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Incidental encoding of emotional pictures: Affective bias studied through event related brain potentials

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Abstract

Emotional stimuli are better remembered than neutral stimuli. Most of the studies taking into account this emotional bias refer to explicit memory, use behavioral measures of the recall and predict better recall of negative stimuli. The few studies taking into account implicit memory and the valence emotional dimension are inconclusive on the effect of the stimulus' emotional valence. In the present study, 120 pictures (30 positive, 30 negative, 30 relaxing and 30 neutral) were shown to, and assessed by, 28 participants (*study phase*). Subsequently, event related brain potentials (ERPs) were recorded during the presentation of 120 *new* (shown for the first time) and 120 *old* (already shown in the study phase) pictures (*test phase*). No explicit instructions or clues related to recovery were given to participants, and a distractor task was employed, in order to maintain implicit the memory assessment. As expected from other studies' data, our results showed that old stimuli elicited an enhanced late positive component 450 ms after stimulus onset (repetition effect). Moreover, this effect was modulated by the stimuli's emotional valence, since the most positively valenced stimuli were associated with a decreased repetition effect with respect to the most negatively valenced stimuli. This effect was located at ventromedial prefrontal cortex. These results suggest the existence of a valence-mediated bias in implicit memory.

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1. Introduction

Studies on the relationship between emotion and memory have focused almost exclusively on conscious or explicit memory (see Cahill and McGaugh, 1998; Maratos et al., 2000; Phelps, 2006), giving implicit memory processes a much lower profile. In our opinion, this approach to the relationship between emotion and memory is insufficient, since most of the information encoded in our memory systems cannot be accessed through intentional or conscious recall. Indeed, research in the last years has approached emotion as an unconscious process that does not always lead to a

conscious experience (Carretié et al., 2005; LeDoux, 2000; Morris et al., 1998).

The existing studies on the relationship between emotion and explicit memory seem to agree on the fact that emotional stimuli are better remembered than neutral or relaxing ones (see reviews in Christianson, 1992; Kensinger, 2004; LaBar and Cabeza, 2006). Interpretations for this *emotional bias* mainly refer to the biological importance of the events that are capable of eliciting emotional responses. On the other hand, enhanced memory depending on the positive or negative emotional valence of the stimuli has been documented for explicit memory in different neuropsychological (Adolphs et al., 1997, 2000; LaBar and Phelps, 1998), behavioral (Burke et al., 1992; Cahill and McGaugh, 1995; Christianson and Loftus, 1991; Coles and Crawford, 2003; Crawford et al., 2003; Heuer and Reisberg, 1990; Kern et al., 2002; Ochsner, 2000; Phelps and Anderson, 1997; Taylor and John, 2004) and neuroimaging (Gläscher et al.,

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2007; Hamann et al., 1999; Taylor et al., 1998) studies, being this enhancement either for positive or negative stimuli.

With respect to the relation between emotion and implicit memory, the scarce studies existing are in most cases behavioral and neuropsychological studies (Barry et al., 2006; Bradley et al., 1992; Lim and Kim, 2005; Padovan, 2002; Richards et al., 1999; Williams et al., 1997). Although results are not clear or conclusive on how implicit recall is affected by the emotional content of incidentally encoded stimuli, Williams et al.'s review of implicit memory bias in anxiety finds evidence for a bias towards negative material, in coincidence with some of the above-mentioned explicit memory studies. This valence-related bias is explained by considering its evolutionary advantages and adaptive functions for survival; the consequences of not recalling an aversive or negative situation can be far more dangerous than the consequences of not recalling a positive one.

