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The added value of the electrical neuroimaging for the evaluation of marketing stimuli

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Abstract. There is a large interest in the marketing world to use the neuroimaging tools as a possible aid to evaluate the efficacy of a commercial advertisement. Such an area of study is called "neuromarketing". Here we illustrate some applications of electrical neuroimaging, a discipline using EEG and intensive signal processing techniques for the evaluation of such marketing stimuli. We will show which kind of information is possible to gather with these methodologies while persons are watching marketing relevant stimuli. Such information is related to the memorization and attention of commercial advertisements. We noted that temporal and frequency patterns of EEG signals are able to return descriptors of cognitive process in subjects that watched such commercial announcements. The described EEG methodologies could be then employed both to better design new products that are going to be promoted on the market as well as to analyse the global cognitive impact of commercial videos already broadcasted.

Key words: EEG, neuromarketing, memory, attention.

1. Introduction

In the last decades, commercial advertisements have the ubiquitous presence in our world. As a consequence, each year a huge amount of money is used by industries to broadcast commercial communications aimed to promote goods and devices to people. It is really important for marketing research to provide benchmarks and evaluations of how such commercial communications are evaluated and received by people. Is a specific broadcasted advertisement perceived as interesting by people? Is the advertisement going to be liked or memorized by people? These are just a few questions that usually are quite important during the preparation and the launch of a new advertising campaign by the person involved in marketing research.

In such kind of research, consumers are directly asked to give a judgment on the observed video commercial, but often they could return imprecise or biased information. Such a bias occurs due to the need of the person to be partially compliant with the interviewer or also because the overt verbalization of the observed commercials is not too much detailed as researchers desired. Taking these limitations into account, researchers in the marketing area looked at the use of neuroimaging tools as a possible solution for the above issues, to quantitatively assess the outcome of a produced advertisement.

Nowadays, neuroimaging devices are largely available in hospitals and research institutes. Hence, it could be really easy (at least in principle) for marketers to access them and to attempt to use such tools in the practical evaluation of an advertisement. The use of neuroimaging tools to assess the brain responses related to commercial stimuli has paved the way to a field usually called "neuromarketing".

From a neurophysiological point of view, neuromarketing is a study of the neurobiological and computational basis of value-based decision making [1]. From the marketers perspective neuroimaging could return information about the perception of the commercials by the persons that are not otherwise available by means of conventional marketing methods such as focus groups and surveys. Therefore, the emerging hope is that the use of neuroimaging tools in the marketing field could help marketers to improve the commercial campaigns based on the collection of information about consumer's preferences unobtainable through conventional methods [2].

Recently, several authors have investigated the capability of subjects to retrieve sensible "commercial" information generated during the observation of TV advertisements or items to purchase [3]. The most employed neuroimaging tool to track the brain response is the functional Magnetic Resonance Imaging (fMRI), a methodology able to return the profile of brain areas that elicited an increased blood flow during the analyzed task when compared to a quiet resting state. However, there are precise limitations for the spatio-temporal resolution of the fMRI technique. While the spatial precision of the returned information offered by fMRI is still unsurpassed (on the order of mm), its intrinsic time reso-

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lution is quite low (several seconds; [4]). In fact, temporal resolution of milliseconds is necessary to track the shifts of brain activity closely related to the processing of visual and acoustic stimuli provided by the fast moving of visual commercial advertisements. As a consequence of this poor temporal resolution, fMRI devices cannot return information on which kind of scenes of an advertisements have been well received by people and which ones have been discarded or overlooked by them. For this reason other researchers in the field adopt different neuroimaging tools such as the magnetoencephalography (MEG) and the electroencephalography (EEG). These techniques are sensitive to the changes of magnetic and electric fields, respectively, that are induced by the electromagnetic brain activity. EEG and MEG are able to detect rapid changes of the neural activity on a temporal scale of milliseconds and on a spatial scale of centimeters. In the last decade the so called high-resolution EEG technology has been developed to enhance the poor spatial information content of the raw EEG in order to estimate the brain activity with a spatial resolution of a squared millimeters and the unsurpassed time resolution of milliseconds [5, 6]. In order to obtain such a result it is necessary to perform the EEG recordings by a large number of electrodes ($\sim$50 and more), to estimate the cortical activity by using a realistic head model and by solving the so-called linear inverse problem for the EEG.

