrauwen B (2012) A bayesian model for exploiting application constraints to enable unsupervised training of a P300-based BCI. PloS one 7: e33758.

[3] Kindermans PJ, Schreuder M, Schrauwen B, Muller KR, Tangermann M (2014) True zero-training brain-computer interfacing{an online study. PloS one 9:e102504.

[4] Orsborn A, Dangi S, Moorman H, Carmena J (2012) Closed-loop decoder adaptation on intermediate time-scales facilitates rapid bmi performance improvements independent of decoder initialization conditions. Neural Systems and Rehabilitation Engineering, IEEE Transactions on 20: 468-477.

[5] Orsborn A, Moorman H, Overduin SA, Shanechi MM, Dimitrov DF, et al. (2014) Closed-loop decoder adaptation shapes neural plasticity for skillful neuroprosthetic control. Neuron 82: 1380-1393.