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Multimodal stimulation for a P300-based BCI

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Abstract. Present-day non-invasive Brain Computer Interfaces (BCI) determine the intent of the user from a variety of different electrophysiological signals. Among others, these signals include P300 potentials recorded from the scalp. In the present study, we investigate the influence of different stimulus modalities (visual, tactile, and auditory) during sessions of P300-based BCI. In all the subjects (n=8), on-line classification displayed the highest percentage (93 %) with visual stimulus modality with respect to the audio (70%) and tactile (68%) modalities of stimulation. The elicitation of P300 was however, affected by the type of stimulus modality thus, preventing the generalization of feature classification in the same subject during P300-based BCI control performed under different modalities of stimulation.

Keywords: P300, BCI

1. Introduction

The P300 event-related brain potential is a positive endogenous potential which occurs over the parietal scalp region, when infrequent or particularly significant stimuli are interspersed with frequent or routine stimuli (Sutton et al. 1965). Because of its stability and reproducibility, the P300 has been proposed as a control signal for brain computer interface (BCI) systems (Donchin et al., 2000). Indeed, a P300-based BCI has an apparent advantage in that it requires no initial user training: P300 is a typical, or naive, response to a desired choice. However, P300 potential can vary according to the type of stimulation utilized to evoke it (Fabiani et al., 1987). In this study, different modalities of stimulation to induce P300 were explored within a P300-based BCI system, and their impact on the on-line classification performance was estimated.

2. Materials and Methods

Eight subjects (23-37 years, 3 males, 5 female) with no previous experience of BCIs, participated to the study. Visual acuity was normal or corrected to normal in all subjects. One of them was color blind. Scalp EEG data (61 channel EEG system; Brain Products, Germany; sampling rate 250Hz) were acquired from each subject during BCI sessions operated by a BCI2000 software (Schalk et al., 2004). Data were stored for offline analysis. A dedicated software was implemented to integrate the BCI2000 framework with a tactor hardware-software system (C-2 Tactors; Engineering Acoustics, Inc, WinterPark, USA) to deliver vibrotactile stimuli.

Each participant underwent 5 sessions (4 run each; 30 min duration) which included one type of stimulation at time with the following order: visual, auditory and tactile stimuli. All targets provided the subject with equivalent visual, auditory and tactile stimulation. To the aim of measuring performances, one of them was delivered during the presentation phase (before the actual stimulation sequence), marking which stimulus the subject should be concentrating on. Responses were collected from each of the eight stimuli (see below), which were repeated 15 times in each sequence. The subjects were required to mentally count the occurrence of the target stimulus.

As for the visual stimulus modality, subjects were provided with 8 different images showing one black circle surrounded by one little red circle moving in 8 different positions. The auditory stimulation was delivered by using 8 different stimuli, ('do', 're', 'mi', 'fa', 'sol', 'la', 'si' and 'ut'; pronounced at the same tone height). Finally, the tactile stimulation was provided by means of eight tactors positioned on different sites of the hands and wrists (frequency of stimulation tuned on a narrow band about 250Hz). As a control condition, an "oddball" like-task ("oddball-like") was designed in which 8 different stimuli were delivered consisting of 7 red circles (no-target stimuli) and one blue square (target stimulus). The best control features were extracted from the EEG data acquired during the first 4 sessions, by using off-line step-wise linear discriminate analysis (SWLDA). The last session consisted of 4 runs, one for each stimulus modality and the extracted best control features were used to classify the responses and to give feedback to the subject accordingly.

3. Results

As shown in Figure 1, the online classification performance reached the highest level in all subjects (93 % in average) with respect to the auditory and tactile stimulation modalities which yielded to a correct classification percentages of 70% and 68% respectively. Similarly, the r^2 computed for the 3 types of stimulation (visual, auditory and tactile) indicated that visual modality of stimulus exhibited higher values than those observed for the auditory and tactile stimuli (Fig. 2). The analysis of the characteristics of the P300 elicited under the 3 different stimulus conditions revealed that the latency of the principal P300 component was increased (600ms peak after stimulus) with auditory and tactile stimuli with respect to the visual stimulation (400ms peak, as in "oddball-like" control condition). No evident changes were observed in the topography of the P300 principal component evoked with different stimulus modalities.

