Effectiveness of Subject Specific Instruction on Mu-based Brain-Computer Interface Training

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Abstract—**Brain-computer interface (BCI) technology is a growing field, becoming a more viable aid for individuals who have lost voluntary motor control. The mu rhythm, a sensorimotor rhythm that is suppressed when one imagines motor activity (Event Related Desychronization [ERD]), has been particularly utilized in BCIs because of its potential for diverse applications. This study aimed to improve participants' BCI performance by giving them specific instructions for imagine motor behavior to improve their control over sustained mu power. Participants were provided with instructions that were either non-specific (NS), specific (SP), or participant specific (PS) to imagine motor behavior. The ability to control the strength of the mu rhythm was studied by using a simple feedback based paradigm and a novel BCI targeting game. The results showed that utilizing specific instructions for mu-based BCI systems can lead to decreased training time, increased BCI literacy, and enhanced control over mu-based BCI devices. These results suggest that instruction type can make mu-based BCI devices more accessible to individuals with impaired motor behavior.**

I. Introduction

A BCI is a device that bypasses normal neural output by translating neural activity into a control command for a computer or other external devices [1]. While many novel implementations of mu BCIs have been developed, little work has been conducted investigating how to improve the neural signal coming from participants. Corbit et al. suggested that specific instructions for imagined movement (ERD) and relaxation (event-related synchrony [ERS]) improve overall strength of mu rhythms [2]. Improved mu power was hypothesized to improve performance on a mu-based BCI device. However, it is important that sustained control over mu power rather than maximum strength of mu rhythm is attained to successfully operate a BCI device.

The current study examines the effect of participant instruction and how it influences BCI performance. By providing participants with specific, guided instruction we were able to evaluate how their performance compared to that of the control group. Bilateral mu power was calculated from two electrodes positioned over the left and right sensorimotor cortices and was compared to the participant's baseline value. We examined changes in mu power which corresponded to feedback displayed on the computer screen for the participant. Participant accuracy and control over mu-rhythms was tested using a targeting game developed in our laboratory. The objective was to move a cursor to a designated location on the screen. The time (sec) in which participants were able to keep the cursor within range of the target corresponded to their accuracy. As in the feedback trials, ERD and ERS were used to move the cursor left and right, respectively. Preliminary evidence showed a significant difference in control over mu power based on the type of instructions provided to the participant. Specific instructions, whether SP or PS, provide greater accuracy and control of mu-power. These data suggest that the success of an individual using a mu-based BCI device may depend on the type of instructions provided.

II. Methods

A. Participants

The study was approved by Lafayette College Institutional Review Board. Twenty-six undergraduate students (12 male and 14 female) were recruited for the study. All participants provided informed consent prior to the experiment.

Participants were randomly assigned to one of three groups (NS, SP and PS) and the corresponding mental imagery task that they were to perform during the experiment. All participants were e-mailed a survey prior to the experiment, asking them to provide basic demographic information. Those in the PS group were also asked to describe a hand-motor task they typical preform. They were asked to bring an object associated with the task into the lab. All objects were placed in front of the participant to aid in their imagination of the specific movement. Fig. 1 shows the setup of the experiment.

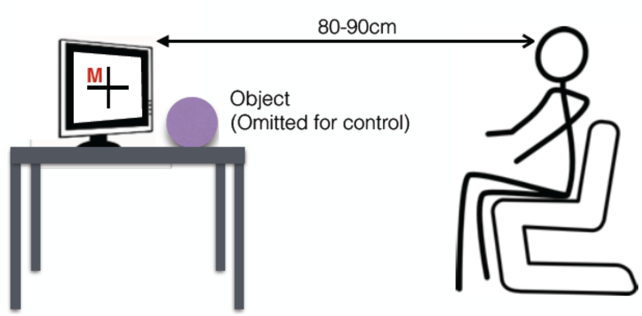

Fig. 1, Experimental setup for the study

B. The BCI system and the Mu-Rhythm Paradigm

EEG data were collected by using the g.HIamp (g.tec, Austria) data acquisition system at a sampling rate of 256 Hz via bipolar active electrodes attached at CP3-FC3, CPZ-FCZ, CP4-FC4, and FZ (ground), based on the International 10-20 system, on a g.tech EEG cap over the sensorimotor cortex. This signal processing sequence was adopted from a Simulink model created by g.tec [2].

