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A New Region-based BCI Speller Design using Steady State Visual Evoked Potentials

Md. A. Haider[1*], B. Cosatto[1,2] , Md. N. Alam[1], K. Tavakolian[1], R. Fazel-Rezai[1]
[1]University of North Dakota, Grand Forks, ND,USA; [2]Ecole d'ingénieurs généralistes, La Rochelle, France
*E-mail: mdali.haider@my.und.edu

Introduction: To implement a brain computer interface (BCI) system, one approach is to use repetitive visual stimuli that develop stable voltage oscillation pattern in electroencephalogram (EEG), namely steady state visual evoked potential (SSVEP). Paradigm presented in this paper was designed to create a SSVEP BCI speller that is based on our previous work in P300 region-based speller [1].
Material, Methods and Results: Figure 1 depicts the visual stimuli as presented on a computer screen. Instead of LED light sources [2], a computer monitor is used to present fast flickering graphical display which is also efficient for instant manipulation of the types of characters including their size, color and adjacency [3]. The implementation was done using PsychToolbox [4] inside MATLAB. The speller paradigm in this study contains seven different group of characters placed on seven locations on the screen [1]. In our earlier study, four different paradigms (single character; row/column; regions with alphabetical order; and regions with the frequency of the characters' usage) were compared [5]. However, the region based paradigm with the frequency of characters' usage outperformed others with more than 90% spelling accuracy. In the proposed SSVEP design (Figure 1), the outermost circular boundary of each region encloses a combination of different geometrical shapes such as a cross vanishing point and a flickering circular bubble. SSVEP frequencies of 15, 16, 17, 18, 19, 20, and 21 Hz were selected for seven regions. In this two-level paradigm, after a region is selected in the first level (Figure 1.a), a character from the same region is identified in the following level (Figure 1.b). In this design, seven objects were flickering simultaneously and the distance between two such adjacent objects was maintained at as high as 5 cm, thereby reducing the subjects' annoyance and fatigue caused by the crowding effect [5]. It was shown that the user acceptability is higher in region-based paradigm than single character and row/column paradigms [5]. The minimum energy method and a linear discriminant analysis has been applied to classify these EEG signals.

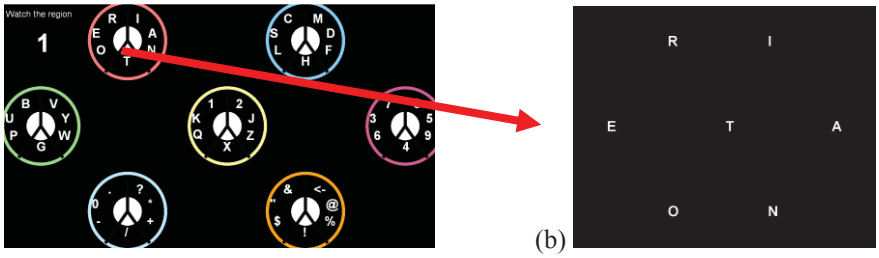

Figure 1. *SSVEP visual stimulation paradigm in level 1 (a) and 2 (b). During the moment the screen shot was taken, the program is asking the user to focus on region one. Each region is colored differenly to indicate that they have different flickering frequency. In the second level, the charcters of the detected region expands as shown on the screen and flicker.*

Discussion: Seven flashing frequency was used in the proposed SSVEP BCI speller paradigm to achieve a speller with 49 characters. The next steps in this study are to (1) combine the proposed paradigm with the P300 region based; (2) compare SSVEP, P300 and hybrid region based paradigms; and (3) compare the developed region-based hybrid speller with the other hybrid spellers [6].

Significance: One of the limitations of a SSVEP paradigms is the number of control commands generated by the SSVEP BCI. In the proposed SSVEP paradigm, 49 characters were controlled only with 7 flickering frequencies. Therefore, the outcome of this study will be a step forward toward implementation of a SSVEP-based BCI in real-life applications.

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