Algoma University
Brain-Computer Interface Lab

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P300-BCI: Disassociating Flash Groups from Physical Organizations Provides Improved Performance

G. Townsend[1], J. Shanahan[1], Gerald E. Frye[2], Eric W. Sellers[2]

1 Algoma University, 2 East Tennessee State University

Introduction

Brain-computer interfaces (BCIs) enable the severely disabled to control computers using only their brain activity. The P300-based BCI allows users to select items from a rapidly flashing matrix of targets by attending to the desired item. Only flashes of the attended item elicit a target response—the P300 potential (Donchin et al, 2000).

The checkerboard (CB) method retains “row-column” organization in the flashing pattern, but hides it from the user by means of virtual matrices (Townsend et al, 2010).

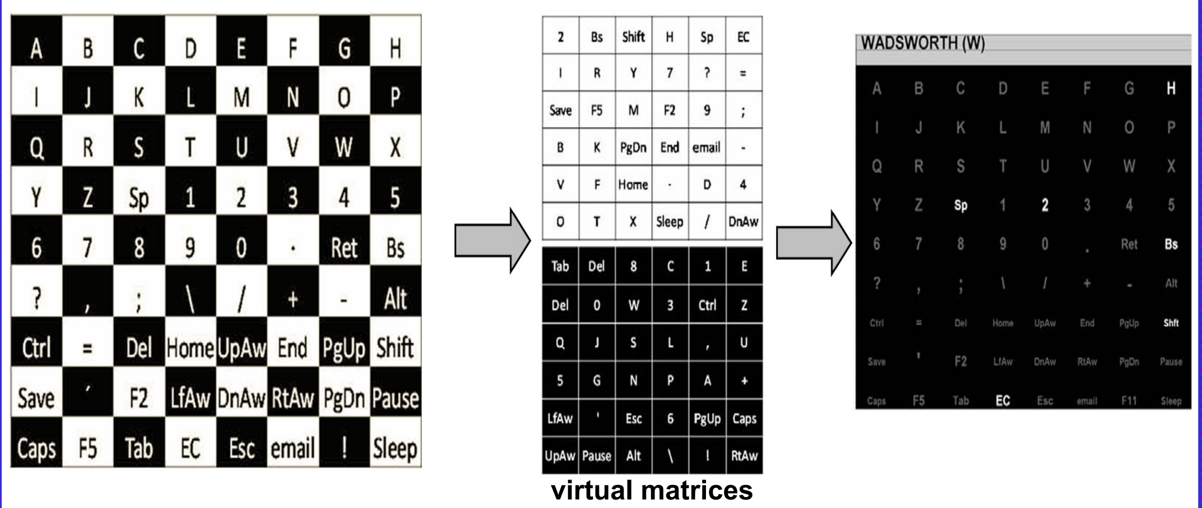

Figure 1. In the CB method the matrix is divided into two virtual matrices, white and black (shown in middle). The rows of both matrices flash followed by the columns. A flash of the top row of the white matrix appears on the right.

Here, we compare the CB to a new method called “n choose m” in which the association between physical targets and flash groups becomes purely abstract. Each target appears m times in a sequence of n flashes. To illustrate this new approach, we use as an example a 36 flash sequence with five target flashes called the five flash (FF) paradigm.

