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An Eye Tracking index for the salience estimation in visual stimuli*

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Abstract— **Every day we face visual stimuli able to catch our attention, but this aspect becomes crucial if the visual material has the purpose to spread a message aimed at engaging the observer. In this framework, a worthy aspect is how to measure the "visual engagement" produced by visual stimuli exposure. To this purpose, in the present study, employing the eye tracking technique, an index of visual attention (VA) has been proposed, and applied to pictures belonging to antismoking public service announcements, so to investigate the saliency of health-promoting messages in a young sample. The VA index is a non-dimensional index, defined as the ratio between the percentage of the total time spent fixating an area of interest (AOI) weighted on the total time the picture is showed on the screen, and the percentage of the area occupied by the AOI weighted on the total dimension of the picture. It could be predicted that AOI reporting higher VA values will be the ones having more saliency. Three antismoking Public Service Announcements (PSAs) images have been selected for the study and for each of them were identified: i) "picture" (such as a young man with a sarcastic expression depicted while smoking a cigarette, or the image of a lady who underwent a tracheotomy) and ii) "writing" (text of the antismoking message) AOIs. Main results of the analysis revealed that writing AOIs obtained statistically significant higher VA values than visual AOIs (p=0.03), but these held true only for an ineffective PSA, probably because the text was not perceived as pertinent with the surrounding image. On the other hand, an effective PSA obtained higher VA values in response to visual than writing AOIs observation (p=0.02). The VA index appears therefore to represent a useful tool to measure the saliency of visual stimuli elements.**

I. INTRODUCTION

We are constantly exposed to visual information able or not to draw our attention and to be stored in our memory. Our reaction towards these stimuli and these cognitive processes become extremely worthy in the case of health-promoting messages.

Eye tracking is a direct measure of attention, which is a substantial precursor to information processing, recall, memory and other decisive features in regulatory science [1,2]. The use of this technology in tobacco control research complements existing methods in tobacco regulatory and communication science; it also can be used to examine the effects of health warnings and other tobacco product communications on consumer behavior in experimental settings prior to the implementation of novel health communication policies [2]. Although the processing of information in health-warning messages is complex, to be effective, a critical first step is to catch attention so that observers can understand, recall, and use the information for health decision making [3]. In this framework, the saliency of advertisements appears to be a feature needing deeper investigation. Previous research showed how the saliency of anti-smoking warnings didn't provide consistent patterns in relation to quit attempts and quitting success, although cognitive responses (thoughts of harm and of quitting) towards the same warnings resulted to be predictive of quit attempts [4]. To this extent, it is important to stress that traditional methods employed to investigate efficacy of advertisings (and also the saliency) are often based on behavioral scores (e.g. in the case of the just mentioned study, participants were asked how often over the preceding month respondents had noticed the warnings, and read or looked closely at them). In fact, nowadays, evidences concerning the effectiveness of tobacco regulatory and communication strategies, such as plain packaging, warning labels, and anti-tobacco advertising, are derived from traditional techniques (e.g. surveys and focus group research) [5,6]. Though such study designs are informative, this way measured attention and cognitive processing, for instance by post hoc recall, are susceptible to bias [7]. In order to overcome this kind of bias, neuroscientific techniques like EEG have been already applied to the study of the effectiveness of antismoking PSAs [8]. Among other neuroscience methods, eye tracking appears particularly suitable to address the afore-mentioned obstacles, since can be used as a mean to identify which specific elements of visual information increase effectiveness (or ineffectiveness) in conveying health information [9]. To support this statement about the potentiality and usefulness of eye tracking application, there is a pioneering study by Fischer and colleagues [10] using eye tracking on printed tobacco advertisement, a sample of adolescents showed that less than 10% of the total advertisement viewing time was spent on the warning, and in 44% of the cases participants did not look at the warning at all. In another study on adolescents, Krugman and colleagues showed the influence of the novelty in terms of font and colors manipulation on the percentages of fixation [11]. A further study manipulating also graphic warning rather than only text ones, highlighted that higher fixations occurred on graphic warnings compared to text warnings [12]. In addition, the study of saliency by eye tracking has been also specifically attempted, for instance comparing the

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position of the virtual fixations with the position of the actual fixations in a picture [13].