Electroencephalographic recording of the event related potentials (ERPs) as a memory recording tool has proved to be very well suited to study the kind of processes we are dealing with (emotion and implicit memory), since events with short latency and duration are not easily recorded through other types of technique, such as haemodynamic ones. Mnemonic processes seem to be well reflected in the *repetition effect*, which consists in a late positive-going wave elicited by repeated stimuli, compared to that evoked by stimuli presented for the first time (see Rugg, 1995 for a review). Data on electrical brain activity in the joint study of emotion and explicit memory seem to indicate that the above-mentioned emotional biases modulate the ERP repetition effect (Canli et al., 2000; Dietrich et al., 2001; Dolcos and Cabeza, 2002; Lang et al., 1998; Palomba et al., 1997; Windmann and Kutas, 2001).

The repetition effect in the ERP recordings has also been reported for implicit memory using indirect memory tests. When non-emotional words are employed as stimuli, the effect consists of a higher positivity between 300 and 500 ms after the presentation of the stimuli that have been shown more than once (Friedman and Johnson, 2000; Guillem et al., 1999; Rugg, 1995; Rugg et al., 1998). The effect appears regardless of participants' awareness of the previous presentation of these stimuli, which seems to show that the effect is reflecting implicit memory processes. Topographically, this effect is maximal at parietal areas of the scalp. Boehm et al. (2005) replicated Rugg et al.'s (1998) findings in a similar study using famous and non-famous faces. Their results show the same repetition effect from 350 to 650 ms, though at fronto-lateral sites. No studies on the latency and spatial distribution of the repetition effect on incidental encoding and retrieval of emotional stimuli have been carried out yet, to the best of our knowledge.

The present study attempts to temporally and spatially characterize the ERP correlates of the repetition effect elicited by incidentally encoded emotional stimuli. In the first place we predict the repetition effect to be reflected as enhanced ERP late positivities for all the 'old' stimuli presented to subjects. Secondly, we expect an effect of the emotional valence of 'old' stimuli in the amplitudes of the repetition effect, reflecting different implicit recall for negative and positive stimuli, in line with the above-mentioned biases observed in studies on explicit memory.

2. Methods

2.1. Subjects

Thirty-one right-handed students from the Universidad Autónoma de Madrid initially took part in the present study. The data from three of the participants were excluded from the analysis, as will be explained later in the Electrophysiological recording section, the final number of participants thus being 28 (14 men and 14 women). Participants were aged between 20 and 30 years (mean = 21.48; S.D. = 2.51), and participated voluntarily and for course credit.

2.2. Stimuli

The stimuli consisted of 240 digitized colour photographs on a black background depicting emotional and neutral scenes. Sixty of the 240 images were Positive (e.g. appetitive meal, smiling baby), 60 Negative (snake, gun), 60 Relaxing (e.g. quiet lake, woman sleeping) and 60 Neutral (e.g. building, spoon). All the photographs were taken from the International Affective Picture System (IAPS, Center for the Study of Emotion and Attention [CSEA-NIMH], 2001) and from other image sources in the Internet, following IAPS classification criteria. All stimuli were assessed by all the participants in the experiment on the Valence and Arousal scales. Results on these assessments will be later described. Valence dimension refers to the level of pleasantness associated with the emotional response to a stimuli and ranges from negative to positive, while the arousal dimension refers to the level of activation and ranges from calming to arousing. These two dimensions explain the main variance of the emotional meaning (Lang et al., 1993; Osgood et al., 1957; Russell, 1979; Smith and Ellsworth, 1985). Width and height of the photographs varied between 12 and 19 cm, the diagonal length ranging from 16.97 to 26.87 cm. The visual vertical angle subtended by the stimuli varied between 16.18° and 25.63°.

2.3. Procedure

Study phase: this first phase of the experiment took place in a silent room. The subject sat alone in front of a computer, on which he or she had to assess 120 of the 240 photographs on both the valence and arousal scales. Before the assessment, the experimenter read the instructions aloud. Average duration of this part of the experiment was 35 min. The task was not explicitly related to memory, but allowed the incidental encoding of the images. These 120 photographs were used as *old* stimuli in the second (test) phase, while the 120 non-evaluated photographs were the *new* stimuli. We were thus able to consider 8 different types of stimuli; *Positive new*, *Negative new*, *Relaxing new*, *Neutral new*, *Positive old*, *Negative old*, *Relaxing old* and *Neutral old*. In order to avoid the primacy and recency effects (Glanzer and Cunitz, 1966; Murdock, 1962), as well as the possible differential effect on incidental encoding due to the physical characteristics of the images, the two blocks of 120 stimuli were counterbalanced, so that they were *new* for one half of the sample, and *old* for the other half.