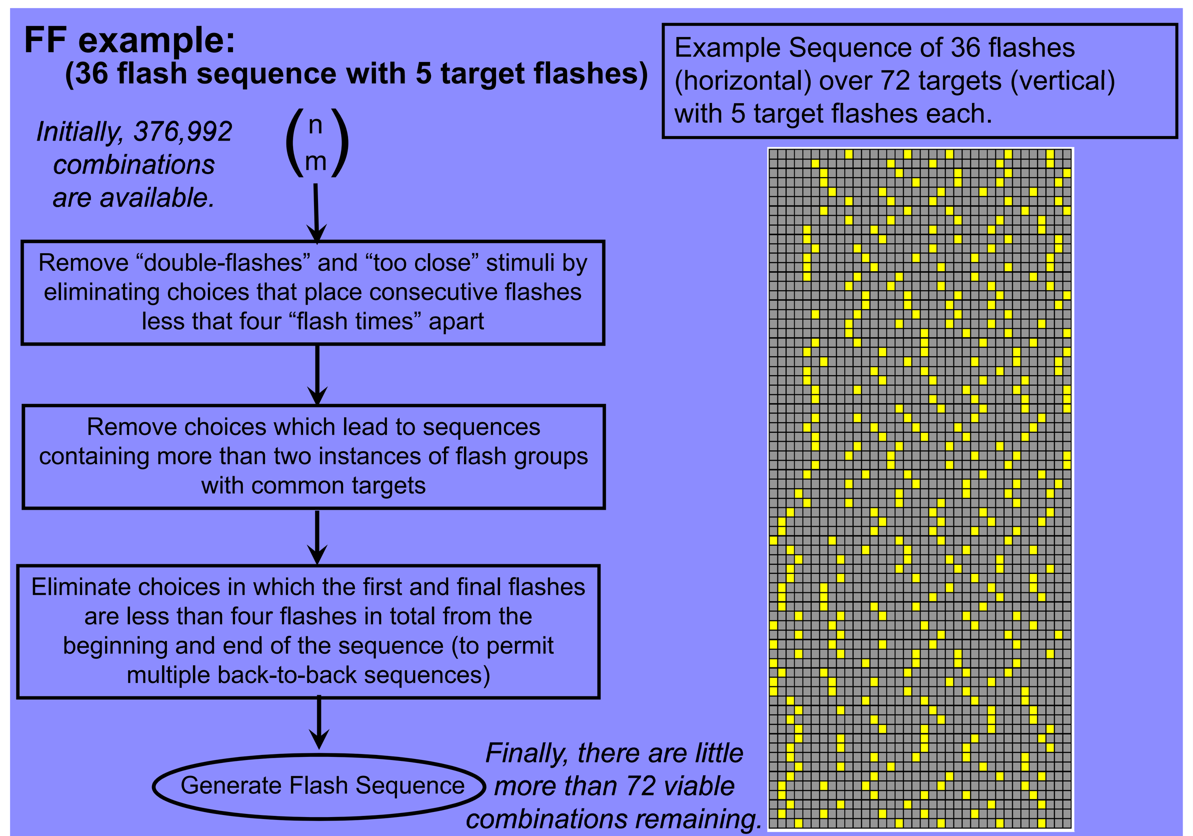

Figure 2. In the $\binom{n}{m}$ method, abstraction of the flash-groups leads to a large number of possible item combinations, however imposing performance-based constraints reduces the number of viable combinations.

