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# The Cognitive Processing of an Educational App with Electroencephalogram and "Eye Tracking"

## El procesamiento cognitivo en una app educativa con electroencefalograma y «Eye Tracking»

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### ABSTRACT

The use of apps in education is becoming more frequent. However, the mechanisms of attention and processing of their contents and their consequences in learning have not been sufficiently studied. The objective of this work is to analyze how information is processed and learned and how visual attention takes place. It also investigates the existence of gender differences. The responses to 15 images are analyzed using "Eye Tracking" and EEG in a sample of 22 young students. The recall and liking of the stimuli is also analyzed. The characteristics of the images are evaluated by experts. The results indicate that there is a different pattern of visual activity between men and women which does not affect subsequent recall. The recall is determined by the emotional value of the image and its simplicity: more complex images demand more time of visual fixation but are less remembered. EEG responses confirm the importance of the playful component of the memory and low involvement processing. The conclusion is that the behavior against an app of this type resembles the low commitment behavior of advertising itself. Finally, some considerations for the app content design are proposed.

### RESUMEN

El empleo de apps en educación es cada vez más frecuente. Sin embargo, no se han estudiado suficientemente los mecanismos de atención y procesamiento de sus contenidos y sus consecuencias en el aprendizaje. El objetivo de este trabajo es analizar cómo se procesa y aprende la información y qué tipo de atención visual se le presta. También se investiga la posible existencia de diferencias de género. Sobre un total de 22 jóvenes se analizan las respuestas de «Eye Tracking» y electroencefalograma (EEG) frente a 15 estímulos de una app de educación en salud. También se analiza el recuerdo y agrado de los estímulos por parte de los sujetos. Las características de las imágenes son evaluadas por expertos. Los resultados indican que existe un patrón de actividad visual diferente entre hombres y mujeres el cual no incide sobre el recuerdo posterior. El recuerdo viene determinado por el valor emocional de la imagen y su simplicidad: las imágenes más complejas absorben más tiempo de fijación visual pero son recordadas menos. Las respuestas del EEG confirman la importancia del aspecto lúdico sobre el recuerdo. La conclusión es que la conducta frente a una app de este tipo se asemeja a la conducta de bajo compromiso propio de la publicidad.

### KEYWORDS | PALABRAS CLAVE

Neuromarketing, neurocommunication, health communication, app, gamification, eye tracking, attention.
Neuromarketing, neurocomunicación, comunicación y salud, app, gamificación, eye tracking, atención.

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## 1. Introduction and state of the art

The aim of this study is to analyse how cognitive processing is produced when using an educational application. The objective is to conduct this analysis using the recent techniques provided by Neuromarketing, more specifically, EEG (electroencephalogram) and Eye Tracking. In this way, the research work will try to set the basis of the new area of neurocommunication, an area that although stemming from Neuromarketing, possesses its own characteristics and objectives. The application of neuroscience to communication studies has very recent origins (Timoteo, 2007). It stems from the evolution produced within the field of neurology, especially in the branch applied to behavioural neurology, which seeks to explain the relationship that exists between neurological processes and their behavioural manifestation. Although it is often forgotten, the origins of this model come from Russian psychophysiology with the works by Pavlov on "conditioned reflexes", where the neuroanatomical and functional basis that would later be used to connect the brain and the behavioural processes, volitional as well as automatic or preconscious, were established. Posteriorly, other Russian authors delved deeper into the discovery of the functional basis of the brain, providing then the basis of the future field of neuroscience. Vygotski's disciple, the neurologist Alexander Luria is notable as well. He authored "The Working Brain" (1973), and "The human brain and psychological processes" (1966). At present, neuroscience is a discipline that incorporates different sciences that together share the objective of studying, from a multi-disciplinary perspective, the structure and the functional organization of the Nervous System, particularly, the brain.