The purpose of this paper is to illustrate the capabilities of the high resolution EEG techniques for the analysis of brain activity related to the observation of commercial advertisements (ads). In particular, we want to illustrate how, by using appropriate statistical analysis, it is possible to recover significant information about cortical areas engaged by particular scenes within the ads analyzed. Moreover, we will show how it is possible to extract EEG indexes which are able to describe the crude memorization and attention processes occurring in the brain during the observation of such ads.

2. Material and methods

2.1. Experimental design. The present study has been carried out at the Neuroelectrical Imaging and BCI lab of the Fondazione Santa Lucia in Rome (Italy) and at the Dept. of Physiology and Pharmacology of the University of Rome “Sapienza”. All the experiments have been conducted after the approval of the ethics committee at both institutions. Informed consent approval has been obtained by each participant before she/he was involved in the study, in agreement with the standard practices at the two Institutions involved.

Experimental subjects are asked to seat comfortably on a reclining chair in an electrically shielded and dimly lit room. They were exposed to the vision of a film of about 30 min. It consisted in a neutral documentary intermingled with three series of commercial advertisements. These three interruptions were generated at the beginning, at the middle and at the end of the documentary. Each interruption was composed by five commercial video-clips of about 30 s. Fifteen commercials were showed during the whole documentary. The TV spots were relative to standard international brands of commercial products – like cars, food, etc. – and no profit associations that have never been broadcasted in the country in which the experiment has been performed. Hence, the advertising material was new to the subject as well as the documentary observed. The signals gathered during the observation of the documentary will be used to avoid the personal baseline activity. While performing the experiment, subjects were not aware that an interview would be held within a couple of hours from the end of the movie. They were simply told to pay attention to what they would have watched and no mention about the importance of the commercial clips was made. In the interview, subjects were asked to recall commercial clips they remembered and tell if they are consumers or not of the products advertised. In such a way we divided the signals of the population recorded into two different datasets. The first pool of data is formed by the electrical activity associated to subjects who affirmed to use the item advertised. This group has been named CONSUMERS. Conversely, the second group comprises all the cerebral activity of subjects who answered telling to not be consumers of the advertised product. We referred to this dataset as NON CONSUMERS.

2.2. Cerebral recordings and signal processing. The cerebral activity of fifteen healthy volunteers (27.5$\pm$7.5 years; 7 women) was recorded by means of a portable 64-channel system (BE+ and Galileo software, EBneuro, Italy). Positions of electrodes were acquired in a 3D space by a Polhemius device and used for the following projection of the signals on the head model employed for the analysis. We collected the EEG activity at a sampling rate of 256 Hz and the impedances kept below 5 kΩ. Raw EEG traces were first band pass filtered (high pass = 2 Hz; low pass = 47 Hz) and the Independent Component Analysis (ICA) was then applied to detect and remove components due to eye movements, such as blinks, and muscular artifacts. EEG traces were then segmented in order to analyze the cerebral activity elicited during the observation of the TV commercials and that associated to the REST period, which is related to a two minutes long sequence of the documentary immediately before the appearance of the spot interruption. The extra-cerebrally referred EEG signals have been transformed by means of the Common Average Reference (CAR) and the Individual Alpha Frequency (IAF) has been calculated for each subject in order to define our bands of interest according to the method suggested in the current scientific literature [7]. 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. Since we are interested in tracking the memorization and attention processing occurring during the observation of such as stimuli, we focused our analysis in two frequency bands of the EEG spectrum. In fact, from literature we know that signs of this cognitive activity can be found within the theta and the range of frequencies of the beta band [7]. Hence, in order to properly extract the variable of interest for the evaluation of the observed ads we first filtered the collected EEG signals in the theta and beta bands, as already described in a previous paper [8].