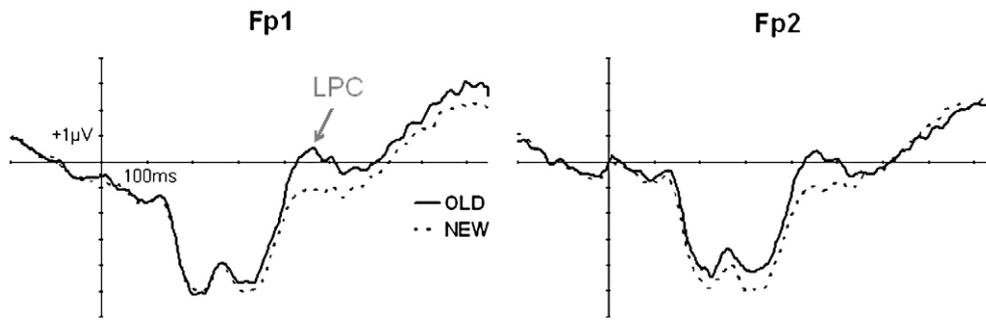


Fig. 1. Grand averages at frontoparietal locations, where the repetition effect was maximal. Emotional categories are averaged together.

Test phase: having finished the assessment, the subject was asked to enter the electrically and acoustically isolated room where the ERP recordings would be carried out. The participant

sat on a comfortable chair, 85 cm from a 17-inch computer screen, which was located outside the room, and visible through a window specifically designed for this purpose.

