Effects of Varying Relevant Content in a Fixed BCI Matrix

L. M. McCane[1], J. Gummadi[1], C. S. Carmack[1], S. Winden[1], D. J. McFarland[1], J. R. Wolpaw[1,2], T. M. Vaughan[1,2]

[1]Wadsworth Center, Albany, NY, USA; [2]Helen Hayes Rehabilitation Hospital, Haverstraw, NY, USA

Correspondence: LM McCane, Wadsworth Center, Laboratory of Neural Injury and Repair, NY State Department of Health, PO Box 509, Empire State Plaza, Albany, NY 12201, USA. E-mail: lmccane@wadsworth.org

Abstract. Wadsworth Center has developed a portable, 8-channel EEG-based BCI system for independent home use by people with ALS and other disorders. This use is enabled by Wadsworth BCI-360, a BCI2000-based software package that ensures reliable operation of the BCI device and provides a range of applications. In BCI-360, the calibration exercise and many of the P300-based applications depend on a 9 x 8 matrix containing 72 cells and 72 items. Other applications may require, and users may prefer, far fewer matrix items. Varying the number of cells in a matrix alters the target-to-target interval (TTI), and changes in TTI have been associated with changes in classification accuracy in a P300 copy-spelling task. Here, we have examined the effects of content (item relevance and number) using a 72-cell, 9 x 8 matrix with fixed TTI on BCI accuracy and P300 amplitude. Initial results from eleven healthy subjects show that content are associated with small changes in the evoked response and classification accuracy. A standard matrix size would simplify design and reduce the training and support needed for independent use of the BCI system.

Keywords: *EEG, ERP, BCI, TTI, Home Use, Augmentative Communication, BCI Applications, Matrix Size*

1. Introduction

Brain-Computer Interfaces (BCIs) allow real-time communication and control through novel neural outputs [Wolpaw and Wolpaw, 2012]. Studies of the P300-based BCI are, by now, quite numerous and many of these studies demonstrate use of the electroencephalographic or EEG-based method by individuals with disabilities [Sellers et al., 2012]. This method requires minimal training and little calibration data, is relatively robust, and provides success for a large portion of the population [Guger et al., 2009]. Studies have demonstrated that longer target-to-target intervals (TTIs), longer inter-stimulus intervals (ISIs), and smaller target-to-non-target (T/NT) ratios can increase the amplitude of the P300 [Gonsalvez and Polich, 2002; Sellers and Donchin, 2006]. McFarland demonstrated that increasing the TTI, on average, increases both the P300 amplitude and the accuracy on a P300 copy-spelling task [McFarland et al., 2010]. The BCI-360, a BCI2000-based software package that ensures reliable independent operation of the P300-based BCI home system, depends on a 72-item, 9 x 8 matrix for the calibration task, WordPad and Email applications. Other applications use matrices with fewer cells. As a consequence, the number of stimuli presented for each trial is reduced; the T/NT ratio is increased; and the TTI is decreased. In this study, we examine only the effects of reduced item number and relevance in a 9 x 8 matrix with a fixed TTI on calibration accuracy and P300 amplitude to determine if a standard matrix can be applied to the home system.

2. Material and Methods

Data are comprised of eight channels of EEG collected from eleven healthy subjects. The EEG was amplified (g.USBamp); digitized at 256 Hz; and band-pass filtered at 0.5-30 Hz. All aspects of the experiments were controlled by BCI2000. The stimuli were presented in groups of cells, assembled in pseudo-random fashion according to the checkerboard paradigm [Townsend et al., 2012], flashed at 8 Hz in a 9 x 8 matrix of 72 cells.

Five displays were configured in the 9 x 8 matrix as follows: A) Standard 72 relevant items; B) 36 relevant items surrounded by 36 dashes for non-relevant items; C) 36 relevant items surrounded by 36 blank cells for non-relevant items; D) 18 relevant items surrounded by 54 dashes for non-relevant items; and E) 18 relevant items surrounded by 54 blank cells. Displays A, B, and D illuminated six items in a group. Displays C and E illuminated one to five items in a group. Ten target characters (1;20!45:Z3) were cued in the same order twice for the five displays over two separate days for a total of 40 items per display. Each target item was flashed ten times in the 120 stimuli presented per character. The TTIs for all displays ranged from 250 to 2750 ms. The initial display for subjects was randomized. Classification coefficients were derived from all five displays using the

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stepwise linear discriminant function (SWLDA) [Krusienski et al., 2008] using day-one data. System accuracy was defined as classification of day-two data using these coefficients. Coefficients derived from day-one Display A data were also applied to Day Two data from the four other displays.

3. Results

The average accuracies for each condition when coefficients derived from Day One data were applied to the same condition on Day Two were the following: A) 72%; B) 73%; C) 80%; D) 75%; and E) 76%. Accuracies for the reduced content matrices (B through E) were not significantly different from the standard 9 x 8 matrix (Display A). Coefficients generated from Display A (Day One) were applied to the Day Two data from the four remaining conditions. The averages for each display were: B) 73%; C) 76%; D) 76%; E) 73%.

The average peak amplitude of the target trials for the P300 (bin: 230-450 ms) at Pz for each display are as follows: A) 1.97 µV; B) 2.83 µV; C) 2.26 µV; D) 2.36 µV; E) 2.56 µV. The amplitudes for the reduced content matrices (B through E) were not significantly different from the 9 x 8 matrix (Display A). The latency range of the P300 for all the conditions fell between 230 ms and 324 ms (mean 251 ms). The greatest mean amplitude for the P300 was noted at location Cz for the combined Blank Displays, C and E (Fig. 1). The greatest amplitude for the Late Negativity (LN) (bin: 400-800 ms) was for Display A (72-item, 9 x 8) at location Cz.

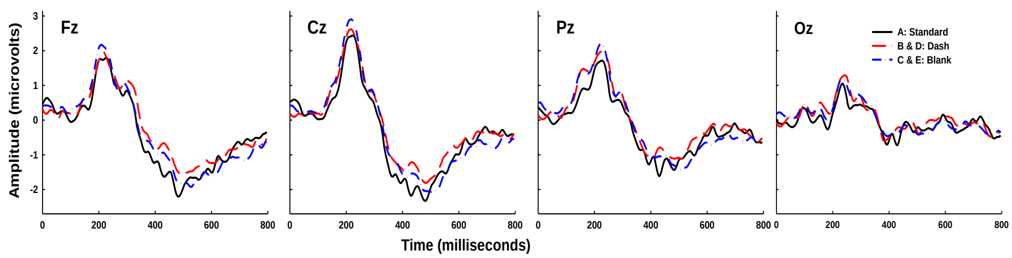

Figure 1. *Averaged waveforms for target trials for all eleven subjects. The solid (black) lines represent responses to the standard Display A (72 items); the dashed (red) line responses to Displays B and D (Dash Displays), and the dot-dash (blue) line to Displays C and E (Blank Displays).*

4. Discussion

In sum, the average amplitude of target P300 increased and classification accuracy improved slightly with reduced content in a 9 x 8 matrix. These changes were not significant. These preliminary results suggest that a standard matrix may be an acceptable alternative to reducing matrix size across P300-based applications in BCI-360. A standardized matrix size, with a consistent TTI, may lead to more stable performance and, thus, reduce training and support for independent users. Further studies of BCI applications use with home-users and with both fixed and variable TTIs will be needed to confirm these results.

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