The cortical activity from the EEG scalp recordings was estimated by employing the high-resolution EEG technologies [9–11] with the use of average head model provided by the McGill University website. The scalp, skull and dura mater compartments were built by using 1200 triangles for each structure. The Boundary Element Model was then employed to solve the forward electromagnetic problem. For each subject, the electrodes disposition on the scalp surface was generated through a nonlinear minimization procedure [12]. The cortical model consists of about 5,000 dipoles uniformly disposed on the cortical surface and the estimation of the current density strength for each dipole was obtained by solving the electromagnetic linear inverse problem according to the techniques described in previous papers [13–15]. For each experimental subject, the statistical significance of the Power Spectral Density (PSD) values elicited during the observation of the TV commercials was then measured against the activity evaluated during the observation of the documentary. This was obtained by computing a time-varying z-score variable for each subject and for each dipole placed on the cortical mantle of the analyzed frequency band. The mean and the standard deviation for such z-score variable was estimated in the documentary period, while the time-varying values of the spectral power in the analyzed frequency bands during the observation of the TV commercial for each dipole were employed as the variable to standardize. By construction, the analyzed maps are then related to the evolution of the time-cortical activity of the spectral power in the selected bands. Only the statistical significant variation of such spectral power, when compared to the documentary period, was highlighted in color. The use of the z-score will allow us to have a variable that can be averaged and used to summarize the results of the entire population investigated. In fact, we highlighted in yellow a voxel of the average brain model if it was a cortical site in which a statistical significant variation of the spectral power between the experimental conditions was found in all subjects; if such brain voxel was statistically significant in all but one of the analyzed subjects, we depicted it in red. In all the other cases the voxel was represented with a gray color.

In addition, in order to summarize the properties of the cerebral activation for the analyzed ad, we also use a couple of indexes that were defined in a previous paper called Memorization Index (MI) and the Attention Index (AI) [8]. Such indexes are linked to the episodic memorization and attention posed to the ad by the experimental population, and they have been previously validated by using a correlation analysis with the answers the subjects gave during the interview. Such interview has been held a couple of hours after they watched the ads. The already described elected frequency bands which have been employed to calculate the Global Field Power (GFP; [8]), and to define the Memorization Index (MI) and the Attention Index (AI), respectively. The rationale behind these two indexes derives from several observations from previous experiments performed. In fact, Summerfield et al. [16] highlighted that there is an increase of the EEG theta activity in the left frontal areas during the observation of complex items which will be later remembered. Moreover, we also experimented this similar phenomenon by showing an enhance of cortical power spectral activity among left frontal cortical areas related to the observation of advertisements which will be later recalled during an interview [8]. Finally, in the scientific literature there are examples showing the existence of spread cortical network among frontal and parietal areas devoted to executive attention which also responds as an increase of EEG beta activity to a variety of non-task and non-stimulus specific factors [7]. Hence, the idea to summarize the activity of several brain areas which have been proved to respond to cognitive processes such as memorization and attention. In particular, we calculated the GFP of the theta EEG activity among left frontal sites as a MI and employed the beta waves to define our AI.

In this way, from the GFP waveforms we calculated the correlation coefficient between the MI and the percentage of spontaneous recall, as reported by subjects during the interview, as well as the duration of peaks elicited on such waveforms. In the following analysis we discarded the signals belonging to two advertisements because of the presence of artefacts.

2.3. Estimation of cortical activity. The solution of the following linear system at a particular time instant t:

$$\mathbf{Ax} = \mathbf{b} + \mathbf{n} \tag{1}$$

provides an estimation of the dipole source configuration **x** at time t that generates the measured EEG potential distribution **b** in the same instant. The system also includes the measurement noise **n**, assumed to be normally distributed [13–16]. **A** is the lead field matrix, where each j-th column describes the potential distribution generated on the scalp electrodes by the j-th unitary dipole. **A** matrix has the dimension of the number of electrodes employed times the number of cortical sources used in the model. The vectors **x** has the dimension of the number of cortical sources employed in the estimation (typical values between 3,000 to 5,000 sources), while the vectors **b** and **n** have both the dimension of the number of electrodes employed for the recordings.