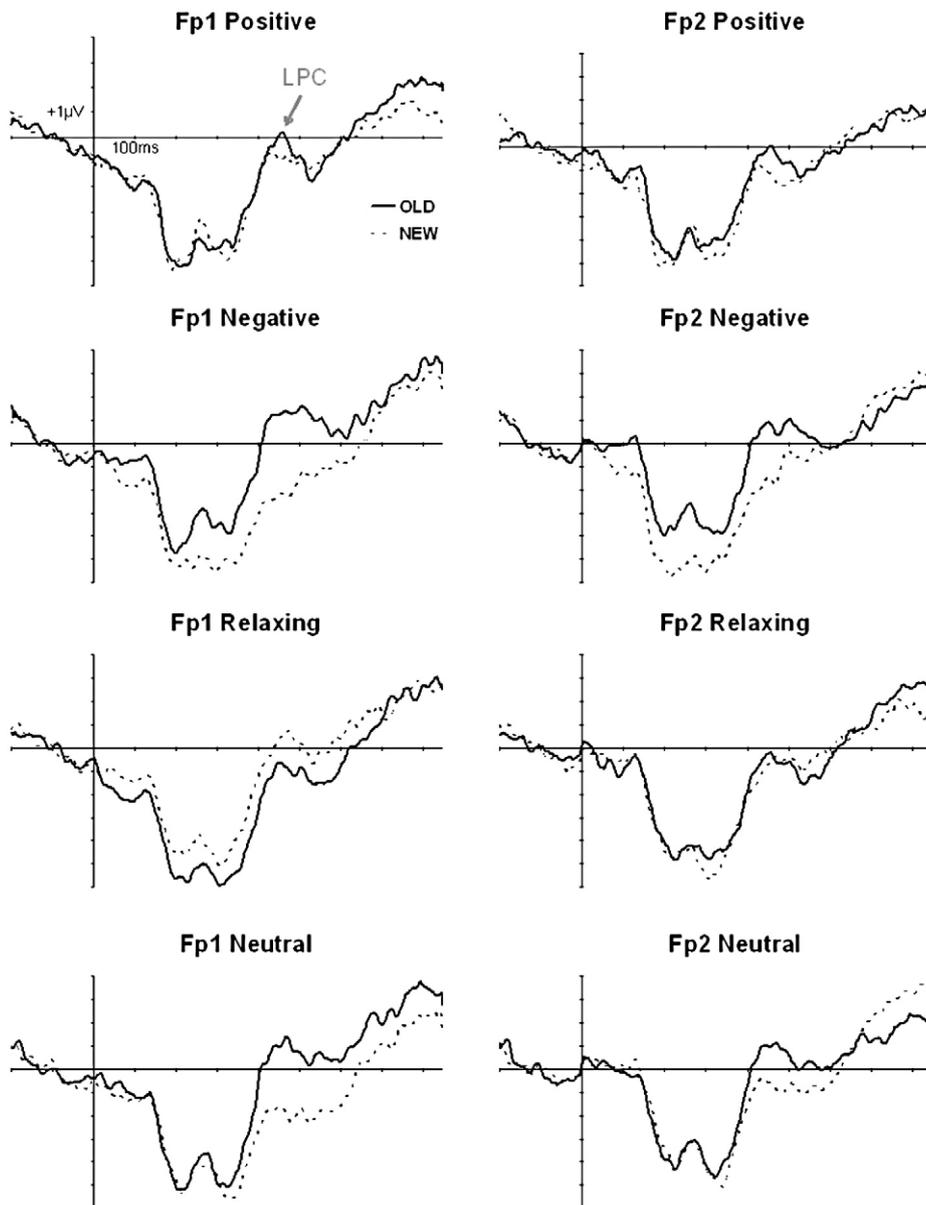


Fig. 2. Grand averages distinguishing emotional categories (Positive, Negative, Relaxing and Neutral) at frontoparietal locations, where experimental effects were more evident.

Once the electrodes had been placed on the subject's scalp, the experimenter read aloud the instructions for this second phase of the experiment. Participants' task was to count and report, after each presentation block, how many *shifts* had taken place, counting one *shift* each time a photograph depicting persons was followed by another with no persons, and vice-versa. A block of ten training trials was presented in order to familiarize participants with the procedure. After the training trials, the 240 photographs (120 already seen in the *study phase* and 120 new ones) were presented, distributed in 6 blocks of 40. Presentation of each block of stimuli lasted 50 s. Each photograph was shown for 220 ms, the inter-stimulus interval being 1050 ms.

Blocks were presented with a one-minute rest period between them. This period of time was employed to let participants blink, for them to inform the experimenter about the number of shifts they had seen, and to prepare for the next presentation block. The purpose of the task was, firstly, to maintain the subject's attention on the stimuli. Secondly, to prevent participants considering some of the stimuli as more important than others (e.g., emotional stimuli more important than neutral ones), so as to avoid the relevance-for-task effect, often described in previous studies (Carretie et al., 1997; Duncan-Johnson and Donchin, 1977: the stimuli on which the task focuses tend to elicit the highest amplitudes in certain endogenous components). Thirdly, and most importantly, the task facilitated an implicit recovery of the stimuli.

Subjects were told to stare at the centre of the screen and to avoid blinking, in order to control eye-movement interference. Number of shifts per block ranged from 14 to 19, and the total number of shifts affected all four types of stimuli in the same way. After presentation of the six blocks, subjects were asked to assess, in the same way as at the beginning of the experiment, the 120 new photographs (photographs not seen in the study phase). Average duration of this assessment was 35 min.

