P300-based Brain-Computer Interface Memory Game to Improve Motivation and Performance

C. Angeloni[2], D. Salter[3], V. Corbit[2], T. Lorence[3], Y-C. Yu[3], L.A. Gabel[1,2]
[1]Department of Psychology, [2]Neuroscience Program, [3]Department of Electrical and Computer Engineering
Lafayette College, Easton, PA 18042

***Abstract* — A brain-computer interface (BCI) relies on a classifier to determine a user's intent through the EEG signals. This classifier needs to be trained with a specific user prior to its usage. Since the effectiveness of a classifier is affected by the user's motivation during training, a memory game using the BCPy2000 platform has been developed for enhancing motivation and performance in using a traditional P300-based BCI system. A pilot study showed that this memory game is accomplishable by human subjects in a BCI system.**

I. Introduction

Brain-Computer Interface (BCI) technology was first described in 1964 by Dr. Grey Walter, but only within the last decade has BCI research rapidly expanded. BCI technology has been employed to improve communication in patients with amyotrophic lateral sclerosis, restore function to individuals with spinal cord injury, and enhancing performance in healthy users. The most widely used EEG-based BCI system utilizes an event-related potential, the P300 wave, as its primary control signal. The P300 wave is a positive deflection in the EEG which occurs 200 to 700 ms after the presentation of a rare, or oddball stimulus [1, 2]. This system has been applied to BCI spellers in which the user is instructed to select a target on an N x N matrix of characters. The matrix flashes in a random array of rows and columns as the subject is attending to the target character. The row and column which elicit the largest P300 responses, over many trials, is selected and the corresponding character is displayed on the screen. This system requires minimal training and calibration and allows for relatively fast on-line communication, making it one of the most widely used BCI platforms in clinical research and application.

However, variable performance has been reported in both healthy and patient populations, creating a need for optimization of P300-based systems. Reference [3] demonstrated that accuracy largely determines the effectiveness of a BCI system by affecting the time it takes to complete a sequence of characters. In a simulation, they show, under optimal working conditions, that a 15% decrease in accuracy (from 95% to 80%) creates a 70% increase in the time it takes to complete a 10-character sequence. A number of factors could contribute to these variable accuracy rates including, but not limited to, learning fatigue or changes in motivation when using the system for prolonged periods of time. Reference [4] demonstrated that poor performer's significantly improved performance when properly motivated to do so.

The goals of the current study were to first produce a reliable P300-based BCI system using modest resources and then to generate a memory game (i.e. Concentration) utilizing the same paradigm. This game was intended to enhance motivation and performance using a P300-based BCI system.

II. Methods

A. Subjects

Five undergraduate students from Lafayette College (four men and one female, ages 20-22) participated in this study which consisted of 5 sessions over 6 weeks. Users had no prior BCI experience. The study was approved by Lafayette College Institutional Review Board; each user gave informed consent.

B. Data Acquisition and Processing

A 20-electrode EEG cap following the international 10-20 standard system (Electro-Cap International Inc., Eaton, OH) and an 8-channel amplification system (EEG 100C, Biopac Systems Inc., Goleta, CA) was used. The 8 channels (C3, Cz, C4, T5, P3, Pz, P4, and T6) were referenced to the left earlobe, and grounded to right mastoid. EEG was bandpass filtered at 1.0-35 Hz and digitized at a rate of 200Hz (PCI-3036E, National Instruments Co., Austin, TX). Data collection was controlled using BCI2000 software system (Wadsworth Center, Albany, NY) which used stepwise linear discriminant (SWLD) analysis to accurately predict character selection with minimal subject training.

C. P300-speller

Users sat approximately 1.4m from a computer screen (19 in. diagonal), viewing a 6 x 6 matrix of characters flashing randomly by row and column. The participant was instructed to focus on the desired character and note the number of times it illuminated. 3 out of the 5 total sessions were dedicated to determining the efficacy of the BCI2000 speller. The first run of each session was used to derive the classification coefficients for the remainder of the experimental session. Each of these 3 sessions was composed of 7 to 14 runs and each run was composed of spelling a 5-letter word. These sessions were performed in copy-spelling mode, in which the target word is displayed on screen and the target letter is indicated in parenthesis at the end of the word [e.g. tale (t); tale is the target word, (t) is the target character during that run]. In the BCI2000 software, a SWLD function applied

978-1-4673-1142-7/12/$31.00 ©2012 IEEE

classification weights after each set of flashes (15 flash sequences at 125 ms ISI). The character with the greatest classification weight is then presented on screen just below the intended word to be spelled, after a 2.0 second delay. The next character is presented in parentheses at the end of the word and the user switched attention to the new character. This process is continued until all characters of the word served as the target. Three additional flash sequences (10, 8, and 5) were also examined for spelling accuracy across participants using either a newly established parameter at the start of a run, or appending a previously used parameter with a new run consisting of 15 sequences. All data were collected in this mode; the user was not given the option to correct mistakes and was instructed at the start of the session to continue until the run was complete.