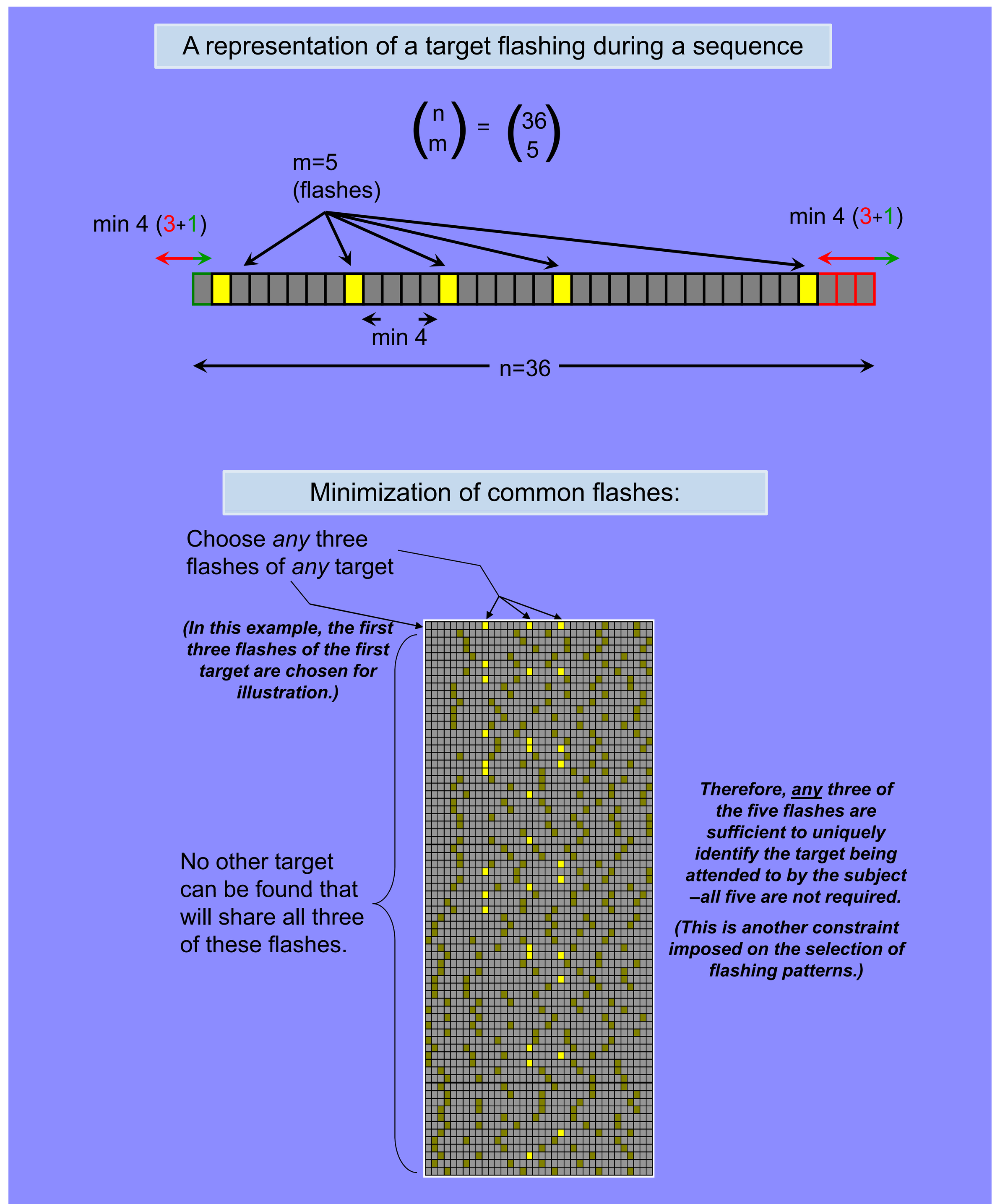

Figure 3. Imposing performance-based constraints. The way the targets are grouped to flash and the time selected for each group to flash must be constrained to eliminated double flashes and other problems.

During test sessions, subjects completed a total of 25 item selections with each method. We compared the waveform morphology, information transfer rates (ITR), and accuracy.

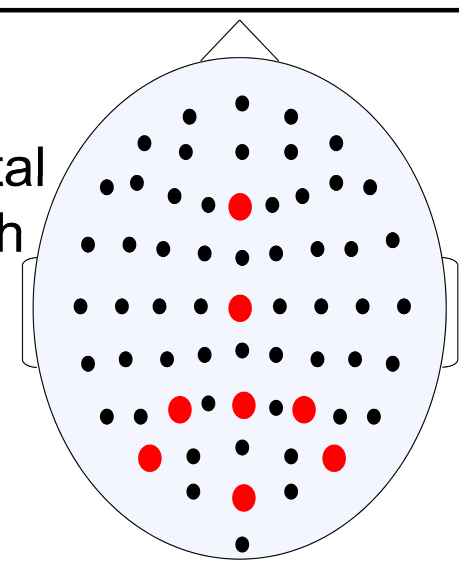

Figure 4. Red locations indicate the electrode locations used by the classifier.