It is from neuroscience and its posterior applications that neuroscience of the consumer and Neuromarketing were born. Disciplines that combine psychology, neuroscience and economy to study how advertising and marketing campaigns affect the minds of potential consumers (Lee, Broderick, & Chamberlain, 2007; Madan, 2010). The term "Neuromarketing" was coined for the first time in the 1980's by Ale Schmidts, Nobel prize winner and professor at the Department of Marketing at the Rotterdam School of Management in The Netherlands (Ramsoy, 2015). Human behaviours are marked by operational processes that are shaped under the threshold of consciousness (Calvert & Brammer, 2012), so that delving into the unconscious plane to understand what brings the consumers to activate a behavioural process is vital for the making of decisions. It is evident that the brain's activity can provide information that is otherwise not able to be obtained through traditional methods of research such as "focus groups", questionnaires or interviews (Ariely & Berns, 2010). A research methodology should be made available that allows for the reaching of these objectives and the understanding of the human cognitive system. Therefore, the direct reaching into the human brain is necessary (Le-Doux 1996; Zaltman, 2003). The use of methodologies that simultaneously combine the techniques of "Eye Tracking" with EEG could be relevant for obtaining information outside of the range of capacities of conventional methodologies. The biometric technique "Eye Tracking", or monitoring of eye movement, allows for the analysis of patterns of visual attention in terms of visual fixation, as eye movement is linearly identified with visual attention (Duchowski, 2013; Añaños-Carrasco, 2015) and offers results on the communicative impact with respect to the variables impact, appeal and effectiveness (Arbulú & del-Castillo, 2013). There is solid empirical evidence that shows the relationship between the stimuli shown and the brain reactions measured with an EEG (Ohmea & al., 2009). All of this allows us to think that these methodologies, which are usually employed in the field of Neuromarketing, could be very useful for the study of communication foundations, thereby constituting the new field of "neurocommunication".

Also, the ICT (Information and Communication Technologies) are defining a new way to communicate, in which the digital audiences demand interactive content that can be adapted to a new pattern of media consumption, in which the "smartphone" and "tablets" occupy a dominant place. These digital natives demand content that connects their information needs, but also their leisure, social and educational needs as well. In this scenario, it is easy to understand the rapid rise of the applications (apps). According to the "5th report on the apps in Spain", presented in 2014 by "The App Date", there are 23 million active app users, 3.8 million apps are downloaded per day, and there is an average of 39 apps installed per "smartphone" (Niño & Fernández, 2015). One of the sectors that has quickly progressed is the sector of health apps. This new field of activity is identified by the concepts "eHealth" and "mHealth", which is an answer to medical practice and public health through mobile devices. The apps used in this field are tools that allow for the fomenting and development of care and prevention of health, and their use in education is becoming ever more frequent. However, until now, the mechanisms of attention and processing of the app's images and content, as well the manner in which these processes influence learning have not been sufficiently studied.

The main objective of this study consisted in analysing a few of the cognitive elements (such as attention and recall) that lie underneath the cognitive process of communication. More specifically, it focuses on the study of these

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mechanisms just as they are produced during the processing of content (images and texts) that are habitually used in specific apps, since, in spite of their increased use (especially among the young), their mechanisms of action have hardly been experimentally studied. In this research work, we have focused the study on the images from a health education app for the younger population: the application Viquiz. This application uses a game-oriented procedure, or "gamification", in the framework of the so-called "serious game", within the context of education entertainment ("edutainment"). We will try to analyse the processing of prototypical images and texts from these apps, employing objective research techniques: the EEG and "Eye Tracking", belonging to the area of neurocommunication. Additionally, we will explore the gender differences in this field, with the objective of understanding the possible existence of different patterns of visual and cognitive conduct.

As the secondary objective, we will try to contribute objective and empirical data that allow the academic community to move forward in the construction of the field of neurocommunication, recovering and adapting techniques and procedures belonging to Neuromarketing to the science of communication and education. There is a limited number of research works that, by applying the techniques of neuroscience and psychobiology, propose the study of cognitive processes of communication. In general, these types of works have focused on applying the result of the brain, visual, electrodermal, cardiac, etc. responses to the study of communication efficiency (advertising, almost always). Hence their origins are Neuromarketing. However, in this work, we present a different focus, in which the main objective is to understand the mechanisms that regulate the cognitive responses when subjects are faced with specific stimuli. Also, we are especially interested in developing this area in the fields of communication and education, more than in the fields of advertising and marketing. Likewise, within the context of the ICT, which are especially important for the young, and more specifically, within the education apps through "gamification", the use of neurocommunication techniques will allow us to objectively study specific gender differences as just discussed. There is empirical evidence that women, in general, pay more attention to health information than men, and also have more interest for the health ICT (Cuesta, 2016). However, objective measurements of visual attention or differences in EEG have never been taken. In this context, the hypothesis of the research planned is the following:

> To achieve greater learning, it is necessary that the content incides in the leisure aspect of the activity, avoiding complex content, as it is not well remembered later even though it captures the attention of the subjects. Also, the data presented indicate the need to be prudent with the application of neurocommunication techniques to academic research. The data indicate that the fact that the subjects focus their vision on specific areas of interest does not imply that there is a greater active attention that results in better recall.

• Hypothesis 1: Women will score higher in the indexes of attention, appeal and recall. On the other hand, taking into account the existing works on attention and perception (Goldstein, 2005; Pinillos, 1975), which suggest that complex images require more time for extracting their meaning ("prise of signification"), we hypothesise that:

• Hypothesis 2: The more complex images will require more time for analysis, which will translate into longer times of observation of the image (ocular fixation time in milliseconds, ms).

Lastly, as we are dealing with a leisure activity belonging to "edutainment", the subjects will find themselves in a situation of "low cognitive involvement", which will induce peripheral processing of information (Petty & Cacioppo, 1983; Cuesta, 2006). Peripheral processing is characterised for extracting meaning through simple processing routes, through "heuristics". Therefore, we hypothesise that:

• Hypothesis 3: Recall will not be linked to the complexity of the stimulus, but to its ability to "appeal", meaning more linked temotional than rational attraction.

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## 2. Materials and methods

Images from the Viquiz app were used as the stimuli. Viquiz is a mobile application for fomenting healthy habits through gaming or gamification, developed by Wake App Health, and has counted with the financial support of the FECYT, the Spanish Foundation for Science and Technology from the Ministry of Economy and Competitiveness. It is available in Google Play for Android devices. It can be downloaded for free through the following link: http://bit.ly/1sX1db1. For the selection of images, the following criteria were used: "All the images on the homescreen or the ones from the start screen from each different section of the game".

A total of 15 images that allowed for studying the interest created by each screen were chosen, allowing for a comparison between the different types of images. Among these 15 images, the first one of them is the homescreen image (image "entry"), and has the advantage of offering, within the same image, different "areas of interest", that are very suitable for being studied through the use of the "Eye Tracking" technology. There is a total of 9 "areas of interest" (entry 1, entry 2, entry 3…). The homescreen image, along with its 9 areas of interest (AI) are shown in figure 1, which also shows the average values obtained with the "Eye Tracking" technology.

The entry images were classified by 2 judges who were experts on "edutaiment" apps, with the aim of classifying them as a function of 2 variables:

• Variable "complexity of the image", using a Likert scale from 0 to 7, with 0=not complex, and 7=very complex, as a function of semionarrative interpretation complexity. It was conducted with the usual "interjudge agreement" (Dubé, 2008). The agreement's Cronbach's coefficient was 100%.

• Variable "type of image", with dichotomic values that depended on the predominance, within the image, of an emotive figure or text, with values being 1=emotive picture, 0=text.

As the measuring tool, the "Eye Tracker" model Tobii X60 (www.tobii.com) was used. For the filtering of data and clean-up of noise, the software program used by Fusión Comunicación based on the methodology and software by SMIVision (www.smivision.com) was utilized. For a review on the use and analysis of data with "Eye Tracking" and the state of the art, please consult the work by Blascheck, Kurzhals, Raschke, Burch, Weiskopf and Ertl (2014). After performing an initial calibration for each subject, a minimum of 95% of the visual recordings were attained. For EEG monitoring, the unit "Emotiv EPOC" was used. This is a high-resolution unit for the monitoring and processing of the neuronal electrical signal that monitors 14 EEG channels. The electrodes were distributed in the positions labelled in Figure 2, according to the "International system of electrode placement" guidelines (Cacioppo, Tassinary & Berntson, 2000). The signals from the prefrontal, frontal, temporal, parietal and occipital regions were recorded. The EEG signal was monitored and recorded continuously during the viewing of the images on the screen.

