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One step beyond rows and columns flashes in the P300 speller: a theoretical description

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Abstract. In the graphical user interface of a P300-BCI, the location and the moment of the flashes can be considered as relevant parameters for increasing the accuracy. The inter stimuli interval has been largely discussed but the location of the flashes, *i.e.*, row/column, has not been investigated so much. We propose a formal description that allows any P300-BCI designer to quickly go beyond the row/column flashes while keeping the exact same number of flashes of the classical row/column method *i.e.*, without losing speed.

Keywords: Brain-Computer Interface, P300, Graphical User Interface, Feedback

1. Introduction

In the P300 paradigm, only flashes of groups containing the attended item should elicit a P300. In the original implementation of the P300-BCI, and in its most recent implementations, flashed items are grouped as rows and columns (RC). One major problem with the RC paradigm is the classical presentations of the different flashes as they involve frequent error around the target. Furthermore, the Graphical User Interface of the P300-BCI has not really evolved for 22 years [Farwell et al. , 1988]. Although, the size, the color and other parameters of the interface have been investigated, the RC paradigm is still one major invariant in the literature. A recent study has proposed an alternative to the RC paradigm where the results were significantly higher [Townsend et al. 2010]. They have proved that the RC paradigm has a direct impact on the performance. Thus, improving the flashing paradigm will improve the performance. We propose to demonstrate that the RC paradigm is just a special case of a more generic model. In this generic model, we propose alternatives to the RC paradigm, which offer interesting properties for P300-BCIs.

2. Method

We denote by $N*N$ the size of the matrix M that contains the different symbols. $M(i,j)$ represents the symbol at the i^{th} row and the j^{th} column. In the RC paradigm, a target can be identified after $2N$ flashes, where N flashes occur on the matrix rows, and the other N flashes are on the matrix columns.

We denote by R and C , the matrices of size $N*N$ that contain the indices of the different possible flashes. For instance, $\forall (a,b) \in \{1..N\}$, if $R(a,b)=f$ and the flash number f must be flashed, then each cell $M(a,b)$ will be intensified. For $N=6$, R and C are defined respectively by:

$$R = \begin{matrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 2 & 2 & 2 & 2 & 2 & 2 \\ 3 & 3 & 3 & 3 & 3 & 3 \\ 4 & 4 & 4 & 4 & 4 & 4 \\ 5 & 5 & 5 & 5 & 5 & 5 \\ 6 & 6 & 6 & 6 & 6 & 6 \end{matrix} \quad C = \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 1 & 2 & 3 & 4 & 5 & 6 \\ 1 & 2 & 3 & 4 & 5 & 6 \\ 1 & 2 & 3 & 4 & 5 & 6 \\ 1 & 2 & 3 & 4 & 5 & 6 \\ 1 & 2 & 3 & 4 & 5 & 6 \end{matrix}$$

Therefore, we have 6 possible flashes for R and C , and each symbol of M can be identified by two flashes extracted from R and C : $M(R(a,b),C(a,b))$. Indeed, the couple $(R(a,b),C(a,b))$ is unique, $\forall (a,b) \in \{1..N\}$. It guarantees that with two flashes, a target can be selected on the matrix. We propose now to

create R and C in relation to a random distribution of the indices representing the symbols in M . In fact, it is possible to get a random distribution of the indices of the symbols represented on the screen while keeping the symbols ordered as we wish, *i.e.*, we can separate the notion of logical and physical coordinate of each item with a simple correspondence table. We define a vector u of size N^2 such that $u(i)=i, i \in \{1..N^2\}$. We now select a random permutation of u that we note \hat{u} . This method allows determining new matrices \check{R} and \check{C} in a random fashion. The construction of \check{R} and \check{C} in relation to \hat{u} can be obtained by estimating $\check{R}(a,b)$ and $\check{C}(a,b)$: $\check{R}(a,b)=1+\text{floor}((\hat{u}(k)-1)/N)$, $\check{C}(a,b)=1+\text{mod}(\hat{u}(k)-1,N)$ where mod and floor are matlab functions and $k=a*N+b$.

3. Flashes with spatial constraints

It is possible to go one step further for establishing a new strategy. It is possible to add some constraints to the subsets of symbols that are simultaneously flashed. As evoked previously, one source of errors in the P300 speller can be the simultaneous flash of contiguous symbols. It is naturally the case in the RC paradigm where aligned symbols are flashed together. We propose a constraint on the matrix \check{R} that does not allow the flashes on 2 contiguous symbols aligned vertically and horizontally. A simple solution to this problem is to consider a row with each flash number (1 to N) and then shift circularly this row by one element on the next row. \check{C} can then be easily built in a random fashion while keeping the constraint that only one couple can represent a cell in M . For $N=6$, we can obtain for instance these two couples of matrices that could be combined across repetitions:

$$\check{R}_1 = \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 6 & 1 & 2 & 3 & 4 & 5 \\ 5 & 6 & 1 & 2 & 3 & 4 \\ 4 & 5 & 6 & 1 & 2 & 3 \\ 3 & 4 & 5 & 6 & 1 & 2 \\ 2 & 3 & 4 & 5 & 6 & 1 \end{matrix} \quad \check{C}_1 = \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 5 & 6 & 1 & 2 & 3 & 4 \\ 3 & 4 & 5 & 6 & 1 & 2 \\ 1 & 2 & 3 & 4 & 5 & 6 \\ 5 & 6 & 1 & 2 & 3 & 4 \\ 3 & 4 & 5 & 6 & 1 & 2 \end{matrix} \quad \check{R}_2 = \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 2 & 3 & 4 & 5 & 6 & 1 \\ 3 & 4 & 5 & 6 & 1 & 2 \\ 4 & 5 & 6 & 1 & 2 & 3 \\ 5 & 6 & 1 & 2 & 3 & 4 \\ 6 & 1 & 2 & 3 & 4 & 5 \end{matrix} \quad \check{C}_2 = \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 3 & 4 & 5 & 6 & 1 & 2 \\ 2 & 3 & 4 & 5 & 3 & 4 \\ 1 & 2 & 3 & 4 & 5 & 6 \\ 3 & 4 & 5 & 6 & 1 & 2 \\ 2 & 6 & 1 & 5 & 6 & 1 \end{matrix}$$

With the proposed strategy, it is also possible to flash randomly the flashes of \check{R} and then the flashes of \check{C} , instead of flashing randomly the flashes contained in both R and C , as it is often performed. Indeed, with the proposed type of flash, the notion of rows and columns disappears to the profit of a new notion: random sets of items, or splotch, first introduced in [Allison, 2003]. Therefore, if we consider an inter-stimuli interval of 200ms, $N=6$ and if the flashes in \check{R} are set first randomly, and then those in \check{C} are set randomly, there will be in average a time of 1.2s between two flashes on the symbols selected by the user. In the worst case, there will be only 200ms. By suppressing the notion of rows and columns, we can keep an oddball paradigm while decreasing by 2 the probability to obtain 2 consecutive flashes on the target.

4. Conclusion

The proposed method for flashing the symbols on the screen in the P300 paradigm is a good alternative to the row-column paradigm. Indeed, it gives all its sense to the oddball paradigm by considering random or pseudo-random subsets of symbols for each flash instead of rows and columns. The odd aspect of the oddball paradigm was limited to the order of the flash (odd in time), it is now formally spatially odd. As the visual stimuli are presented in an odder way, it is possible to separate the blocks of flashes and reduce the probability of consecutive flashes on the target.

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