2.4. Electrophysiological recording

An electrode cap (Electro-Cap International) with tin electrodes was employed. Electrodes were placed at Fp1, Fp2, Fz, F3, F4, F7, F8, FC5, FC6, Cz, C3, C4, T7, T8, CP5, CP6, Pz, P3, P4,

P7, P8, POz, O1 and O2. Interconnected ear lobes were used as reference. Electrooculographic (EOG) data were recorded supra- and infraorbitally (vertical EOG) and from the left versus right orbital rim (horizontal EOG), in order to detect and control the ocular interferences. Electrode impedance was kept below 5 k Ω , and a 0.3–40 Hz bandpass filter was applied.

The channels were continuously digitizing data at a sampling rate of 300 Hz. The continuous recording was divided into 1050-ms epochs for each trial, beginning 200 ms before stimulus onset. Visual inspection was also carried out, epochs with eye movements or blinks being eliminated. Data from two participants had to be removed from the final analysis, one because the number of blinks surpassed 30% of trials, and the other due to data loss. The ERP averages were categorized according to type of stimulus (*Positive new, Negative new, Relaxing new, Neutral new, Positive old, Negative old, Relaxing old* and *Neutral old*).

3. Results

Fig. 1 shows the grand averages of the global repetition effects (distinguishing only between old and new stimuli) at some representative scalp locations, once the baseline (average of the prestimulus recordings) had been subtracted from each ERP. Fig. 2 shows the repetition effects separately for the different types of stimulus (Positive, Negative, Relaxing and Neutral), where experimental effects (described later) are more evident.

3.1. Detection and quantification of the ERP components

Components explaining most ERP variance were detected and quantified through a covariance-matrix-based temporal principal component analysis (tPCA). This technique has been repeatedly recommended for these tasks, since the exclusive use of traditional visual inspection of grand averages and voltage computation may lead to several types of misinterpretation (Carretie et al., 2004; Chapman and McCray, 1995; Coles et al., 1986; Donchin and Heffley, 1978; Fabiani et al., 1987). The main advantage of tPCA is that it presents each ERP component with its clean shape, extracting and quantifying it free of the influences of adjacent or

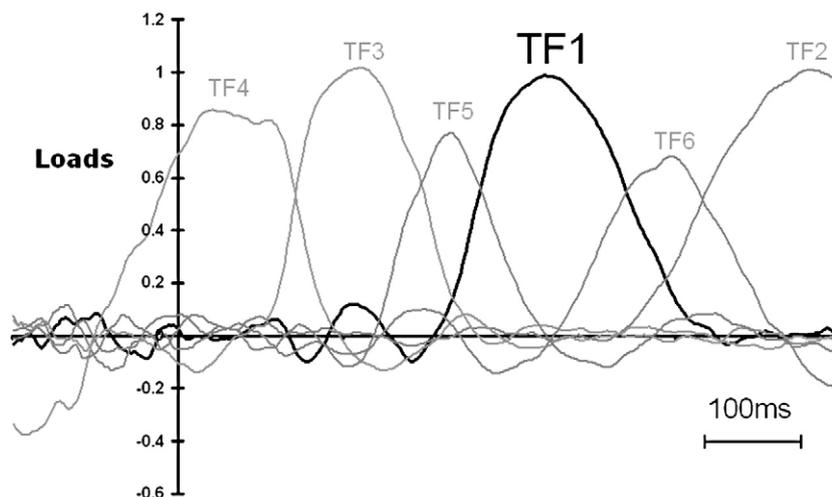


Fig. 3. Factor loadings after varimax rotation. Temporal factor 1 (TF1), which is sensitive to the experimental effect, is drawn in black.

