ICONO 14, Revista de comunicación y tecnologías emergentes, 20(2), 2022. ISSN: 1697-8293
https://doi.org/10.7195/ri14.v20i2.1816

Monográficos

The effectiveness of environmental advertising: an analysis of advertising memory through neuroscience

La efectividad de la publicidad medioambiental: un análisis del recuerdo publicitario a través de la neurociencia

A eficácia da publicidade ambiental: uma análise da recolha de publicidade através da neurociência

Diego Gómez-Carmona[1]*
Pedro Pablo Marín Dueñas[1]**
Francisco Muñoz-Leiva[2]***
Francisco Liébana-Cabanillas[2]****

[1] Department of Marketing and Communication (Universidad de Cádiz), España
[2] Universidad de Granada, España

* Acting professor. Department of Marketing and Communication (Universidad de Cádiz), Spain
** Associate Professor PhD. Department of Marketing and Communication. (Universidad de Cádiz), Spain
*** Professor of the Department of Marketing and Market Research. (Universidad de Granada), Spain
**** Professor of the Department of Marketing and Market Research. (Universidad de Granada), Spain

Conflicts of Interest: The authors declare no conflict of interest.

Received: 23/12/2021; Revised: 19/02/2022; Accepted: 09/06/2022; Published: 12/09/2022

Translation to English: Proof-Reading-Service.com

To cite this article: Gómez-Carmona, Diego; Marín-Dueñas, Pedro Pablo; Muñoz-Leiva, Francisco; & Liébana-Cabanillas, Francisco. (2022). The effectiveness of environmental advertising: an analysis of advertising memory through neuroscience. *ICONO 14. Scientific Journal of Communication and Emerging Technologies, 20*(2). https://doi.org/10.7195/ri14.v20i2.1816

Abstract

One of the key variables when analyzing advertising effectiveness is message recall. An advertisement is not only effective if it captures the public's attention; it must also remain in the public's memory. Neuroscience can help in the study of effectiveness based on the analysis of memory. Some papers study the effect of environmental concern and its social relevance. This research seeks to understand the role of environmental concern on ad focus and the recall of positive ads while analyzing the brain areas that are active during information processing. To do this, an fMRI experiment was implemented using scanners and supported by questionnaires on the attitude of 50 people towards the messages they had viewed. Our analyses indicate that subjects with a higher concern for the environment remember negative advertisements (X#=3.1 images) to a greater extent. More specifically, the combination of self-report and neuroimaging techniques has confirmed the link between the memory of negative messages in environmentally concerned subjects and activity in regions that anticipate greater recall during message encodings, such as the amygdala (r=0.481; p<0.00) and prefrontal medial cortex (r=0.281; p<0.048).

Keywords: Advertising effectiveness; advertising memory; environmental issues; neuroscience; neuroimaging; neuromarketing

Resumen

Una de las variables clave a la hora de analizar la efectividad publicitaria es el recuerdo del mensaje. Un anuncio no es efectivo únicamente por captar la atención del público, sino que debe conseguir permanecer en la memoria de éste. Y de las muchas metodologías existentes, la neurociencia es la que más puede ayudar en el estudio de dicha efectividad a partir del análisis del recuerdo. Por otra parte, la preocupación medioambiental cada vez tiene una mayor relevancia social; por lo que esta investigación tratará de conocer el papel del enfoque del anuncio y la preocupación por el medio ambiente, al analizar el recuerdo provocado por los anuncios y determinar qué zonas cerebrales se activan. Para ello se implementó un experimento utilizando imágenes de resonancia magnética funcional (fMRI) y apoyado por cuestionarios sobre la actitud de 50 personas hacia los mensajes que habían visualizado. Nuestros análisis indican que los sujetos que tienen un mayor nivel de preocupación por el medio ambiente, recuerdan en mayor medida los anuncios negativos (X#=3,1). Más específicamente, la combinación de técnicas de autoinforme con técnicas de neuroimagen ha permitido confirmar la vinculación entre el recuerdo de mensajes negativos en sujetos preocupados por el medio, con la actividad en las regiones que anticipan un mayor recuerdo durante la codificación del mensaje, como son la amígdala (r=0,481; p<0,000) y el corteza media prefrontal (r=0,281; p<0,048).

Palabras clave: Efectividad publicitaria; Recuerdo publicitario; Preocupación medioambiental; Neurociencia; Neuroimagen; Neuromarketing

Resumo

Uma das variáveis-chave ao analisar a eficácia da publicidade é a recordação da mensagem. Uma publicidade não só é eficaz porque capta a atenção do público, como também deve conseguir permanecer na memória do público. E das muitas metodologias existentes, a neurociência é a que mais pode ajudar no estudo desta eficácia com base na análise da recordação. Por outro lado, as preocupações ambientais estão a tornar-se cada vez mais relevantes socialmente; por conseguinte, esta investigação tentará compreender o papel do foco da publicidade e a preocupação com o ambiente, analisando a memória provocada pela publicidade e determinando quais as áreas do cérebro que são activadas. Para tal, foi implementada uma experiência de fMRI utilizando scanners e apoiada por questionários sobre a atitude de 50 pessoas em relação às mensagens que tinham visto. As nossas análises indicam que os sujeitos que têm um maior nível de preocupação com o ambiente se lembram mais dos anúncios negativos (X#=3,1). Mais especificamente, a combinação de técnicas de auto-relatação e neuro-imagem confirmou a ligação entre a recordação de mensagens negativas em assuntos relacionados com o ambiente e a actividade em regiões que antecipam uma maior recordação durante a codificação de mensagens, tais como a amígdala e a CMPF.

Palavras-chave: Eficácia publicitária; Recordação publicitária; Preocupação ambiental; Neurociência; Neuroimagem; Neuromarketing

1. Introduction

Several authors have used measures of message recall in their research to analyze advertising effectiveness (Muñoz-Leiva et al., 2019). Previous literature has established that advertising effectiveness is not only achieved by capturing the audience's attention; it is also necessary for the marketing stimulus to remain in the short- or long-term memory (Barreto, 2013). To date, few investigations have analyzed the effect of the environmental message using neuroimaging; this study is the first to analyze the recall generated by advertisements with different valence in the viewer's mind.

As mentioned above, the scientific community has demonstrated that advertisements with emotional content manage to generate a more effective recall in the consumer's memory using studies based on self-report techniques (Putrevu, 2008). Among the research conducted to explain the successful encoding of information within emotional memory, variables such as individual differences (Haas & Canli, 2008) or the role of social relevance are analyzed. Other later works, such as that of Bakalash & Riemer (2013), partially analyzed the impact of emotion on memory, considering only the role of arousal and neglecting the influence of valence on memory encoding and consolidation.

Specifically, some research has tried to explain which type of valence generates greater recall in viewers' minds. For example, Bolls et al. (2001) conducted research that failed to demonstrate the effect that message valence generated on participants' recall. However, when analyzing anti-smoking public service announcements, Leshner & Cheng (2009) demonstrated that negative messages framed in a loss end state required more time to process and were remembered more than positive announcements with a gain end state. In this same line, different authors suggest that images showing negative stimuli generate greater recall than those presenting positive stimuli (Adelman & Estes, 2013).

