Brain Activity Quantification for Sport Audiovisual Content Visualization using EEG

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Abstract: This study aims to analyse the brain activity occurring during the observation of football videos randomly intermingled in a documentary. The electroencephalography recording is employed to measure the signal scalp of 20 healthy subjects. The signal preprocessing is performed using Independent Component Analysis (ICA) and ADJUST. The cerebral activity is quantified through Global Field Power (GFP) in order to classify the clips following an emotive scale, to establish differences between positive and negative video stimuli. Results are summarized as follows: (1) Comparing the cerebral activity of a positive video with its predecessor neutral stimulus, significant differences were obtained (p = .0019). However, the same analysis for negative videos shows no significant differences (p = .096). (2) The number of peaks in brain activity allow us to classify the videos used in the study. (3) The brain activity in theta and beta bands presents different distribution of peaks, occurring at different frames.

1 INTRODUCTION

Today there is an increasing interest in understanding the human behaviour in certain situations. Using various sensors it is possible to collect physiological signals from people and to obtain metrics that quantify feelings, emotions, and memory among others (Sulaiman et al., 2010; Sulaiman et al., 2011; Brouwer et al., 2011; Norhazman et al., 2012).

Researchers within the consumer neuroscience community promote the view that findings and methods from neuroscience complement and illuminate existing knowledge in consumer research in order to better understand consumer behaviour (Klucharev et al., 2008). In the literature, there are recent interesting works (Vecchiato et al., 2010a; Vecchiato et al., 2010b) where Electroencephalography signal (EEG), Galvanic Skin Response (GSR) and Heart Rate (HR) were employed to analyse the brain activity during the "naturalistic" observation of commercial ads.

In this paper, the same methodology used in the observation of commercials has been applied to a new field, sport, of vital importance to society.

The present work is a preliminary study that analyses the brain activity occurring during the observation of football videos randomly intermingled in a documentary in order to understand the behaviour and feelings of fans when they are watching a match in the stadium and when they are enjoying a title earned by their football clubs.

The experimental questions to be studied in this work are the following:

- Are there differences in cerebral activity during the observation of positive and negative emotional videos?
- May the cerebral activity be objectively quantified and may this objective measurement be used to sort all videos from low to high emotionality?
- Is it possible to automatically determine the video frames that produce a significant increase or decrease in cerebral activity?

The paper is organized as follows: in Section 2 the main stages of the proposed method are described, including information of participants, the experimental design of the study and the procedures for EEG recording and analysis. Section 3 shows the experimental results and discussion. Finally, Section 4 provides conclusions and some future work lines.

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2 METHODS

2.1 Subjects

In the experiment twenty Valencia C.F fans were involved (18 males and 2 females), aged between 22 to 50 years old. However, EEG data from one male participant were removed due to corrupted data. The corrupted data caused standard deviation greater than average value for Theta and Beta bands. Therefore, the study consisted of 17 males and 2 females. All participants had normal or corrected-to-normal vision and hearing. They had not participated in a brain study before. Participants were duly informed about the entire protocol of the study before signing the consent form.

2.2 Experimental Design

The procedure of the experimental task consisted in observing a thirty-minute documentary of Valencia city sequences in which three Valencia C.F video blocks of two minutes were inserted: the first one after eight minutes from the beginning, the second one in the middle and the last one at the end of the trial. Each of these blocks was formed by two emotional videos of important moments of the football team history. These videos were randomly distributed within the blocks according to one of the following configurations: positive-positive, positive-negative, negative-positive, negative-negative. During the whole documentary, a total of six emotional videos were presented. The chosen clips showed highlights of the club's history, for example: Two Champions' League's finals that the team lost (2000 and 2001), the titles won in the 2003-2004 season (Spanish League and UEFA cups), the goals scored in the last season and some sequences of club's junior teams. Randomization of the occurrence of Valencia C.F videos within the blocks was made to remove the factor "sequence" as possible confounding effect in the later analysis.

