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Brain response to antismoking PSA, an EEG study.

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Abstract. Public service antismoke announcements (PSA) are essential tools for promoting messages worthy of society. In 2015 the Italian Government released an anti-smoking PSA to raise young people's awareness of the smoking dangers. To demonstrate the effectiveness of that campaign, the present study investigated the mental response of 56 participants while watching the PSA through the Electroencephalogram (EEG). The EEG is frequently employed in neuromarketing to face the limitations of verbal declarations, allowing to evaluate the advertisings' efficacy objectively. The present study analyzed the PSA, considering the smoking habit of participants by dividing them into smokers and non-smokers. Some main segments of the PSA were identified and separately analyzed for evidencing the most effective part for the anti-smoking message. Three main EEG indexes have been explored in the analysis: mental engagement index (ME), spectral asymmetry index (SASI), and the mental effort index. The t-test performed on the index values showed an increase of the ME and the SASI for smokers compared to non-smokers ($p<0.005$). While the repeated measures ANOVA pointed out that the indexes were differently modulated by the parts of the PSA, showing the effectiveness of the smoking symptoms' description and the claim at the brain level.

Keywords: EEG, neuromarketing, emotions, mental engagement, mental effort, anti-smoking PSA

1. Introduction

Europe has the highest prevalence of tobacco smoking among adults (28%) and some of the highest prevalence of tobacco use by adolescents (*www.euro.who.int*). For this reason, the European Commission recently allocated conspicuous funds for supporting projects that promoted antismoking messages (Vardavas et al., 2019). In Italy, in 2015, out of 52,3 million inhabitants older than 14 years old, the number of smokers was about 10,3 million (19.5%) (www.salute.gov.it). The government, facing this alarming data, tried to determine a strategy for countering the growing number of smokers in the country. One of the means it relied on was broadcasting an anti-smoking public service announcement (PSA), titled "Ma che sei scemo? Il fumo fammale!" (Are you stupid? Smoking is bad!), aired on national TV for almost one year. The campaign aimed to be viral on the social networks, but rather, as shown by La Torre in his paper (La Torre, 2020), its dissemination was law. However, data reported in 2017 by Doxa S.p.A., a company leader in marketing research and public opinion, (*http://old.iss.it/binary/fumo4/cont/OsservatorioFumo_Alcol_e_Droga_presenta_il_Rapporto_Nazionale_sul_Fumo_2017_Roberta_Pacifici.pdf.pdf*), showing the reduction of cigarettes' purchase from 2015 to 2016, might demonstrate the efficacy of this anti-smoking PSA, broadcasted on national TV just in that time. In the present paper, we studied the mental state of a sample of participants while watching the above-mentioned PSA. The response to the anti-smoking campaigns at the brain level was already explored in literature. Fairchild in her review (Fairchild et al., 2018), reported six different studies which investigated the effect of anti-smoking health messages and videos by mean of functional magnetic resonance imaging (fMRI) and electroencephalography (EEG). She pointed out that anti-smoking campaigns elicited the activation and cooperation of brain regions, such as the amygdala, hippocampus and some region of the prefrontal cortex, generally related to two main processes: executive functions and emotions. The importance of the emotional contents for the PSA effectiveness is argued by Borawska and his colleagues (Borawska et al., 2020) that analyzed the EEG activity during the observation of advertising that promoted safe driving. Despite the fact that they did not find any neural correlation with the different types of emotions elicited by the ad, they deduced from the declarative responses that the negative emotional content of the PSA affected the driving intentions of the participants. Still, in this regard, Chaouachi (Chaouachi et al. 2010) showed that the emotions might impact the human engagement in accomplishing a task, analysing the mental engagement (ME) by mean of an EEG index computed as defined by Pope and his colleagues (Pope et al., 1995). In particular, he found a higher mental engagement for both positive and negative emotions with high arousal. Furthermore, he pointed out that the ME index was also an indicator of learning performance, showing that higher engagement was associated with better performances. This concept also was evidenced by Khedher (Khedher et al., 2019), who found that engagement had a significant positive impact on students' outcomes. Therefore, it is reasonable to assume that the effectiveness of the PSA message could be assessed by the evaluation of the mental engagement index, as already showed by Cartocci and colleagues (Cartocci et al., 2019). In their study, the EEG activity was investigated on participants while watching anti-smoking PSAs, and they found that the ME index was significantly higher for smokers compared to non-smokers. Behind the ME also the emotional response was investigated in the study by mean of the spectral asymmetry index (SASI), generally related to the depression (Hinrikus et al., 2009) but also inversely correlated to the emotions felt as showed by Wu and collaborators (Wu et al., 2017), who proved that the values of SASI increased after negative stimuli while they decreased for the positive ones. An additional aspect considered in the EEG analysis was the mental effort associated with the PSA's messages. As already demonstrated in the literature (Cartocci, Maglione, et al., 2017), the effort related to the cognitive processes can be described by mean of the mental effort index, which reflects the frontal EEG activity in theta band (Wascher et al., 2014; Wisniewski et al., 2015).