Other research has shown that when the information is self-relevant, people who report having a positive mood remember more damaging information. For example, when inducing a positive mood in subjects who report high caffeine consumption and showing them positive (vs negative) stimuli, subjects recall more negative than positive data about caffeine consumption (Raghunathan & Trope, 2002). However, inducing a positive mood state in subjects who report low caffeine intake does not enhance the recall of negative information. Although it is unclear whether this effect is mediated solely by motivation, the authors suggest that mood may explain the inconsistent recall of people experiencing positive affect.

The neuroscientific literature has shed light on the encoding of positive events concerning negative and neutral stimuli, affirming that greater activity is generated in the parietal and fronto-parieto-cingulate areas, leading to better subsequent memory (Mickley & Kensinger, 2008). In addition to these regions, research dedicated to the study of emotion and memory, in line with works using self-reporting, indicate that a highly emotionally arousing stimulus improves recall, because it activates specific neural mechanisms, such as the amygdala (Gutchess & Kensinger, 2018). That is, when the advertisement possesses high levels of arousal and elicits high arousal in the viewer, interaction between the amygdala and the medial temporal lobe (MTL) will enhance the recall elicited by the stimulus (Bakalash & Riemer, 2013). The literature predicts arousal processing with activity between the amygdala and the MTL. Neither region interacts in isolation, but they interact with other brain regions, namely the prefrontal cortex (PFC), whose involvement also appears to be susceptible to valence-related effects; their interactions are important for encoding negative and positive items (Dolcos et al., 2012).

The work of Ritchey et al. (2008) analyzed brain activity in participants at three different times: 1) while encoding negative and neutral images, 2) twenty minutes after encoding and 3) one week after encoding the images. These authors found a relationship between encoding after one week and activity between the amygdala and MTL, concluding that the interaction between the amygdala and MTL plays an important role in the consolidation and persistence of emotional memories over time. Subsequent research by Ritchey et al. (2011) finds this interaction between the amygdala and MTL to successfully memorize negative stimuli. In contrast, an interaction between the MTL and the PFC will be activated to a greater extent when encoding positive stimuli into memory.

On the other hand, environmental concern is becoming more and more socially relevant; this greater relevance goes beyond the two essential elements that make up the emotional dimensions (arousal and valence), including the processing and encoding of information, a complex relationship between social cognition and emotion in memory. In this sense, information about the progressive deterioration of the planet provokes appropriate social behaviors, including respect for the environment, learning social norms (cardboard to the blue garbage can, plastic to the yellow garbage can, organic waste to the green garbage can) and a distinction between "what is good and what is bad" in situations related to the environment around us (environmental protection) (Tsukiura & Cabeza, 2008). Therefore, the social dimension that the environmental problem is reaching seems to be a personal and relevant factor that can influence the development of emotional memory.

Considering that environmental information may have emotional meaning, it should influence memory through mechanisms similar to emotion. However, due to its complexity, it may also involve different regions or distinct brain processes. Consistent with the idea that environmental information, like the social dimension, needs more elaborate processing, the literature suggests that encoding in memory improves when sufficient cognitive resources are devoted to information processing (Sakaki et al., 2012). Previous work has found that while processing emotional stimuli increases activity in the amygdala and visual cortex, processing social stimuli requires more elaborate processing involving the amygdala and CMPF. Some neuroimaging studies have revealed the involvement of the amygdala and CMPF in complex social functions, such as gain or loss processing, revealing their link in emotional memory encoding and the subsequent retrieval of social information (Botzung et al., 2010; Tsukiura & Cabeza, 2008). Therefore, the amygdala's role in emotional memory goes beyond the encoding of emotional stimuli and is also involved in memorizing personal or socially relevant stimuli (Botzung et al., 2010), such as concern for the environment. Likewise, the amygdala has also been implicated in memorizing personal episodes (Northoff et al., 2009).

Our research will try to determine the role of the focus of the advertisement and the concern for the environment, by analyzing the recall provoked by different advertisements. For this purpose, and based on previous literature, we pose the following hypotheses and research questions:

H_1: There is an association between the activation of fronto-parieto-cingulate areas, PFCM, orbitofrontal cortex (OFC) and the recall generated by messages with positive valence and final gain state.
H_2: There is an association between the activation of the temporo-occipital region and the recall generated by messages with negative valence and final state of loss.
H_3: There is an association between amygdala activation and CMPF in subjects more concerned about the environment and the recall of affective stimuli (positive or negative).
C_1: Which message frame elicits the highest recall by level of concern?

2. Materials and Methods

2.1. fMRI experiment data collection

The recruitment of participants was based on quota sampling, trying to achieve a representation of the population under study. Participation was voluntary, with participants being compensated with 40 €. The final sample consisted of 25 men and 25 women (all in good health and all right-handed). In addition to gender, we took into account the average age of the consumer profile of organic products in Spain (43.38 years), so we selected half of the participants aged between 18-43 and the remaining fifty percent aged 43 years or older.

Table 1. *Technical data sheet of the study*

Population	*Spanish population of legal age*
Type of sampling	Non-probabilistic, by quotas
Type of survey	Manual questionnaire
Final sample size	50 adopters of renewable energy (RREE)
Sampling error	13.9%
Fieldwork period	April 2018 - May 2019