Methods

Each participant (n=8) completed one test session using the CB and one using the FF. Prior to the test sessions, each subject generated 10 minutes of calibration data in order to characterize their unique ERP response 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).

Results

Waveform morphology for each subject and the grand average:

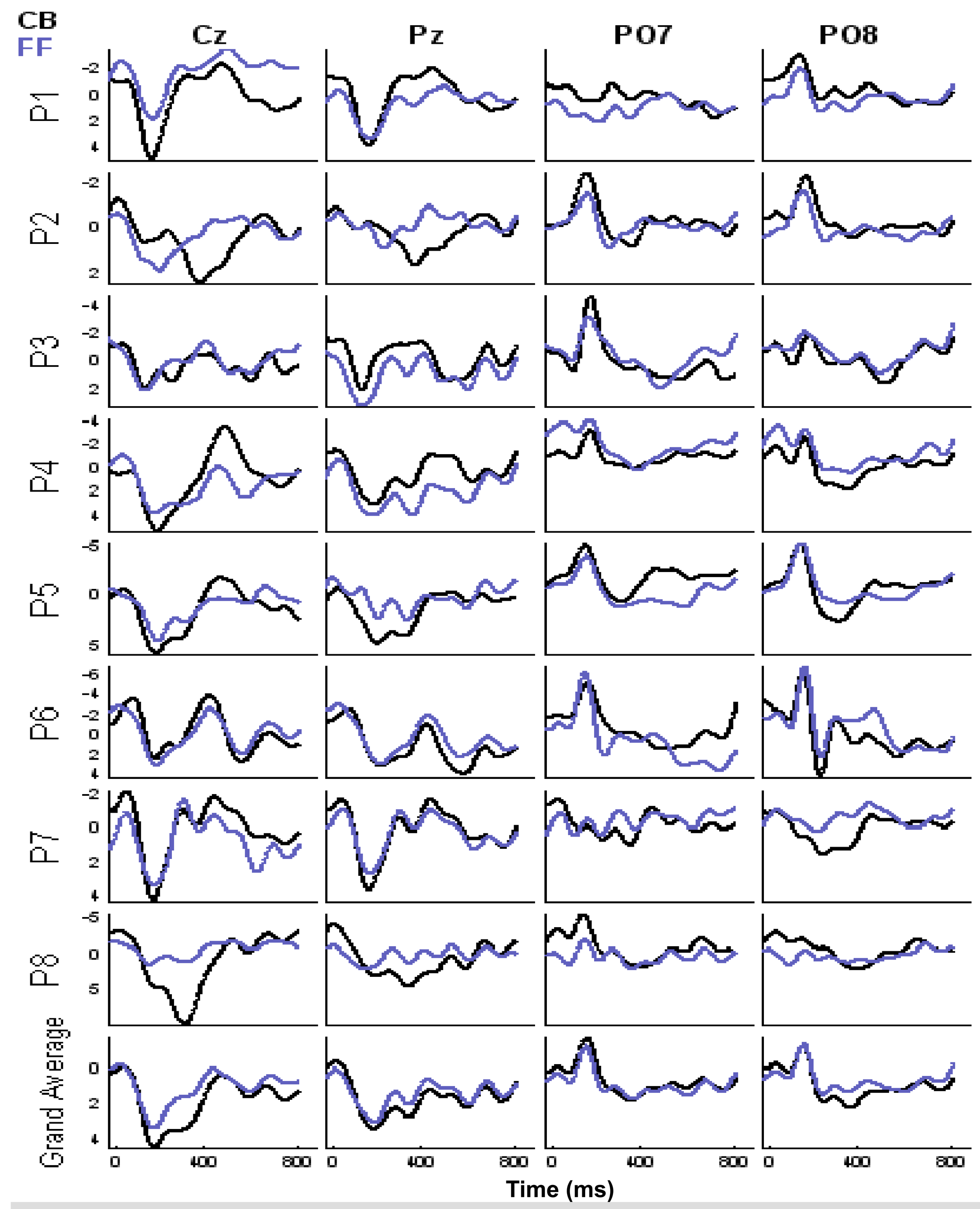

Figure 5. In general, the target waveforms in the FF paradigm appeared to have a diminished amplitude as compared to the ones in the CB paradigm, but both followed a similar time course otherwise.

Accuracy

There was no significant difference (ρ=0.1) in terms of mean accuracy between the CB (93%) and FF (88%) paradigms.

Information Transfer Rate

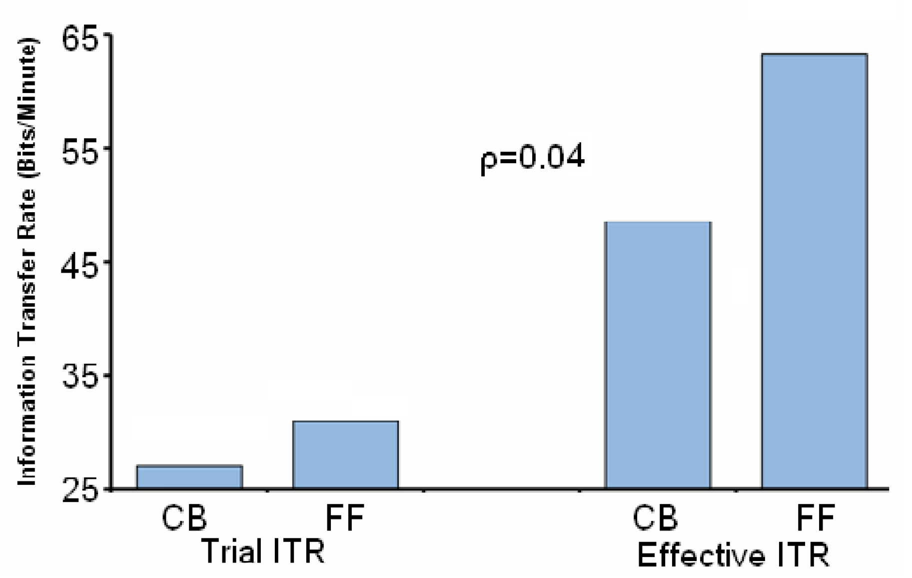

Figure 6. Mean information transfer rates for trial (left: 27.8 CB and 31.2 FF) and effective (right: 48.3 CB and 63.3 FF). The trial ITRs include the “dead” time between sequences while the effective times do not.

Variations of $\binom{n}{m}$

Importantly, “n choose m” is very general and the FF variation is only one possible example of its implementation. A preliminary study that tests another variation of “n choose m,” in which each item flashes 3 times in a series of a 20 flashes, the $\binom{3}{20}$ method, has produced encouraging results (n=3). Mean accuracy is 90% with an ITR of 44 bmp (trial) and 133 bmp (effective). Unlike the FF paradigm, this variation imposed the CB constraint concerning adjacent squares suggesting that it might be an essential constraint.

Conclusions

- The present ITRs are among the highest to date and further demonstrate the utility of the CB paradigm. In addition, the FF is one example of the more general “n choose m” paradigm and resulted in a higher ITR than the CB.
- “n choose m” is a novel method that provides purely abstract flash-groups. By completely dissociating the rows and columns, and placing any number of constraints on the flash pattern, the “n choose m” method is a powerful method that can further optimize the P300 BCI flash pattern.
- The $\binom{3}{20}$ method demonstrates the power of “n choose m” as it is only the second variation tested and the preliminary results suggest that it may lead to the highest accuracy and ITR to date.

Acknowledgements

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