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The mu-rhythm paradigm was used in the pre-experiment calibration and the feedback trial. The calibration was performed to determine the participant-specific weighting factor to be used in the feedback trial. Participants were asked to produce the power of their mu-rhythm based on the group they were assigned to. All participants were prompted to imagine either hand motor movement or relaxation by the presence of an M or R respectively on the computer monitor in front of them (Fig. 2a). When prompted, participants in the PS group were asked to think of a hand-motor activity they frequently preform and to imagine doing that movement repeatedly with both hands. Participants in the SP group were told to imagine using both hands to squeeze stress balls. Both PS and SP groups were asked to focus on their breathing during the relaxation task. The control group (NS) was given no specific instruction and was asked to imagine hand motor movement or relaxation when prompted to by the paradigm. A feedback bar (Fig. 2a), representing the strength of the mu-power, was provided to the user in real-time during the trials. The experimental procedure and signal processing were adopted from [2].

C. BCI Targeting Game Paradigm

Following the feedback trials, participants were instructed to play a game by applying the same mental imagery strategies to move a cursor (e.g. motor imagery-left; relaxation imagery-right) to an identified target. Participants need to correctly alternate between the two imagery tasks to move the cursor and hit the target, without being prompted on the type of imagery to employ. Nine possible target locations spanned the base of the screen (Fig. 2b), and were presented randomly. All nine targeted locations were presented once. After the initial presentation of all nine targets, the four least accurate positions were re-presented. Each participant completed the game twice. Before the second run the game was calibrated based on the four least accurate target positions, such that the farthest point reached during the first game was used to adjust the horizontal axis for the second game. The game ran for a maximum of 369s.

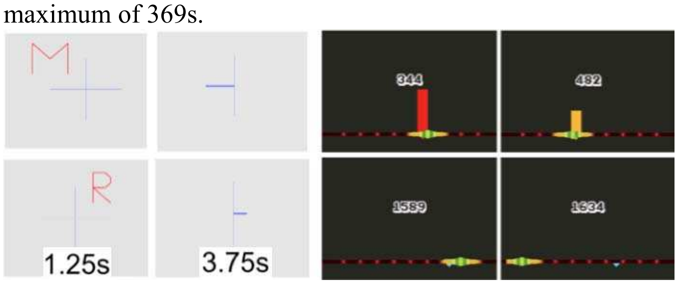

Fig. 2. (a) The user interface for the Mu-Rhythm Paradigm and (b) the BCI targeting game

III. Results

Data from the mu-rhythm paradigm and from the targeting game indicate that Instruction Type influences how successfully naive subjects can control a mu-based BCI device in a single session. There was a marginally significant ($p=.064$) three way interaction with maximum mu power values between condition x session x type of trial. Mu power was greatest during specific mental-imagery tasks; particularly when the imagery task was participant specific. Furthermore, participants who utilizing specific mental tasks showed better accuracy when their performance was assessed with the goal-oriented targeting game as shown in Fig. 3.

IV. Discussion

Instructions given to participants can affect the maximal mu-power a participant can generate. Specific instruction increases a participant's success at controlling a mu-based BCI device. The ability to generate a large maximum amount of mu-power is useful to illustrate the extent to which mu-rhythm ERD/ERS can be consciously evoked [3]. The BCI targeting game simulated the demands that would be made by an actual communication device and provided a way to assess a participant's ability to control their mu rhythm. Participants must alternate between mu-rhythm or relaxation to move and maintain the cursor at the given locations and to prevent over-, or undershooting, the location. Both of these factors are highly relevant to the development of a BCI communication device. Our data demonstrate that 100% success rate can be achieved in a single session using a mu-based BCI device.

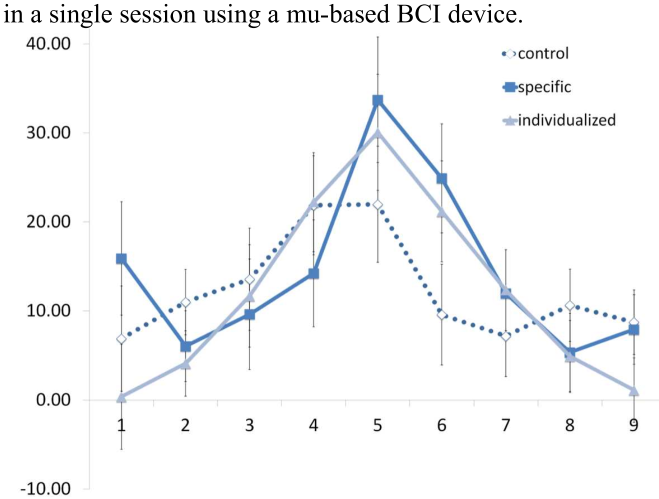

Fig. 3. Accuracy for hitting targets during the BCI game

Acknowledgement

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