Source: Own elaboration

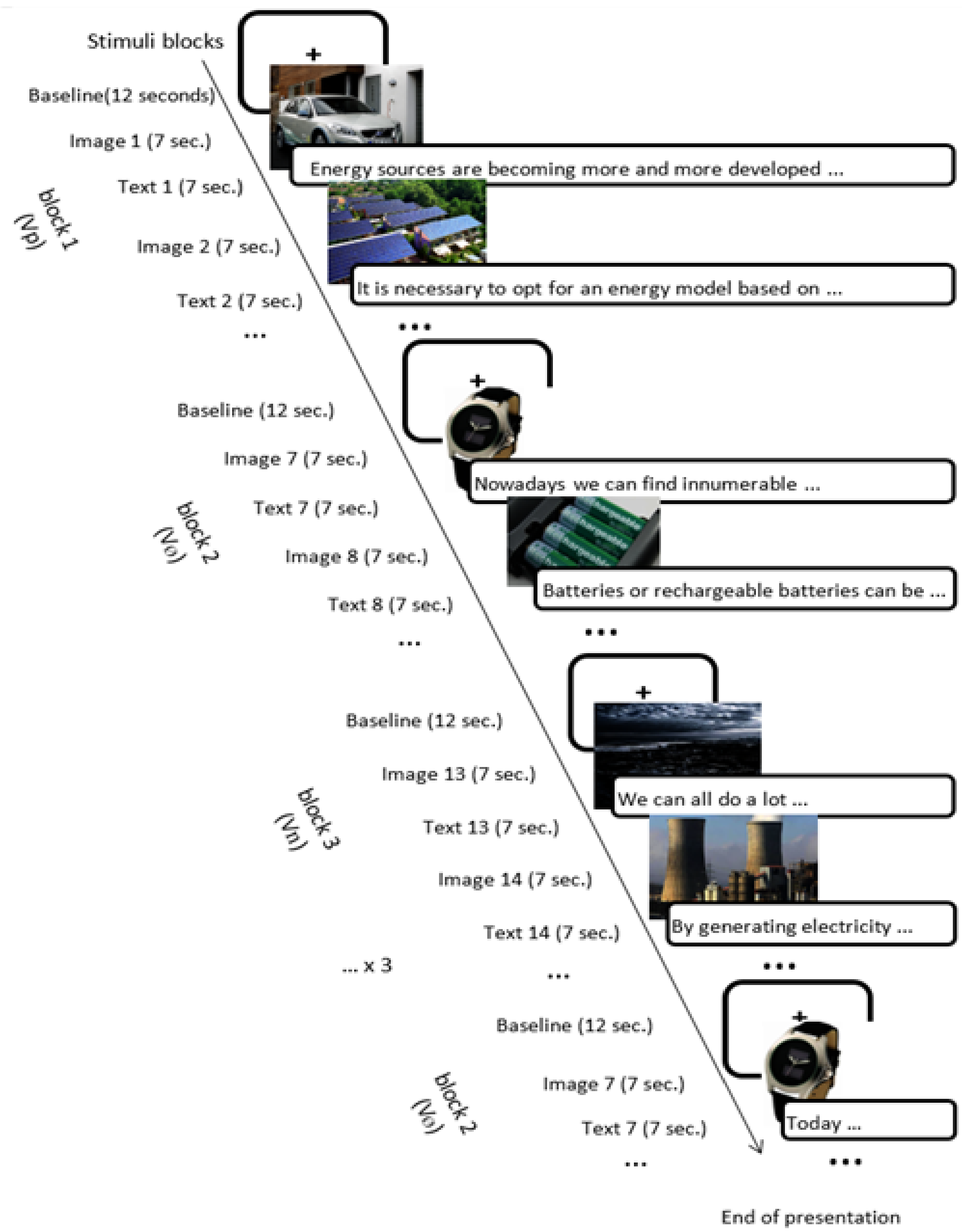
Participants came to the laboratory half an hour before the fMRI experiment. During this period, they were given an explanation of what the task consisted of and completed a questionnaire about their pro-environmental concerns and socioeconomic issues. Once the previous questions were finished, they completed the informed consent through a questionnaire, a document that complies with the protocol of the World Medical Association. They were then accompanied to the scanner and the fMRI scans were performed, acquiring structural and functional images. While the functional images were being acquired, participants within the scanner performed a passive visualization task, presenting them with different stimuli in the form of images and content about the environment in general and RDEs in particular (Figure 1). After completing the scans, the participants evaluated questionnaires on their attitude towards the messages they had visualized. Subsequently, they were sent a questionnaire with the images used in the messages and other similar images to record the memory generated.

2.2. Experimental design in fMRI testing

The experimental design aimed to isolate the effect of the emotion generated by the ecological messages using different valence and end states, also considering the level of concern of the participants. For this purpose, a 3x2 mixed design was developed based on an *a priori* manipulated within-subjects factor: positive valence and gain end state (Vp), neutral valence and neutral end state (VØ) and negative valence and loss end state (Vn), as well as a between-group factor, derived from the level of concern (high (Ap) and low concern (Bp)).

Each advertisement (Vp, VØ and Vn) consisted of six images and descriptions. This set of stimuli was presented by simulating how an individual might read an environmental message in favor of adopting EERR, alternating images and text.

Figure 1. Schematic drawing of the experimental design



Source: Own elaboration

During the scan, each participant viewed the three advertisements three times, alternating the order in which the advertisements were viewed (Vp/AØ/Vn; VØ/Vn/Vp; Vn/VØ/Vp). The repetition of the message helps to understand the message clearly and therefore increases the ability to process the arguments. It also causes the activation of neural networks and their consequent automation (Benavidez & Flores, 2019); this allows us to obtain more accurate and reliable images of brain activity (Rodriguez, 2015). The total duration of the experiment was 14.4 minutes.

2.3. Measuring scales

To measure the subject's level of environmental concern, the measurement scale previously used in the work of Dunlap et al. (2000) was adopted. While the majority of consumers are concerned about environmental issues, the level of concern varies among the population, with the majority of cases concentrated around the higher values. In addition, these groups with higher or lower environmental concerns will perceive the problem differently. This high and low concern may influence their responses to environmental advertising messages, suggesting that the general distribution of this construct is appropriate for use as a potential moderator of the hypothesized relationships. Reliability analysis from Cronbach's alpha internal consistency indicators showed a fairly high value (α = 94.9%). These high levels of reliability (α ≥0.90) allow summary variables to be obtained in the data analysis by averaging the items of the construct that captures the variability of the data. This decision will preside over the formation of two levels of concern (low and high).

After finishing the fMRI session, each participant moved to an adjoining room where they were shown three advertisements based on the composition of each block or type of stimulus (Vp, VØ and Vn), asking them their attitude toward thean advertisement (from Venkatraman et al., 2015). The Cronbach's alpha internal consistency indicators for each advertisement, measured by the semantic differential scale, also yielded values higher than α = 0.90.

One month after participating in the study, a questionnaire was sent out that collected the level of recall of each message in a suggestive manner. These data allowed triangulation of the results of fMRI recordings with the self-report data. In particular, a scale composed of two propositions on the study theme and the experiment and 36 images (including the 18 used in the study and 18 fictitious ones) was used.

2.4. Stimulus analysis and synchronization software

The experimental ad exposure was programmed with the help of the synchronization software E-Prime 2.0 (http://www.pstnet.com/, 2020). The fMRI data were analyzed using the statistical parametric mapping functions package (SPM) v12 (The Wellcome Centre for Human Neuroimaging, London) integrated into the numerical computation software Matlab 12.

For visualization and localization of the active regions in each contrast applied to the functional images, we used the image visualization tool Xjview. To delimit the regions of interest (ROI), we used the MarsBar tool. Finally, the statistical analyses applied to the data coming from SPM were performed using the IBM SPSS statistical package version 23.

2.5. Acquisition and preprocessing of anatomical and functional images

Brain scanning during the visualization task was performed using a Siemens Trio 3T scanner equipped with a 32-channel head coil. Functional T2 scans used a planar echo imaging sequence (TR= 3,000 ms; TE=35 ms, flip angle 90º and a planar reduction of 3 x 3 x 3 x3 mm corresponding to the slice thickness). The distance factor was 25%, obtaining a total of 36 slices, a 64 x 64 mm matrix and a field of view of 192 mm with axial orientation. A total of 387 functional scans were acquired.

The data from the first functional image were realigned and the functional and structural images were subsequently co-registered. After this, the data were normalized (with 3 x 3 x 3 x 3 mm voxels) conforming to the space proposed by the Montreal Neurology Institute (MNI). Finally, the functional images were smoothed with a Gaussian Kernel (FWHM = 8 mm).

2.6. fMRI data modeling

The canonical hemodynamic response was modeled according to the following conditions: positive message x high concern (Vp x Ap), positive message x low concern (Vp x Bp), negative message x high concern (Vn x Ap), negative message x low concern (Vn x Bp). The fixation points included between ad blocks were treated as baseline. In the General Linear Model implemented by SPM 12, the subject's brain was considered as a rigid body, for which three rotation and three translation parameters had to be included in that model as noise covariates. The data obtained passed a high-pass filter of 128 s.

