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How to Measure Cerebral Correlates of Emotions in Marketing Relevant Tasks

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Abstract Nowadays, there is a growing interest in measuring emotions through the estimation of cerebral variables. Several techniques and methods are used and debated in neuroscience. In such a context, the present paper provides examples of time-varying variables related to the estimation of emotional valence, arousal and Approach-Withdrawal behavior in marketing relevant contexts. In particular, we recorded electroencephalographic (EEG), galvanic skin response (GSR) and heart rate (HR) in a group of healthy subjects while they are watching different TV commercials. Specifically, results obtained in the Experiment 1 shows a significant increase of cortical power spectral density across left frontal areas in the alpha band and an enhance of cardiac activity during the observation of TV commercials that have been judged pleasant. In the Experiment 2, frontal EEG asymmetry, GSR and HR measurements are used to draw cognitive and emotional indices in order to track the subject's internal state frame by frame of the commercial. A specific case study shows how the variations of the defined Approach-Withdrawal and emotional indices can distinguish the reactions of younger adults from the older ones during the observation of a funny spot. This technology could be of help for marketers to overcome some of the drawbacks of the standard marketing tools (e.g., interviews, focus groups) usually adopted during the analysis of the emotional perception of advertisements.

Keywords EEG · Heart rate · Emotions · TV commercials · Neuromarketing

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Introduction

Importance of Emotions in Decision Making

The study of emotions is achieving a growing importance in the neuroscience field. For decades, researchers have been approaching decision-making tasks by assuming that humans use only rational aspects of a situation. The consensus at that time was that decision making followed three distinct steps: first asking what the best choice is, second doing it and finally experiencing the feeling that is generated by the outcome. In the last 10 years, this perspective has been challenged, mainly by the results obtained by Damasio [1, 2]. According to his theory, "emotions" have a main role in the whole decision-making process; they are the humans' guide for choices, finally executed. Hence, it becomes clear that the study of emotions, associated to the decision making, is fundamental for a deep understanding of the human behavior. Supporting Damasio's studies, Bargh and Chartrand [3] affirm that, although humans are definitely capable of conscious deliberation, many economically relevant decisions rely on automatic, fast and effective processes, which are not under the direct volitional control. Moreover, the human beings are influenced by unrecognized and finely tuned affective mechanisms, which often play a decisive role in decision making and action [4, 5]. Many of these processes have been shaped by evolution in order to serve social purposes [6–8] while decision making and evaluation in economic contexts are influenced by mechanisms dedicated to social interaction. For instance, in man, the observation of different cultural objects associated with wealth and social dominance (e.g., sports cars) elicits activation in reward-related brain areas [9, 10].

Emergence of Neuromarketing

In these last years, it observed an increasing interest in the use of brain imaging techniques for the analysis of brain responses to commercial stimuli as well as for the investigation of purchasing attitudes, using hemodynamic [11, 12] and neuroelectromagnetic measurements [13–16] (see [17, 18] for a review). Such interest is also justified by the possibility to correlate the observed brain activations with the proposed commercial stimuli, in order to derive conclusions about the adequacy of such stimuli in terms of interest or emotional engage for the investigated sample. So far adopted standard marketing techniques often involve the use of in depth interviews or focus groups during which customers are exposed to the product before its massive launch (ad pretest) or afterward (ad posttest). However, it is now recognized that the verbal advertising pretest is biased by the respondents' cognitive processes activating during the interview [19]. In addition, it was also suggested that the interviewer may have a great influence on the respondent recalls as well [20, 21]. Taking all these considerations in mind, neuroscientists have started to investigate the brain activity gathered during the watching of TV commercials by measuring variables linked to the cognitive and emotional engagement. In fact, there are high hopes that neuroimaging technology could solve some of the problems that marketers face, such as streamline marketing processes and save money by providing more efficient trade-off between costs and benefits. In fact, neuroimaging is thought to reveal information about consumer preferences that are unobtainable through the use of conventional interviews [22].

Approaching Emotions by Dimensions and Categories

Many scientists have focused their research in order to achieve a gold standard in the measure of emotion, which could be approached from both dimensional and discrete perspectives (see [23, 24] for reviews). Scientific evidence suggests that measuring people's emotional state is one of the most vexing problems in affective science. There are a few fundamental dimensions that organize emotional response. The most commonly assumed dimensions are three: valence, arousal and Approach-Withdrawal [25–29]. The valence dimension contrasts states of pleasure (e.g., happy) with states of displeasure (e.g., sad), and the arousal dimension contrasts states of low arousal (e.g., quiet) with states of high arousal (e.g., surprised). Approach motivation is characterized by tendencies to approach stimuli (e.g., as would likely be facilitated by excitement), whereas avoidance motivation is characterized by tendencies of avoidance (e.g., as would likely be facilitated by anxiety). In contrast, the discrete perspective shows that each emotion corresponds to a unique profile in experience, physiology and behavior [30]. As far as the behavioral response is concerned, early and recent evidence highlights that facial expression signaling supports the discrimination of basic categories [31, 32]. Although dimensional and discrete perspectives differ in how they conceptualize and describe emotional states [33], it seems possible to reconcile the two theoretical frameworks by proposing that each discrete emotion represents a combination of several dimensions [34, 35].

Autonomic Nervous System Measurements for Emotions

As signs of the autonomic nervous system (ANS), the activity of the sweat glands on the hands and the heart rate (HR) variation are the neurophysiological variables often used to describe variations of emotional states according to the couple of orthogonal axes of valence and arousal [27, 36, 37]. The idea that discrete emotions have distinct autonomic signatures is not fully supported by experimental findings [38]. Instead, relevant studies often point to relationships among dimensions, particularly those of valence and arousal, and ANS responses [39, 40]. In particular, the galvanic skin response (GSR) is typically quantified in terms of skin conductance level (SCL) or short-duration skin conductance responses (SCRs), while the most commonly used cardiovascular measure is the HR. By monitoring autonomic activity using devices able to record the variation of the skin conductivity and the HR, it is possible to assess the internal emotional state of the subject. In fact, the GSR is actually viewed as a sensitive and convenient measure for indexing changes in sympathetic arousal associated with emotion, cognition and attention [41]. Studies using functional imaging techniques have related the generation and the maintenance of the electrodermal activity level to different specific brain areas. These specific regions are the ventromedial prefrontal cortex, the orbitofrontal cortex, the left primary motor cortex and the anterior and posterior cingulate, which have been shown to be associated with emotional and motivational behaviors [41, 42]. Such findings also indicate that the association of peripheral and central measures of arousal re-emphasize the connections among electrodermal activity, arousal, attention, cognition and emotion. Also, several papers reported as the HR correlates with the emotional valence of a stimulus, e.g., the positive or negative component of the emotion [43–46]. Moreover, in experimental psychology, it has been proposed and used the affect circumplex, in which emotions are mapped in a two-dimensional space in which horizontal and vertical axes are related to valence and arousal, respectively [27, 47]. Thus, the joint measurement of HR and GSR and their positioning on the affect circumplex returns the emotion perceived by the subject during a specific experimental task.