2.3 EEG Recording

The cerebral activity was recorded by means of a stationary 32-channel system (TMSI hardware and Neurolab Software) Ag/AgCl water based electrode. All subjects were comfortably seated on a reclining chair, in an electrically-shielded, dimly-lit lab room. They watched the audiovisual content of the experiment on a large screen through a projector with the purpose of simulating that the subject was at the football stadium in stimulating phases (Figure 1). EEG activity was collected at a sampling rate of 256 Hz while impedances kept below 5kΩ. For the experiment, we used thirty electrodes and the bracelet ground located on the opposite wrist to the habitual subject hand. The montage followed the International 10-20 system (Sanei and Chambers, 2007) and is shown in Figure 2.

Figure 1: Subject using the 32-channel system in the experiment.

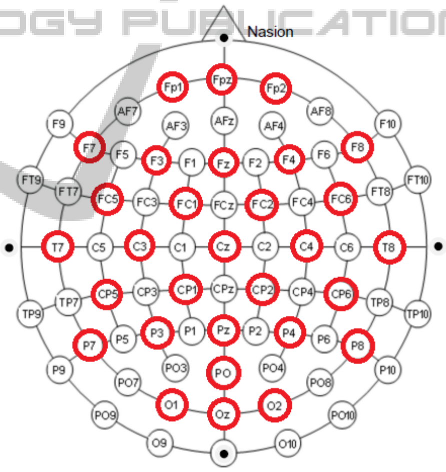


Figure 2: Position of electrodes used following 10-20 International system.

2.4 EEG Analysis

First, the baseline of EEG traces was removed and the output dataset was band pass (0.5 - 40 Hz) filtered. Then, the corrupted data channels were rejected and the stimuli events were integrated into the data in order to segment the EEG signal. Next step was to calculate the kurtosis of the extracted segmentation epochs in order to reject the epochs with high kurtosis level. Later, Independent Component Analysis (ICA) was applied to detect and remove components due to eye movements, blinks and muscular artefacts using a electroencephalography software in Matlab (EEGLAB) (Delorme and Makeig, 2004). An automatic method (ADJUST) (Mognon et al., 2011) was used to discriminate the artefacted components of EEG signals by combining stereotyped artefact-specific spatial and temporal features.

Each artefact-free trace EEG was band pass filtered twice in order to isolate the only spectral components in theta (4 - 7 Hz) and beta (13 - 24 Hz) bands. These frequency bands are associated with human memorization process (Vecchiato et al., 2010a; Vecchiato et al., 2010b).

The record obtained directly from the scalp shows intra-cranial synchronous activation of many neurons. To quantify the amount of cerebral activity the Global Field Power (GFP) (Lehmann and Skrandies, 1980) was employed using (1).

$$GFP = \sqrt{\frac{\sum_{i=1}^{N_e}\sum_{j=1}^{N_e}(u_i - u_j)^2}{N_e}} \quad (1)$$

where u_i is the potential at the electrode i (over time), u_j is the potential at the electrode j (over time) and N_e is the total number of electrodes employed to compute the GFP.

Frontal areas are the cerebral locations mainly involved in the phenomena we are interested in investigating (Vecchiato et al., 2010a). Thus, the frontal electrodes were used to compute GFP, concretely the signals coming from the following frontal, pre-frontal and central electrodes of the 10-20 International system (Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, Fc5, Fc1, Fc2 and Fc6) were taken into account in the calculation. A GFP signal was then calculated for each band considered in the experiment, theta and beta. Finally, these GFP signals were normalized according to (2), obtaining the corresponding *Zscore* measurements.

$$Zscore = \frac{GFP_i - \overline{GFP_B}}{\sigma(GFP_B)} \quad (2)$$

where GFP_i is the Global Field Power during the stimulus under analysis, $\overline{GFP_B}$ is the GFP mean during a period of two-minute neutral documentary, considered as baseline, and $\sigma(GFP_B)$ is the standard deviation of the same period.

For each positive and negative stimulus and subject the most significant peaks for *Zscore* variables were obtained, considering a peak all values that exceeds the threshold of $Zscore >= 3$, associated with a $p < 0.05$ in the gaussian curve fitted over *Zscore* distribution (averaged for all participants).

