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Spectral EEG frontal asymmetries correlate with the experienced pleasantness of TV commercial advertisements

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Abstract The aim of this research is to analyze the changes in the EEG frontal activity during the observation of commercial videoclips. In particular, we aimed to investigate the existence of EEG frontal asymmetries in the distribution of the signals' power spectra related to experienced pleasantness of the video, as explicitly rated by the eleven experimental subjects investigated. In the analyzed population, maps of Power spectral density (PSD) showed an asymmetrical increase of theta and alpha activity related to the observation of pleasant (unpleasant) advertisements in the left (right) hemisphere. A correlation analysis revealed that the increase of PSD at left frontal sites is negatively correlated with the degree of pleasantness perceived. Conversely, the de-synchronization of left alpha frontal activity is positively correlated with judgments of high pleasantness. Moreover, our data presented an increase of PSD related to the observation of unpleasant commercials, which resulted higher with respect to the one elicited by pleasant advertisements.

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1 Introduction

In these last years, we assisted to an increased interest in the use of brain imaging techniques for the analysis of brain responses to commercial advertisements or for the investigation of purchasing attitudes [2, 6, 14, 16, 19]. This interest is justified by the possibility to correlate the particular brain activations observed with different characteristics of the proposed commercial advertisements to derive conclusions about the adequacy of such stimuli for the consumer. So far, standard marketing techniques to test advertising stimuli use verbal interviews of subjects after their exposure to novel commercial advertisements. This procedure is usually performed before the massive launch of the advertisings campaign itself (ad pre-test). However, it is now recognized that often the verbal advertising pre-test interviews are flawed by the underlying will of the subjects to be compliant with the interviewer. This usually hides to the interviewer the real thoughts of the subjects with respect to the advertising observed. Hence, it became relevant in this context to measure quantitatively the emotional engage of the subjects during the observation of an advertising using neuroscience-based techniques.

Nowadays, researchers are attempting to investigate the signs of the brain activity correlated with an increase of attention, memory, and emotional engagement during the observation of commercial advertisements [18, 22]. In fact, indirect variables of emotional processing could be gathered by tracking variations of the activity of specific anatomical structures linked to the emotional processing activity in humans, such as the pre- and frontal cortex (PFC

and FC, respectively, [11]). The PFC region is structurally and functionally heterogeneous but its role in the generation of the emotions is well recognized [9]. EEG spectral power analyses indicate that the anterior cerebral hemispheres are differentially lateralized for approach and withdrawal motivational tendencies and emotions. Specifically, findings suggest that the left PFC is an important brain area in a widespread circuit that mediates appetitive approach, while the right PFC appears to form a major component of a neural circuit that instantiates defensive withdrawal [8, 10].

In this scenario, our purpose is to investigate the modulation of the Power spectral density (PSD) of the EEG rhythms elicited in the FC and PFC during the observation of commercial advertisements. In particular, the aim of this study is to analyze the EEG frontal asymmetrical activations occurring while subjects are watching emotional scenes of a TV advertisement. Moreover, we would like to define a cerebral index strictly correlated with the degree of pleasantness perceived by the experimental subjects. In particular, with this study we would like to answer to the following experimental questions:

1. Is there exists any EEG frontal asymmetrical activity when we are watching pleasant and unpleasant commercial advertisements?
2. Is it possible to extract from the EEG signals a descriptor which is strictly correlated with the degree of perceived pleasantness?