The current density solution vector $\boldsymbol{\xi}$ of Eq. (1) was obtained as [15]:

$$\xi = \arg\min_{x} \left(\|\mathbf{Ax} - \mathbf{b}\|^2_{\mathbf{M}} + \lambda^2 \|\mathbf{x}\|^2_{\mathbf{N}} \right), \tag{2}$$

where **M**, **N** are the matrices associated with the metrics of the data and of the source space, respectively, λ is the regularization parameter and $||\ \mathbf{x}\ ||_M$ represents the M norm of the vector **x**. Thus, **M** is a square matrix whose dimensions are the number of sensors, while **N** is a square matrix whose dimensions are the number of cortical sources employed. The solution of Eq. (2) is given by the pseudo-inverse operator **G**:

$$\begin{gathered} \xi(t) = \mathbf{G}\mathbf{b}(t), \\ \mathbf{G} = \mathbf{N}^{-1}\mathbf{A}'\left(\mathbf{A}\mathbf{N}^{-1}\mathbf{A}' + \lambda\mathbf{M}^{-1}\right)^{-1}. \end{gathered} \tag{3}$$

By construction, the pseudo-inverse operator **G** has the dimensions of the number of cortical sources times the number of electrodes employed. An optimal regularization of this linear system was obtained by the L-curve approach [15].

As a metric in the data space we used the identity matrix (i.e $M = I$), while as a norm in the source space we used the following metric:

$$\left(\mathbf{N}^{-1}\right)_{ii} = \|\mathbf{A}_{\cdot i}\|^{-2}, \tag{4}$$

where $(\mathbf{N}^{-1})_{ii}$ is the i-th element of the inverse of the diagonal matrix **N** and all the other matrix elements N_{ij} are set to 0. The L_2 norm of the i-th column of the lead field matrix **A** is denoted by $||\mathbf{A}_{\cdot i}||$.

3. Results

From the 15 advertisements proposed to the subjects, only 13 were analyzed while 2 were taken out because of technical reasons. In Fig. 1 we present two series of film segments spanning the length of a particular TV commercial in which we illustrate the statistically significant differences of cortical activations concerning both the CONSUMERS (panel A) and NON CONSUMERS (panel B) groups in the theta band. This figure is composed by a series of subsequent strips each containing two images: the upper one represents frames of the TV commercial, taken at 0, 15 and 30 seconds from the beginning of the clip, while the lower one displays the corresponding average brain activity. In particular, the image at the bottom of the strip shows four different views of the average brain model organized in two rows: the upper row comprises the front and left perspective while the lower one the rear and right brain view. The temporal axes are related to the length of the particular presented ad. In particular, the panel A of the presented picture shows the cerebral activity of the CONSUMERS which is characterized by wide cortical activations in several key frames, located in cortical areas mostly involving frontal and parietal lobes. Conversely, in the same key frames, the cortical activations related to the NON CONSUMERS (panel B) present less activations when contrasted with the observation of the documentary. By comparing the two experimental groups, it is possible to observe that this advertisement elicited an increase of PSD in the theta band for the only group of CONSUMERS. Since an increase of frontal theta PSD is linked to the memorization process, the present result could suggest that the ad presented is more adequate to promote the item in the CONSUMERS population than in the other one. The above consideration cannot be performed without such kind of brain imaging analysis.