Objective of the present study is to apply a quantitative approach through the eye tracking technique, able to measure the visual attention towards PSAs' elements, disentangling the saliency from the size of the elements of the PSAs themselves.

II. METHODS

A. Participants

21 healthy subjects (aged 16 – 19 years old) have been enrolled on a voluntary base. Informed consent was obtained by all participants after the explanation of the study. In the case of minors, a parent signed the informed consent. Concerning the smoking habits 7 were not smokers, 9 light smokers (≤ 5 cigarettes/day) and 6 heavy smokers (> 5 cigarettes/day). The experiment was performed in accord to the principles outlined in the Declaration of Helsinki of 1975, as revised in 2000, and it was approved by the University ethical committee. The participants were sitting on a comfortable chair in front of a computer screen and no particular task has been assigned to them, just to watch the stimuli limiting movements and to stay as much relaxed as possible.

B. Stimuli

Three images belonging to three different anti-smoking campaigns advertised the last fifteen years have been selected for the study. The campaigns have been classified as "Effective" and "Ineffective" on the basis of data of health/economic improvements promoted, estimated through independent key performance indicators [14,15]. In addition a third PSA was classified as "Awarded", on the basis of the amount of prizes received by specialized committees. The selected images were:

- Effective (Centers for Disease Control and Prevention, CDC - USA, 2012-2015) (Fig. 1 - left)
- Ineffective ("Feel free to say no" - European Commission, 2003) (Fig. 1 - center)
- Awarded ("Quit the Denial by BBDO Toronto" – Canada, 2013) (Fig. 1 - right)

In each image have been identified "graphical" (such as the picture of a young man with a sarcastic expression, depicted while smoking a cigarette; or the image of a lady who underwent a tracheotomy) and ii) "text" (text of the claim or the antismoking message) AOIs. a series of 10 antismoking PSAs was played. The three target images were interspersed into a train of stimuli in a randomized order. Immediately before and after the PSAs train were placed 8 neutral images taken from IAPS database [16]. All the stimuli were presented for 9 seconds each on a 19'' flat screen with a distance from the subject varying from 50 to 60 cm. Between each pair of stimuli a black cross on a white field was shown, so to re-establish a central fixation point.

Figure 1. Effective (left), Ineffective (center) and Awarded (right) antismoking PSAs images.

C. Eye-Tracker

Eye-tracking data have been acquired by a remote eye-tracker (Eye Tribe) with a sampling frequency of 30 Hz, in order to identify eye fixations on the proposed stimuli. In the first place, all the point of gaze that were artifactual or not physiological have been removed. Then all the points belonging to eye movements (such as saccades or smooth pursuit) were removed by an I-DT (Dispersion-Threshold Identification) algorithm [17], that uses two thresholds, a temporal one, set at 100 ms, and a spatial one, set at 60 pixels (for the identification of a fixation point on a picture [18]). Then, eye tracking data were analyzed through a software for the extraction of information about fixations in each area of interest (AOI), such as number of fixations and total time of fixation spent on each AOI.

Each AOI (graphical and text) has been measured in relation to the size of the entire image in order to weight the time of fixation spent on the AOI, since, evidences show that the size of a visual target influence the amount of time spent on it [19]. In this way, an index of Visual Attention (VA) has been defined as follows (1):

$$VA = \%TFD / \%AREA \quad (1)$$

Where %TFD (Total Fixation Duration) is the total time spent fixating an AOI weighted on the total time the image is shown on the screen, and %AREA is the area of the AOI weighted on the total dimension of the image. This formula allows therefore the obtainment of a non-dimensional index that can be employed to compare different AOIs. It can be predicted that elements gaining higher VA values will have more saliency. In addition, since the essence of a scene is acquired very quickly (about 100 ms) in the first fixations [20], therefore it is reliable to hypothesize that elements characterized by higher VA values will elicit more interest in the subject with a top-down mechanism.

