Optimized P300-Based BCI Using a Multi-Faces Pattern

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Abstract. Recent work showed that the face paradigm was superior to the canonical flash approach that has dominated P300 BCIs for over 20 years. However, face repetition effects may occur if the same face was shown repeatedly. Repetition effects would decrease the amplitude of ERPs, and thereby decrease BCI classification accuracy. To decrease these repetition effects, two new stimulus patterns called "masked face pattern" and "multi-faces pattern" were presented in this paper. Two other stimulus patterns (canonical flash pattern and face pattern) were also evaluated as control conditions. The multi-faces pattern yielded the highest accuracy and information transfer rate among four patterns and succeeded in improving the face pattern.

Keywords: BCI, ERP, Face pattern, Masked face pattern, Multi-faces pattern, face repetition effects

1. Introduction

It has been proved that face stimulus is better than flash stimulus [Kaufmann et al., 2011]. However, all face paradigms only use the same face as stimulus, which will lead to face repetition effects [Neumann et al., 2008]. Face repetition effects will decrease the performance of ERP identification. The First goal of this paper is to survey the method to avoid the face repetition effects, which could improve the performance of ERP-based BCI system. [Martens et al., 2006] proved that masked face could decrease the face repetition effects. Based on this result, a new paradigm using masked face was designed for BCI system. Another paradigm using multi-familiar faces was also presented to avoid face repetition effects. The second goal of this paper is to decrease the error motion of key functions.

2. Material and Methods

Two healthy subjects (aged 21 and 27) participated in this pilot study. Eight more subjects are being studied in an adapted online version, and additional details will be submitted as a full journal paper. EEG signals were recorded with a 64 channel g.USBamp and a g.EEGcap with a sensitivity of 100 μV, band pass filtered between 0.1 Hz and 30 Hz, and sampled at 256 Hz. 62 channels were used (see Fig. 1A).

Fig. 1B shows the display presented to all subjects, which was a 3×4 matrix with blue boxes. Gray function icons are beside the boxes. Instead of grouping the flashed characters into rows and columns, we developed an alternate flash pattern approach based on binomial coefficients [Jin et al., 2010]. We used the set of k combinations ($k = 2$) from set $n = 12$. Only the gray cells (3×4 matrix) flash and are used as function buttons (see Fig. 1C). Hence, there were twelve flash groups, and between one and three boxes changed during each flash (see Fig. 1B and 1C). There were four conditions in the study, which differed only in the way that these boxes changed. In different conditions, some of the boxes would change by changing to green, changing to a face, changing to a masked face, or changing to randomly selected faces (one of 5 different faces) (see figure 1D). Most face images were obtained by photographing the people who the subjects considered familiar. In all conditions, the delay between the onset of each flash pattern was 250 ms.

In systems to control wheelchairs or other mobile robots, "forward" and "backward" are critical functions. Errors could be especially dangerous. Non-targets in the same flash group as the target are more likely to be incorrectly classified as target than other non-targets [Townsend et al., 2010]. In Fig. 1C, "5, 11" and "6, 12" represent icons to move the system continuously forward or backward. To decrease errors in these functions, flash groups 5 and 11 are only related to one icon (forward) and flash groups 6 and 12 are only related to one icon

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(backward) (see Fig. 1B and 1C). Our new design prevents false positives that result from incorrectly selecting a non-target icon within the same flash group as either of these critical functions.

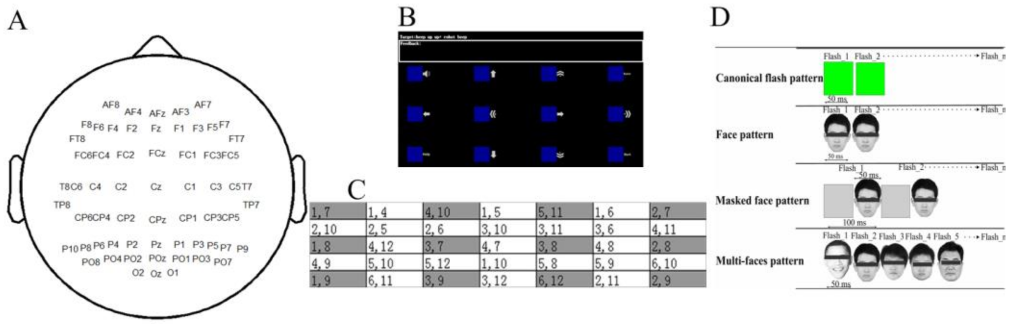

Figure 1. *Screen, configuration of stimuli, stimuli pattern and electrodes Only the gray boxes in panel C were relevant to the 3x4 matrix used in this work; the white boxes are presented only for comparison with our earlier work. In panel D, faces are portrayed with censor boxes (during the experiment, censor boxes were not presented).*

3. Results

Since this is a study in progress, we present preliminary offline results from two subjects. Fig. 2 shows that the multi-faces pattern yields better performance than the other patterns. This result suggests that face repetition effects could be decreased by using multiple faces as described here, and that further improvements are likely.

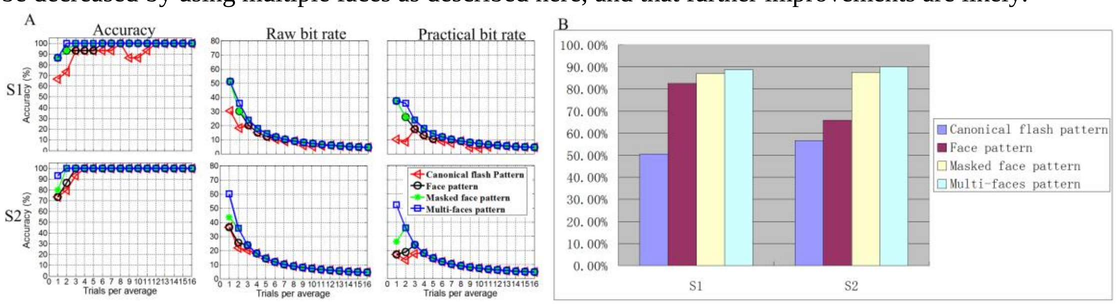

Figure 2. *A: classification accuracy, raw bit rate (RBR) and practical bit rate (PBR) based on offline data; B: classification accuracy using single trials.*

4. Discussion

This paper introduces two improvements. (1) Using the multi-faces pattern could decrease face repetition effects and improve the performance of BCI systems. (2) Our new design reduces the likelihood of erroneously selecting icons that correspond to critical functions, such as wheelchair movement.

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