D. User Specific Parameters

After an initial calibration session with 15 flash sequences, user-specific parameters were generated using the SWLD algorithm after the user spelled a 16 character phrase. The subsequent spelling sessions compared the use of an appended parameter (one 15-sequence run from the beginning of each session was added to the old parameter) to a new parameter (several 10-sequence runs from the current session were combined to create a new parameter). In addition to varying the parameter, the number of flash sequences was also varied between 10, 8, and 5 sequences.

E. Generation of P300-memory game on BCPy2000

A 3 x 4 matrix of face cards were generated using BCPy2000 which used a Python-based application module within BCI2000. The program utilized the same 15 flash sequence of the P300-speller system to illuminate larger areas of the screen (250 x 250 pixel card size). The parameter files were generated and data acquired using the same methods described above. Unlike the copy-spelling mode of the P300-speller, the user decided which target to attend to during each session. Following the completion of the 15 flash sequence a SWLD function applied classification weights and the object with the greatest classification weight is then presented on screen face-side up. The user then has 2.0 s to direct his gaze to the user-defined intended target before the flash sequence begins. Once the object is selected and presented face-side up, the program makes a decision to keep the cards facing up if they match or face down if they do not match. The program continues until all matches have been made.

F. Data Analysis

Accuracy was defined by the number of correct targets selected in a 5-character word for the P300-speller paradigm. A two-way repeated measured ANOVA was performed to determine if a newly generated parameter or appending a previously developed parameter file influenced spelling accuracy, if the number of flashes within a sequence (i.e. 20, 18, or 10) significantly influenced performance and the potential interaction between variables to influence the outcome. For the memory game, the total number of card flips to complete the game, and the number of errors made during the completion of the game (i.e. selecting a target that was already flipped) was recorded.

III. RESULTS

A. Accuracy of P300 system

Users achieved an average overall accuracy of 88.47 ± 0.14% (range 50%-100%) using the P300-speller in copy-mode over a 17-day period. Examination of variations in subject-specific parameters, specifically the number and recency of trials used to generate the parameters did not yield any significant differences suggesting that the algorithm being used in this study is sufficiently robust to generate P300-spelling accuracy as long as the user parameters are updated with one new trial of current data (94.48 ± 0.11%). We also found that lowering the flash number from twenty (93.79 ± 0.12%) to eighteen (92.50 ± 0.15%) to ten (79.13 ± 0.20%) still allows for successful spelling in shorter amounts of time.

B. Memory Game

Two subjects successfully completed the memory game (i.e. making all possible matches). The first completing the game in 16 flips with 1 error, while the second completing in 21 flips with 8 errors.

IV. DISCUSSION

Previous research has shown that training in cognitive tasks can improve performance on a similar task and motivation is a driving force in the successful use of these devices. A memory game (i.e. Concentration) fits naturally with the classical flashing matrix system of traditional the P300-speller and the game format keep participants more engaged in the task. We propose that utilizing this memory game, a user can be trained to produce a more reliable P300 signal, which will result in improved performance on other P300-based BCI system. Using this program, researchers will be able to obtain more reliable results and help the still growing field of BCI research to flourish.

ACKNOWLEDGMENTS

The authors would like to thank Dr. J. Wolpaw, T. Vaughan, D. MacFarland and G. Schalk for significant advice and support in the completion of this project. This work was supported in part by the Lafayette College faculty development grant and the National Science Foundation under Grant ECCS-1126707.

REFERENCES

[1] Farwell *et al*., "Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials," *Electroencephalogr Clin Neurophysiol*, 70, pp. 510-523, 1988.

[2] Nijoboer *et al*., "A P300-based brain-computer interface for people with amyotrophic lateral sclerosis," *Clin Neurophysiol*, 119, pp. 1909-1916, 2008

[3] Sellers *et al*., "Brain-computer interface research at the University of South Florida Cognitive Psychophysiology Laboratory," *IEEE Trans Neural Syst Rehabil Eng.*, 14, pp. 221-224, 2006.

[4] Leeb *et al*., "Brain-computer communication: motivation, aim, and impact of exploring a virtual apartment," *IEEE Trans Neural Syst Rehabil Eng.*, 15, pp. 473-482, 2007.