A MULTI-PROPOSAL MOBILE EEG SYSTEM

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Abstract: Abstract: *A multi-proposal mobile system for electroencephalography recording is here presented, which is based on a previous modification of a consumer EEG equipment, with the intention to be used for BCI proposes. Still, for test purposes, a reference displacement was done to compare the data with its original position. To validate this equipment, SSVEP and ERD/ERS trials analysis were done, with both reference placement, and the results compared to measure the reliability of the system.*

Keywords: *Motor Imagery, Brain-Computer Interfaces, EEG, Virtual Reality Environment, 3D Virtual Environment.*

Introduction

To acquire brain activities, different measurement systems have been developed so far. These equipment can be classified in two groups regarding the way the electrical activity is acquired in relation to the subject's body: from invasive recording techniques, in which electrodes are implanted into/over the cortex by craniotomy, to non-invasive ones. This last one can be exemplified by Magnetoencephalography (MEG), Electroencephalography (EEG), Positron Emission Tomography (PET) or Functional Magnetic Resonance Imaging (fMRI). EEG is an old technique, done by H. Berger for the first time in 1924. It is the most widely used technique in current BCI (Brain Computer Interface) studies as it has sufficient spatial resolution to register brain activity [1], [2]. MEG, PET or fMRI presents a better spatial resolution than EEG equipment, however, these equipment are too expensive and bound to the laboratory because of its size. EEG equipment are often cheap and sometimes even portable, but it has limited spatial resolution and signal-to-noise ratio [3].

One of the major goals for BCI research is to provide a new communication channel for people with severe neuromuscular disabilities bypassing the normal output pathways. It is an advantage, in the BCI field, to use portable EEG equipment, since it would allow anyone to take the equipment to the place the subject is. The main propose of this work is to build and test a low cost EEG system which could acquire data from sensorimotor brain regions and, at the same time, portable, wireless, with a fast and easy set up, and with dry electrodes. Emotiv EPOC™ is a portable wireless equipment, but its electrodes placement lacks the sensorimotor regions. For this reason, several authors used modified versions of Emotiv EPOC™. To test the reliability of the equipment, ERD (event-related desynchronization) ERS (event-related synchronization) and SSVEP (steady state visually evoked potential) were used. Brain oscillations are typically categorized according to specific frequency bands which are named after Greek letters (delta: below 4 Hz, theta: 4-7 Hz, alpha: 8-12 Hz, beta: 12-30 Hz, gamma: above 30 Hz). The decrease of oscillatory activity energy in a specific frequency band is ERD. Correspondingly, the increase of oscillatory activity in a specific frequency band is called ERS. ERD/ERS patterns can be found in sensorimotor areas following both voluntary movement and somatosensory stimulation [4], [5]. On the other hand, SSVEP are response signals to visual stimulation at a specific frequency. When a subject focus his/her view on a flickering target, the amplitude of the SSVEP increases at the fundamental frequency of the target, and at the second and third harmonics [6]. The amplitude and phase of the SSVEP depend on stimulus parameters such as repetition rate. After visual stimulation with an alternating checkerboard, evoked potentials can be recorded from occipital lobe [7], [8].

Materials and Methods

To build this evaluated EEG equipment, the hardware from Emotiv EPOC™, a consumer EEG equipment, 14-channel wireless (128 Hz sampling rate; 0.1645 Hz band-pass) was used. The external plastic structure was removed and the wires were replaced. The electrodes placement scheme was obtained from a previous similar EEG equipment construction [9]. In their work, Debener et al. used an Easycap© electrode cap in replacement for the original Emotiv EPOC™ electrodes. This cap uses conductive gel to build the contact of the electrodes to the user's scalp, so the subject needs to wash his/her hair after the experiment. This is not required with the Emotiv EPOC™ system as electrode impedance is lowered by a saline liquid [10]. The first version of our evaluated EEG equipment used Easycap© as Debener et al., but for the reason cited above, another cap was built using neoprene and o-rings to fix the original Emotiv EPOC™ electrodes on it, thus making usage of its dry electrodes. The circuit boards, battery and wires were allocated in a plastic box, which can be fixed to the back of the neoprene cap (Figure1).

It transfers the data wirelessly to the computer. Fourteen electrodes were positioned according to the international 10-20 system. The grounding electrode was positioned at FZ position, and for the reference electrode, 2 different positions were tested. The first one was placed at FCz, the same position used for Debener et al. [9]. The second one, for testing purposes, was placed between Pz and CPz. Figure 2 shows the electrodes position.

