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Enhancing Brain-Computer Interface Performance in an ALS Population: Checkerboard and Color Paradigms

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Abstract. A brain-computer interface (BCI) speller provides non-muscular communication via detection of EEG features. In a non-disabled population, a Checkerboard (CB) stimulus presentation has been shown to improve BCI performance over the standard Row/Column (RC) paradigm. Another improvement is a gray-to-color (CL) paradigm that presents perceptually-salient targets defined by nine unique colors. The current study examines the RC, CB, and CL paradigms in an amyotrophic lateral sclerosis (ALS) population (N = 7). Pilot data suggest improved performance of CB and CL over RC. The results suggest matrices including CB and CL provide more efficient communication and higher user satisfaction in an ALS population.

Keywords: Assistive Devices, Brain-Computer Interface, EEG, P300 Event-Related Potential, Rehabilitation

1. Introduction

Noninvasive brain-computer interface (BCI) provides non-muscular communication via detection of EEG features. In a non-disabled population, and in pilot data from participants with amyotrophic lateral sclerosis (ALS), the checkerboard (CB) presentation paradigm provided better performance than the standard row/column (RC) presentation paradigm [Townsend et al., 2010]. In non-disabled participants, a color condition (CL) that changes groups of gray matrix items to one of nine unique colors improved performance as compared to the standard condition in which gray matrix items change to white [Ryan et al., 2011]. This study examines if these improvements generalize to an ALS population.

2. Material and Methods

The current study uses a 6 x 6 matrix to compare three conditions in an ALS population: 1) CL, 2) CB, and 3) RC (see Fig. 1A). Each participant completed all three conditions in a pseudo-randomized order. The RC condition flashes entire rows and columns of items in random order. The CB condition flashes groups of items in a quasi-random order. The CB has two constraints in selecting the flash groups. The first prevents any adjacent item from flashing simultaneously in the same row or column. The second constraint requires an item to be absent from four or five (depending on the virtual matrix cells that are presented) subsequent flash groups before it flashes again. The CL condition used the same presentation method of the CB and consisted of items represented in gray (stimulus off) that flashed a unique color (stimulus on) to the eight items surrounding it in the matrix. Stimulus presentation, and online processing was conducted with BCI2000 [Schalk et al., 2004]. Electroencephalogram (EEG) was recorded from sixteen electrodes; eight of the electrodes were used for classification (Fz, Cz, P3, Pz, P4, Po7, PO8, & Oz; [Krusienski et al., 2008]). Thirty item selections were used to serve as training data for a stepwise linear discriminate analysis (SWLDA), the resulting SWLDA coefficients were then used for online response classification. Thirty additional selections were presented in the online condition. After each selection the subject was presented with the result of the BCI's character selection to inform the subject whether or not the BCI accurately classified their EEG responses. The number of stimulus presentations was held constant at seven sequences per item selection (one sequence is complete when every item of the matrix has flashed two times) for calibration and online testing. Participants were given a survey to assess their opinion of which condition they preferred.

3. Results

Statistical analyses were not performed due to the small sample size. Nonetheless, some trends are evident in the data. Accuracy in the CL condition was higher than the CB and RC conditions (90%, 80%, & 79% respectively). Information transfer rate (ITR) was higher in RC condition than in the CL and CB conditions (9.63, 7.73, & 6.58

respectively). The CB (and CL) constraints require 33% more flashes of smaller groups than the RC. Resulting in more time required per sequence in the CB, which accounts for the difference in ITR.
Of the seven participants, four preferred the CL and three preferred CB condition. As show in Fig. 1B, the CL and CB conditions require fewer flashes to achieve higher accuracy than the RC condition.