2.7. Analysis of variance and covariance

In order to obtain the regions linked to emotions, at this first level, the following contrasts were performed to analyze the *a priori* manipulated intrasubject factors combined with the intersubject ones:

Positive message (Vp x Ap + Vp x Bp) vs. negative message (Vn x Ap + Vn x Bp) and vice versa.

A two-sample t-test was performed during the comparisons above to examine significant between-group brain activation (Ap vs. Bp) at the second level. The significance level, in our case, was set at the threshold $p<0.001$ uncorrected, with a voxel group (k) >8.

To explore the brain regions where message-derived activation is linked to evaluations of attitudes toward the combinations of each message shown in the posttest, two-sample t-tests (Vp x Ap vs. Vp x Bp; Vn x Ap vs. Vn x Bp) were conducted and differences in attitude evaluations toward each message (Ap-An) were considered as covariates.

2.8. Self-report recall analysis

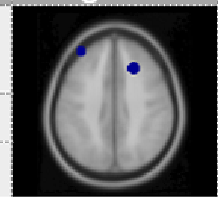
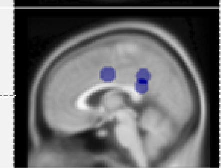
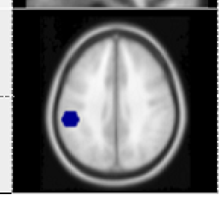
As described above, to analyze the recall of the messages, each participant was sent a questionnaire with 36 images (18 images used for the design of the advertisements made and another 18 fictitious images with environmental content and use of EERR). After obtaining the responses, we performed a Friedman test to discover the existence of differences between the recall of the different messages among all participants and also a Mann-Whitney U test, to analyze whether there are differences between the images remembered by subjects who indicate that they are more and less concerned about the environment.

2.9. Analysis of correlations between recall and areas of interest

Using ROIs in fMRI analyses is useful to determine the activity in certain areas of interest previously traced for each condition about other variables of interest (Poldrack, 2007). Vn and, vice versa, recall was included as a covariate; brain regions were delimited to subsequently link the activity of these regions to other variables of interest, in this case self-reported recall. Taking into account these recommendations, in our analysis we will mark those regions whose activity favor an effective recall in the consumer's mind derived from the coding of the advertisement as ROIs. Specifically, the regions to be delimited will be:

1. **Positive message (Vp):** fronto-parieto-cingulate areas, the PFCM and the CPOF.

Table 2. *Regions anticipating positive recall*

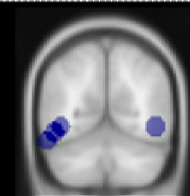
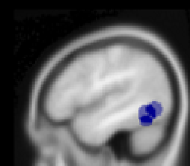
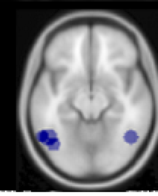
Author	Area Broadman	Region	Image ROIs
Mickley & Kensinger (2008)	6;8 Bilateral	Prefrontal cortex	
Botzung et al. (2010)	9	Prefrontal cortex	
Erk et al. (2005)	11;37	PFC Orbital and medial	
Mickley & Kensinger (2008)	23;31	Cingulate gyrus (CC)	
Botzung et al. (2010)	-	CC	
Mickley & Kensinger (2008)	40	Lower parietal	
Botzung et al. (2010)	40	Lower parietal	

* Significant peaks at p005 of FWE corrected to ROI level

Source: Own elaboration

2. **Negative message (An):** the medial temporal lobe and the temporo-occipital region.

Table 3. *Regions anticipating negative recall*

Author	Area Broadman	Region	Image ROIs
Maureen Ritchey et al. (2011)	39;37	GTM y GTI	
Mickley & Kensinger (2008)	19	GTI	
Mickley & Kensinger (2008)	19;37	Occipital gyri (GO)	
		GTI	

* Significant peaks at p005 of the FWE corrected at ROI level

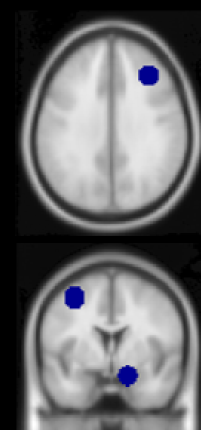
Source: Own elaboration

Three masks were created (prefrontal cortex including the medial and orbital, the parietal region and the cingulate gyrus), each related to one of the regions of interest encoding positive stimulus recall (Botzung et al., 2010; Northoff et al., 2009). At the same time, we created two masks for the GTI and GTM and another for the GO; these regions collect the areas with the highest activity when encoding negative stimuli (Kensinger & Schacter, 2008). Each mask contained different 10 mm radius spheres based on anatomical coordinates obtained from previous studies (Tables 2, 3 and 4). This type of analysis attempts to pre-specify a set of anatomical ROIs and subsequently relate the activation of these regions to recall one month after viewing the messages.

To test hypotheses H1 and H2, which states the existence of an association between the neural responses to the visualization of the messages and the recall generated. Two association tests were performed between the parameters extracted from each ROI and the recall generated by each advertisement.

Our H3 approach, linking amygdala and CMPF activation in subjects more concerned about the medium and the recall of affective stimuli, led us to the extraction of these regions as an ROI in the two-sample analyses (Vp x Ap + Vp x Bp) vs. (Vn x Ap + Vn x Bp) and vice versa. Once we extracted the parametric data for the regions, we associated this neural response of both preoccupied and unconcerned subjects with the recall elicited by viewing the stimuli. As in the previous section, we turned to the literature to delimit the ROIs. We marked those regions whose activity is linked to memorizing socially relevant stimuli that favor effective recall in the consumer's mind, in this case derived from environmental concern. Specifically, the study regions were:

Table 4. *Most active regions in concerned participants*

Author	Area Broadman	Region	Image ROIs
Botzung et al. (2010)	9; 6	CMPF CMPF Amygdala	

* Significant peaks at p 005 of the FWE corrected at ROI level

Source: Own elaboration

To ascertain the association's existence, we performed two association tests based on the χ2 between the parameters extracted from the ROI and the recall reported in each message.

3. Results

3.1. Analysis of brain activity-recall association

In order to determine the existence of an association between the neural responses to the visualization of the messages and the elicited recall (hypotheses H1 and H2). An association test was performed, linking the parameters extracted from each ROI (previously delimited according to the regions established by the literature), with the measures of self-reported recall. The results obtained are shown below:

1. For positive messages with final gain state, the fronto-parieto-parietal cingulate areas, the PFCM and the COF are bounded.

The recall of the positive message (according to the number of recalled images) is significantly correlated with the activation of the parietal areas (r=0.336; sign.=0.017), with the prefrontal cortex (r=0.477; sign.=0.000) and with the cingulate (r=0.468; sign.=0.001). Therefore, we can confirm our first hypothesis, stating that there is a correlation between the activity of these regions after processing positive stimuli.