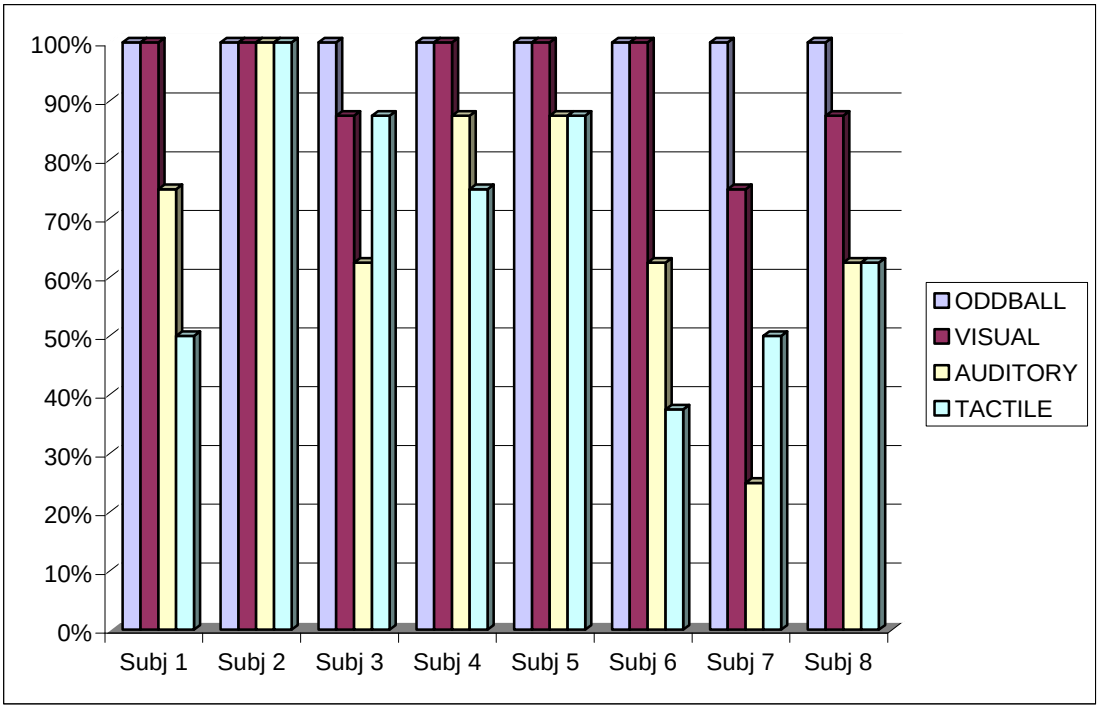

Figure 1. *Histogram showing the on-line classification performance (in percentage) obtained for each stimulus modality (5th session).*

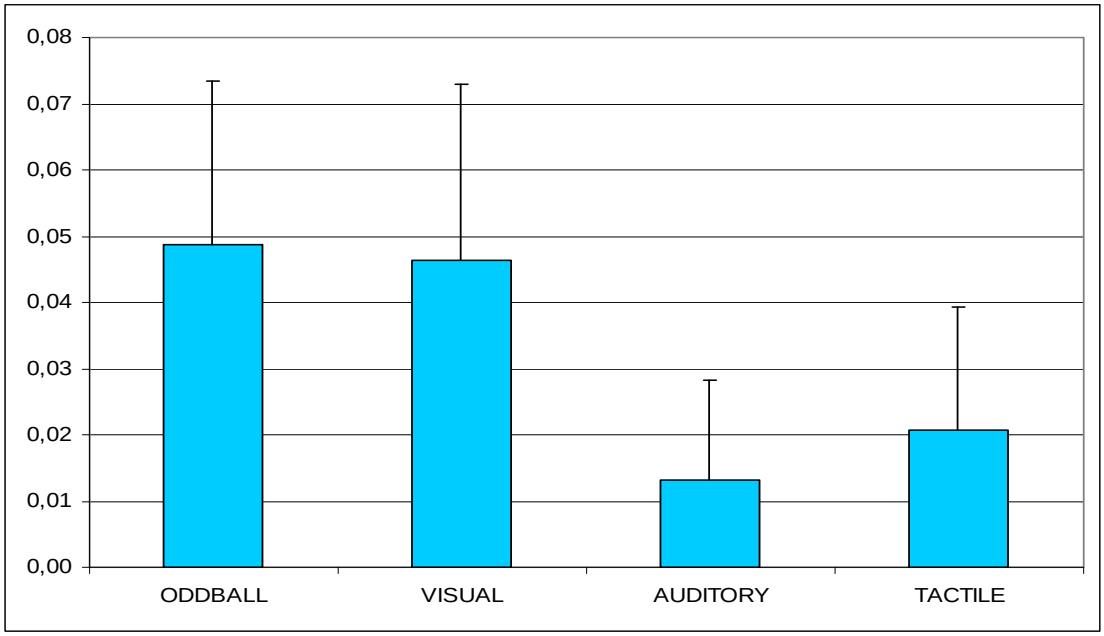

Figure 2. *Histogram of the r^2 mean values obtained for all subjects during each stimulus modality.*

4. Discussion

These preliminary findings suggest that multimodal stimulation can be of considered in a P300-based BCI application. The increase in P300 latency observed with auditory and tactile stimulation can be presumably related to a more demanding level in task accomplishment (target recognition) with respect to what occurs under visual presentation of the target. The finding of P300 characteristic modification as function of the stimulus modality indicates that it is required to tune control feature according to the stimulus modality for a successful P300-based BCI applications.

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