The present study aimed to characterize the mental activity of participants while watching an anti-smoking PSA, by means of EEG indicators. Based on previous studies, these indicators are hypothesized to be differently modulated by participants' smoking habits classified as smokers and non-smokers (Cartocci, Caratù, et al., 2017; Modica et al., 2018). Furthermore, the response to five key segments identified in the PSA was analysed to assess the anti-smoking message's more effective parts.

2. Material and Methods

2.1 Protocol

Fifty-six participants (30 males and 26 females) took part in the experiment. They were divided into smokers (at least five cigarettes per day) and non-smokers. Participants were healthy volunteers aged between 23 and 55 years, rewarded for their participation. The experiment was part of the protocol conceived in the context of the EU project SmokeFreeBrain (*http://smokefreebrain.eu/*) (Bamidis et al., 2017). It was performed under the approval of the Ethical Board of Sapienza University of Rome, in charge of the Department of Molecular Medicine, and it respected the principles outlined in the Declaration of Helsinki of 1975, as revised in 2000. Participants, after signing the consent form and the relative information sheet, were asked to comfortably sit in front of a screen while watching ten different anti-smoking PSAs, among which there was the target stimulus: "Ma che sei scemo? Il fumo fammale!" (Are you stupid? Smoking is bad!). The task lasted around 9 minutes, and it was preceded and followed by a documentary excerpt lasting 1 minute, chosen to be neutral and used as baseline(Cartocci, Cherubino, et al., 2016; Cherubino P. et al., s.d.; Vecchiato et al., s.d.). The target PSA aimed at empowering young smokers to take care of their own health, describing the effects of smoking on the health, such as an increase in mortality, infertility, and a higher risk of impotence. In this PSA the anti-smoking campaign was coupled with the prevention of serious motorcycle accidents, encouraging young people to use the helmet. A famous Italian actor already served as a trustworthy protagonist of radio and video commercials was chosen as a testimonial in order to convey the anti-smoking message with the affectionate tone that would have a parent or friend concerned about the protagonists' health. Five main parts have been identified in the spot: 1) the entrance of the testimonial, saying to some guys who smoke, "Are you stupid? Smoking is bad!" 2) the description of the smoking symptoms by a voice-over, 3) the combination of the messages, introducing the second message about the importance of wearing a helmet, 4) the claim in which the two messages are repeated in a written form, 5) the ironic part in which the testimonial jokes with the young guys.

2.2 EEG Signal Processing

During the experimental task execution, the EEG activity has been recorded from participants by mean of a portable 24-channel system (BEmicro, EBneuro, Italy) and an EEG frontal band with ten electrodes (Fpz, Fp1, Fp2, AFz, AF3, AF4, AF5, AF6, AF7, and AF8). Impedances were kept below ten kΩ, and signals were acquired at a sampling rate of 256 Hz. EEG signals were cleaned of the power-supply interference by the application of a notch filter at 50Hz, and, they were bandpass filtered by a 5th order Butterworth filter ([2 ÷ 30] Hz). The artifacts coming from the eye-blink signals, overlapped to the EEG activity, were removed through the independent component analysis (ICA). Further artifacts were removed by employing three different criteria on the signals' amplitude and trend (Delorme & Makeig, 2004). The EEG bands of interest have been defined according to the individual alpha frequency (IAF), computed for every participant while keeping the eyes opened. In particular, three main frequency bands have been investigated in the analysis: theta [IAF − 6 ÷ IAF − 2 Hz], alpha [IAF − 2 ÷ IAF + 2 Hz], and beta [IAF + 2 ÷ IAF + 14 Hz] (Klimesch, 1999). The global field power (GFP) (Skrandies, 1990) was computed for the EEG activity over the frontal electrodes and filtered for the three frequency bands of interest. The analysis, three indexes have been computed and normalized concerning the baseline. The mental engagement (ME) was calculated as the ratio between the GFP in the beta band and the GFP's sum in the alpha and theta band over the frontal electrodes (Pope et al., 1995). The spectral asymmetry index (SASI) was computed as the ratio between the difference of frontal GFP in the beta and theta band and the sum of the frontal GFP in the same bands (Wu et al., 2017). The mental effort was defined as the GFP over the frontal electrodes in the theta band (Cartocci et al., 2018; Cartocci, Modica, et al., 2016; Modica et al., 2018)