2. For negative messages with a final state of loss: the medial temporal lobe and the temporo-occipital region.

The recall of the negative message is significantly correlated with the activation of the inferior temporal region (BA17) (r=0.308; sign.=0.03) and with the (BA37) (r=0.315; sign.=0.026) and with the occipital region (BA19 and 37) (r=0.321; sign.=0.023), but we found no association between the medial region of the temporal lobe (BA39) and the recall of these messages. Therefore, we can partially confirm our second hypothesis, confirming that there is an association between inferior temporal (BA17) and (BA37) and occipital region (BA 19) activity when encoding negative messages.

3.2. The role of worry in the activity-recall association

Given the social relevance that concern for the environment is reaching on the one hand and the influence of the amygdala and CMPF in encoding stimuli in emotional memory the other, we next evaluated whether there is an association between both regions and the subsequent recall of the visualized messages. In particular, this analysis is interesting because we found differences between worried and non-worried subjects when recalling negative messages in the previous tests.

Table 5. *Association between recall of negative messages and level of worry*

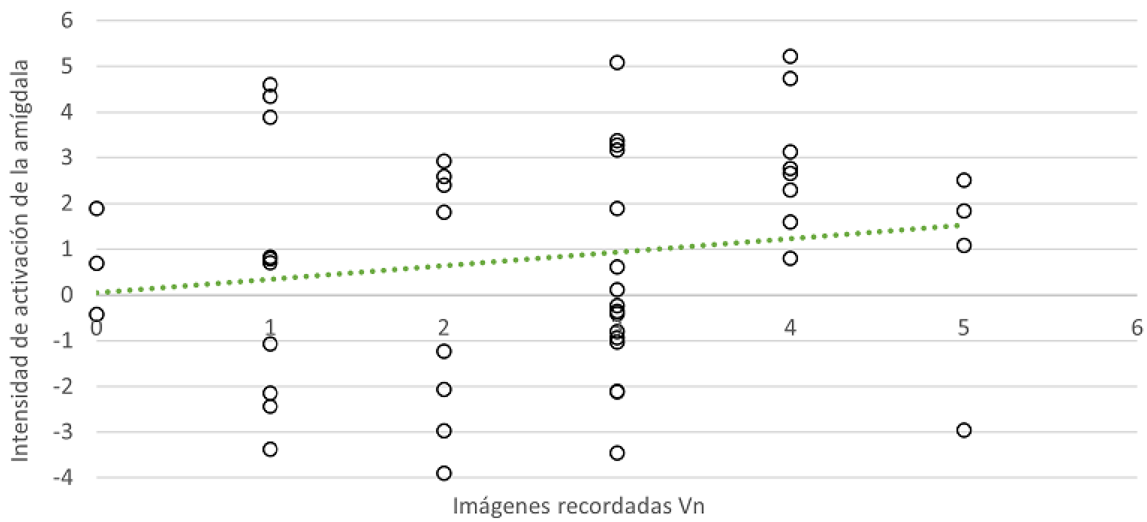
ROI´s	Concerned	Not concerned
Amygdala	r=0.481	r=-0.082
	sign.=0.000	sign.=0.570
CMPF	r=0.281	r=0.205
	sign.=0.048	sign.=0.152

Source: Own elaboration

The results of the analyses performed confirm the third hypothesis of the study, showing that there is an association between the activation of the amygdala and the medial prefrontal cortex in subjects who are more concerned about the environment and the recall of affective stimuli, in this case, negative and with a final state of loss.

The relationship between the amygdala and the recall of these messages in more environmentally preoccupied subjects is depicted below (Figure 1). In particular, the results show a positive and significant relationship between both variables.

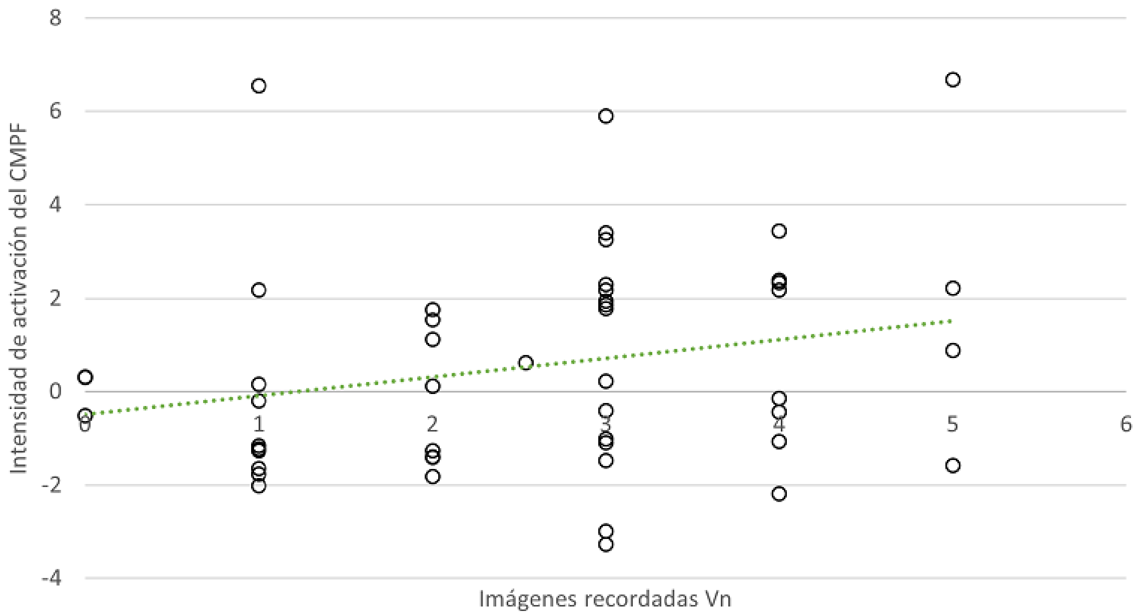
Graphic 1. Relationship between amygdala activation and the number of images remembered from the An



Source: Own elaboration

Finally, a new graphical representation of the relationship between CMPF and recall among the most worried subjects can be seen (Graphic 2). Specifically, the results show a weaker but positive relationship than the previous one between the CMPF and the number of images recalled (Table 5).

Graphic 2. Relationship between CMPF activation and the number of images remembered from the An