D. Statistical analysis

Repeated measures ANOVA analysis has been performed taking into account the variable CATEGORY which has three levels ("Effective", "Ineffective" and "Awarded"), related to the type of PSA, and the variable ELEMENT with two levels ("Graphical" and "Text"), related on how the picture is composed. Duncan post hoc test has been performed on statistically significant effect resulted from the ANOVA analysis.

III. RESULTS

The interaction of the CATEGORY x ELEMENT (Fig. 2) was statistically significant ($F = 30.02$ $p < 0.01$). Concerning the Effective PSA, Duncan's post hoc test reported a statistically significant VA increase for the graphical elements in comparison to the text ($p = 0.02$); the VA values obtained by the texts of the Ineffective PSA were statistically higher than the ones of all the investigated elements ($p < 0.01$); and the visual elements of the Awarded

PSA captured more VA than the texts of the Effective PSA (p = 0.03).

The variable ELEMENT (Fig. 3) showed a statistically significant effect (F = 4.94 p = 0.03) with the text elements reporting higher VA values than the graphical ones.

The variable CATEGORY (Fig. 4) obtained a statistically significant effect (F = 10.22 p < 0.01). Duncan's post hoc test revealed that the Ineffective PSA captured increased VA values than the other PSAs (p < 0.01).

IV. DISCUSSION

The analysis performed showed that in general the text elements of the antismoking PSAs gained more VA than the graphical elements (Fig. 3), in accord to Rayner and colleagues [21], who showed how people tend to look more and for a longer time at texts in comparison to images. This phenomenon appears to occur particularly when observers aim at gaining information on what is promoted by the advertising [22], promotion of tobacco quitting or discouraging from starting smoking in the present case.

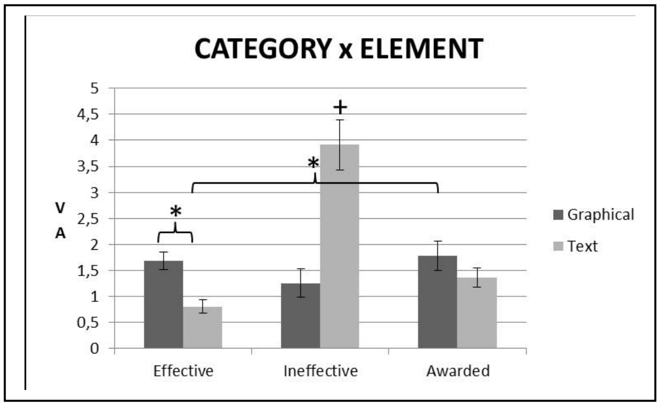

Figure 2. ANOVA results of the interaction CATEGORY x ELEMENT. Standard error reported as bars on the histograms. * symbol denotes a significance at p < 0.05 level; + symbol denotes the mean value statistically different from all the other means with all level of significance p < 0.01.

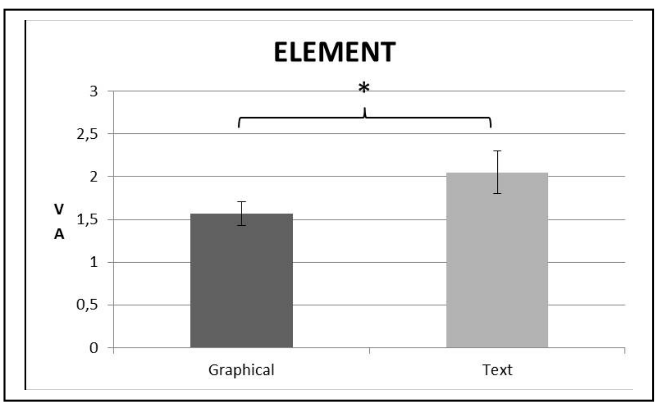

Figure 3. ANOVA results for the variable ELEMENT. Standard error reported as bars on the histograms. * symbol denotes a significance at the p < 0.05 level.