Approach-Withdrawal Neural Origins: The Role of PFC in Emotions

As to Approach-Withdrawal, such parameter can be obtained by measuring variations of the pre- and frontal cortex (PFC and FC, respectively; [4]). Despite this is a region structurally and functionally heterogeneous, its role in emotion is well recognized [48]. The role of the PFC in emotion has also addressed by recent fMRI studies, which highlight the reciprocal relation between amygdala and ventromedial PFC (vmPFC) in the encoding of emotional valence [49]. In particular, the connectivity patterns between amygdala and vmPFC could vary with the role played by emotional task, being the vmPFC preferentially engaged to utilitarian and emotional assessments during moral judgments [50]. In addition, studies with patients showed minor recruitment of the dlPFC involved in cognitive reappraisal, suggesting focal and aberrant neural activation during volitional, self-regulation of negative affective states [51], whereas vmPFC lesions also exhibited potentiated amygdala responses to aversive images and elevated resting-state amygdala functional connectivity [52]. Finally, ventrolateral PFC (vlPFC) deficits in positive emotions are correlated with social anhedonia and schizophrenia [53]. The relationship between PFC and hedonia is also discussed in studies performing emotional decision-making tasks. Specifically, Lin and colleagues [54] suggest a late participation of the vmPFC in preference decision making, whereas Li and colleagues [55] showed that the vmPFC is part of a network coupling both memory and emotional processes. Finally, Santos and colleagues [56] affirm that activation of the vmPFC was found when comparing positive with indifferent or fictitious brands. Such activation is stronger after the choice than during the decision process itself. All these results provide evidence for the critical role of the PFC in regulating emotions in humans supporting also the notion that vmPFC may be unimportant in the decision stage concerning brand preference.

Relationship Between Approach-Withdrawal and EEG-Based Lateralized Measurements

Electroencephalographic (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 [57, 58]. Sutton and Davidson [59] found that greater left-sided activation predicted dispositional tendencies toward approach, whereas greater right-sided asymmetry predicted dispositional tendencies toward avoidance. In contrast, the frontal asymmetry measure did not predict dispositional tendencies toward positive or negative emotions, suggesting an association of frontal asymmetry with Approach-Withdrawal rather than with valence. Other sources converge on a similar model of frontal asymmetry. Of particular importance are studies that link anger, an unpleasant but approach-related emotion, to greater left-hemispheric activation [60, 61]. Also, tendencies toward worry, thought to be approach-motivated in the sense of being linked to problem solving, have been linked to relatively greater left frontal EEG activity [62]. Thus, the emerging consensus appears to be that frontal EEG asymmetry primarily reflects levels of approach motivation (left hemisphere) versus avoidance motivation (right hemisphere). More recently, resting EEG, self-report measures of Behavioral Activation and Inhibition System (BAS and BIS) strength, dispositional optimism and a measure of hedonic tone, were collected and correlated with alpha asymmetry measures, which yielded significant frontal and parietal asymmetry correlation patterns [63]. The BAS is conceptualized as a motivational system that is sensitive to signals of reward, nonpunishment, and that is important for engaging behavior toward a reward. The BIS, conversely, inhibits behavior in response to stimuli that are novel, innately feared, and conditioned to be aversive. In particular, higher BAS was uniquely related to greater left-sided activation in the middle frontal gyrus. Optimism was associated with higher activations in the left-superior frontal gyrus (BA10) and in the right-posterior cingulate cortex (BA31). Moreover, Santesso and colleagues [64] examined the relationship between measures of sensation seeking and the pattern of resting frontal EEG asymmetry, thought to reflect a biological predisposition to approach new experiences. Findings showed that high sensation seeking was related to a greater relative left frontal activity at rest. Urry and colleagues [65] also reported that greater left than right frontal EEG activity was associated with higher hedonic well-being. Pizzagalli et al. [66] reported that current density in the left (but not right) prefrontal cortex was related to reward bias suggesting that these regions may underlie individual differences in approach-related behavior.

Emotions Miss Specific Spatial Location

Hence, EEG seems to converge into the dimensional perspective of emotions by concluding that relative left-hemisphere activation is reflective of approach-related states, whereas relative right-hemisphere activation is reflective of avoidance-related states, although such activations are not intended to discriminate emotions completely. On the other side, other neuroimaging techniques, such as fMRI, may be better suited than EEG to reveal emotion specificity in the brain (see [24] for a review). The debate on this topic (dimensional vs discrete perspective) is far from the conclusion, and it has to be further investigated since different brain regions can participate in multiple emotions.

Emotional Signatures in Response to TV Advertisements

Ioannides and colleagues [14] have employed magnetoencephalography (MEG) to study the neuronal responses in subjects viewing TV advertisements. Those MEG data suggest that cognitive advertisements activate predominately posterior parietal and superior prefrontal cortices, whereas effective material modulates activity in orbitofrontal cortices, the amygdala and the brainstem. The results seem to imply that cognitive rather than affective advertisements activate cortical centers associated with the executive control of working memory and maintenance of higher-order representations of complex visual material. Other researchers also focus on the EEG frontal imbalance. In fact, Polish researchers found out that the observation of two versions of the same TV commercial generated significantly different emotional impact in terms of EEG frontal asymmetry [67]. However, difference in cerebral activity coding the pleasantness can be also observed by event-related potentials (ERPs) analysis. In particular, Handy and colleagues [68] proved that visuocortical processing shows an increase of the early positive component (named P1), at central and parietal sites, along with an increase of the later negative component (named N2), at parietal and occipital sites, related to the observation of disliked logos. Taken together, these mentioned examples bring evidences that it is possible to link some properties of the collected EEG rhythms during the watching of some TV advertisements with the overt preferences of the observers in terms of emotions. This link could be used to generate a metric that automatically points to parts of the advertisings examined that are emotionally OK and part that are not. This information could be used “a posteriori” to redraw partially the advertising in order to increase the appearance of the “like” parts while depressing the “dislike” parts. Such reduction or modification of the broadcasted TV advertisings could be then performed using EEG techniques thanks the high time resolution provided by this methodology.

Theses and Outline of the Work

In this scenario, the aim of the present paper is to show how the variation of the EEG frontal cortical activity, GSR and HR, is differently related to the general appreciation and the emotional feeling perceived during the observation of commercial TV advertisements. According to the aforementioned theoretical framework, we expect that:

1. the EEG frontal imbalance describes appreciation of TV commercials, showing major (minor) activation on

the left frontal lobe during the observation of pleasant (unpleasant) scenes…

2. increase (decrease) of GSR and HR variables distinguish high (low) arousing and positive (negative) valence emotions elicited during the observation most (less) liking advertisements.

Although there could exist a degree of correlation between GSR (arousal) and HR (valence), we do not address this issue in the present work but do exploit the illustrated theory. In addition, we provide an example of how it is possible to apply neuroscientific tools to real marketing contexts. For this purpose, we are interested to analyze the brain activity occurring during the ecologic observation of commercial advertisings (ads) intermingled in a random order within a documentary. To measure both brain activity and autonomic parameters of the investigated subjects, we used simultaneous EEG, GSR and HR measurements during the whole experiments. We link significant variation of EEG and autonomic measurements with the perceived pleasantness, as declared in the following subject's verbal interview. In order to do that, different indices are used to summarize the cerebral and autonomic measurements performed, later used in the statistical analysis. The goal was to recreate, as much as possible, an ecologic approach to the task, in which the observer is viewing the TV screen without particular requirements to accomplish. In fact, subjects were not instructed at all on the aim of the experiment, and they were not aware that an interview about the observed TV commercials would be generated at the end of the video clip.