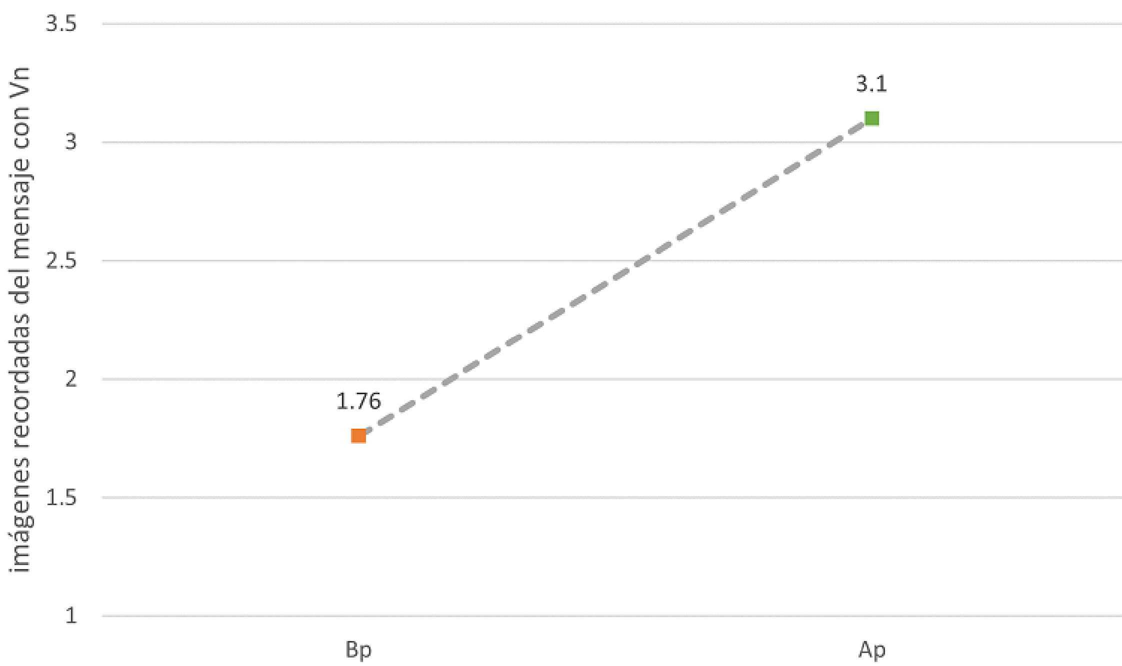


Source: Own elaboration

3.3. Self-report recall analysis

Next, we analyzed the influence of environmental concern on message recall using the Mann-Whitney U test. The results show no differences between the most and least concerned participants in recalling the images of the positively valenced messages (Z=-1.712; sign.=0.87) nor in recalling the images of the neutral messages (Z=-1.356; sign.=0.175). However, we found significant differences (Z=-3.472; sign.=0.001) in recalling negative message images between subjects who say they are more (x#= 3.1) or less (x#= 1.76) concerned about the environment. This result demonstrates that messages with a final state of loss are better remembered among subjects who express greater concern for the environment. This answers the first research question (C1).

Graphic 3. Recall of negative messages in subjects with low (Bp) and high (Ap) concern



Source: Own elaboration

4. Discussion and Conclusions

Using fMRI analysis, we confirmed our first hypothesis, which anticipated an association between the activity of frontoparietal cingulate areas, the PFCM and the COF when processing positive advertisements and the recall of these advertisements. Our findings are in line with work showing that recall of positive stimuli is linked to activity in the frontal and parietal regions (Kensinger & Schacter, 2008); furthermore, these findings find support other studies showing that positive encoding information is related to activity in specific regions within the PFC (Dolcos et al., 2004; Botzung et al., 2010). Specifically, our results associated greater PFCM and COF activity with the recall of positive advertisements (Erk et al., 2005). Overall, our research links the activity of these regions to the processing of positive messages with end-state gain, aligning our results with studies that associate their activation with positive, rewarding and relevant experiences (Tsukiura & Cabeza, 2008). These findings suggest that the involvement of specific regions such as the front-parieto-cingulate regions, the PFCM or the COF may be related to the recall of positive emotional information, specifically with images of RREE.

In line with previous articles, our study has also demonstrated that the second research hypothesis proposed that the recall of negative stimuli is linked to activity in temporal and occipital regions compared to positive stimuli (Mickley & Kensinger, 2008). Other research indicates that temporo-occipital regions are involved in encoding negative emotional valence events. Specifically, work by Brühl et al., (2011) shows that the temporo-occipital region is activated when encoding negative emotional stimuli. According to Herwig et al. (2007), activity in these temporo-occipital regions may be involved in processing negative stimulus information that generates an unknown expectancy. This expectation processed within the temporo-occipital regions could lead to sensory processing, resulting in recalling negative items in more detail (Kensinger & Schacter, 2008).

Using neural scanning techniques, we have contrasted activity in the regions that the previous literature considers necessary for the effective registration of positive and negative messages. Despite this, this technique does not determine which message achieves better recall among the studied viewers.

4.1. Influence of worry on message recall

Our analyses of self-report measures indicate that subjects with a higher environmental concern recall negative ads to a greater extent. These findings are in line with those of Rayens et al. (2016), showing that subjects with higher awareness of the risk caused by tobacco smoke recall a higher percentage of loss-framed ads, but this is not the same in the case of gain messages. Subjects who are more concerned about the environment may have a greater knowledge of the risk of consuming fossil energies, identifying and valuing, to a lesser extent, the ads framed in a loss derived from their continued use. According to Hull & Hong (2016), when the message frame matches the viewer's way of thinking, the persuasive power of the advertisement is enhanced. Several studies have shown that a match between the viewer's mindset and the message frame enhances elaboration by positively influencing the viewers' ability to recall message information (Aaker & Lee, 2001) and discern strong and weak arguments (Updegraff & Rothman, 2013).

The combination of self-report and neuroimaging techniques has allowed us to confirm our third research hypothesis, which links self-reported recall of negative messages in environmentally preoccupied subjects with activity in regions that anticipate better recall during message encoding, such as the amygdala and CMPF. The activity of the amygdala has been linked to the arousal caused by the stimulus received, being responsible for forming associations between these stimuli and punishment or reward. Specifically, activation of this region is indicative of the importance of possible emotion-provoking situations and generates behavioral adjustments associated with the current emotion (Alpers et al., 2009). Its location and relationship with other regions make it a basic structure in emotional processing, i.e., it receives afferences from all sensory association areas (Sánchez-Navarro & Román, 2004). The amygdala can respond to the coding of the valence of images (Kensinger & Schacter, 2006); in addition, it involves other regions of the cortex to provide the emotional component to complex information that requires a certain degree of processing (Sánchez-Navarro & Román, 2004). In this case, in subjects more concerned about the environment, who consider it a social problem to continue consuming fossil fuels, the encoding of information when visualizing negative advertisements with a final state of loss will activate regions linked to social cognitive processes that can improve the recall of information (Bakalash & Riemer, 2013). This cognitive processing employs brain regions that are also involved in thinking about others (vs. self-reflection), specifically the CMPF (Mitchell et al., 2005). These social stimuli will need further processing involving the amygdala and the CMPF (Sakaki et al., 2012).

Therefore, as in our case, a higher recall of messages using negative images is achieved. These results, confirming our third hypothesis, are in line with those of the study by Missaglia et al. (2017) when analyzing social awareness of female genital mutilation, who found that the social advertisement which used a negative valence was significantly better remembered.

Furthermore, the neuroimaging results are consistent with the behavioral data, suggesting that the negative emotion elicited by the messages may be present in the processing mode in more environmentally concerned, detail-oriented subjects, leading them to fixate on the specific images in the message by encoding the stimuli more accurately (Anderson, 2005). Accordingly, when the information is self-relevant, negative stimuli are better remembered (Raghunathan & Trope, 2002). In contrast to our results, we found works that show more significant activity in the amygdala when encoding future positive versus negative events, as seen in the case of ultras followers of a basketball team, where positive plays are more personally significant than negative ones; therefore, this greater relevance could lead to increased activity in the amygdala and the better recall of positive personal events (Northoff et al., 2009). We can therefore confirm that, in our work, the magnitude of activity in these regions (amygdala and CMPF) is linked to the greater recall of negative emotional stimuli, enhancing the recall generated by these images in emotional memory.