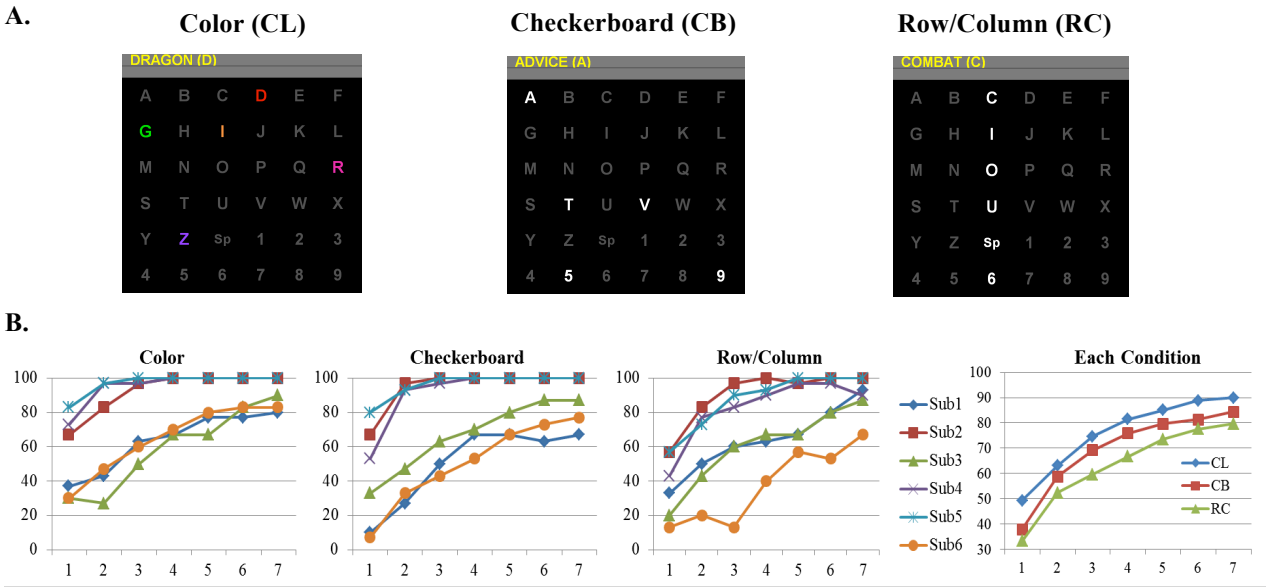

Figure 1. A) *The three conditions examined: Color (CL), Checkerboard (CB) and Row/Column (RC).* ***B)*** *Percent correct by sequence for each participant and for each condition averaged across participants. The performance curve revealed higher initial accuracy in the CL condition for all participants. Participants 2, 4, & 5 reached 100% by the 3rd sequence in CL and CB. This accuracy was not achieved until the 5th sequence in R/C.*

4. Discussion

Pilot data suggest enhanced performance of CL over RC in a ALS population. In addition, CL and CB were preferred over the standard RC paradigm by all participants, despite higher ITR.The current study presented a fixed number of stimulus presentations for each participant and condition. Reducing the number of stimulus presentations should result in higher ITR for the CL and CB condition than RC. The results suggest matrices including CB and CL provide more efficient communication and higher user satisfaction in an ALS population.

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References

Krusienski DJ, Sellers EW, McFarland DJ, Vaughan TM, Wolpaw JR. Toward enhanced P300 speller performance. *J Neurosci Meth*, 167:15-21, 2008.

Ryan DB, Gates NA, Colwell K, Throckmorton S, Collins LG, Winnen KAM, Brown RW, Sellers EW. Improving BCI Performance: Giving the P300 Speller Some Color. *Society for Neuroscience annual meeting, Washington DC*, 2011.

Schalk G, McFarland DJ, Hinterberger T, Birbaumer N, Wolpaw JR. BCI2000: a general-purpose brain-computer interface (BCI) system. *IEEE Trans Biomed Eng*, 51:1034-1043, 2004.

Townsend G, LaPallo BK, Boulay CB, Krusienski DJ, Frye GE, Hauser CK, Sellers EW. A novel P300-based brain-computer interface stimulus presentation paradigm: Moving beyond rows and columns. *Clinical Neurophysiol*, 121:1109-1120, 2010.