Introducing Experiment 1 and Experiment 2

The next sections of the paper are articulated in order to present and comment separately the results of two different neuromarketing experiments. In particular, Experiment 1 aims to explain the methods and results and discusses the theoretical basis as well as some practical aspects of the research; Experiment 2 shows methods and results of a concrete application, followed by a general discussion. Specifically, Experiment 2 introduces two neurophysiological indices to describe emotions during the perception of TV commercials. These indices are derived by a combination of GSR and HR, whereas the second measures the unbalance of the EEG frontal power exploiting the aforementioned neurophysiological background. The aim of this section is to provide the reader with an example of the capabilities of the neuroelectrical measurements in a real marketing context. The provided results represent a case study, which could be hopefully of help to describe the time sequence of a commercial advertisement. For this reason, we use a representative video clip, which we believe to highlight clearly the potentiality of the defined neurophysiological indices to measure emotions in this kind of experimental tasks.

Experiment 1

Methods

Subjects

Fifteen healthy volunteers (mean age 27.5 ± 7.5 years; 7 women) have been recruited for this study. Informed consent was obtained from each subject after explanation of the study, which was approved by the local institutional ethics committee. Subjects had no personal history of neurological or psychiatric disorder. They were free from medications, alcohol and drugs abuse.

Experimental Paradigm

The procedure of the experimental task consisted in observing a 30-min-long documentary in which we inserted three advertising breaks, each composed by two TV commercials, according to the schema illustrated in Fig. 1. Each interruption was formed by the same number of commercial video clips, each lasting about thirty seconds. During the whole documentary, a total of six TV commercials were presented. The clips were related to standard international brands of commercial products, like cars and food, and public service announcements (PSA) such as campaigns against violence. Randomization of the occurrence of the commercial videos within the documentary was made to remove the factor "sequence" as possible confounding effect.

The experimental subjects enrolled in this experiment are asked to comfortably seat in front of a computer screen by means of which we present a documentary intermingled with several commercial breaks, the target stimuli of the experiment. During the whole video, the cerebral (EEG) and autonomic signals (HR, GSR) were collected from the subjects. The signals gathered during the observation of the documentary will be used to estimate the personal neurophysiological baseline activity. During the experiment, subjects are not aware that an interview would be held within a couple of hours from the end of the data recording. They are simply told to pay attention to what they will watch. The video consisted in a documentary related to geography, with the aim to elicit no particular emotional engage. After data recording, an interview is performed. At this stage, the experimenter asks the subjects to recall spontaneously the commercial video clips they memorized. Then, the experimenter verbally listed the sequence of

Experiment 1	Break 1			Break 2			Break 3		
DOC	Ad_1	Ad_2	DOC	Ad_3	Ad_4	DOC	Ad_5	Ad_6	DOC
5'	30''	30''	5'	30''	30''	5'	30''	30''	2'

Fig. 1 Picture presents the schema describing the video stimulation for the Experiment 1. *Gray boxes* indicate the time slots related to the portions of documentary, whereas the *white boxes* are related to the time slots of the TV commercials. Durations in minutes and seconds, for documentary and spots, respectively, are also indicated (Color figure online)

advertisements presented within the documentary asking the subjects to tell which advertisement they remember. Successively, the experimenter showed on a paper several frame sequences of each advertisement inserted in the movie. Analogously, the experimenter also showed several pictures related to an equal number of advertisements that were not inserted in the commercial break (distractors). This was done to provide the subjects the same number of distractors when compared to the target pictures. Finally, the experimenter asked subjects to give a score ranging between 1 and 10 according to the level of pleasantness they perceived during the observation of each remembered ad (1, lowly pleasant; 5, indifferent; 10, highly pleasant). This was performed to divide the gathered neurometric data in two samples: They comprise the data related to the clips rated from 7 to 10 (LIKE dataset) and those regarding the clips rated from 1 to 4 (DISLIKE dataset). In this report, we do not analyze the data related to a medium pleasantness score (e.g., from 5 to 6). In such a way, we divide the EEG, HR and GSR signals of the population recorded into two different datasets that will be compared in the following of this study by discarding the data related to the middle of the pleasantness scale. For each subject, a 2-min EEG segment related to the observation of the documentary has been further taken into account as baseline activity. No specific question related to the documentary was asked during the interview.

The items of the administrated questionnaire are the following:

1. During the movie, you have watched some advertisements have been showed. Do you remember some of them? Which one? (if subject does not remember any advertisement, go to item 3).
2. Are you able to tell me the plot of the advertisements you remembered?
3. Did you watch any of the following advertisements in the movie? (the experimenter verbally list a set of advertisements).
4. Now, I am going to show you some images. You should tell me whether these images are extracted from the advertisements you have watched or not.
5. Please, rank the following advertisements according to the degree of pleasantness you perceived while watching them. You should give a number between 1 (lowest pleasantness) and 10 (highest pleasantness).
6. Have you watched some of these advertisements before?

EEG Recordings and Signal Processing

The cerebral activity was recorded by means of a portable EEG 64-channel system (BE + and Galileo software, EBneuro, Italy) according to the 10–20 international system configuration. All subjects were comfortably seated on a reclining chair, in an electrically shielded, dimly lit room. Electrodes positions were acquired in a 3D space with a Polhemus device for the successive positioning on the head model employed for the analysis. Recordings were initially extra-cerebrally referred and then converted to an average reference off-line. We collected the EEG activity at a sampling rate = 256 Hz while the impedances kept below 5 kΩ. Each EEG trace was then converted into the Brain Vision format (BrainAmp, Brainproducts GmbH, Germany) in order to perform signal preprocessing such as artefacts detection, filtering and segmentation. 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 and blinks.

These EEG traces were then segmented to extract the cerebral activity during the observation of the TV commercials and the one associated to the documentary (baseline period). Then, this dataset has been further segmented into one-second length trials. Later, a semi-automatic procedure has been adopted to reject such EEG trials that present muscular and other kinds of movement artefacts. Only artefacts-free trials have been considered for the following analysis.

Estimation of Cortical Power Spectral Density

In this work, cortical activity from EEG scalp recordings was estimated by employing the high-resolution EEG technologies [69–73] with the use of a realistic head model known as average head model from McGill University. The scalp, skull and dura mater compartments were built using 1,200 triangles for each structures, and the Boundary Element Model was then employed to solve the forward electromagnetic model. For each subject, the electrodes disposition on the scalp surface, through a nonlinear minimization procedure, has been generated [74]. The cortical model consists of about 4,000 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 techniques described in previous papers [75–77]. Each dipole was modeled to be perpendicular to the cortical surface.

The power spectral density (PSD) of the estimated cortical signals was calculated using the Welch method [78] and then mapped onto the average cortex model (MNI template, 4,096 cortical dipoles) as described above. This procedure allowed us to obtain a measure of PSD values for each estimated cortical location and for each trial for all subject's datasets, in the frequency range of [1, 40] Hz with a resolution of 1 Hz.