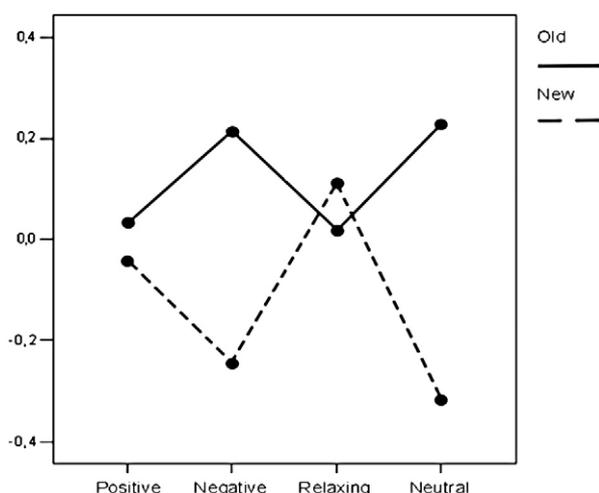


Fig. 4. Mean LPC factor scores (directly related to amplitudes: the more negative, the higher the LPC amplitude) for the frontal spatial factor in response to the four types of stimuli (Positive, Negative, Relaxing and Neutral).

subsequent components (traditional grand averages often show components in a distorted way, and may even fail to show some of them). The decision on the number of components to select was based on the scree test (Cliff, 1987). Extracted components were submitted to varimax rotation. Following this selection criterion, six components were extracted from the ERPs (shown in Fig. 3).

3.2. Analyses on experimental effects

In order to figure out which components were sensitive to the experimental effects, the activity recorded through the 24 channels was grouped in different regions. This regional grouping was carried out by means of a spatial Principal Components Analysis (sPCA) applied to the factor temporal scores previously obtained. Factor scores, the parameter in which temporal factors or components are quantified, are calculated for each individual ERP, and reflect the amplitude of each component. This method is more reliable than the a priori subdivision into geometrically defined scalp regions (Carretié et al., 2003; Spencer et al., 1999), since sPCA demarcates the regions according to the real behavior of each scalp-point recording (basically, each region or spatial factor

is formed with the scalp points where recordings tend to covary). As a result, the shape of the sPCA-configured regions is functionally based, and scarcely resembles the shape of the traditional, geometrically configured regions. Moreover, each spatial factor can be quantified through the spatial factor scores, a single parameter that reflects the amplitude of the entire spatial factor. The sPCAs extracted two spatial factors for temporal factors 1, 2, 4 and 5, four for temporal factor 3 and five for temporal factor 6. Repeated-measures ANOVAs with respect to *Repetition* (two conditions: old and new) and *Emotional category* (four categories: Positive, Negative, Relaxing and Neutral) were carried out to determine which spatial factor was sensitive to the interaction of the two experimental variables. The Greenhouse–Geisser (G–G) epsilon correction was applied to adjust the degrees of freedom of the *F*-ratios where necessary. Only spatial factor 1 of the temporal factor 1 (TF1SF1) was sensitive to both, repetition ($F(1,27)=6.769, p<0.015$) and to the interaction repetition \times emotional category ($F(3,81)=4.041, G-G$ corrected $p<0.025$). Factor peak-latency (450 ms) and topography characteristics (frontal electrodes) associate it with the wave labelled LPC in grand averages shown in Figs. 1 and 2 (this label will be employed hereafter to make the results easier to understand). Bonferroni post-hoc tests ($\alpha<0.05$) subsequently applied revealed that the repetition effect was significant between old and new neutral and negative stimuli. Experimental effects on LPC amplitudes are illustrated in Fig. 4.

3.3. Source location

In order to locate three-dimensionally the cortical regions that were sensitive to the experimental effects, standardized low-resolution brain electromagnetic tomography (sLORETA) was applied. sLORETA is a 3D, discrete linear solution for the EEG inverse problem (Pascual-Marqui, 2002). Although, in general, solutions provided by EEG-based source-location algorithms should be interpreted with caution due to their potential error margins, sLORETA solutions have no location error in ideal conditions (Greenblatt et al., 2005; Sekihara et al., 2005; Soufflet and Boeijinga, 2005). Furthermore, the large sample size employed in the present study ($n=28$), the use of tPCA-derived factor scores instead of direct voltages (which leads to more accurate source-

