Evaluating Hold-Release Functionality in a P300 BCI

R. Alcaide-Aguirre[1], J. E. Huggins[1]
[1]*University of Michigan, Ann Arbor, MI, USA*

Correspondence: R. Alcaide-Aguirre, University of Michigan 401 Washtenaw AVE, Ann Arbor, MI, USA.
E-mail: pharoram@umich.edu

Abstract. We propose a novel P300 BCI functionality in which activation (hold) and deactivation (release) of a P300 BCI speller can be separately controlled. This allows for control of the duration of activations, faster response time for the deactivations and a more analog-like control than using the traditional P300 BCI method.

Keywords: P300, EEG, Perceptual Errors, Activation Characteristics, and Deactivation Characteristics

1. Introduction

To date, P300 spellers have simply produced the selection the user desires, often with the selection used only within the P300 speller application. However, as BCIs move toward clinical use, their role as interfaces to other technology is expanding [Sellers et al., 2010; Thompson and Huggins, 2011]. Assistive technology control interface theory describes interface activation and interface deactivation as distinct properties of any control interface [Cook and Hussey, 2001]. Separating control of activation and deactivation allow precise timing of the duration of the activation. We propose a novel P300 BCI functionality in which activation (hold) and deactivation (release) can be separately controlled. To drive a power wheelchair a traditional P300 BCI, the user would need to choose a predefined direction and distance they want to move. Alternatively, a BCI with hold-release functionality would enable the user to select the direction they want the wheelchair to move and hold that selection until they want to stop. During the holding process, the only information required by the BCI to stop the wheelchair is when the user changes i.e. releases their selection. This allows the BCI to make a release decision from a very few flashes instead of after multiple sequences of flashes. For the BCI user this means a faster response time and a more analog-like control than using the traditional P300 BCI method. We demonstrate that hold-release functionality is possible with a P300 BCI through off-line analysis of data recorded while subjects were performing hold-release tasks. .

2. Material and Methods

To get data to test hold-release functionality we created a 5x6 matrix for a P300 speller with rows and columns flashed for 31.2 milliseconds with 125 milliseconds between flashes and classifier weights created with the least squares option of the BCI2000 P300_GUI. This simulated an eventual application in which a specific release target appears when a selection with hold functionality is initially selected. Two “selectable objects” simulated the hold-release functionality. One object was an ‘X’ in the upper left hand corner of the matrix and the other was ‘O’ in the lower right hand corner.

Two variations on the layout were tested. In layout 1, the rest of the matrix contained numbers to provide the visual clutter typical of a P300 BCI. Layout 2 was designed to remove two common perceptual issues in P300 BCI spellers; adjacency response errors and double flashing errors [Fazel-Rezai and Ahm, 2011]. To remove adjacency response errors we surrounded each selectable option with white space. Therefore no space adjacent to a hold-release object would flash. All other locations were filled with ‘*’ characters for reduced visual clutter of characters while maintaining the same number of rows and columns and thus the same target-to-target characteristics. To remove double flashes we insured that the sequence of flashes never contained flashed groups that created a double flash.

Data was recorded from three able-bodied subjects (1 woman, ages 21, 24 and 57 years) using a 16 EEG electrode cap from Electrode-cap International with electrode location as in (Thompson et al., 2012). Subjects sat in front of a computer screen that contained one of our BCI layouts. We instructed our subjects to select and hold an object until a tone sounded to indicate a switch of target object. Subjects “held” the object by counting how many times it flashed. The target in the upper left corner was designated as the starting target. Subjects performed 10 hold-release runs, 5 using layout 1 and 5 using layout 2. The order in which they used the layouts was pseudo-random. The tone played five times per run creating five transitions between objects. The timing for the tones was pseudo-random and happened 10-60 flashes (7500-12500 ms) apart. All tones where separated by at least 5 flashes, no tones played when a selectable object was flashing and no tones played during the first or last 5 seconds of each run. Subjects were not given feedback regarding whether the object they were holding was selected or not.

3. Results

Accuracy for the hold-release algorithm was 80% or higher for all subjects when calculated with information from one flash of a hold-release object. Using information from two flashes (from any combination of the two selectable objects) increased accuracy to 100%. Mean accuracy from one flash of a hold-release object using layout 1 was 82 +/- 3.0% and mean accuracy using layout 2 was 90 +/- 2.0%. Two-way ANOVA across subjects and layouts showed a strong significance in accuracy depending on the layout used (p=0.0003). The average time for a flash of a selectable object was about 106.25 +/- 81.25 for layout 1 and 103.13 +/- 71.88 for layout 2. Thus classification time took time for an incoming flash plus the 800 ms window after the flash.

4. Discussion

Our results demonstrate that hold-release functionality is possible using P300 BCIs. Using hold-release allows us to extend the use of P300 BCIs to applications that require fast and/or analog-like responses. We tested hold-release functionality using two different layouts. The layout that minimized perceptual errors greatly increased single flash classification accuracy.

Unlike traditional P300 BCI's our paradigm is able to accurately classify a user's decision (between the hold and release selections) after single flashes of a hold-release object instead of after a sequence of flashes. For this reason our paradigm is significantly faster than a traditional BCI. For example a traditional BCI running at four to eleven sequences takes about 8-20 seconds to make a selection while the hold-release decision would take about 1 second. This faster response time comes from a decrease in the amount of information needed to make a classification among fewer targets. Traditional P300 BCIs requires enough information to determine what the new selection is from a large number of targets. Our method only requires knowledge of when a classifier value from a flash is significantly different from what we expect when a user is holding a selection. The largest time requirement for our paradigm is the collection of 800ms of EEG activity after each flash of a hold-release object. The 800ms window of data was chosen to guarantee that the P300 event was captured. Optimization of this time window could further increase the interface responsiveness.

Future work should test hold-release functionality in a real world application such as moving a wheelchair. We have found overall BCI performance to not be significantly affected by wheelchair tilt, but hold-release functionality could be more sensitive to this type of disruption [Thompson et al., 2011].

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