2 Methods

2.1 Experimental paradigm

Eleven voluntary and healthy undergraduate students of our faculty participated in the study (age, 22–25 years; 8 males). Written informed consent was obtained from each subject after the explanation of the study, which was approved by the local institutional ethics committee of the Scientific Institute for Research, Hospitalization and Health Care, "Fondazione Santa Lucia" in Rome. Subjects had no personal history of neurological or psychiatric disorder. They were free from medications, or alcohol or drugs abuse. For the EEG data acquisition, subjects were comfortably seated on a reclining chair in an electrically shielded and dimly lit room. They were exposed to the vision of a movie of about 30 min and asked to pay attention to the above stimuli. Subjects were not aware about the aim of the experiment and did not know that an interview would have been performed after the recording. The movie consisted in a neutral documentary. Three interruptions have been generated: one at the beginning, the second at the middle, and the last one at the end of the documentary. Each interruption was composed by six 30 s long commercial videoclips. Eighteen commercials were showed during the whole documentary. The TV spots were relative to standard international brands of commercial products, such as cars and food, and no profit associations, such as FAO and Greenpeace. They have never been broadcasted in the country in which the experiment has been performed (Italy). Hence, the advertising material was new to the subjects as well as the documentary they observed. After 2 h from the end of the EEG recording, each experimental subject was re-contacted and an interview was performed. In such interview, the experimenter asked the subjects to recall the videoclips they remembered. First, the operator verbally listed the sequence of advertisements presented within the documentary asking the subjects to tell which advertisement they remembered, one by one. Successively, the interviewer showed on a paper several frame sequences of each advertisement inserted in the movie. Analogously, the interviewer also showed on the paper several pictures of an equal number of advertisements which we did not choose as stimuli. This was done to provide to the subjects the same number of distractors when compared to the target pictures. Finally, for each advertisement the subjects remembered, we asked them to give a score ranging between 1 and 10 according to the level of pleasantness they perceived during the observation of it (1, lowly pleasant; 5, indifferent; 10, highly pleasant). The EEG signals were segmented and classified in different datasets according to the rated pleasantness score. Moreover, for each subject, a 2 min EEG segment related to the observation of the documentary has been further taken into account as baseline activity. In order to avoid outliers, we considered only those pleasantness scores which have been expressed at least by three subjects in the population analyzed. According to these criteria, we discarded the EEG activity related to the advertisements that have been scored with 1, 2, and 10. The EEG signals associated to the lowest pleasantness ratings from 3 to 5 have been labeled as DISLIKE dataset; conversely, the ones related to the higher ratings from 7 to 9 have been labeled as LIKE dataset.

2.2 EEG recordings and signal processing

A 96-channel system with a sampling frequency of 200 Hz (BrainAmp, Brainproducts GmbH, Germany) was used to record the EEG electrical potentials by means of an electrode cap which was built according to an extension of the 10–20 international system to 64 channels. Linked ears reference was used. Since a clear role of the frontal areas have been depicted for the investigated phenomena [9–11], we used the left and right frontal and prefrontal electrodes

of the 10–20 international system to compute the following spectral analysis. In such a case, we considered the following couples of homologous channels: Fp_2/Fp_1, AF_8/AF_7, AF_4/AF_3, F_8/F_7, F_6/F_5, F_4/F_3, and F_2/F_1. The EEG signals have been band pass filtered at 1–45 Hz and depurated of ocular artefacts by employing the Independent Component Analysis (ICA).The EEG traces related to our datasets of interest have been further segmented in several EEG trials with a length of 1 s each. Later, a semi-automatic procedure has been adopted to reject such EEG trials that present muscular and other kinds of movement artefacts. Only artefact-free trials have been considered for the following analysis. The EEG data have been re-referenced by computing the Common Average Reference (CAR). Individual Alpha Frequency (IAF) has been calculated for each subject to define four bands of interest according to the method suggested in [15]. Such bands were in the following reported as IAF + x, where IAF is the Individual Alpha Frequency, in Hertz, and x is an integer displacement in the frequency domain which is employed to define the band. In particular, we defined the following two frequency bands of interest: theta (IAF-6, IAF-2), i.e., in the frequency band between IAF-6 and IAF-2 Hz and alpha (IAF-2, IAF + 2). The higher frequency ranges of the EEG spectrum have been also analyzed, but we do not report here any results since their variations were not significant. The spectral EEG scalp activity has been calculated by means of the Welch method [23] for each segment of interest. In order to discard the single subject's baseline activity, we used the Z-score transformation [24]. With such transformation, we contrasted the EEG power spectra computed during the observation of the commercial videoclips with the EEG power spectra elicited during the observation of the documentary. In particular, for each frequency band of interest the employed transformation is described as follows:

$$Z = \frac{\overline{X} - \mu}{\sigma/\sqrt{N}} \tag{1}$$

where X denotes the distribution of PSD values (of cardinality N) elicited during the observation of advertisements and the superscription is the mean operator, μ denotes the mean value of PSD activity related to the documentary and σ its standard deviation [24]. In such a way, we removed the variance due to the differences in EEG power spectra among the subjects during the baseline period.