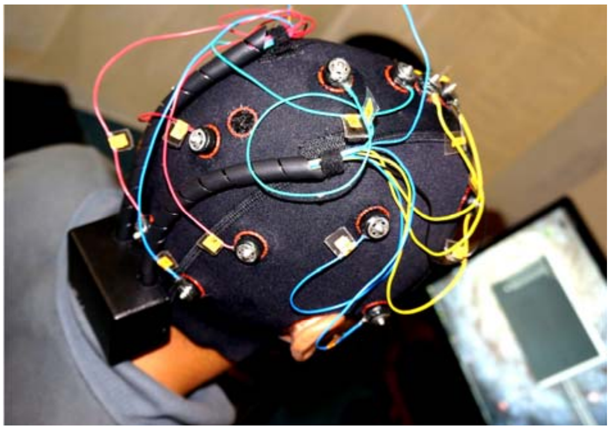

Figure 1: Neoprene cap with Emotiv EPOC™ modified hardware.

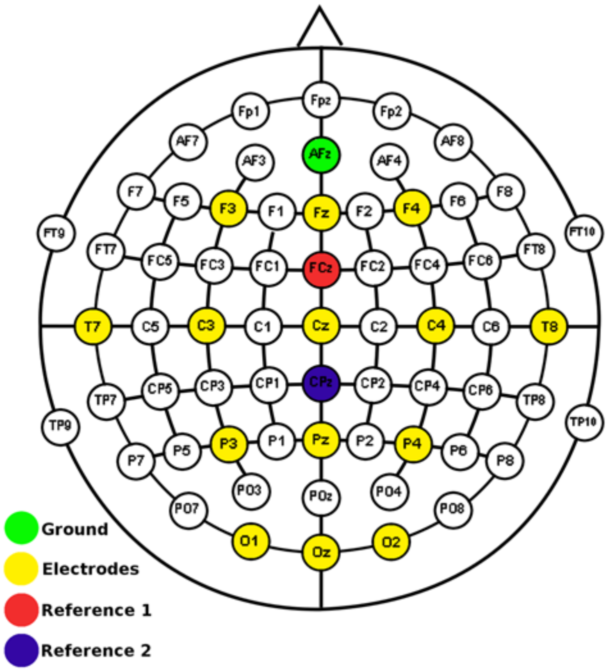

Figure 2: Electrodes positioning.

Regarding the experimental environment, a MOR© Gazebo 3x3 meters tent was used to visually isolate the subjects. Seven right-handed subjects, 2 female and 5 male, participated the tests. They were instructed to sit with their hands resting on their legs, to stay as still as possible and to observe the center of the screen. A LCD monitor was placed on a table 70 cm in front of the subject. For the SSVEP task, an alternating checkerboard was displayed in the middle of the LCD monitor, at a frequency of 8.0 ± 0.01 Hz. To produce such frequency, a code was written in C language using OpenGL® library, run at a Linux Mint© terminal. Fifty trials of 4 seconds long were used at the SSVEP protocol. For the tapping task, a 1 till 10 seconds count up timer was displayed at the LCD screen. The subject was instructed to raise his/her index finger at second 4 and tap at second 5. Figure 3 shows a block diagram of the taping task.

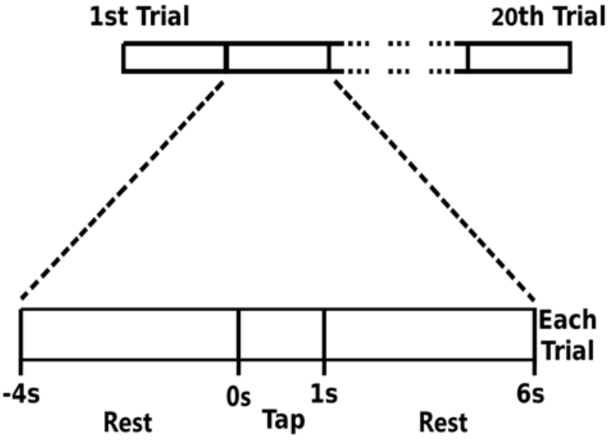

Figure 3: block diagram for the taping task.