The study was divided into two different phases as far the procedures.

In Phase 1, the EEG and "Eye Tracking" were monitored on 22 subjects, 11 men and 11 women, who were students at the Faculty of Information Science in Madrid (aged 19-21 years old). This specific sample was used as the app analyzed was designed for

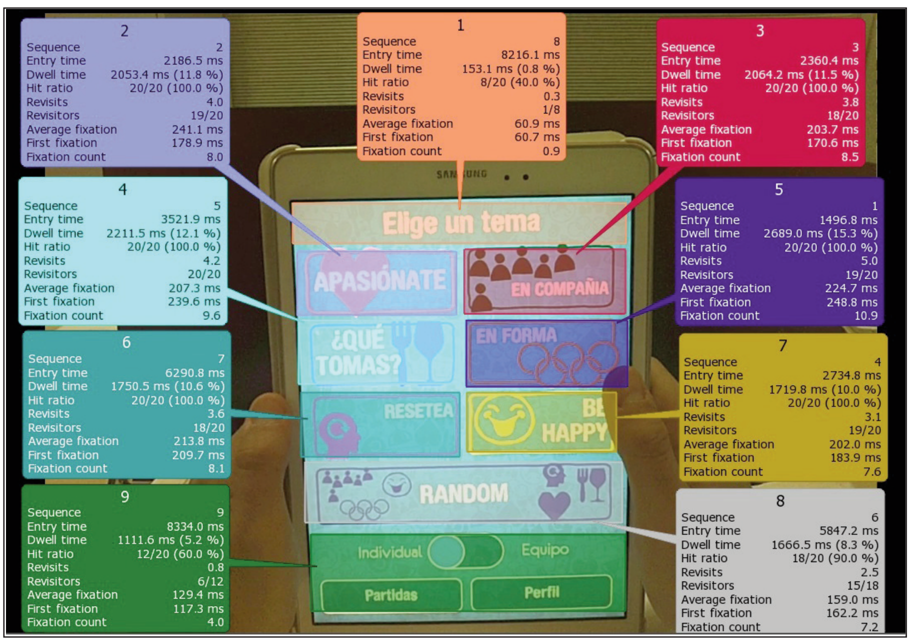


Figure 1. "entry" image where the 9 AI and the global "Eye Tracking" values are shown.

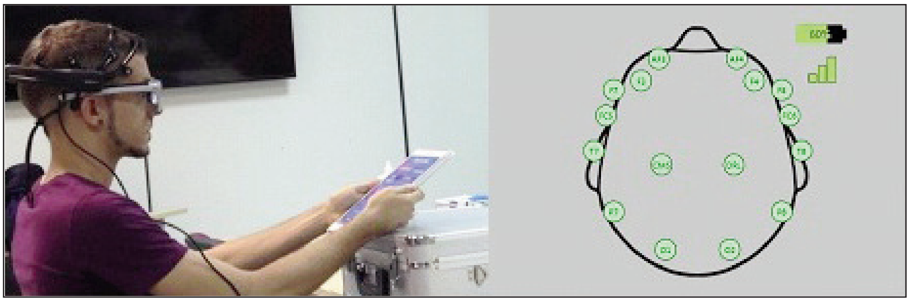

Figure 2. Simultaneous monitoring of the EEG and "Eye Tracking", and the position of the EEG sensors.

a young target audience with a mid-to-high socio-cultural status. All the subjects took part in he study voluntarily, without receiving additional university credits. They were briefly informed individually about the activity to perform, explaining to them that it would consist on viewing images from a health app that suggests a competitive game, but that they would not be competing. They would only view the screens. As the selection criteria, their lack of previous knowledge about the app was the deciding factor. All the subjects were subjected to the same experimental setting, and would view the same previously-mentioned stimuli while they were monitored. Therefore, an exploratory study with an intra-subject design and with the random assignment of the different levels of experimental treatment (sequences of images), is conducted. The stimuli were presented randomly, and the display of each of them was randomly rotated as well. When the monitoring was finalized, all the subjects completed a questionnaire in which they were asked about the sections or images that were most interesting to them (open-ended question), with the aim of measuring the "salience" of the images in order to detect the ones that had special impact.