In this way, two parameters were calculated: the number of peaks inside the time window defined by the clip duration (Np_s) and the number of peaks inside a window of the same length during the visualization of the documentary immediately preceding the stimulus under analysis (Np_{ps}). Figure 3 shows the EEG traces for a subject during an interval of the experiment. Blue bars delimit the block of documentary previous to the stimulus under analysis and red bars delimit the stimulus. Np_s and Np_{ps} were obtained only considering the yellow window shown in Figure 3, because both time intervals (pre-stimulus and stimulus) must have the same length.

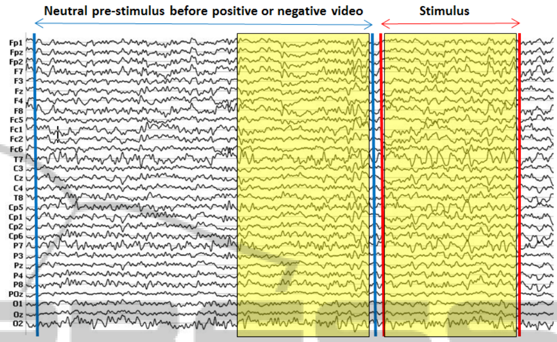


Figure 3: Temporal window in stimulus and pre-stimulus.

Besides Np_s and Np_{ps}, an average value of *Zscore*, $\overline{Zscore}$, was calculated for subject and stimulus by means of:

$$\overline{Zscore} = \frac{1}{N}\sum_{n\in W} Zscore[n],$$

where W is a window of duration N (stimulus length).

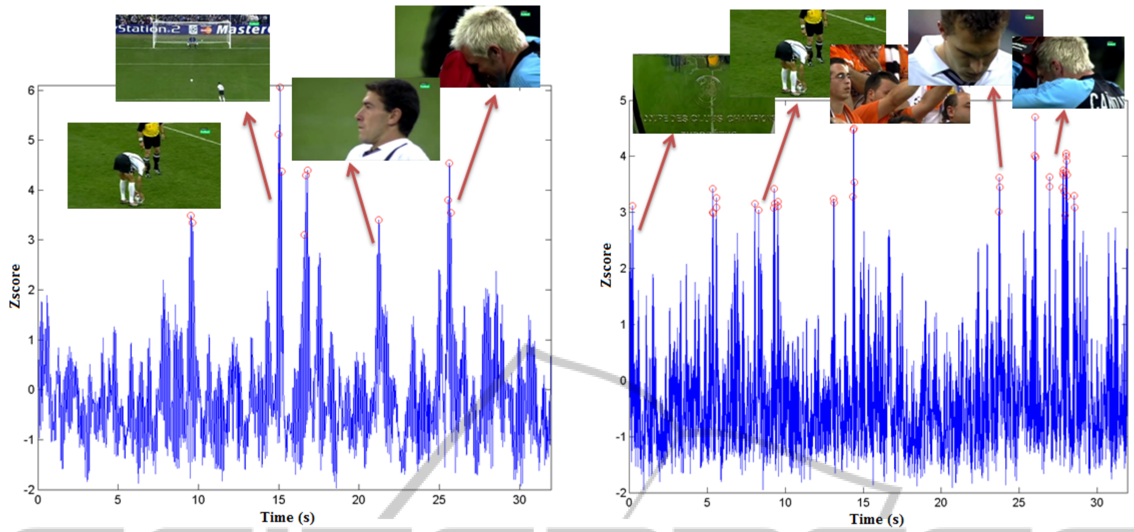
These parameters, $\overline{Zscore}$, Np_s and Np_{ps}, were obtained for both bands of interest (theta and beta).

3 RESULTS AND DISCUSSION

In this section two different kind of results will be shown. Firstly, the results of the *Zscore* evolution for a typical subject will be presented, showing moreover the results of peak detection as well as the frames corresponding to these peaks of activation (key frames). Besides that, the statistical analysis of $\overline{Zscore}$ and Np_s versus Np_{ps} was performed by using the Analysis of Variance (ANOVA) for different factors.