To study the EEG frontal activity, we compared the LIKE activity against the DISLIKE one by evaluating the difference of their average spectral values as follows:

$$Z = Z_{\text{LIKE}} - Z_{\text{DISLIKE}} \tag{2}$$

where Z_{LIKE} is the Z score of the power spectra of the EEG recorded during the observation of commercial videoclips rated pleasant ("liked") by the analyzed subjects in a particular frequency band of interest. Analogously, Z_{DISLIKE} is the Z-score value of the EEG recorded during the observation of commercial videoclips rated unpleasant by subjects. This spectral index has been mapped onto a real scalp model in the two bands of interest. Moreover, in order to investigate the cerebral frontal asymmetry, for each couple of homologous channels, we calculated the following spectral imbalance:

$$Z_{IM} = Z_{dx} - Z_{sx} \tag{3}$$

This index has been employed to calculate the Pearson product moment correlation coefficient [24] between the pleasantness score and the neural activity, in the theta and alpha band for each couple of channels we analyzed. Finally, we adopted the student's t-test to compare the Z_{IM} index between the LIKE and DISLIKE conditions by evaluating the corresponding indexes.

3 Results

In Fig. 1, the scalp distribution of the Z-score values for the theta and alpha bands is presented. In the Z-score distribution for the theta band, it is possible to observe a major activation for the condition Z_{DISLIKE} at the electrodes F_2 and AF_8, roughly overlaying the right frontal cortex (FC) and the prefrontal cortex (PFC). It is also present an enhanced spectral activity in the left hemisphere (site F_3). However, it is possible to observe as the EEG spectral power is also increased at the Fp_1 electrode, for the Z_{LIKE} dataset. The right side of Fig. 1 shows the differences in EEG spectral power for the alpha band. They are mainly located at the electrode F1 which roughly overcame the left

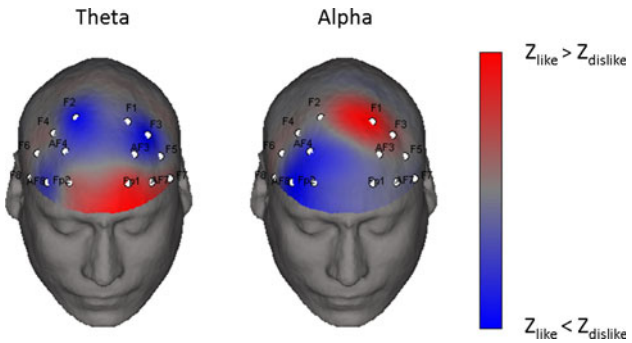

Fig. 1 The two scalp maps in figure represent the Z-score distribution for the Theta (*left*) and Alpha band (*right*) in the population analyzed. Z values are mapped onto a realistic scalp model, seen from a frontal perspective. Colorbar codes scalp areas in which the LIKE spectral activity is greater than the DISLIKE (*red*) and regions in which the DISLIKE spectral activity is greater than the LIKE (*blue*). *Gray* indicates regions with no difference between the two experimental conditions

Table 1 Correlation coefficients between Z_{IM} index and pleasantness score, for each couple of electrodes, for the theta and alpha band

	Fp_2/Fp_1	AF_8/AF_7	F_8/F_7	F_6/F_5	AF_4/AF_3	F_4/F_3	F_2/F_1
Theta	*−0.17 (P = 0.04)*	*−0.17 (P = 0.04)*	*−0.21 (P = 0.01)*	−0.11 (P = 0.16)	−0.02 (P = 0.81)	0.07 (P = 0.40)	*0.17 (P = 0.04)*
Alpha	−0.11 (P = 0.19)	−0.15 (P = 0.07)	−0.15 (P = 0.06)	−0.09 (P = 0.26)	−0.02 (P = 0.80)	0.05 (P = 0.58)	*0.16 (P = 0.04)*

Statistically significant values are highlighted in italics

FC. Conversely, differences are also visible in the right hemisphere at scalp sites AF_8 and AF_4 roughly overlying the right PFC.

In order to further investigate the frontal EEG asymmetry and its implications with the pleasantness perceived by our experimental subjects, we calculated the Pearson product moment correlation index between the imbalance index Z_{IM}, described in Eq. 3, and the pleasantness scores provided by the subjects. This computation was performed at each scalp location and in each frequency bands of interest. These results are summarized in Table 1. As for the theta band, we found out significant negative correlations at pre-frontal and lateral sites, while only the couple of electrodes F_2/F_1 present a significant positive correlation between the Z_{IM} and the pleasantness score. Instead, for the correlation in the alpha band, we obtained a significant positive correlation for the couple F_2/F_1.