The EEG was acquired at a sampling rate of 128 Hz. The signal processing was performed on MATLAB® 8.01. All cited software were used on a Hewlett-Packard© G42-240Br notebook running Linux Mint© Cinnamon 64 bits, with a Intel™ Core i3-350M, 2.26 GHz processor, 4GB of RAM memory, and a HDD of 320 GB.

An automatic trial rejection counted the number of contaminated samples in each trial to provide the percentage of samples with artefacts or outliers. The percentage obtained was used to define the threshold of an a posteriori probability of the classifier and its acceptance or rejection about the trial analysed. Its algorithm is designed to use the raw data and calculate its medium value. With this result it makes a subtraction from the raw EEG data and medium value, and then it separates positive and negative results. Later, it calculates the medium again and the positive threshold is defined as 2 times the new positive medium value. Then, it counts of the contaminated samples in each trial to provide the percentage of samples with artefacts or outliers. Welch peridiogram was used to calculate the EEG signal power spectrum of the electrodes O1, O2 and Oz [11]. ERD/ERS were computed on EEG signals obtained from C3, C4 and Cz electrodes during a motor task [12].

Results

Figure 4 was generated using the SSVEP trials, plotted with frequency at the X axis and amplitude at the Y axis, and the 3 different lines plotted represent O1, O2 and Oz electrodes results. Figure 4 (a) was generated using data obtained with the reference 1, and Figure 4 (b) was generated using data obtained with reference 2. At both results it is possible to notice the stimulus peak and its harmonics. It is noticeable that using reference 1 the power spectrum is clearer then when using reference 2.

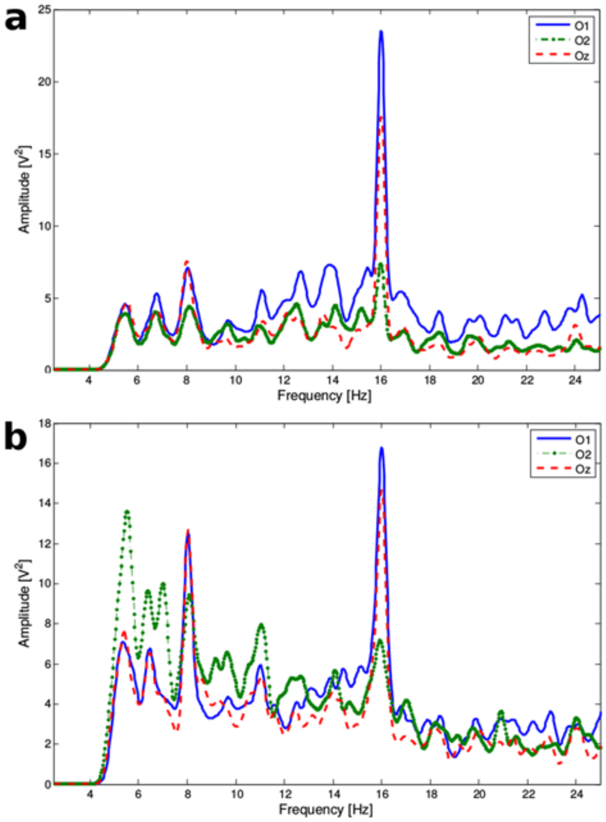

Figure 4: SSVEP trials. (a) reference 1; (b) reference 2.

As described at the methodology, the tapping trials were used to generate motor task results. Figure 5 shows the ERD/ERS results using C3 C4 and Cz electrodes channels. At this same figure, (a) was obtained using data from reference 1, and (b) was obtained using data from reference 2.