4.2. Message recall by level of concern

First, we cannot confirm the suggestion from a previous study that emotionally affective information elicits greater recall than neutral information (Kensinger, 2009). In our case, we found that the explanation for these results is the measure of arousal possessed by the stimuli used. As explained in the methodology section, the matching in this dimension of emotion may be generating this effect in the participants' memory. Furthermore, according to Bradley et al. (2001), images showing pollution or inert objects (such as solar panels, cities with smoke or sundials used in this work) are close to the lower point of the function representing arousal.

In contrast to these results, we found a higher recall generated by the images used for negative valence messages in subjects expressing greater concern than in those expressing low environmental concern. It is possible that viewing images which present the current environmental risks of fossil energy consumption (e.g., images of nuclear power plants or heavily polluted cities) generates more detailed and accurate recall in the memory of more concerned viewers or brings memories of past events to the present. In line with Mostafa et al. (2018) findings, our work argues that ads with negative appeal elicit stronger recall in viewers' minds. Specifically, in subjects with greater concern for the medium, messages with negative valence are better remembered; these findings are in line with the study of Rayens et al. (2016), in which subjects with greater risk awareness recall a higher percentage of loss-framed ads. Moreover, they are in line with those reported by Varan et al. (2015), who showed that consumers recall ads of brands that they are less willing to buy. This seems to indicate that what viewers reject manages to reinforce their recall.

To conclude, we can state that all of these findings provide an answer to our research question.

Authors' Contribution

Diego Gómez-Carmona: Conceptualization, Data Curation, Formal analysis, Investigatión, Methodology, Software & Writing-original draft. **Pedro Pablo Marín-Dueñas**: Data Curation, Methodology, Visualization, Software, Writing-original draft, Writing-review & edition. **Francisco Muñoz-Leiva**: Formal analysis, Funding acquisition, Resources & Software. **Francisco Liébana-Cabanillas**: Formal analysis, Funding acquisition, Resources & Software. All authors have read and agreed to the published version of the manuscript.

Acknowledgments

This work was supported by the Andalusian Program for R&D (grant number P20-01021)

References

Aaker, Jennifer L., & Lee, Angela Y. (2001). “I” Seek Pleasures and “We” Avoid Pains: The Role of Self-Regulatory Goals in Information Processing and Persuasion. In *Journal of Consumer Research*.

Adelman, James S., & Estes, Zachary (2013). Emotion and memory: A recognition advantage for positive and negative words independent of arousal. *Cognition, 129*(3), 530–535. https://doi.org/10.1016/j.cognition.2013.08.014

Alpers, Georg W., Gerdes, Antje B. M., Lagarie, Bernardette, Tabbert, Katharina, Vaitl, Dieter, & Stark, Rudolf (2009). Attention and amygdala activity: An fMRI study with spider pictures in spider phobia. *Journal of Neural Transmission, 116*(6), 747–757. https://doi.org/10.1007/s00702-008-0106-8

Anderson, Michael L. (2005). Why is AI so scary?. *Artificial Intelligence*, Vol.169, no 2, 201-208, 2005. https://doi.org/10.1016/j.artint.2005.10.008

Bakalash, Tomer, & Riemer, Hila (2013). Exploring ad-elicited emotional arousal and memory for the ad using fMRI. *Journal of Advertising, 42*(4), 275–291. https://doi.org/10.1080/00913367.2013.768065

Barreto, Ana Margarida (2013). Do users look at banner ads on Facebook? *Article in Journal of Research in Interactive Marketing*. https://doi.org/10.1108/JRIM-Mar-2012-0013

Benavidez, Verónica & Flores, Ramón (2019). La importancia de las emociones para la neurodidáctica. *Wimb lu*, vol. 14, no 1, p. 25-53.

Bolls, Paul D., Lang, Annie, & Potter, Robert F. (2001). The Effects of Message Valence and Listener Arousal on Attention, Memory, and Facial Muscular Responses to Radio Advertisements. *Communication Research, 28*(5), 627–651. https://doi.org/10.1177/009365001028005003

Botzung, Anne, Rubin, David C., Miles, Amanda, Cabeza, Roberto, & LaBar, Kevin S. (2010). Mental hoop diaries: Emotional memories of a college basketball game in rival fans. *Journal of Neuroscience, 30*(6), 2130–2137. https://doi.org/10.1523/JNEUROSCI.2481-09.2010

Bradley, Margaret M., Codispoti, Maurizio, Cuthbert, Bruce N., & Lang, Peter J. (2001). *Emotion and Motivation I: Defensive and Appetitive Reactions in Picture Processing*. https://doi.org/10.1037/1528-3542.1.3.276

Brühl, Annette Beatrix, Viebke, Marie Caroline, Baumgartner, Thomas, Kaffenberger, Tina, & Herwig, Uwe (2011). Neural correlates of personality dimensions and affective measures during the anticipation of emotional stimuli. *Brain Imaging and Behavior, 5*(2), 86–96. https://doi.org/10.1007/s11682-011-9114-7

Dolcos, Florin, Denkova, Ekaterina, & Dolcos, Sanda (2012). Neural correlates of emotional memories: a review of evidence from brain imaging studies. *Psychologia, 55*(2), 80–111. https://doi.org/10.2117/psysoc.2012.80

Dolcos, Florin, Labar, Kevin S., & Cabeza, Roberto (2004). Dissociable effects of arousal and valence on prefrontal activity indexing emotional evaluation and subsequent memory: An event-related fMRI study. *NeuroImage, 23*(1), 64–74. https://doi.org/10.1016/j.neuroimage.2004.05.015

Dunlap, Riley E., Van Liere, Kent D., Mertig, Angela G., & Jones, Robert E. (2000). New Trends in Measuring Environmental Attitudes: Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *Journal of Social Issues, 56*(3), 425–442. https://doi.org/10.1111/0022-4537.00176

Erk, Susanne, Martin, Sonja, & Walter, Henrik. (2005). Emotional context during encoding of neutral items modulates brain activation not only during encoding but also during recognition. *NeuroImage, 26*(3), 829–838. https://doi.org/10.1016/j.neuroimage.2005.02.045

Gutchess, Angela & Kensinger, Elizabeth (2018). Los mecanismos compartidos pueden respaldar los beneficios mnemónicos de la autorreferencia y la emoción. *Tendencias En Ciencias Cognitivas*.