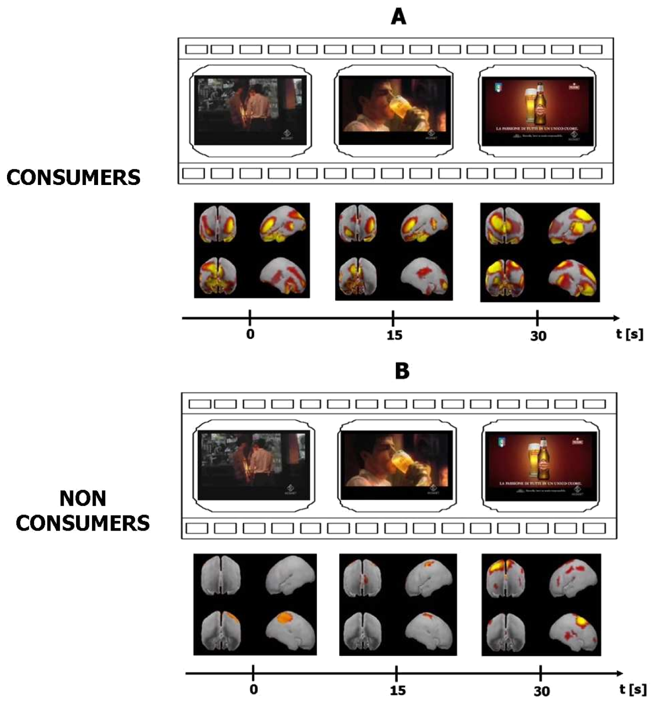

Fig. 1. Figure 1 shows the average brain activity related to the observation of a commercial advertisement for the two experimental groups CONSUMERS and NON CONSUMERS, panel A and panel B of the picture respectively. Each panel has two strips: the upper one represents three frame segments of the commercial of interest at time instant 0, 15 and 30 seconds; similarly, the lower strip shows the related brain activity for each time instant. The average cortex model is seen from four different perspectives (frontal, right, posterior and left side from the left to right and from the top to the bottom respectively). Yellow voxels highlight cortical sites in which a statistical significant variation of the spectral power has been found in all subjects between the experimental conditions. If such brain voxel was statistically significant in all but one of the subjects analyzed, we depicted it in red. In all the other cases the voxel was represented with a grey color

The results presented for a particular advertisement tested (a beer) could be obtained for each one of the total amount of 13 commercial advertisements proposed to the investigated populations. This means the large prefrontal and parietal activation in the CONSUMERS group are always present during the brand occurrence, when compared to the NON CONSUMERS group. As far as concern the analysis of the Memorization and the Attention Index, on average we obtained values of MI = 0.37 and AI = 0.36 across all subjects, while the mean value of spontaneous recall is 31%, across all TV commercials. In order to further stress the link between the variation of EEG spectral power and the quality of the memory recall of the advertising, we performed a correlation analysis between the MI and the percentage of spontaneous recall as illustrated in Fig. 2. In the presented scatterplot, the mean percentage of spontaneous recall is presented, for each advertisement (described on the graph as Ad1, Ad2 etc etc) showed to the population, against the related value of Memorization Index. A couple of advertisements presented at the end of recordings (Ad14 and Ad15) were not presented due to the amount of artifacts detected in a major part of the investigated population. In Fig. 2 each point represents the mean value of spontaneous recall for each advertisement, although the numbering does not follow the order of presentation within the movie. The percentage of spontaneous recall is then linearly correlated with the value of MI ($R2 = 0.68$, $p < 0.01$). These values are distributed along the regression line, as showed in the figure.

Panel A of Fig. 3 shows the percentage of spontaneous recall for different combinations of MI and AI. In particular, we report that when both MI and AI are under their average values the percentage of spontaneous recall (18%) is under average as well. This percentage is slightly increased (20%) when the AI exceeds the average threshold. We obtained the highest values of spontaneous recall when the MI is over average. In fact, in this case the percentage reaches the value of 33% when the AI is under average and the value of 41% when both MI and AI are over average.

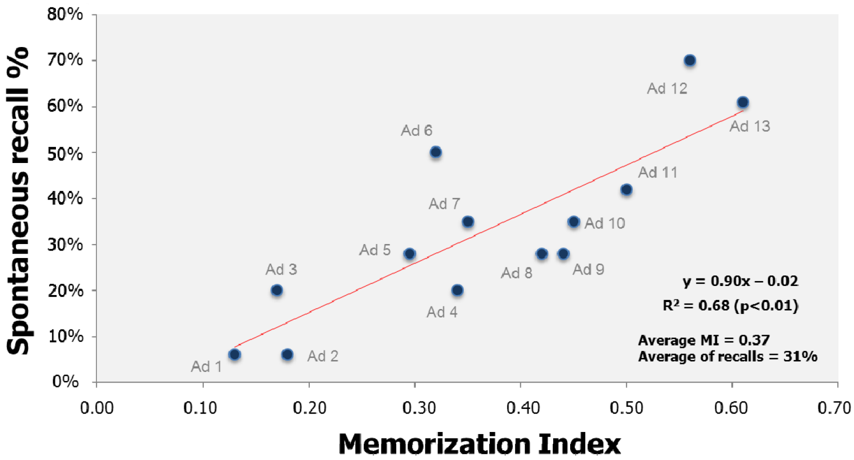

Fig. 2. In this picture the correlation result between the Memorization Index (MI, on the x-axis) computed on the base of variation of EEG spectral power and the percentage of spontaneous recall (on the y-axis) is presented. The figure shows the linear correlation between the two variables along with a summary of the analysis results and the average values of both MI and spontaneous recall. Each dot shows the value of MI and spontaneous recall for each advertisement (Ad1, Ad2 etc.)