Individual alpha frequency (IAF) has been calculated for each subject in order to define four bands of interest according to the method suggested in the literature [79]. 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 ranges. In particular, we focused the present analysis in the following frequency bands: theta (IAF-6, IAF-2), i.e., in the frequency band between IAF-6 and IAF-2 Hz, alpha (IAF-2, IAF + 2).

To avoid personal baseline, the z-score computation [80] has been performed for the PSD of each cortical dipole and subject using the data related to the observation of the documentary as reference. Then, signals related to the LIKE and DISLIKE groups have been averaged and statistically compared by means of z-score subtraction to obtain the results illustrated in the following sections. In order to take into account subjects' personal baseline activity, we used the neurophysiological signals (mean and standard deviation) related to the observation of the documentary to transform into z-score variables the values of spectral power of the datasets related to the commercials according to the following formula:

$$Z_{\mathrm{spot}} = \frac{X_{\mathrm{spot}} - \mu_{\mathrm{doc}}}{\sigma_{\mathrm{doc}}} \quad (1)$$

where Z_{spot} is the z-score value related to the TV commercials dataset, whereas μ_{doc} and σ_{doc} are mean and standard deviation related to the documentary dataset. Such procedure has been used to contrast the PSD for each cortical dipole, and the Bonferroni correction for multiple comparisons was also adopted [81, 82].

Autonomic Recordings and Signal Processing

The GSR and the HR has been recorded by means of the PSYCHOLAB VD13S system (SATEM, Italy) with a sampling rate of 10 Hz. Skin conductance was recorded by the constant voltage method (0.5 V). Ag–AgCl electrodes (8 mm diameter of active area) were attached to the palmar side of the middle phalanges of the second and third fingers of the subject's nondominant hand by means of a velcro fastener. SATEM also provided disposable Ag–AgCl electrodes to acquire the HR signal. Before applying the sensors, subjects' skin has been cleaned by following procedures and suggestions published in the literature [83–85]. GSR and HR signals have been continuously acquired for the entire duration of the video and then filtered and segmented with in-house MATLAB software. As to the GSR signal processing, we used a band-pass filter with a low cutoff frequency of 0.2 Hz in order to split the phasic component of the electrodermal activity from the tonic one, and a high cutoff frequency of 1 Hz to filter out noise and suppress artefacts caused by Ebbecke waves [83, 86]. As explained in the previous section, besides the autonomic activity of the subjects during the observations of the video clips we used a part of the documentary to estimate the mean and standard deviation of the electrodermal activity and the cardiac frequency rate signal in order to compute their z-score variables. These variables have been computed for each TV spot analyzed and subject recorded. Specifically, the z-score variables have been computed for the tonic component of the GSR and for the entire HR signal. They were used to form the experimental datasets previously described (LIKE, DISLIKE) to be statistically compared.

Results

Behavioral Results

The experimental subjects have been divided in two subgroups, LIKE and DISLIKE, according to the pleasantness score they gave during the interview performed after the recording session. Their median = 8 and iqr = 2, and median = 3 and iqr = 1.75 (Kolmogorov–Smirnov test: $d = 1$, $p < 0.001$) for LIKE and DISLIKE groups, respectively. The six TV commercials have been spontaneously remembered 32 times across all subjects. The advertisements have been all remembered after the experimenter verbally and graphically stimulated the subjects. We did not ask any specific judgement related to the observation of the documentary.

Neurophysiological Results

A Student's t test has been performed between cortical z-score distributions of the LIKE and DISLIKE groups. Figure 2 presents the related statistical cortical maps

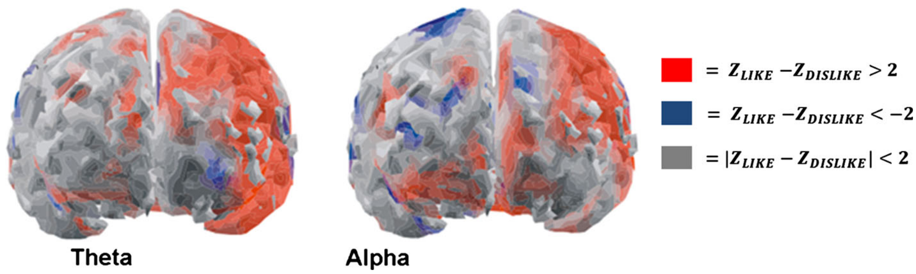

Fig. 2 Figure presents two cortical statistical maps, in the theta and alpha bands. Legend represents cortical areas in which increased statistically significant activity occurs in the LIKE group when compared to the DISLIKE group in *red*, while *blue* is used otherwise ($p < 0.05$, Bonferroni corrected). *Gray color* is used to map cortical areas where there are no significant differences between the cortical activity in the LIKE and DISLIKE groups (Color figure online)

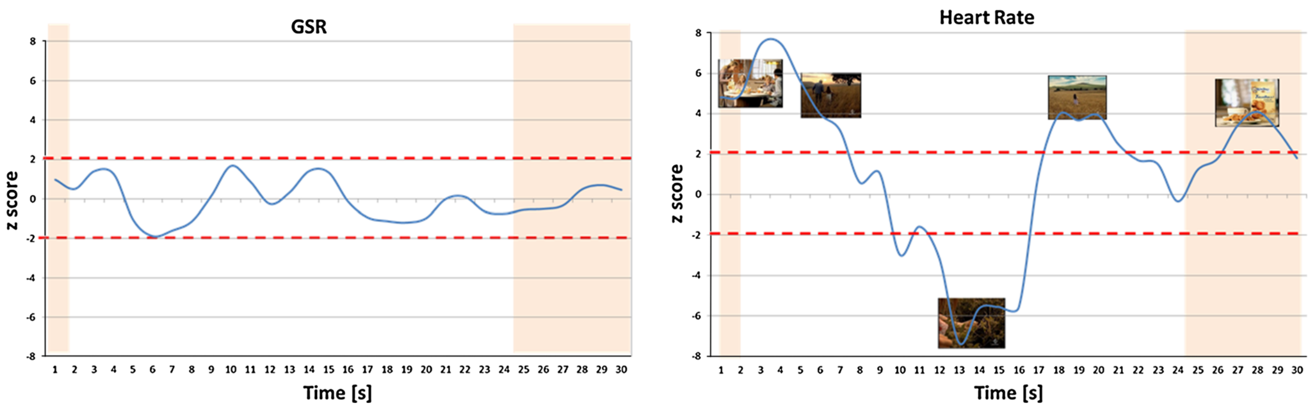

Fig. 3 Figure presents the *z*-score values of GSR (*left*) and HR (*right*) averaged on the entire population during the observation of a commercial video. The *colored rectangles*, at the beginning and at the end of the time scale, depict the interval in which the brand is overtly presented in the spot. In such case, the brand corresponds to a particular and well-known kind of biscuits in Italy. The time scale is in seconds. *Dotted lines* at $z = -2$ and $z = 2$ indicate the thresholds of statistical significance at $p < 0.05$ (Color figure online)

viewed from a frontal perspective. The color scale employed to color dipoles on the cortex codes the statistical significance: Gray color is used where the activity of cortical areas does not differ between the two conditions. The red (blue) color is used when the cortical areas present a significant increase of power spectral activity for the population that liked (disliked) the commercial videos with respect to the other. Hence, the picture presents the contrast between the LIKE and DISLIKE groups in the frequency bands considered in this analysis. The significant increase of the frontal activity in the theta band is clearly visible (in red) in the LIKE group when compared to the DISLIKE one (upper left part of the Fig. 2). Scattered increased of cortical activity on the left hemisphere is also present in the DISLIKE group (in blue). In the alpha frequency band (upper right of Fig. 2), significant increase of cortical activity is present on the left hemisphere and on the orbitofrontal right hemisphere in the LIKE group when compared to the DISLIKE one.

