Novel Stimulus Presentation Pattern in a P300-Based Brain-Computer Interface

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Introduction

Brain-computer interfaces (BCIs) can reestablish communication and environmental control for patients whose neuromuscular ability has been abolished by severe disease. BCIs allow people to control computer programs and external devices without motor activity by detecting and responding to volitional changes in brain activity (Figure 1).

P300-based BCIs allow users to select items from an onscreen matrix (Figure 2); each item emulates a keyboard command. To select an item, users attend to that item while all of the characters in the matrix 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, Sellers and Donchin, 2006).

Here, we compare the traditional presentation method, in which character sets are flashed in groups organized by rows and columns (RCM), to a method that flashes randomly organized groups (virtual matrix method, VMM). We hypothesized that the VMM method would reduce errors caused by overlapping target responses and distraction from the flashing of adjacent cells.

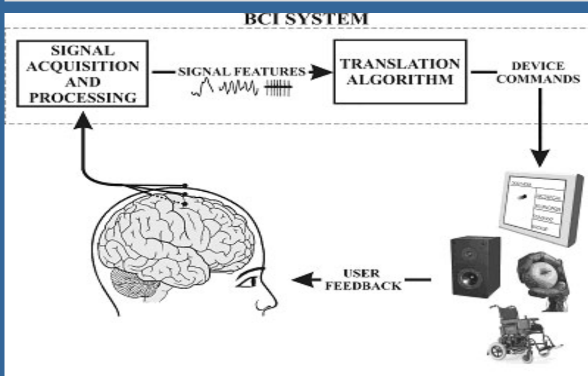

Figure 1. BCI design and operation. Electrodes acquire signals from the brain, and the BCI system processes them to extract specific signal features that reflect the user's intent. The BCI translates these features into commands that operate external devices (McFarland and Wolpaw, 2008).

Methods

Each subject (n=12) completed one test session using the RCM and one using the VMM. Prior to these test sessions, each subject generated 12 minutes of calibration data in order to characterize their unique EEG responses to target flashes. In the test sessions, a 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, 2006).

Users select an item (e.g., letter, number, command) by attending to the multiple flashes of only that item. In the RCM, the target character is identified as the intersection of the row and column whose flashes elicit the most target-like responses. Using the VMM, individual items are classified as either target or non-target based on the collective responses of all of their respective flash groups.

During test sessions, subjects completed a total of 31 item selections with each method. We compared the information transfer rates (ITR), accuracy, and error locations of both methods.

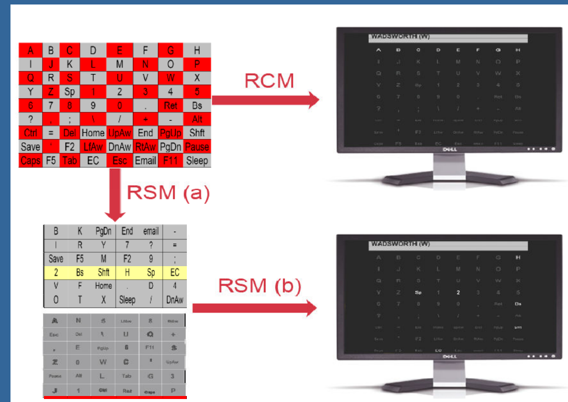

Figure 2. In the RCM (top), characters flash with their respective row and column. In the VMM, (a) non-adjacent characters sort into separate virtual matrices. (b) Character flashes grouped by VM row and column result in a dispersed stimulus in the visual matrix.