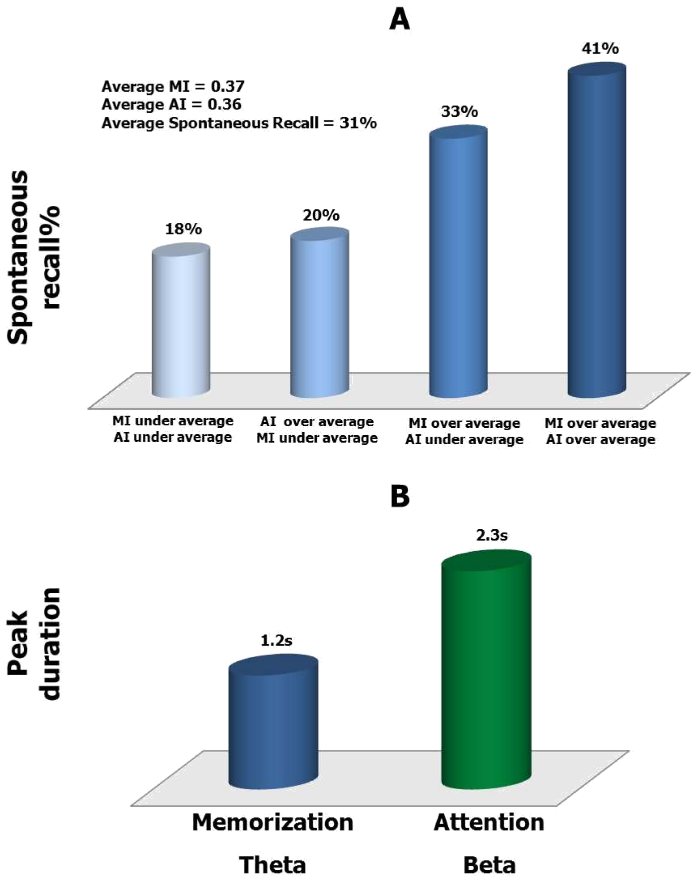

Fig. 3. Panel A shows the percentage of spontaneous recall when Memorization Index (MI) and Attention Index (AI) are above or below their average value. Panel B illustrates the average duration of peaks elicited in the GFP waveforms in the theta and beta bands, related to the memorization and attention process respectively

Finally, from the GFP waveforms we also calculated the duration of the activation peaks. In panel B of Fig. 3, we show that the mean duration of peaks occurred during the observation of advertisements, across subjects and commercials, is 2.3 s for those elicited in the beta band and 1.2 s for peaks in the theta band, associated to the activity of attention and memorization processes respectively.

4. Discussion

In the present paper we illustrated how it is possible to track the cortical activity elicited during the observation of TV commercials and how the indexes extracted from the EEG activity could be correlated with the crude processes of memorization of the advertisements occurring in the brain.

The presented electrical neuroimaging technique allowed us to lock the brain activations occurred during the observation of commercials to each particular frame segment of the analyzed clip. The variation of patterns of cortical activity along the time return information useful to identify particular key frames within each advertisement that are crucial for eliciting good brain responses in terms of memory or attention.