Figure 3 presents the *z*-score average waveforms of GSR and Heart Rate (HR) for a representative TV commercial

From the above picture, it is possible to appreciate the different time scale of HR signal, during the observation of the commercial videos. It is possible to appreciate the time intervals of the HR when exceed the level of statistical significance ($|z| > 2$, $p < 0.05$). When the signal is within the range $z = [-2, 2]$, no difference between HR and documentary appears. Particularly, with respect to the observation of the documentary, the average values of *z*-scores show an increment of cardiac activity at the beginning and at the end of the commercial when the brand is advertised. Also, similar increase of activity has been elicited during the observation of scenes showing the actors in a wheat field. However, the central time interval of the commercial presents a negative activation when subjects watch actors in several dark scenes.

As it is possible to see in picture, the average waveform of the GSR did not exceed the level of statistical significance.

The analysis of the average values of the autonomic variables gathered in the experimental group was performed using a repeated-measures ANOVA with factor AUTONOMIC, with two levels (GSR and HR, including the transformed z-score of the GSR and HR recordings, respectively) and the factors BRAND (levels BRAND and NO BRAND related to the activity gathered during the observation of the brands and in the other frame segments, respectively) and REPORT (LIKE, DISLIKE). Although the repeated-measures ANOVA did not highlight any significant result for the main factors BRAND and REPORT, it returned a statistically significant interaction between all the factors employed, with a AUTONOMIC × BRAND × REPORT significance of $p < 0.05$. The interactions between the main factors AUTONOMIC × REPORT is also statistically significant, with a $p < 0.05$ while there are no interactions between the factors BRAND × REPORT ($p < 0.48$). The post hoc analysis performed with the Duncan test returns that the values of the HR are statistically significantly higher in the LIKE group versus DISLIKE group in the BRAND condition ($p < 0.05$) while there is a trend that is not statistically significant in the NO BRAND condition ($p < 0.08$). There are no significant differences between the values of the GSR variable between the LIKE and DISLIKE groups, for both BRAND ($p < 0.54$) and NO BRAND conditions ($p < 0.43$).

Discussion

The analysis of the statistical cortical maps in the conditions LIKE versus DISLIKE suggested that the left frontal hemisphere was highly active during the LIKE condition, especially in the theta and alpha band. The results here obtained for the LIKE condition are also congruent with other observations performed with EEG in a group of 20 subjects during the observation of pictures from the International Affective Picture System (IAPS, [87, 88]). Both studies indicated an increase of the EEG activity in the theta and alpha bands for the anterior areas of the left hemisphere. It is worth to note that there were methodological differences between the cited studies and the present one that are related to the use of different stimuli and processing algorithms. We could argue that the cerebral regions involved for processing emotions for static pictures are also involved for processing emotions during the observation of moving scenes, such as TV commercials. A strong involvement of frontal and prefrontal areas has also been already experienced in a previous study performed with high-resolution EEG, functional connectivity and graph theory tools [89–93]. The convergence of these results, obtained in the ecologic conditions of the observation of commercial videos within the documentary with those of more controlled memory and affective tasks, deserves attention.

The measurements of the HR report a statistically significant difference when the population watched commercial videos that resulted pleasant (LIKE vs. DISLIKE). In particular, during the observation of the commercials for the LIKE condition, the z-scored HR is statistically different when compared to the DISLIKE group. On the contrary, the z-score levels of the GSR variable during the LIKE/DISLIKE cannot be statistically distinguished. Hence, since variation of GSR relates to level of arousal [41, 42], we could conclude that the average level of arousal did not change across the entire set of the commercial videos presented, irrespective of the experimental conditions.

Moreover, the indications provided by the autonomic measurements in the analyzed population suggest that HR is a variable that is useful to track the occurrence of pleasantness of the commercial videos. In addition, we observed as the proposed commercials did not elicit particular changes of GSR in the investigated population. This is important since it was previously known that participants react to the viewing of highly aversive films with HR deceleration and a marked electrodermal increase [43–45, 94]. In this particular case, due to the particular nature of the video clips presented (commercial advertisements with a limited arousal content), such orienting and aversive reaction was not generated.

Experiment 2

Methods

Subjects

In the Experiment 2, we show a concrete application of the neuroelectrical tools to a real case study. The whole experimental sample is formed by 24 subjects (25–54 years, 12 women), which will be in the following divided in two subgroups (younger adults and older adults) differing by age. Written informed consent was obtained from each subject after the explanation of the study. The present advertisement has been divided into 5 time intervals showing different key scenes of the video clip (as shown in Fig. 5) in which we computed the AW and EI for the Like and Dislike groups.

Experimental Paradigm

The procedure of the experimental task consisted in observing a 20-min-long documentary in which we inserted two commercial breaks, after 5 and 15 min from the beginning of the movie, respectively. Each interruption was formed by seven commercial video clips of different length (30″, 20″ and 15″). The TV commercial we use here for case study was unknown to the subjects, and it has been showed only once during the experiment. Randomization

Experiment 2	Break 1								Break 2							
DOC	Ad_1	Ad_2	Ad_3	Ad_4	Ad_5	Ad_6	Ad_7	DOC	Ad_8	Ad_9	Ad_10	Ad_11	Ad_12	Ad_13	Ad_14	DOC
5'	30"	30"	30"	30"	30"	30"	30"	5'	30"	30"	20"	30"	30"	30"	30"	3'

Fig. 4 Picture presents the schema describing the video stimulation for the Experiment 2. *Gray boxes* indicate the time slots related to the portions of documentary, whereas the white *boxes* are related to the time slots of the TV commercials. Durations in minutes and seconds, for documentary and spots, respectively, are also indicated (Color figure online)

of the occurrence of the all commercial videos within the documentary was made to remove the order effect as possible confounding effect. The specific advertisement is the one aired by Air Action Vigorsol, a famous brand and type of chewing gum, which has as protagonists a pair of lovers who live far away from each other. The TV commercial can be watched at the following link: http://www.youtube.com/watch?v=o8RCOb3WQOs. The specific feature of the present advertisement consists in generating an exhilarating climax with some not-so-nice images.

The present advertisement has been divided into 5 time intervals showing different key scenes of the video clip (as shown in Fig. 5) in which we computed the AW and EI for the Like and Dislike groups.