During phase II of the study, the subjects were presented with a recall questionnaire a week after Phase I. This time interval is sufficient for producing a "forgetting curve" that allows for discriminating recall (Cuesta, 2006), although a few authors have proposed 3 weeks (Allende, 2010). This questionnaire evaluated two variables: a) Recall: the subjects describe the images they remember (the % recall is calculated); b) Appeal: the subjects have to score, the image's appeal, using a scale of 0 to 10 ("liking" scale).

The dependent variables were the following:

1) Degree of attention paid to the images, evaluated from the "Eye Tracking" data, measured with two of the most-utilized parameters in this type of research studies (Añaños, 2015): a) Duration of ocular fixation (in ms); b) Number of ocular fixations.

2) Cognitive activity provoked by the images according to the EEG: a) Attention: divided into short-term (instant) and long-term (minutes); b) Degree of involvement: concentration with the content of the image. Implication: the degree of cognitive re-enforcement dedicated to the image; c) Appeal: level of positive emotion that the image provokes; d) Recall and appeal of the images seven days after their viewing.

As for the independent variables, the following were used: a) The images described; b) Gender (man, woman); c) The image characteristics according to the evaluation by the experts: Complexity of the image (Likert scale 0-7) and Type of image (1=emotive, 2=text).

## 3. Analysis and results

As shown in the heatmaps in Figure 3, the ocular fixations were concentrated in the points of greater interest for the subjects. The analysis of these ocular fixation targets comprise an objective measurement of the areas of perceptual interest of the subjects. However, the empirical evidence available is not consistent with respect to what exactly the attention given to the stimulus indicates (Ohme, Reykowska, Wiener, & Choromanska, 2009). The heatmaps are very useful when developed in the field of applied Neuromarketing, where it is used for detecting global areas of interest of the consumer. For example, to detect fixation points in a product line in a large surface area shop. However, this information is qualitative in nature, and does not allow for the empirical analysis of cognitive processes (attention, activation, recall, etc.) that underlie this behaviour.

To quantitatively analyse this cognitive-perceptual behaviour, areas of interest (AI) were defined through "Eye Tracking", as defined in the methods section and shown in Figure 1. The recording of the ocular behaviour (average time of fixation and number of ocular fixations) and the EEG recordings were simultaneously conducted for these AI. The quantitative data obtained for both cases, together with the data obtained by the questionnaires, were processed with the IBM SPSS Statistics 22 software program. The results of "Eye Tracking", did not support hypot-

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hesis 1 (Women will score higher in the indexes of attention, appeal and recall). Table 1 shows results that were contrary to what was expected: women had an ocular behaviour that was characterized by a greater number of fixations (2,056 as compared to the 1,720 in men), which implied a greater frequency of fixations per second (2.34 versus 1.96 in men), as well as faster fixations (386 ms as compared to 459). This means that the ocular behaviour of women showed a faster pattern of movements. This movement was more visually "saccadic" than that of men. Saccadic movements are the fast and intermittent jumps of the eye's position when fixing onto a foveal object.


Figure 3. "Heat map" of the "entry" stimulus..

It is very likely that these results are due to the ocular behaviour pattern of women, which is independent of the type of task they are facing. Although visual conduct has barely been studied from the point of view of differences in gender according to optical psychophysiology, there is some evidence that suggests the presence of a different behaviour between men and women in this field (Stemmler, 2005). The EEG results (Table 2) show that women scored higher in the "appeal" variable with respect to the men, without showing differences in the rest of the EEG variables: attention (short and long-term), degree of involvement and implication ($p<.055$). However, this result was only found in the image that showed a spontaneous recall of 100% in the final questionnaire ("salience" questionnaire, or impact of stimulation), while the average value for spontaneous recall for all the images was 37%, which allowed us to suppose that the image had a special impact on the subjects, given its high score as compared to the average recall value, and given that it was the only one that was recalled 100% (image 14 of the heading "sexual conduct", showed a condom). This result could indicate that when faced with an image of high impact (high ability of impact, in terms of Neuromarketing or advertising) the EEG shows higher values with the variable appeal, especially among the women group. Table 2 shows the results found through an ANOVA, which was performed for the 5 EEG dependent variables (short and long-term attention, appeal, involvement and implication).