By inspecting the statistical maps of the cortical activity in each subject during the observation of the proposed audiovisual stimuli, it is possible to highlight their reaction to a particular item advertised or to a particular scene in the video. Such information could be important from the marketers point of view. In fact, the electrical neuroimaging tools showed how the cortical spectral patterns could vary according to the different experimental groups analyzed. In particular, our results illustrated that the CONSUMERS' activity elicited during the observation of the TV commercial is characterized by several peaks of EEG cortical spectral activity which are significantly higher than those elicited during the observation of the documentary. The increase of brain activity is located among areas spread across the cortex and over the whole time duration of the clip, mostly involving the prefrontal and parietal areas. These results highlight a prevalence of a prefrontal bilateral activation in all subjects analyzed during the observation of the particular commercial showed, although a stronger engagement of the left frontal areas has been noted. The present findings are in agreement with the suggested role of these cortical regions during the transfer of sensory percepts from short-term memory to the long-term storage [16–20]. Conversely, the cortical spectral patterns of NON CONSUMERS did not elicit particular changes when compared to those associated to the observation of the documentary during the observation of the same stimuli. Most of them are condensed in the last frame segments of the clip, where the brand advertised is presented on the screen. From the presented findings we may argue that this kind of commercial is mostly engaging for persons who are usually used to drink such kind of beer, while the non-users (i.e. the persons who usually do not drink such kind of beer) seem to be not attracted by the story told in this video clip. This information could be useful for marketers whose aim is to promote a new product. For instance, they could be interested in knowing the effect of spreading the brand or the advertised service to people belonging to different market segments. In such a case, supposing that the purpose of the advertisement is to persuade non consumers to start drinking that kind of beer, we might say that the effect of this video clip is to reinforce the power of the brand for people already consumer of the product. At the same time it does not seem to encourage the people that are not user of that brand to buy the brand of beer advertised. Summarizing, the enhancement of the EEG theta activity observed in the CONSUMERS group suggests a better memorization of the present advertisement with respect to the NON CONSUMERS group. Hence, this videoclip could be considered as more efficient for the former group. However, it must be noted that the adopted experimental paradigm is not able to return neural predictors of the purchase [3] to be made by the subjects analyzed, but it offers nevertheless a suggestion about the effectiveness of the advertising tested on the analyzed subjects.

From a different perspective, the analysis performed showed that it is possible to extract from the EEG signals a cerebral index conveying useful information about the process of memorization of the TV commercial seen. The statistical analysis revealed a positive correlation between the Memorization Index (MI) and the percentage of spontaneous recall in the population analyzed. It may be argued if this correlation still holds between the spontaneous recall and MI when the investigated population would be splitted in the CONSUMERS and NON-CONSUMERS groups. In the present case, a correlation between the percentage of memory recall and groups for CONSUMERS and NON-CONSUMERS will return uncertain statistical results due to the experimental size employed and was not performed here. The present finding confirms that an enhance of spectral EEG activity in the theta band is strictly connected with an increase of the probability to remember a commercial seen on TV. In addition, this probability also depends on the variation of activity of the beta band. In fact, we reported that an increase of the Attention Index contributes to enhance this probability. However, the present analysis also showed that only less than 1% of the estimated GFP is involved in significant peaks of activations. The information about the occurrence of this significant GFP activity could be used to better shape the commercial advertising.

5. Conclusions

The present paper aimed at illustrating how, by means of appropriate mathematical and statistical methods, it is possible to gather information hidden in the cerebral activity about the memorization of a TV commercial. In fact, by employing the high resolution EEG techniques, we were able to reconstruct the cortical activations elicited during the ad observation and link such activations with some important variables related to the brain processing, such as episodic memorization and attention. It is worth of note that improving the quality of the marketing messages would allow industries to match better the demands of people related to the goods to be publicized. Such demands were only in part intercepted by other simpler marketing approaches, such as focus groups and surveys, [21–24]. The approaches that are more complex and therefore harder to implement, such as market tests, could provide more accurate results than the methodology described above but at an higher cost Marketers hope that neuroimaging will provide a more efficient trade-off between costs and benefits than the standard focus group and surveys. At the present time the results provided in literature suggest caution in the adoption of only neuroscience to support marketing-related decisions about advertisements, although it is clear that such instrument could provide useful insights for industries. Only time will tell whether neuromarketing will eventually provide acceptable tools for commercial activities. John Wannemaker, the inventor of the first mall in US, said "I know that half of my money spent in advertising is wasted, but I don't know which is such half". If successful, the use of neuroimaging tools in the evaluation of the commercial ads could help to reduce the half part of the money that were wasted in advertisement industry, by preserving the correct one.

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