Wadsworth Center
NYS Department of Health

778.21

The P300 Brain-Computer Interface: A New Presentation Method

E.W. Sellers[1], G. Townsend[2], C. Boulay[3,4], B.K. LaPallo[3,4], T.M. Vaughan[4], J.R. Wolpaw,[3,4]
1 East Tennessee State University, 2 Algoma University, 3 University at Albany, 4 Wadsworth Center

Introduction

Brain-computer interfaces (BCIs) can reestablish communication for patients whose neuromuscular ability has been abolished by severe disease. BCIs can allow people to control computer programs and external devices without motor activity by detecting volitional changes in brain activity.

P300-based BCIs allow users to select items from an onscreen matrix (Figure 1); each item in the matrix emulates a keyboard command. To select an item, participants attend to a specific item while all of the matrix items rapidly flash in a random order. Flashes of the attended item elicit a target response—the P300 potential—while flashes of unattended items do not (Donchin et al, 2000).

Here, we compare the traditional presentation method, which flashes rows and columns of items (RC), to a method that flashes randomly organized groups of non-adjacent items derived from a virtual checkerboard (CB). We hypothesized that the CB method would reduce errors due to temporal overlap of target flashes and to distraction from flashing of adjacent items.

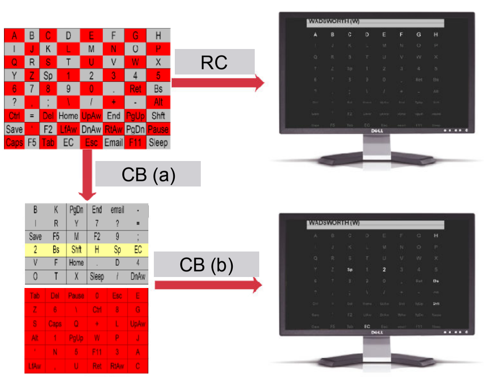


Figure 1. In the RC method (top), items flash with their respective row and column. In the CB method, (a) non-adjacent characters sort into separate virtual matrices. (b) Items grouped by CB rows and columns result in a dispersed stimulus in the visual matrix.

Methods

Each participant (n=12) completed one test session using the RC and one using the CB. Prior to the test sessions, each subject generated 12 minutes of calibration data in order to characterize their unique EEG responses to flashes of the target item. In the test sessions, a stepwise linear discriminant classification algorithm identifies flash responses as target or non-target based on their similarity to the target response defined by the calibration data (Krusienski et al, 2008).

During test sessions, subjects completed a total of 38 item selections with each method. We compared the waveform morphology, information transfer rates (ITR), accuracy, and error locations of both methods.

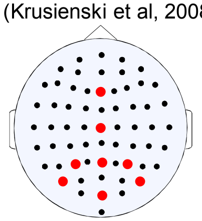
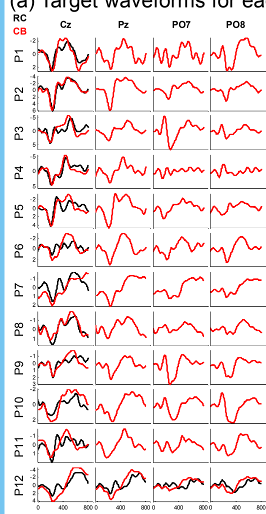


Figure 2. Red locations indicate the electrode locations used by the classifier.

Results

Waveform Data

(a) Target waveforms for each participant



(b) Average waveforms

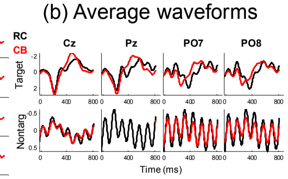


Figure 3. (a) Average target waveforms for each of the 12 participants. (b – top row) Grand average target waveforms. The neg. peak on Cz at 500ms is larger for the CB than the RC (p=.001). The pos. peak on Pz at 220ms and the neg. peak at 480ms are larger for the CB (p=.04; p=.002). On PO7 and PO8, the neg. peak at 200ms is larger for the RC (p=.02; p=.008). In addition, the pos. peak is earlier for the CB (270ms) than the RC (380ms) (PO7, p<.001; PO8, p=.006). (b – bottom row) Grand average non-target waveforms. The mean non-target amplitude is less for the CB than the RC on Pz, PO7, and PO8 (p=.03; p=.04; p=.04).