A new Analysis of Variance conducted after the EEG of this high-impact image (image 4-14) as compared to a medium-impact image (image 7-17), showed the following pattern: the EEG variables involvement, attention (ST and LT) and implication had higher values ($p<.000$) as compared to the variable appeal with respect to the medium-impact image, while the pattern is inverted for the high-impact image. These data suggests the existence of a possible EEG response pattern in this type of experimental design, leading us to conduct an analysis of the factorial structure of the EEG responses to the entire set of stimuli presented. A principal component factor analysis with Varimax rotation was performed. The results are shown in Table 3.

The data show the appearance of 3 factors in the EEG responses:

• In the first factor, the variables "involvement" and "implication" are saturated. This could represent a factor of "cognitive effort", as both involvement and implication are variables that have been traditionally associated to the effort a subject is willing to make when processing information.

• In the second factor, both short-term and long-term "attention" variables are saturated. This represents the degree of "focusing or overall attention" paid by the subject.

• The third factor is saturated with the variable "appeal", which represents the appeal value of the stimulus for the subjects.

The EEG factor analysis seems to indicate that the cognitive activity in this type of game-based learning tasks through an app can be grouped into three areas: a) cognitive effort; b) attention; c) appeal. Both cognitive effort and appeal are not completely orthogonal, which allows for proposing the following idea: the EEG discriminates two cognitive activities between the subjects: one linked to effort and attention, and another linked to appeal. Hypothesis 2 (the most complex images will require more time for analysis,

**Table 1. Kruskal Wallis test (*p<.01)**

| Analysis of the ocular fixations and their duration as a function of gender | Men | Women |
|---|---|---|
| Nº total de fixations | 1.720 | 2056* |
| Frecuency of fixations per second | 1,96 | 2,34* |
| Total fixation time (ms) | 791.729 | 758.062* |
| Average duration of each fixation (ms) | 459 | 368* |

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which will translate into longer times of observation of the image) was analysed together with hypothesis 3 (recall will not be linked to the complexity of the stimulus, but to its ability to "appeal", meaning more emotional than rational attraction). Pearson's correlation was used for this, and it was conducted on all the variables included in the hypotheses: viewing time (fixation of the areas of interest in ms), recall and appeal (evaluated with a questionnaire) and emotiveness and complexity of the image (defined by external evaluators with interjudge agreement). The analysis was conducted on the 9 areas of interests (AI) of the "entry" image (home-screen). The results are shown in Table 4.

**Table 2. ANOVA of image "home screen 14"**

| Variables: EEG (ST and LT attention, Appeal, Involvement and Implication) and Gender (Men, Women) | | Sum of squares | Degrees of freedom | Quadratic mean | F | Sig. |
|---|---|---|---|---|---|---|
| I4_ATEN_LT | Between groups | 12.525 | 1 | 12.525 | 1.073 | .313 |
| | Intra groups | 233.453 | 20 | 11.673 | | |
| | Total | 245.978 | 21 | | | |
| I4_APPEAL | Between groups | 80.512 | 1 | 80.512 | 4.252 | .055 |
| | Intra groups | 321.925 | 17 | 18.937 | | |
| | Total | 402.437 | 18 | | | |
| I4_INVOLVE | Between groups | .495 | 1 | .495 | .155 | .698 |
| | Intra groups | 63.980 | 20 | 3.199 | | |
| | Total | 64.475 | 21 | | | |
| I4_ATEN_ST | Between groups | 28.865 | 1 | 28.865 | 2.064 | .166 |
| | Intra groups | 279.705 | 20 | 13.985 | | |
| | Total | 308.571 | 21 | | | |
| I4_IMPLICA | Between groups | .409 | 1 | .409 | ,571 | .459 |
| | Intra groups | 14.325 | 20 | .716 | | |
| | Total | 14.735 | 21 | | | |

The results indicate the following: a) a statistically-significant negative correlation ($p<.024$) between the variables recall and image complexity; b) a positive correlation between recall and emotiveness of the image ($p<.007$); c) a negative correlation between emotiveness and complexity ($p<.017$).

