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Unsupervised BCI Calibration as Possibility for Communication in CLIS Patients?

M. Spüler[1], W. Rosenstiel[1], M. Bogdan[1,2]

[1] *Wilhelm-Schickard-Institute for Computer Science, University of Tübingen, Sand 13, 72076 Tübingen, Germany*

[2] *Computer Engineering, University of Leipzig, Johannisgasse 26, 04103 Leipzig, Germany*

Correspondence: M. Spüler, Sand 13, 72076 Tübingen, Germany. spueler@informatik.uni-tuebingen.de

Abstract. In this paper we present first results that a Brain-Computer Interface (BCI) can be calibrated online in a completely unsupervised manner. Thereby it is possible to provide a user with contingent feedback without the need for any goal-directed action. Since the extinction of goal-directed thinking is the assumed cause, why there are no reports of successful BCI communication in patients suffering from complete locked-in syndrome (CLIS), we discuss if unsupervised calibration could be used to enable communication in those patients.

Keywords: Brain-Computer Interface (BCI), complete locked-in syndrome (CLIS), goal-directed thinking, unsupervised learning

1. Introduction

The main motivation for Brain-Computer Interface (BCI) research is to give paralyzed patients a new means for communication. Although BCI communication works for patients who have some remaining muscle-control, using other communication methods that utilize the remaining muscle control are more effective in most cases. Therefore, the use of BCI technology would be especially interesting for people suffering from complete locked-in syndrome (CLIS), who have no remaining muscle control. Despite the extensive research in this area, so far there are no reports of successful BCI communication in CLIS patients.

One reason that BCI did not work for CLIS patients yet, is the assumed extinction of goal-directed thinking [Kübler and Birbaumer, 2008]. Due to the CLIS, the patient lacks voluntarily motor control and thereby feedback. Since cognitive activity does not result in any feedback, the missing feedback might be responsible for the extinction of goal-directed thinking.

Disregarding the recent introduction of classical conditioning for BCI control, there are two approaches, how a person is enabled to control a BCI: (1) In the neurofeedback approach the user is given feedback of certain parameters of his brain activity and the user learns to voluntarily control his brain activity to alter the feedback. (2) In the supervised machine learning approach the computer learns to decode the user's brain activity. Therefore, a supervised calibration phase is needed in which certain instructions are given to the user which actions to perform or which stimuli to attend. To ensure that the machine learning is working properly, the user is required to voluntarily follow these instructions.

Taking under consideration the assumed extinction of goal-directed thinking in CLIS patients, both approaches do not work, because: (1) the patient is not able to voluntarily alter his brain activity and (2) the patient is not able to voluntarily follow any instructions and perform voluntary actions.

In this paper we show first results of a BCI based on code-modulated visual evoked potentials (c-VEPs) that can be calibrated with unsupervised machine learning and we discuss that an unsupervised BCI calibration may provide the user with contingent feedback without the need for the user to voluntarily alter his brain activity or follow any instructions.

2. Material and Methods

Based on our recent developments for improved classification [Spüler et al., 2012] in a c-VEP BCI and a method for unsupervised online adaptation [Spüler et al., 2012a], we developed a method that allows a completely unsupervised calibration of the c-VEP BCI. This method will be presented elsewhere in more detail. Although the c-VEP BCI can be used with 32 stimuli, only 2 stimuli were used during the unsupervised calibration.

To show that an unsupervised calibration is possible, the method was evaluated offline on data from 18 sessions (9 healthy subjects, 2 sessions each) with each session consisting of 640 trials. The first 64 trials were used for unsupervised calibration, while the remaining 576 trials were used for accuracy estimation.

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To show that the unsupervised calibration can also be used online, we performed an online study with 8 healthy subjects. The subjects were instructed to decide freely, which target to attend, but not to switch the target consistently every trial and not to attend one target for more than 5 consecutive trials.

3. Results

The offline analysis resulted in an average accuracy of 90.85% (± 12.58%), with only 2 sessions having an accuracy below 70% and 6 sessions having an accuracy of 100%. In the online study, the 8 subjects achieved an average accuracy of 85.06% (± 9.9%) and only 1 subject had an accuracy below 70%.

4. Discussion

With the offline analysis and the online study we have shown that an unsupervised calibration of a c-VEP BCI is possible and can be used online for BCI control. In this paper we do not concentrate on the methodology used for unsupervised calibration, but rather want to discuss the implications that an unsupervised calibration might have for communication in CLIS patients.

Arguably, the c-VEP BCI system with unsupervised calibration mentioned in this paper won't be useable by CLIS patients, since it depends on visual stimulation. But we have shown that an unsupervised calibration of a BCI is possible and enables BCI control without (1) the user voluntarily altering his brain activity and (2) without the user voluntarily following any instructions which target to attend. Thereby we are able to give the user feedback which stimulus he is (voluntarily or involuntarily) attending to without the need for any goal-directed action. Since the unsupervised calibration method is giving feedback during calibration, it can run continuously and without the need for an operator to start or stop the BCI or change any parameters. Therefore it would be possible to give the user contingent feedback 24 hours a day.

One could argue that this would be also possible with steady state visual stimulation without the need for unsupervised learning. But for this to work, the stimuli are needed and precise knowledge about the nature of the stimuli (i.e., the frequency of the steady state stimulation) and how they influence brain activity.

In theory, unsupervised learning could be used to calibrate BCIs without external stimulation just based on internal brain states, without any goal-directed action of the user. If such a calibration would be possible in a reliable way, CLIS patients could be provided with contingent feedback linked to some arbitrary internal brain state. Since missing contingent feedback is the assumed cause for the extinction of goal-directed thinking [Kübler and Birbaumer, 2008], regaining contingent feedback may reverse extinction. [Birbaumer et al., 2012] point out analogies between REM-sleep and CLIS, since both result in complete paralysis and missing voluntary behavior. But in contrast to REM-sleep, it is still unknown if voluntary behavior can return in CLIS patients.

Since the authors have a strong computer science background, but lack a solid psychological education, this paper aims at encouraging a discussion if unsupervised calibration might open new possibilities regarding communication in CLIS patients and if research in this direction should be pursued.

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