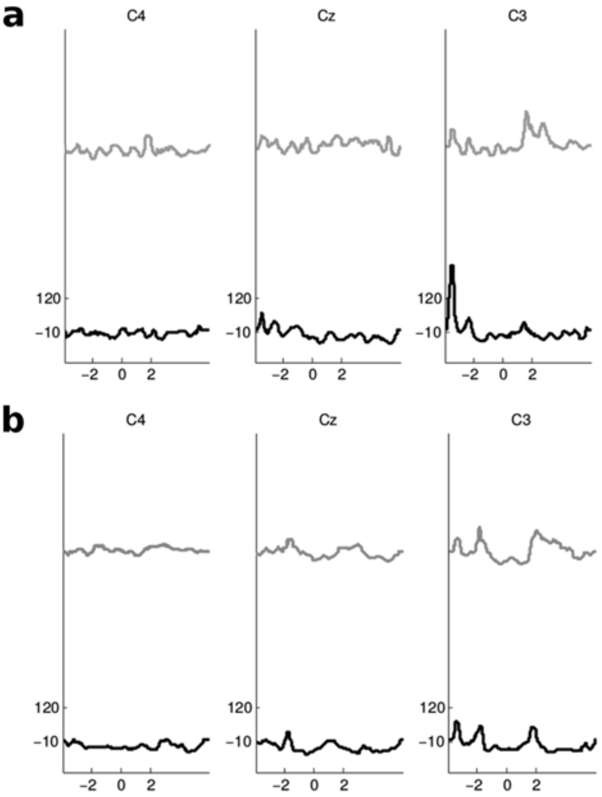

Figure 5: ERD/ERS results using C3 C4 and Cz electrodes. (a) reference 1; (b) reference 2.

The results for the reference electrode positioning are presented in Figure 6 (a) and (b). For both, the X axis contains the values to calculate the threshold, and with these results the numbers of artefacts contaminated samples are calculated, and the Y axis contains the amount of rejected samples in percentage. Figure 6 (a) was generated using SSVEP trial, and Figure 6 (b) was generated using motor tasks trial (tapping). Comparing the results shown in this figure for the placement of the references, reference 1 placement obtains a lower trial rejection for every threshold value. It demonstrates that the usage of the reference 1 placement is a better option for this equipment. A Wilcoxon Signed-Ranks test (WSR) was used to evaluate the difference between the means of rejection trials at reference 1 and reference 2, and the results shows that there was not statistical significance (p-value>0.05) and the effect size was medium [14].

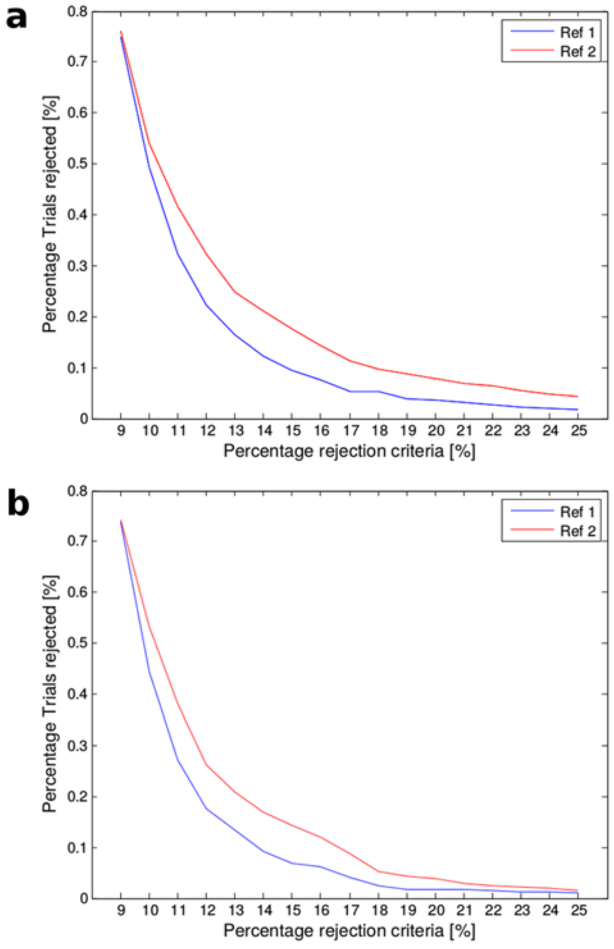

Figure 6: Reference placement result comparison. (a) was generated using SSVEP trial; (b) was generated using motor task trials (tapping).

Conclusion

With this work we can conclude that the different positioning of the reference electrode did not show significant statistical difference, but with these rejection analyses it is shown that the reference 1 position is less affected by artifacts. The modifications done at the Emotiv EPOC™ equipment, with the electrodes displacement, opened the possibility to the system to be used with SSVEP BCIs and motor task BCIs. The cap, when compared with the original Emotiv EPOC™ system, let us ensure that the electrodes remain fixed on their position. The usage of the original dry electrodes from Emotiv EPOC™ is an advantage, since it is important to make the equipment as comfortable as possible to its users. For future works, we will test the built cap with stroke subjects to evaluate the possibility of its usage on rehabilitation BCIs.

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