Therefore, hypothesis 2 is supported, but only marginally: there is a "tendency" towards the direction proposed by the hypothesis, but the degree of significance is marginal ($p<.070$). In summary: the most complex images require a longer ocular fixation time (marginally significant) but are less remembered, while the most emotive images are better remembered. This could be due to the "edutainment" or a leisure game effect: the condition of a leisure context provokes a state of "low involvement ", belonging to peripheral or weak processing. This could mean that the more complex images are not remembered because the subject does not make the necessary effort for its mnesic storage.

This could also fit with the EEG pattern found after the factor analysis: the images with greater impact (salience) provoked a greater appeal according to the EEG, which would link it to the greater recall of this situation of low involvement. Something similar occurred with hypothesis 3, which was only partially accepted: recall does seem to be linked to the image emotiveness ($p<.007$), but not to its "appeal" or impact (measured with the "liking" scale used by the subjects). However, this result could be consistent with the current bibliography on Neuromarketing (Ariely & Berns, 2010); it is very common for authors to say that the reasoning behind the use of psychophysical measuremens (such as the EEG) in motivation research related to advertising is due to the fact that sometimes the verbal responses of the subjects do not always co-incide with the emotions they truly feel (Khushaba & al., 2013).

## 4. Discussion and conclusions

The data seems to back the existence of a visual behaviour "model" that is different in women as compared to men: the visual behaviour of women in these types of tasks seems to be characterized by a more "saccadic" pattern as compared to the men. This means that they "travel" through the images faster than men, also blinking more times and faster than them. However, this pattern of visual behaviour does not result in greater learning (recall) of the stimulus, as statistically-significant differences were not found between men and women for the variable recall. Through the factorial analysis of the EEG, a pattern of responses of three factors was detected: appeal, attention and involvement. In this pattern, the variable recall was linked to the variable impact (saliency of the stimulus). However,

**Table 3. Factorial analysis of principal components**

| EEG Variables | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| INVOLVEMENT | .974 | .126 | .069 |
| ATTENTION_LT | .197 | .944 | .216 |
| ATTENTION_ST | .091 | .956 | .237 |
| APPEAL | .114 | .318 | .941 |
| IMPLICATION | .969 | .139 | .101 |

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the complexity of the stimulus would be more linked to attention and the degree of involvement with the stimulus according to the EEG pattern: it's possible that the more complex stimuli demand greater attention by the subjects, which obliges them to be more involved in their visual analysis. Nevertheless, the fact that they are more involved and dedicate more viewing time does not mean that they will remember it more due to the "low involvement" that entails peripheral processing (Petty & Cacioppo, 1983). In this type of processing, the stimuli that are easiest to perceive are more easily memorized, although according to the Elaboration Likelihood Model (ELM), learning is also weaker, and the stimuli are forgotten sooner (Petty & Cacciopo, 1981; Petty & Cacciopo, 1986). In the present research, only a week was used as the interval of forgetfulness, which does not allow for the analysis of the forgetting curve with respect to this last item.

**Table 4. Pearson's correlation between variables from hypotheses 2 and 3**

| Correlations | | Time | Recall | Visits | Appeal | Complexity | Emotiveness of the image |
|---|---|---|---|---|---|---|---|
| TIME | Pearson's correlation | 1 | -.744* | -.033 | -.491 | .775* | -.717 |
| | Sig. (2-tail) | | .090 | .951 | .323 | .070 | .108 |
| RECALL | Pearson's correlation | -.744* | 1 | -.227 | .313 | -.870** | .931*** |
| | Sig. (2- tail) | .090 | | .665 | .546 | .024 | .007 |
| APPEAL | Pearson's correlation | -.491 | .313 | -.638 | 1 | -.527 | .620 |
| | Sig. (2- tail) | .323 | .546 | .173 | | .283 | .189 |
| COMPLEXITY OF THE IMAGE | Pearson's correlation | .775* | -.870** | .232 | -.527 | 1 | -.892** |
| | Sig. (2- tail) | .070 | .024 | .659 | .283 | | .017 |
| EMOTIVENESS OF THE IMAGE | Pearson's correlation | -.717* | .931*** | -.472 | .620 | -.892** | 1 |
| | Sig. (2- tail) | .091 | .007 | .344 | .189 | .017 | |

** The correlation is significant to 0.10 (2-tail).
** The correlation is significant to 0.05 (2-tail).
*** The correlation is significant to 0.01 (2-tail).