The procedure of Experiment 2 is the same already illustrated for Experiment 1, therefore not reported here. The schema of the video sequence is shown in Fig. 4.

EEG Recordings and Signal Processing

The cerebral activity was recorded by means of a portable EEG system (BEmicro and Galileo software, EBneuro, Italy). Informed consent was obtained from each subject after explanation of the study, which was approved by the local institutional ethics committee. All subjects were comfortably seated on a reclining chair, in an electrically shielded, dimly lit room. Electrodes were arranged according to an extension of the 10–10 international system. Since a clear role of the frontal areas has been depicted for the investigated phenomena [9–12, 95], we used the following channels: AF7, Fp2, Fpz, Fp1, AF6, F5, AF3, AFz, AF4 and F6. Recordings were initially extra-cerebrally referred and then converted to an average reference off-line. We collected the EEG activity at a sampling rate = 256 Hz while the impedances kept below 5 kΩ. Each EEG trace was then converted into the Brain Vision format (BrainAmp, Brainproducts GmbH, Germany) in order to perform signal pre-processing such as artefacts detection, filtering and segmentation. 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 data have been re-referenced by computing the common average reference (CAR). Individual alpha frequency (IAF) has been calculated for each subject in order to define the alpha as alpha = [IAF-2, IAF + 2] [79].

Approach-Withdrawal Index

In order to define an Approach-Withdrawal Index (AW) according to the theory related to the earlier introduced EEG frontal asymmetry theory, we computed such imbalance as difference between the average EEG power of right and left channels. The formula we used is the following:

$$\begin{aligned} AW &= \frac{1}{N_P}\sum_{i\in P} x^2_{\alpha_i}(t) - \frac{1}{N_Q}\sum_{i\in Q} y^2_{\alpha_i}(t) \\ &= \text{Average Power}_{\alpha_{right\,frontal}} - \text{Average Power}_{\alpha_{left\,frontal}} \end{aligned} \quad (2)$$

where x_{α_i} and y_{α_i} represent the ith EEG channel in the alpha band that have been recorded from the right and left frontal lobes, respectively. In addition, $P = \{\mathrm{Fp2, AF6, AF4, F4}\}$ and $Q = \{\mathrm{Fp1, AF7, AF3, F5}\}$, N_P and N_Q represent the cardinality of the two sets of channels. In such a way, an increase of AW will be related to an increase of interest and vice versa. The AW signal of each subject has been *z*-score-transformed and then averaged to obtain an average waveform.

Emotional Index

The emotional index is defined by taking into account the GSR and HR signals. As far as the construction of such variable concerns, we refer to affect circumplex [27] where the coordinates of a point in this space are defined by the HR (horizontal axis) and the GSR (vertical axis). As presented in the Introduction section, several studies have highlighted that these two autonomic parameters correlate with valence and arousal, respectively (see [23] for a review).

In order to have a mono-dimensional variable, we describe the emotional state of a subject by defining the following emotional index (EI):

$$EI = 1 - \frac{\beta}{\pi} \quad (3)$$

where.

$$\beta = \begin{cases} \frac{3}{2}\pi + \pi - \vartheta & \text{if } GSR_Z \geq 0, HR_Z \leq 0 \\ \frac{\pi}{2} - \vartheta & \text{otherwise} \end{cases} \quad (4)$$

GSR_Z, HR_Z represent the *z*-score variables of GSR and HR, respectively; ϑ, in radians, is measured as arctang (HR_Z, GSR_Z). Therefore, the angle β is defined in order to transform the domain of ϑ from $[-\pi, \pi]$ to $[0, 2\pi]$ and obtain the EI varying between $[-1, 1]$. This is why we have two ways to calculate β. According to Eqs. 2 and 3 and the affect circumplex [27], negative ($HR_Z < 0$) and positive ($HR_Z > 0$) values of the EI are related to negative and positive emotions, respectively, spanning the whole affect circumplex.

Although in Experiment 1 we could not highlight statistical difference for the GSR, we preferred to maintain this variable for the emotional index definition due to evidence published in the literature [41, 42].

Results

Behavioral Results

The recording of the neurometric response included the detection of the EEG signals, HR and GSR parameters on a sample of 24 subjects (39.56 ± 8.11 years; 12 men) that rated the TV commercial with a pleasantness score distribution with median = 7 and iqr = 6. The experimental subjects have been divided in two subgroups differing by age (10 younger adults: 31.33 ± 3.31; 14 older adults: 44.86 ± 5.24; Student's $t = 7.57, p < 0.01$). Younger adults resulted rating the proposed advertisement with higher pleasantness score (median = 8 and iqr = 1) with respect to the older adults (median = 3.5, iqr = 5; Kolmogorov–Smirnov test: $d = 0.78$, $p < 0.01$). Later, we also divided the whole experimental sample in LIKE and DISLIKE groups according to the pleasantness score they gave during the interview (LIKE: median = 8, iqr = 1.5; DISLIKE: median = 1, iqr = 1.5; Kolmogorov–Smirnov test: $d = 1, p < 0.01$). This commercial advertisement has been spontaneously recalled by the 12.5 % of the population. However, all subjects remembered it when verbally and graphically stimulated. We did not ask any specific judgement related to the observation of the documentary. In Fig. 5, the segmentation frame by frame of the commercial is shown.

Cerebral Indices Results

By analyzing the AW and EI, shown in Fig. 6, it was evident that the investigated commercial video arouses