Information Transfer Rate

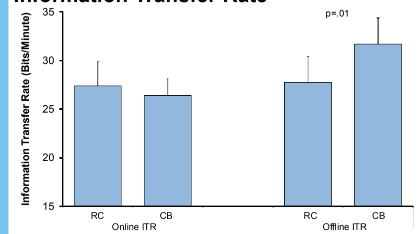


Figure 4. Mean online (left) and offline (right) information transfer rates. The online ITRs were similar between the two methods (27.4 RC and 26.8 CB). Offline ITRs were higher for the CB method (27.7 RC and 31.7 CB).

Accuracy

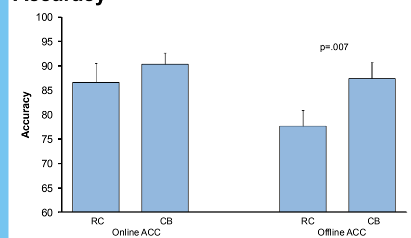


Figure 5. Mean online (left) and offline (right) accuracy. Online accuracy was similar between the two methods (86.6% RC and 90.4% CB). Offline accuracy was higher for the CB method (means 77.7% RC and 87.4% CB).

Pilot Data with Severely Disabled ALS Patients

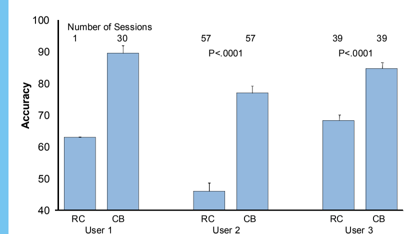


Figure 6. Online accuracy for three people severely disabled by ALS. On average, accuracies were 24.6% higher for the CB method than the RC method (means 59.1% RC and 83.7% CB).

Error Locations

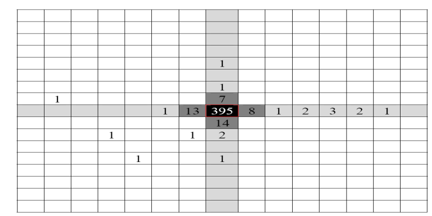


Figure 7. RC error locations. 68.9% of errors occurred in cells adjacent to the target (dark gray). An additional 24.6% of errors were in the same row or column as the target (light gray). Only 6.5% or errors occurred elsewhere.

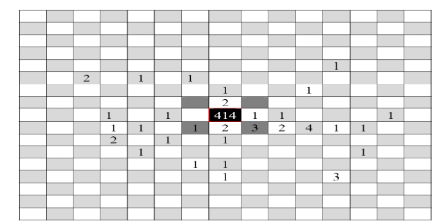


Figure 8. CB error locations. 64.3% of errors were in the same virtual matrix (dark. & light gray cells). 35.7% of errors occurred in the opposite matrix. Only 9.5% of errors occurred in locations diagonal to the target item.

Conclusions

- Most importantly, disabled users did better with the CB method.
- AND, every participant preferred the CB method.
- The ITRs reported here are the highest to date recorded for the RC method. No other study has examined the CB method.
- The CB method can reduce errors, and it disassociates target items from neighboring items.
- The CB and RC methods produce different target and non-target waveforms, leading to differences in performance.

Acknowledgements
NCMRR, NICHD, NIH (HD30146); NIBIB/NINDS, NIH (EB00856); NIH (R13EB005114-01); J.S. McDonnell Foundation; Helen Hayes Hospital; NEC Foundation