In summary, the results of this research can be interpreted in the following manner: women have a different visual pattern than men (they are less "saccadic"), but this differential pattern does not affect the posterior recall of the stimuli viewed. The immediate recall (impact) seems to be linked to the emotional stimulus variable ($p<.007$) and non-complexity ($p<.024$), as the recall is negatively correlated with the complexity of the stimulus. In line with this idea, the data showed a correlation between the time dedicated to the stimulus and its complexity ($p<.070$) and a negative correlation between time and recall ($p<.090$). This means that dedicating more time for viewing more complex elements in order to extract meaning does not mean that they are better memorized, as memory depends on the emotiveness of the stimuli. Also in line with this result, the EEG showed that it was the pattern of brain waves classified as appeal (due to the factorial analysis), the ones that better predicted recall. This phenomenon is similar to what has been shown in the reception to advertising: the most efficient advertisement is the simplest one and the one that touches upon the affective/valorative aspect of the spectator (audience or target), not the most rational. In 1965, Krugman named this phenomenon "learning without involvement" when speaking about passive or low involvement audiences. Later, Krugman (1971; 1980) tried to validate his theory through the analysis of an EEG during the viewing of a TV ad, becoming the pionner of modern Neuromarketing techniques.

The data are sufficiently significant as to recommend the developers of this type of app that the design of their content should be emotive and low in complexity. To achieve greater learning, it is necessary that the content incides in the leisure aspect of the activity, avoiding complex content, as it is not well remembered later even though it captures the attention of the subjects. Also, the data presented indicate the need to be prudent with the application of neurocommunication techniques to academic research. The data indicate that the fact that the subjects focus their vision on specific areas of interest does not imply that there is a greater active attention that results in better recall. These results are in agreement with other research studies using "Eye Tracking" on the usability of 2.0 tools, in which it was verified that the measurements of attention through "Eye Tracking" and the self-informed recall differed between them (Hernández-Méndez, Muñoz-Leiva, Liébana-Cabanillas, Marchito, 2016).

In the famous "Eye-mind hypothesis" from Just and Carpenter (1976a; 1976b) it was specified that a noticeable delay was not produced between the object a person fixes his/her sight on and what is being processed, so that when a person looks at a word or an object, it is cognitively processed during exactly the same amount of time of ocular fixation. This hypothesis resulted in an important boost of "Eye Tracking" studies. Already some authors have postulated on the relationship between attention and ocular fixation, specifying that the direction of the stare was linked to the focus of attention, therefore providing a mechanism with which the information received by the organism could be filtered (Deutsch & Deutsch, 1963; Posner & Peterson, 1990; Treisman, 1964). However, this hypothesis has been frequently called into question, as modern research has systematically shown that the shifting of attention without ocular movement frequently occurs (Posner, 1980), and as soon as attention is directed to a new position, the eyes can conduct different types of fixations, which are not always linked to the stimulus that had originally capture the subject's attention (Hoffman, 1998).

The questions that arise are evident: what characteristics evoque the shifting of attention to specific stimuli?, what is the nature of the emotional and motivational processes that underlie visual attention?

The limitations of this study include the size of the sample as well as its composition. Another limitation has been the use of images that were specific to the Viquiz app. In future research, it will be necessary to increase the size of the sample in order to analyse the behaviour of adult and senior subjects. This will allow us to understand if the results found were dependent on learning or on basic cognitive principles. The young subjects (aged 19-21 years old) had a specific behaviour when facing gamification tasks using apps. It seems that these digital natives have developed specific patterns of behaviour within these audiovisual environments (Payne, 2014). It could also be, as shown by Añaños (2015), that the seniors do not modify their processes of attention, doing so with the processing of information, so that their conduct with these types of apps could be different. It would be necessary to widen the samples of stimuli to be used, within the realm of the "serious game" but widening the composition of the stimuli. The behavior in high/low involvement situations of the subjects should also be studied (manipulating the involvement through instructions, for example) and also increasing the interval of forgetfulness so that it is longer than a week.

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