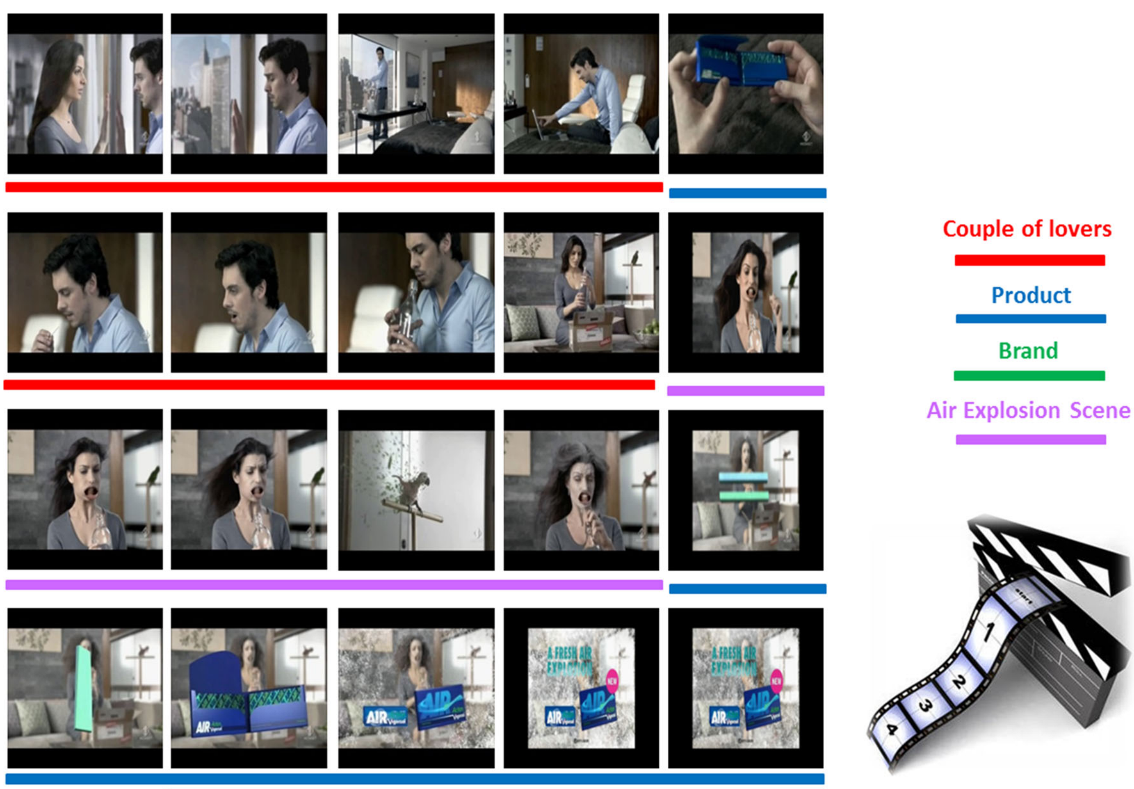

Fig. 5 Frame sequence of the Air Action Vigorsol TV commercial for each second of the video clip. The *underlying colors* highlight the different scenes in which it is possible to divide the advertisement, as the legend on the *right* shows. In such segments, the average values for the estimated indices were computed (Color figure online)

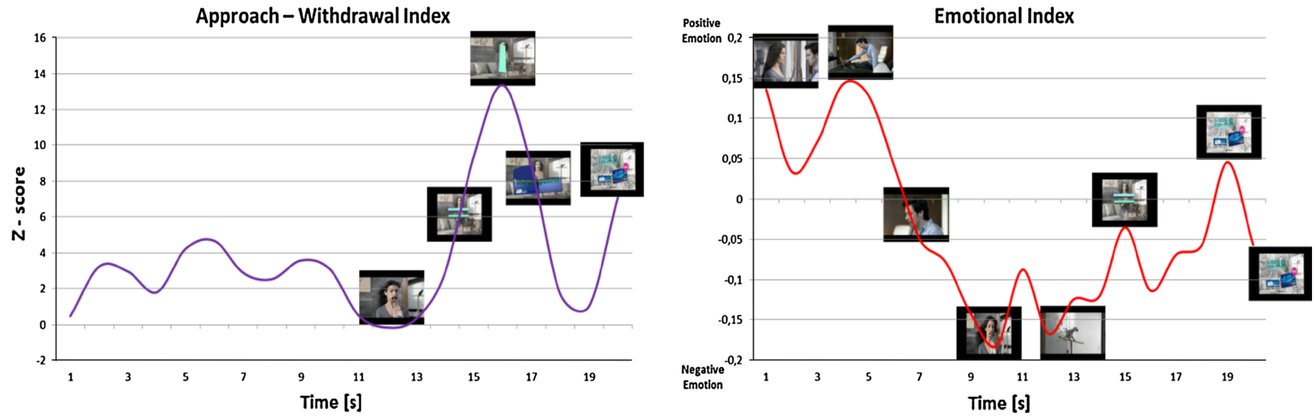

Fig. 6 Picture presents the average Approach-Withdrawal (*left*) and Emotional (*right*) profiles, across the whole experimental sample, related to the observation of the Air Action Vigorsol TV commercial. Both the *horizontal axis* describes the time evolution of the clip (from 1 to 20 s). The *vertical axis* of the considered Approach-Withdrawal Index describes the amplitude of the variable in *z*-score values. *Vertical axis* of the Emotional Index indicates positive emotion from 0 to 0.15 values and negative emotions for values from 0 to −0.2 values. Note that the zero value is the average value of the analyzed index during the baseline phase. Particular frames of the advertisement are showed on the AW and EI waveforms

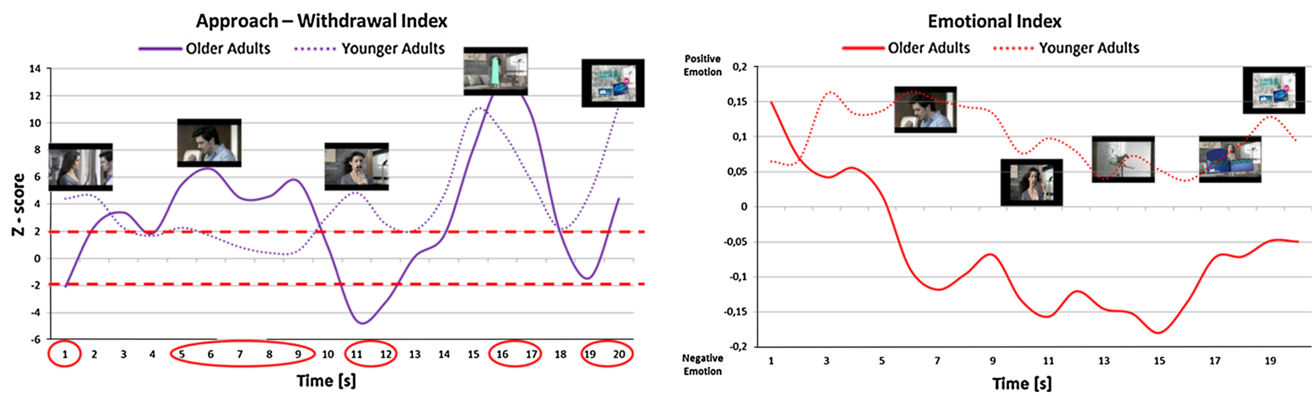

Fig. 7 Picture presents the average Approach-Withdrawal (*left*) and Emotional (*right*) profiles across the two analyzed sub-targets, older adults (*continuous line*) and younger adults (*dotted line*), related to the observation of the Air Action Vigorsol TV commercial. Both *horizontal axes* describe the time evolution of the clip (from 1 to 20 s). The *vertical axis* of the considered Approach-Withdrawal Index describes the amplitude of the variable in *z*-score values. *Dotted lines* at $z = -2$ and $z = 2$ indicate the thresholds of statistical significance ($p < 0.05$) between the single waveforms and the level related to the documentary. Instead, *red circles* in the *horizontal axis* highlight statistically significant differences between the two groups, older adults and younger adults ($p < 0.05$, Bonferroni corrected). *Vertical axis* of the Emotional Index indicates positive emotion from 0 to 0.15 values and negative emotions for values from 0 to −0.2 values. A zero level of the EI or AW estimators represents the average value for that estimators during the documentary seen before the TV commercial analyzed. Particular frames of the advertisement are showed on the AW and EI waveforms

different responses with respect to the two used indices. In particular, as far as concern the investigated sample, the final frames elicited high value related to the Approach-Withdrawal index.