2.3 Statistical Analysis

The PSA effect at the brain level was explored using a statistical analysis led on the indexes. Two types of analysis were performed: 1) t-test between the trend of the indexes averaged among smokers and non-smokers participants; 2) repeated measures ANOVA considering factors the five main parts of the spots and the smoking habits of the participants (smokers/non-smokers). The indexes were averaged for the three seconds corresponding to each part, and they were grouped for smokers and non-smokers participants. Duncan post-hoc has been applied to analyze the significant effects and interactions further.

3. Results

The T-test between the mean trend of the indexes computed for smokers and non-smokers shows a difference in participants' general reaction, depending on their smoking habit. In particular, we found a significant difference in the values of ME (*p<0.005*) and SASI (*p<0.005*) between groups. T-test performed on ME demonstrated a higher value of the index computed for participants who smoked Fig.1.a. The same trend was found for the SASI index, which increased for the smokers compared to the non-smokers Fig.1.b.

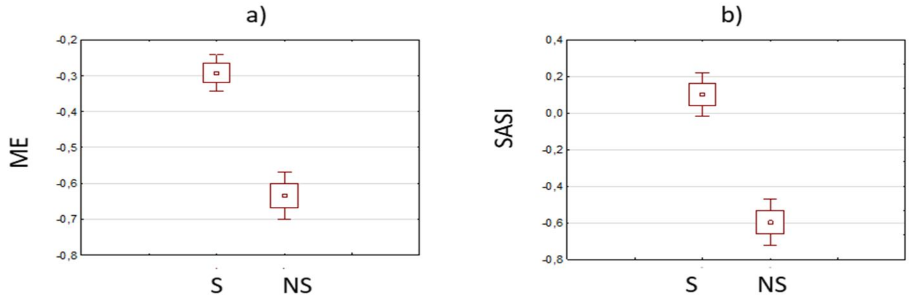

Figure 1. *t-test performed on mean values of ME a) and SASI b) for smokers (S) and no-smokers (NS). The indexes for the two populations were significantly different (p<0,005 for both tests).*