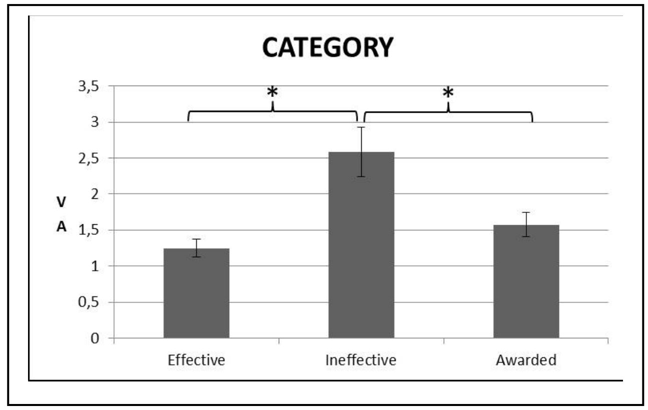

Figure 4. ANOVA results for the variable CATEGORY. Standard error reported as bars on the histograms. * symbol denotes a significance at the p < 0.01 level..

Nevertheless, looking at the interaction of the variables taken into account (Fig. 2), it can be observed that only in the case of the Ineffective PSA this assumption holds true, because in the Awarded and in the Effective PSAs the elements that gained lower VA values were the writings (reporting a significant difference in the Effective PSA case). In fact, a possible explanation is that in the Ineffective PSA the graphical elements didn't give a clue about the purpose of the campaign, because only faces of young teenagers were depicted, so the observer is forced to seek information about the PSA by the writings flanking the pictures. The inability to obtain in a quick way information from the Ineffective PSA is reflected also by Figure 4, where it can be inferred that subjects spent more time on informative parts of the picture than in the other kinds of PSA. Probably even the writings present in the Ineffective PSA were very poor in conferring information about the purpose of the campaign and there was little or no correlation with the graphical elements next to the writings [23], this would lead observers to spend a lot of fixation time trying to understand the purpose or the message of the PSA [18].

While the conclusion that writings attract more VA in commercial advertisings can be referred to the Ineffective PSA, in the present study it can be suggested that in the case of the Effective PSA the main focus of the visual information was the graphical element of the image (Fig.2) (with similar trend in the Awarded one), in accordance with Harris and colleagues [24]. Actually, the graphical element in the Effective PSA was a very emotive element depicting a woman who underwent a tracheotomy as a consequence of smoking addiction. This element captured most of the focus of attention to the writing, that consequently received lower fixation time in relation to its dimension on the picture (in fact its VA value didn't reach 1, suggesting that for the percentage of the area considered, the AOI received a low percentage of fixations). Meanwhile the visual element in the Awarded PSA depicted a man, presenting a sarcastic expression on his face, caught in the act of smoking a cigarette, strictly related to the funny statements reported in the text of the PSA. Also in the Awarded PSA, the originality of the advertisement gained slightly higher VA in the graphical elements than in the text ones, in accord to Radach and colleagues [25], but the elements of the picture resulted to be well balanced, as suggested by the fact that both the kinds of elements gained a similar amount of VA.

V. Conclusion

The present study suggested the usefulness of the VA formula application to the study and comparison of different kinds of AOIs. In particular, the calculation performed showed how the visual attention was differently distributed depending on the type of PSA proposed. The presence of pictures with high emotional and informative impact appears to be a good way to ease the acquisition of information as showed for the Effective and Awarded PSAs. While when the message appears to be less clear (as for the Ineffective PSA), it is suggested that more fixating time is required to obtain information.

As future steps, it will be important to extend the application of the VA index to a larger set of stimuli and in a larger sample of participants, in order to verify present data. Furthermore, it will be interesting to apply this approach also to video PSAs, so to test the influence of the movement on the visual attention and emotion [26], with high resolution EEG technologies [27-29].

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