The negative effects measured for the emotion on the opening of the bottle in the video clip has been reported as the average value for the whole experimental sample. However, it is possible to prove that such effect was sensitive to the age of the sample subjects. In particular, Fig. 7 shows the results in terms of AW and EI estimators related to the two age-generated subgroups, younger and older adults. According to the variations of the AW index, older adults present an increase of activation in the initial part of the commercial (story telling), whereas younger adults show a similar increment in the middle of the spot (funny scenes). The Emotional Index, except for the initial part, is always higher for younger adults. In particular, the average EI values for the younger adults if 0.09 ± 0.04 while for the older adults shows a level of -0.06 ± 0.08 (Student's $t = 10.57$, $p < 0.01$). This result is in agreement with the subjects' behavioral ratings as it is possible to appreciate in the previous section.

The whole experimental sample has been also divided according to the pleasantness score in order to form the LIKE and DILIKE groups. These two sub-targets have been further analyzed to highlight difference in terms of AW and EI in particular time segments of the TV

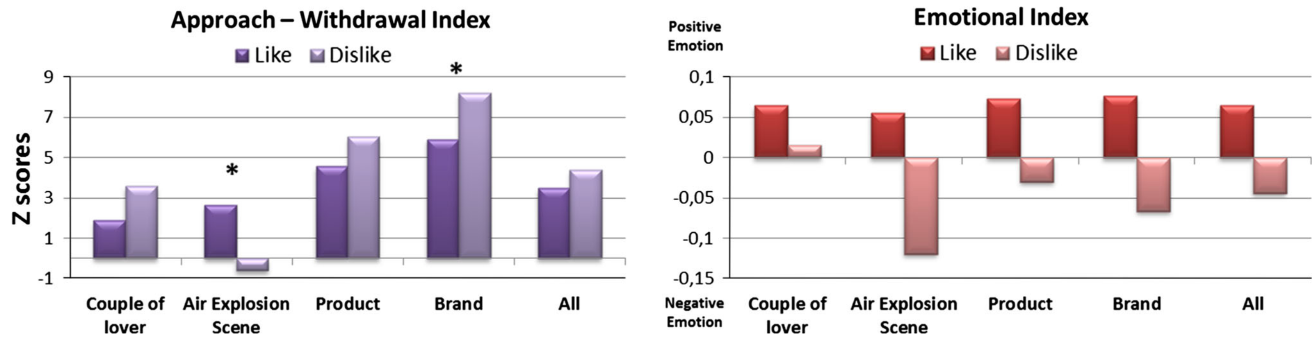

Fig. 8 Picture presents the average Approach-Withdrawal (*left*) and Emotional (*right*) indices calculated within particular segments of interest of the Air Action Vigorsol TV commercial for the two analyzed sub-targets, LIKE and DILIKE. On the *horizontal axis*, the labels of the particular segments are shown. The *vertical axis* of the considered Approach-Withdrawal Index describes the amplitude of the variable in *z*-score values. *Vertical axis* of the Emotional Index indicates positive emotion from 0 to 0.15 values and negative emotions for values from 0 to −0.2 values. A zero level of the EI or AW estimators represents the average value for that estimators during the documentary seen before the TV commercial analyzed. Statistically significant differences in the time segments are highlighted with the symbol*

commercial. Figure 8 shows the variation of AW and EI for the defined time intervals. As to the AW index, data highlight a statistically significant difference for two segments (Air Explosion Scene, Brand). Instead, the EI does not present statistically significant differences between the Like and Dislike groups across the time segments. However, it is possible to appreciate how the Like group presents higher values of EI in all the specific time intervals.

Discussion

The analysis of the Approach-Withdrawal and the Emotional Index returned, at least apparently, discordant interpretation. The difference between them is evident in terms of emotional reaction to the spot (as indicated by the EI), whereas there is a difference in terms of neuroelectrical reaction to the spot, just in the central scene, according to the AW index. In particular, as to the Approach-Withdrawal index, the older adults prefer the initial part, when the story is told. At the seconds 11″–15″, when the humor of the TV commercial comes on in the scenes, they watch the ad with more detachment, while the younger adults are more interested. In fact, what we can observe that at first sight the cerebral Approach-Withdrawal index is characterized by positive values, whereas the analysis of autonomic signals through the Emotional Index shows negative emotions. The interpretation of this phenomenon has to be read in the different nature of the two indices. The former mostly highlights the cerebral attractiveness or the refusal toward a stimulus; the latter shows the experienced internal state, through the cardiac and cutaneous "body markers." We could speculate interpreting the described results as a sign of high cerebral curiosity but an emotional detach of the gathered sample related to the TV commercial analyzed.

Results suggest that the ugly scenes of the TV commercial elicit negative peaks of emotions but high peaks of AW index (e.g., approach tendency). A possible interpretation is that such scenes are able to elicit interest from the subjects although the sudden events depicted in the video generated negative emotions.

These considerations could be enforced after analyzing the results of the two different subgroups: younger adults and older adults. Specifically, the former group not only shows higher values of the Approach-Withdrawal index, when compared to the latter, but also highlights a positive emotion waveform. In this case, it appears that just older adults have been negatively impressed by some ugly scenes of the clip. Younger adults, instead, perceive the commercial with a positive emotion along its whole length. From these last considerations, we can argue that the analyzed advertisement resulted particularly convincing and effective for the investigated younger sample. In addition, the analysis in different time segments, between the LIKE and DISLIKE groups, highlighted that there are some particular short periods within the advertisement that we can assume to do most of the work in actuating advertising performance measures [96]. However, the obtained results relate to a single and specific TV commercial and could be performed similar analysis and description for additional TV commercials. Here, we do not provide such results because we believe that it could not add more information to the presented results.

General Discussion

Our results highlight an involvement of frontal and prefrontal cerebral regions during the observation of TV commercials that will be judged pleasant. These activations mostly concern the left frontal lobe showing a de-synchronization of the EEG alpha rhythm. In agreement with the Approach-Withdrawal theory, the present results affirm that there are two distinct brain networks processing the pleasant and unpleasant commercials, which mostly lie in the left and right frontal areas, respectively. The specific activation of frontal areas related to the observation of pleasant TV commercial has been also investigated by several scientists.

Finally, we presented a novel index for the estimation of the emotions during the observation of TV commercials. Such neurophysiological variable relies on the measurement of GSR and HR as orthogonal axes of arousal and valence dimensions, respectively. Our results show that the increase of such emotional index can discriminate subjects who liked the advertisements they watched from the one that did not. Although the increase of HR we found out is in agreement with previous studies [43, 44], our experimental paradigm did not elicit significant enhance of activity for the GSR. However, since we did not explicit measure the behavioral arousal, further investigation is needed to claim results for this autonomic variable.

The neuroimaging methodology illustrated can then provide additional indications related to the preferences of people with respect to observation of TV commercials that are quite different from the standard market research studies, often based on the generation of written or verbal questionnaires. This neurometric approach could be useful to test different ideas or product concepts quite rapidly in the process of the generation of a new product.

Conclusion

The illustrated results showed an increase of both HR and cerebral activity, mainly in the theta and alpha bands in the left hemisphere, when subjects watched pleasant TV commercials. Specifically, the EEG activity highlights a frontal unbalance between left and right frontal hemispheres in different frequency bands. These results have been summarized in two neurophysiological indices, which could be used in neuromarketing research for the evaluation of already existing TV commercials as well as concepts and idea of the product, even before their real production. How far this measurement and interpretation process will bring the marketing research in the next years is still too early to state at the light of the present knowledge.

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