3.1 GFP Evolution

Figure 4 shows the typical responses of the *Zscore* variable obtained by the GFP of frontal electrodes in theta (Figure 4.a) and beta (Figure 4.b) bands for a representative Valencia C.F fan during the observation of a emotionally negative video within the documentary. As can be seen, the *Zscore* in each band presents different response, showing different number and distribution of peaks, occurring at different frames of the stimulus (Vecchiato et al., 2010a).



(a) (b)

Figure 4: Responses of the *Zscore* computed on frontal electrodes in theta (a) and beta (b) frequency bands and peaks of cerebral activity ($Zscore >= 3$) with the corresponding keyframes detected for a representative subject during the observation of a negative emotional video within the documentary.

3.2 Differences Between Stimuli

As mentioned in the introduction section of this work, another purpose of this study was to explore the possibility of distinguishing between the emotional character of the stimuli (positive or negative) by means of cerebral activity quantification. Significant differences (F = 6.054, p = .0019) were obtained when the mean number of peaks (Np_s) of positive emotional videos was compared with the mean number of peaks of the predecessor neutral stimulus (Np_{ps}). However, when the same comparison for negative stimuli was done, the results were not significant (F = 2.916 , p = .096). The average of *Zscore* was computed but not significant differences were obtained in the statistical analysis.

For the classification of the different videos employed in the study according to the brain activity quantification, the average number of peaks for all subjects for each video has been used.

According to Figure 5 videos that showed higher cerebral activity were positive 2 (the UEFA title won) and positive 4 (the Spanish League title won). Otherwise the two negative videos registered the lowest number of peaks therefore the lowest cerebral activity. A negative video is emotional for subjects because they remember those moments but a positive video is more rewarding for them.

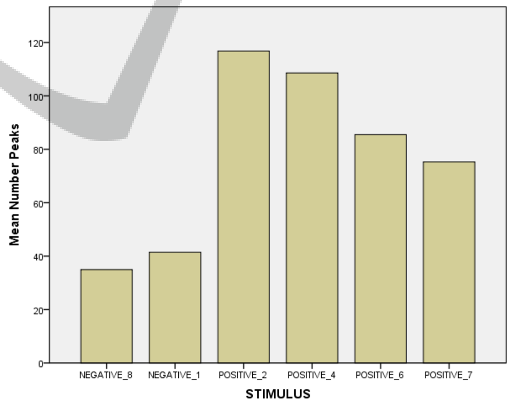


Figure 5: Average number of peaks measured at each stimulus.

4 CONCLUSIONS

Results of the present study suggests the following answers to the questions elicited in the introduction section:

- After analysing all stimuli presented in the experiment using the cerebral activity quantification based on the number of peaks, a different behaviour between positive and negative video has been found out. Comparing the cerebral activity of a positive video (Np_s) with its predecessor neutral stimulus (Np_{ps}), significant differences were obtained. However, the same analysis for negative videos doesn't show significant differences. An increase in brain activity was recorded when positive emotions are stimulated.

- The quantification of the brain activity has been performed using GFP. As a result, an emotional classification of the videos was made taking into account the average number of peaks across the subjects for each stimulus. As it was shown in previous question, an increase in cerebral activity occurs while the positive videos are displayed.
- Using the *Zscore* index obtained from the GFP, it is possible to analyse frame by frame each video in order to study the moments of the video where the subject shows higher cerebral activity (key frames). *Zscore* in theta and beta bands presents different distribution of peaks, occurring at different frames. The key frames detected for most of the subjects were the same, showing similar patterns. Celebration of goals and titles by players and fans were the frames where the highest brain activity was measured.

In conclusion, the football videos analysed in this study provoked an increase in the cerebral activity in relation to the viewing of the documentary. Moreover, during the visualization of positive videos the subjects experimented on average an increase in cerebral activity higher than the experimented during the visualization of negative videos.

In future research, observations and conclusions of this work will be widely validated. The human behaviour in diverse audiovisual content will be evaluated in order to understand better the emotions and feelings processed in the brain.

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