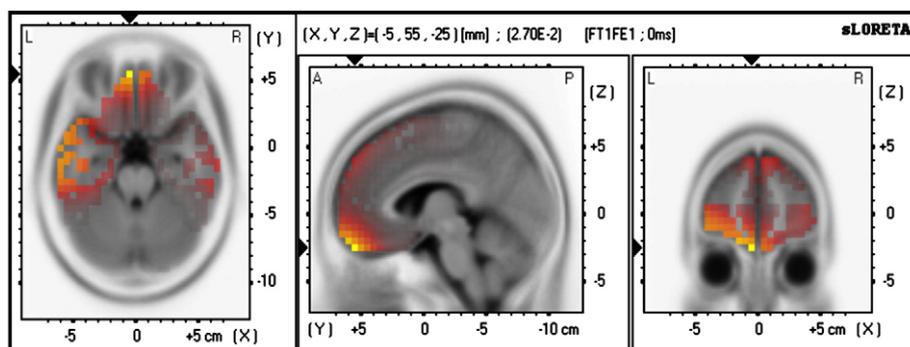


Fig. 5. Images of neural activity computed with LORETA factor scores. The main focus is represented through three orthogonal brain views in Talairach space, sliced through the region of the maximum activity. Left slice: axial, seen from above, nose up; center slice: sagittal, seen from the left; right slice: coronal, seen from the rear. Talairach coordinates: *x* from left (L) to right (R); *y* from posterior (P) to anterior (A); *z* from inferior to superior.

Table 1
Mean and standard error of means (in brackets) of the arousal and valence assessments of the 4 types of stimuli

	Arousal	Valence
Positive	3.82 (0.06)	4.03 (0.06)
Negative	4.35 (0.06)	1.74 (0.04)
Relaxing	2.15 (0.07)	4.06 (0.06)
Neutral	2.97 (0.04)	3.16 (0.02)

Arousal scale: 1 = very relaxing and 5 = very arousing. Valence scale: 1 = very negative; 5 = very positive.

location analyses: (Carretié et al., 2004), and the estimation of convergence with sPCA data, contribute to reducing potential error margins. Solutions are projected on the Montreal Neurological Institute (MNI) standard brain.

sLORETA was applied to frontal factor scores, where experimental effects were significant. Following the procedure described by Dien et al. (2005), a matrix was calculated from the product of spatial loadings by temporal factor scores, so that data submitted to sLORETA was linearly related to original voltages. As can be seen in Fig. 5, this specific analysis revealed the ventromedial prefrontal cortex as the origin of the frontal LPC ($x = -5, y = 55, z = -25$; BA 11) and, consequently, of the experimental effects.

3.4. Control analyses

Statistical analyses were carried out on the subjects' assessments of the pictures used as stimuli, in order to confirm first that the pictures' affective valence was as assumed a priori, and second, that positive and negative pictures were balanced with respect to their arousal levels. Table 1 shows the means and standard error of means of both dimensions (arousal and valence) for each of the 4 types of stimuli. Arousal and Valence correlations between the four types of stimuli (Positive, Negative, Relaxing and Neutral) were analyzed; Negative and Positive photographs were given very similar Arousal ($r = 0.594, p < 0.01$) but different Valence scores ($r = -0.132, p > 0.4$). Likewise, Positive and Negative photographs differ from the Neutral and Relaxing ones in Arousal, while the Negative photographs differ from all the other types of stimuli in Valence, since no significant correlation was found between their respective scores.