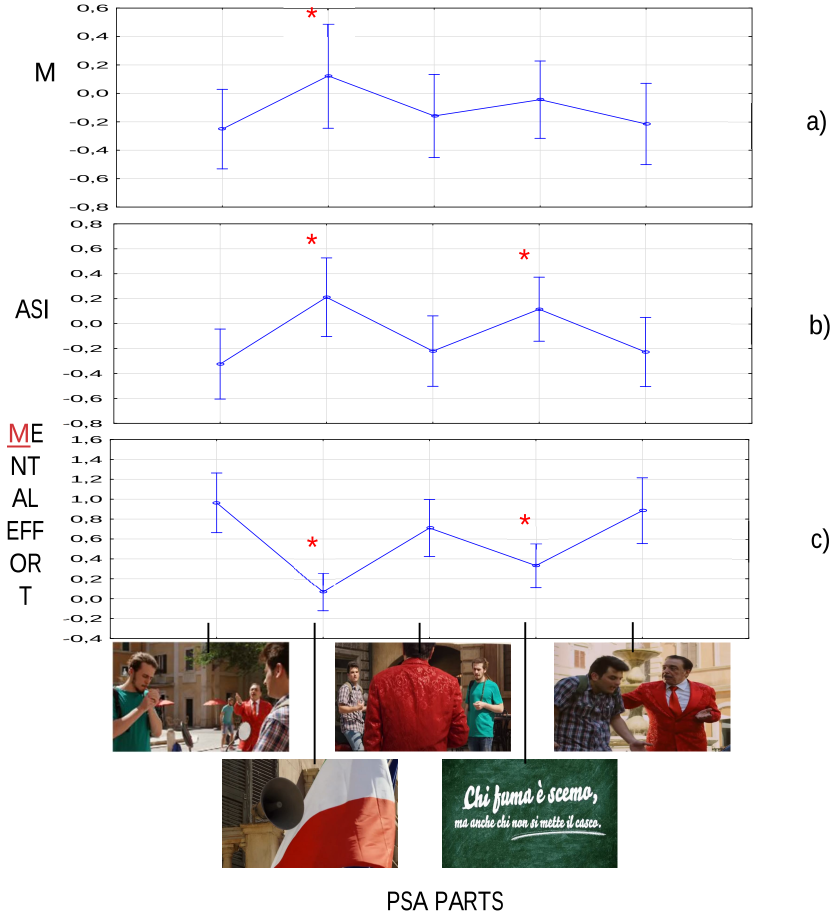

Figure 2. *Repeated measures ANOVA performed on the mean index values during five main parts of the PSA: 1 testimonial entrance; 2 smoking symptoms; 3 message combination; 4 claims; 5 ironic part. The effect of the PSA parts was significant for the three analysed indexes: a) F(4, 200)=7.3820, p=0.00001; b) F(4, 200)= 16.317, p<0.005; c) F(4, 200)=11.815, p<0.005. Duncan's post-hoc test revealed that the second part was significantly different from all the other parts for the three indexes. The fourth part was significantly different from the first, third, and fifth parts, except for the ME, in which the difference did not exist between the fourth and third parts. Vertical bars in the graphs denote a 95% confidence interval.*

The repeated measures ANOVA was performed to investigate the effect of the different main parts of the PSA. The analysis was led considering the five main parts of the PSA as within factor and the smoking habit as a categorical factor. We didn't find any effect of the smoking habit, but we found a difference between the parts of the PSA for every index, expressed by the fact that the ANOVA performed on the ME, SASI, and mental effort index showed a significant effect of the PSA on the indexes values (F(4, 200)=7.3820, $p<0.005$; F(4, 200)=11.815, $p<0.005$; F(4, 200)= 16.317, $p<0.005$ respectively). The Duncan post-hoc revealed that the indexes ME, SASI, and mental effort index computed for the smoking symptoms part and the claim part were different from those of the other PSA parts. In particular, in these two conditions, ME and SASI were higher than the values they assumed for the other parts of the PSA Fig.2.a and Fig.2.b, while the mental effort was significantly lower Fig.2. c.

4. Discussion

The present study aimed at describing the mental reaction of participants who watched a specific anti-smoking PSA. Through the EEG analysis, it was demonstrated that the PSA was differently perceived by participants with respect to their smoking habit. The statistical analysis performed on the data pointed out that smokers were generally more engaged during the PSA vision, as showed by the higher values of ME. Furthermore, the PSA caused an emotional reaction, inducing smoker participants in a negative mood reflected by the higher value of the SASI. Considering that smokers would be particularly susceptible to personification with the smoking character, modifying their mood in a pejorative direction might have determined the effectiveness of the anti-smoking campaign, as supported by Borawska (Borawska et al., 2020). The second part of the analysis revealed the effect of PSA's five main parts in conveying the anti-smoking message. Although the effect of the smoking habit was not found in this case, we pointed out some parts of the PSA's efficiency with respect to some others. Specifically, the smoking symptoms' part produced the highest engagement on participants who probably were very involved in listening to the damage caused by smoking, as also suggested by the high level of SASI, however without finding any issue of comprehension as demonstrated by the low level of workload (Modica et al., 2018). The same was found for the claim part, suggesting that the anti-smoking message was more effective when it was written, compared to when the testimonial said the same message in the first part. The higher level of SASI for both the smoking symptoms and the claim parts demonstrated the effect of the PSA at the emotional level, inducing a negative mood on participants. It implied the success of the PSA in involving viewers in the conveyed anti-smoking message. Moreover, considering that the smoking habit did not show any significant effect between the PSA parts, we can assess that the message was universally valuable, reaching both smokers and non-smokers. For further analysis, it would be necessary to include very young people in the experiment, to demonstrate whether they respond in the same way at the PSA. In fact, that population needs to be mostly sensitized about the smoking danger. Furthermore, some questionnaires might be proposed to participants to demonstrate the possible link between what they declare and what the EEG indexes show.

5. Conclusions

Analyzing the EEG activity through three indicators, we characterized the participants' mental reaction while watching a specific anti-smoking PSA. The indicators showed a general sensitivity to the smoking habit, demonstrating a stronger effect on smokers than non-smokers. However, studying the five key segments of the campaign separately, we found that the anti-smoking message was effective among the entire population, independent of smoking. Thanks to this research, we objectively demonstrate the success of the anti-smoking PSA, as hypothesized by the reduction of cigarettes' purchases during the period in which it was broadcasted on national TV.

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