Haas, Brian W., & Canli, Turhan (2008). Emotional memory function, personality structure and psychopathology: A neural system approach to the identification of vulnerability markers. In *Brain Research Reviews* (Vol. 58, Issue 1, pp. 71–84). https://doi.org/10.1016/j.brainresrev.2007.10.014

Herwig, Uwa, Baumgartner, Thomas, Kaffenberger, Tina, Brühl, Aannette, Kottlow, Mara, Schreiter-Gasser, Ursula, Abler, Birgit, Jäncke, Lutz, & Rufer, Michael (2007). Modulation of anticipatory emotion and perception processing by cognitive control. *NeuroImage, 37*(2), 652–662. https://doi.org/10.1016/j.neuroimage.2007.05.023

Hull, Shawnika J., & Hong, Yangsun (2016). Sensation seeking as a moderator of gain- and loss-framed HIV-test promotion message effects. *Journal of Health Communication, 21*(1), 46–55. https://doi.org/10.1080/10810730.2015.1033113

Kensinger, Elizabeth. A., & Schacter, Daniel. L. (2006). Amygdala activity is associated with the successful encoding of item, but not source, information for positive and negative stimuli. *Journal of Neuroscience, 26*(9), 2564–2570. https://doi.org/10.1523/JNEUROSCI.5241-05.2006

Kensinger, Elizabeth A. (2009). Remembering the details: Effects of emotion. *Emotion review*, vol. 1, no 2, p. 99-113. https://doi.org/10.1177/1754073908100432

Kensinger, Elizabeth A., & Schacter, Daniel L. (2008). Neural processes supporting young and older adults' emotional memories. *Journal of Cognitive Neuroscience, 20*(7), 1161–1173. https://doi.org/10.1162/jocn.2008.20080

Leshner, Glenn, & Cheng, I-Huei. (2009). The effects of frame, appeal, and outcome extremity of antismoking messages on cognitive processing. *Health Communication, 24*(3), 219–227. https://doi.org/10.1080/10410230902804117

Mickley, Katherine R., & Kensinger, Elizabeth A. (2008). Emotional valence influences the neural correlates associated with remembering and knowing. *Cognitive, Affective and Behavioral Neuroscience, 8*(2), 143–152. https://doi.org/10.3758/CABN.8.2.143

Missaglia, Anna L., Oppo, Annalisa, Mauri, Maurizio, Ghiringhelli, Barbara, Ciceri, A., & Russo, Vincenzo (2017). The impact of emotions on recall: An empirical study on social ads. *Journal of Consumer Behaviour, 16*(5), 424–433. https://doi.org/10.1002/cb.1642

Mitchell, Jason P., Banaji, Mahzarin R., & Macrae, C. Neil (2005). The link between social cognition and self-referential thought in the medial prefrontal cortex. *Journal of Cognitive Neuroscience, 17*(8), 1306–1315. https://doi.org/10.1162/0898929055002418

Mostafa, Aya, Mohammed, Heba T., Hussein, Rasha, Hussein, Wafaa, Elhabiby, Mahmoud, Safwat, Wael, Labib, Sahar & Fotouh, Aisha (2018). Do pictorial health warnings on waterpipe tobacco packs matter? Recall effectiveness among Egyptian waterpipe smokers & non-smokers. *PLoS One*, vol. 13, no 12. https://doi.org/10.1371/journal.pone.0208590

Muñoz-Leiva, Francisco, Hernández-Méndez, Janet, & Gómez-Carmona, Diego (2019). Measuring advertising effectiveness in Travel 2.0 websites through eye-tracking technology. *Physiology and Behavior, 200*, 83–95. https://doi.org/10.1016/j.physbeh.2018.03.002

Northoff, Georg, Schneider, Felix, Rotte, Michael, Matthiae, Christian, Tempelmann, Claus, Wiebking, Christina, Bermpohl, Felix, Heinzel, Alexander, Danos, Peter, Heinze, Hans-Jochen., Bogerts, Bernhard, Walter, Martin, & Panksepp, Jaak (2009). Differential parametric modulation of self-relatedness and emotions in different brain regions. *Human Brain Mapping, 30*(2), 369–382. https://doi.org/10.1002/hbm.20510

Poldrack, Russell A. (2007). Region of interest analysis for fMRI. *Social Cognitive and Affective Neuroscience, 2*(1), 67–70. https://doi.org/10.1093/scan/nsm006

Putrevu, Sanjay (2008). Consumer responses toward sexual and nonsexual appeals: The Influence of Involvement, Need for Cognition (NFC), and Gender. *Journal of Advertising, 37*(2), 57–69. https://doi.org/10.2753/JOA0091-3367370205

Raghunathan, Rajagopal, & Trope, Yaacov (2002). Walking the tightrope between feeling good and being accurate: Mood as a resource in processing persuasive messages. *Journal of Personality and Social Psychology, 83*(3), 510–525. https://doi.org/10.1037/0022-3514.83.3.510

Rayens, Mary Kay, Butler, Karen M., Wiggins, Amanda T., Kostygina, Ganna, Langley, Ronald E., & Hahn, Ellen J. (2016). Recall and Effectiveness of Messages Promoting Smoke-Free Policies in

Rural Communities. *Nicotine & Tobacco Research, 18*(5), 1340–1347. https://doi.org/10.1093/ntr/ntv197

Ritchey, Maureen, Dolcos, Florin, & Cabeza, Roberto (2008). Role of Amygdala Connectivity in the Persistence of Emotional Memories Over Time: An Event-Related fMRI Investigation. *Cerebral Cortex, 18*(11), 2494–2504. https://doi.org/10.1093/cercor/bhm262

Ritchey, Maureen, LaBar, Kevin S., & Cabeza, Roberto (2011). Level of processing modulates the neural correlates of emotional memory formation. *Journal of Cognitive Neuroscience, 23*(4), 757–771. https://doi.org/10.1162/jocn.2010.21487

Sakaki, Michiko, Niki, Kazuhisa, & Mather, Mara (2012). Beyond arousal and valence: The importance of the biological versus social relevance of emotional stimuli. *Cognitive, Affective and Behavioral Neuroscience, 12*(1), 115–139. https://doi.org/10.3758/s13415-011-0062-x

Sánchez-Navarro, Juan Pedro, & Román, Francisco (2004). Amígdala, corteza prefrontal y especialización hemisférica en la experiencia y expresión emocional. *Anales de Psicología, 20,*((2)), 223–240.

Tsukiura, Takashi, & Cabeza, Roberto (2008). Orbitofrontal and hippocampal contributions to memory for face-name associations: The rewarding power of a smile. *Neuropsychologia, 46*(9), 2310–2319. https://doi.org/10.1016/j.neuropsychologia.2008.03.013

Updegraff, John A., & Rothman, Alexander J. (2013). Health Message Framing: Moderators, Mediators, and Mysteries. *Social and Personality Psychology Compass, 7*(9), 668–679. https://doi.org/10.1111/spc3.12056

Varan, Duane, Lang, Annie, Barwise, Patrick, Webe, René & Bellman, Steven (2015). How Reliable Are Neuromarketers' Measures of Advertising Effectiveness?: Data from Ongoing Research Holds No Common Truth among Vendors. *Journal of advertising research*, vol. 55, no 2, p. 176-191. https://doi.org/10.2501/JAR-55-2-176-191

Venkatraman, Vinod, Dimoka, Angelika, Pavlou, Paul A., Vo, K., Hampton, William, Bollinger, Bryan, Hershfield, Hal E., Ishihara, Masakazu, & Winer, Russell S. (2015). Predicting Advertising success beyond Traditional Measures: New Insights from Neurophysiological Methods and Market Response Modeling. *Journal of Marketing Research, 52*(4), 436–452. https://doi.org/10.1509/jmr.13.0593