4. Discussion

Previous studies concerning the effect of emotion on explicit memory, suggest that encoding and retrieval are enhanced for emotional visually presented stimuli (see reviews in Christianson, 1992; Kensinger, 2004; LaBar and Cabeza, 2006). The experimental task employed in the present study ensured the incidental encoding of the emotional stimuli. Thus, in contrast to the studies reviewed, no clues were given to participants about the mnemonic nature of the study and test phases, so as to control that explicit related-to-memory instructions would interfere with the implicit recall. For this same reason, no behavioral measure of recall was carried out. Implicit recall was quantified exclusively through the

ERP repetition effect (higher late positivities in response to repeated or 'old' stimuli than to 'new' stimuli). In fact, as it was observed in the first studies in which the repetition effect was described for emotionally neutral stimulation (see Rugg, 1995 for a review), our results show a significantly enhanced late positive component (LPC) for the stimuli that participants had viewed in the study phase ('old' stimuli), this being an indicator of incidental or non-intentional recall. The temporal characteristics of LPC (peaking at 450 ms), are convergent with proposals that relate the early portion of the ERP (<500 ms) to perceptual implicit memory and the latter portion to explicit memory processes (Joyce et al., 1999; Paller et al., 2003; Rugg and Allan, 2000).

Another objective of our study was to investigate the existence of a valence-mediated bias in implicit memory. In relation to this, our results indicate that the most positively valenced stimuli (relaxing and positive categories) are associated with a decreased repetition effect with respect to the most negatively valenced stimuli (negative category). These novel results on valence-mediated biases in implicit memory are convergent with some previous studies on explicit memory in which emotionally negative stimuli tend to be better remembered as compared to positive (Christianson and Fallman, 1990; Ochsner, 2000), a mnemonic pattern that is probably favoured by evolution. Nevertheless, several studies on explicit memory find the greatest memory enhancement for both valence dimension extremes (positive and negative) compared to emotionally neutral stimulation (Christianson, 1992; Kensinger, 2004; LaBar and Cabeza, 2006). Differences between our results and those in the above-mentioned studies may be due to various factors. In the first place, the nature of the stimuli used is different from one study to another, and in most cases words are employed as stimuli, rather than photographs. They may be as well reflecting the differences between the explicit (intentional) and incidental mnemonic nature of the encoding or retrieval employed in most studies, since the different structures underlying explicit and incidental processes would provide different brain responses. Interestingly, we have also observed a significant repetition effect for neutral stimuli, in line with previous ERP studies using non-emotional (neutral) faces (Boehm et al., 2005) and non-emotional words (Rugg et al., 1998). The fact that positively valenced stimuli (both relaxing and positive categories) fail to elicit a significant repetition effect, while non-positive (both negative and neutral) elicit it, suggests a bipolar pattern in the emotional modulation of implicit memory.

Concerning the scalp distribution of the observed effects, our data locate maximal effects at frontal electrodes. This result may be considered novel since, as it was mentioned before, no data on the spatial distribution of the repetition effect associated with implicit memory for emotional stimuli have previously been reported. In line with this, data on implicit memory using non-emotional stimuli locate the repetition effect at both parietal (Rugg et al., 1998) and frontal scalp sites (Boehm et al., 2005) using words and pictures as stimuli respectively. The source of the frontal LPC was found at ventromedial prefrontal cortex (VMPFC, defined here as the conjunction between ventral and medial cortex). Some neuropsychological and imaging studies in humans have implicated VMPFC in emotional memory (Bechara

et al., 1999, Bechara et al., 2000; Bremner et al., 1999; Paradiso et al., 1999). Furthermore, the existing interconnections between the VMPFC and the amygdala deeply involve this cortical area in the processing of negative stimulation (Emery and Amaral, 2000). These two structures send outputs to executive areas of the brain, so they may organize a response to cope with the unpleasant or dangerous events. With respect to implicit memory, VMPFC seem to provide an interface between the evolutionarily old implicit processing systems within the limbic system, and the higher-order control systems within the dorsolateral prefrontal cortex, required for decision making and goal-directed behavior (Windman and Kutas, 2001).

Summarizing, our results show the repetition effect previously observed in implicit non-emotional memory, and find a bipolar valence modulation of this effect that probably has an evolutionary facilitation. The repetition effect is reflected in the frontal LPC, whose origin was located at the VMPFC, previously implicated in emotional processes and, among them, in emotional memory.

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