Finally, we performed a *t*-test analysis between the Z_{IM} values of the pre-frontal and lateral electrodes for the theta band (Fp_2/Fp_1, AF_8/AF_7, F_8/F_7, F_6/F_5) and the medial ones for the alpha band (AF_4/AF_3, F_4/F_3, F_2/F_1). In Fig. 2, the results of the statistical test revealed a significant difference of Z_{IM} values between the conditions LIKE and DISLIKE, in both theta ($t = -3.2$, $P = .0014$) and alpha band ($t = 2.2$, $P = .0298$). In fact, it is possible to observe a greater absolute value of Z_{IM} value for the DISLIKE condition in both theta and alpha bands.

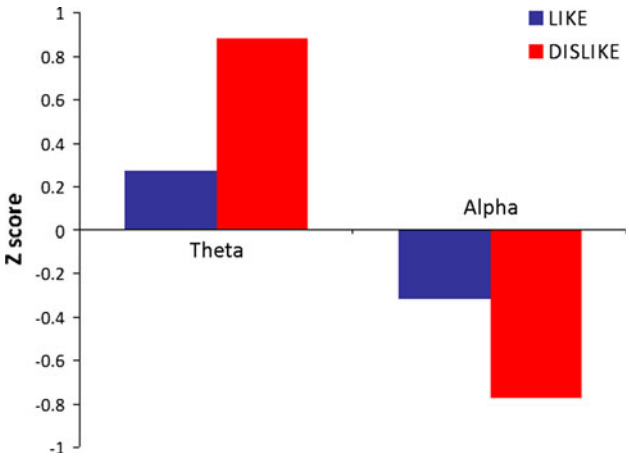

Fig. 2 Representation of the mean values of the Z_{IM} index for the LIKE (*blue*) and DISLIKE (*red*) conditions in the Theta (*left*) and Alpha band (*right*). Both differences are statistically significant (theta: $t = -3.2$, $P < 0.001$; alpha: $t = 2.2$, $P < 0.01$)

4 Discussion

In the analyzed population, the LIKE and DISLIKE datasets are characterized by different EEG power spectral maps in theta and alpha bands. It is worth of note that the activity in the left frontal hemisphere is related to the observation of commercials that have been judged pleasant by the analyzed population. On the other hand, the right frontal sites highlighted neuroelectrical activations concerning the observation of advertisements that have been judged less pleasant by the same population. Moreover, this imbalance in the activations was linearly correlated with the degree of pleasantness expressed by the subjects. The correlation analysis revealed that pleasantness scores are negatively correlated with the theta imbalance index, mostly concerning the pre-frontal and lateral frontal sites. Conversely, at the alpha frequencies the imbalance index is positively correlated around the medial frontal region. It could be noted that the adopted correlation index (Pearson's *r*) assumed that the distribution of the variables employed follow a gaussian distribution. While light departures from this normality assumption do not alter the significance of the correlation obtained, other correlation coefficients can be computed by using non parametric statistics (such as Spearman's *R* and Kendall's Tau) [24]. Here, we used parametric statistic correlation coefficient (Pearson's *r*) due to its higher statistical power.

These data showed that the spectral index we defined is able to describe the degree of pleasantness' feeling perceived by subjects while watching TV commercial advertisements. In particular, the scalp regions on the left frontal and pre-frontal areas are mostly activated when subjects perceived pleasant feelings during the watching of the TV advertisements. On the other hand, the right frontal lobe is more activated while the subjects watched TV commercials that have been scored as unpleasant. Overall, the right frontal activity is significantly greater than the one in the left frontal lobe, both in theta and alpha bands. All together, these results are in line with previous findings suggesting the presence of an asymmetrical EEG activity when subjects experienced emotional stimuli [9–11]. Moreover, the greater EEG spectral activity elicited in the right frontal

areas during the observation of unpleasant TV advertisements could also be congruent with literature associating the insula/parainsula [7, 17] and the ventral anterior cingulated cortices [13, 20] with the processing of negatively valenced emotions in social situations. These statements need to be confirmed by further studies employing high resolution EEG techniques which will allow us to estimate and investigate the underlying cortical patterns from superficial EEG recordings [1, 3–5, 12, 21].

In conclusion, at the light of the results obtained we answer to the questions posed at the beginning of the introduction section by stating that there exists a frontal EEG asymmetry elicited by the observation of pleasant TV commercials. In particular, there is a stronger activation in the left hemisphere related to pleasant advertisings and, conversely, an enhance of spectral power associated to unpleasant ads. Moreover, we could also state that the degree of the perceived pleasantness linearly correlates with the unbalance of the EEG power spectra estimated between selected right and left scalp sites.

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