Results

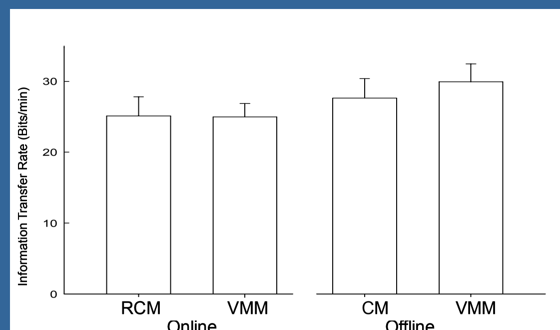

Figure 3. The information transfer rates were similar between the two methods (online mean bit rates=25.1 and 25.0 bits/min for RCM and VMM, respectively; offline mean bit rates=27.6 and 29.9).

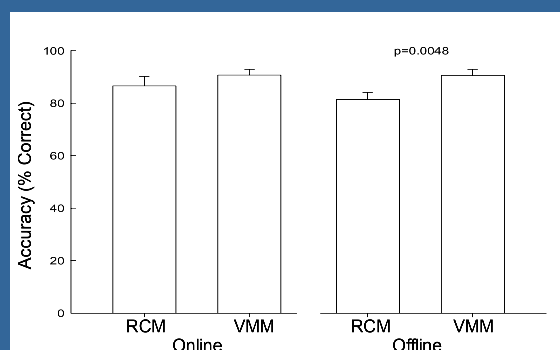

Figure 4. Accuracies were similar between the two methods (Mean RCM accuracy=86.6%, VMM=90.8%). In offline simulations, the VMM was more accurate (RCM= 81.0%, VMM=90.5%).

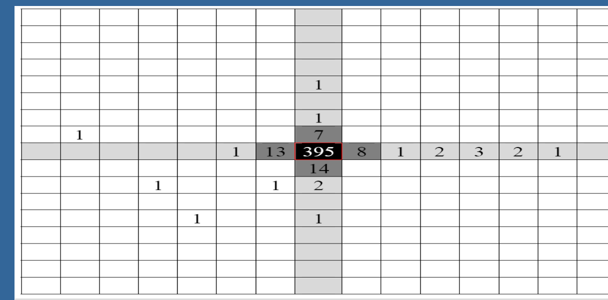

Figure 5. RCM error locations. 68.9% of errors they occurred in cells adjacent to the target (dk gray). 24.6% of errors were in the same row or column as the target (lt gray). 6.5% occurred elsewhere.

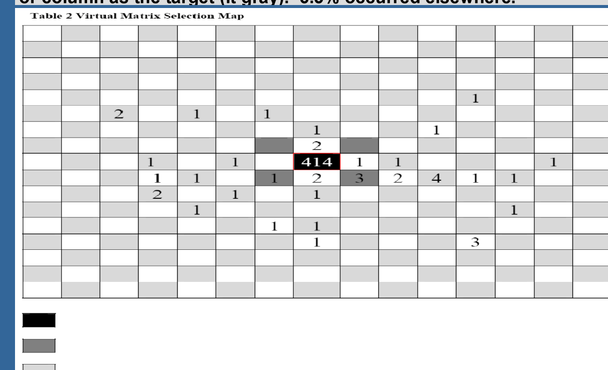

Table 1. Comparison between published P300 ITRs and this study

Paper (first author, year)		Information Transfer Rate (bits/min)	Accuracy	Number of subjects
Donchin, 2000	Online	5.5	56.0%	10
	Offline	12.1	90.0%	10
Serby, 2005	Online	17.3	79.5%	6
	Offline	20.6	92.0%	6
Lenhardt, 2008	Online	17.4	83.3%	12
	Offline	-	-	-
This study	Online	25.1	90.8%	12
	Offline	29.9	90.5%	12

Conclusions

- The ITRs reported here are the highest to date using the RCM method, no other study has examined the VMM.
- ITRs were similar between the two methods, but the VMM is new, and future efforts will likely reduce the time it takes to present stimuli, which should increase ITR.
- Subjects reported a preference for the VMM; greater accuracy in the VMM could enhance user experience and quality of life.
- In initial data from an ongoing study of 3 ALS patients using the VMM, performance increased by up to 20%.

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