Recognition of emotional pictures: Behavioural and electrophysiological measures

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Available online: 25 Nov 2011


To link to this article: http://dx.doi.org/10.1080/20445911.2011.613819

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Recognition of emotional pictures: Behavioural and electrophysiological measures

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The effects of emotional content of images on recognition memory were studied, bringing together electrophysiological (Event-Related brain Potentials, ERPs) and behavioural (accuracy and speed of recognition, and remember/know judgements) indices. In the study phase, participants assessed 120 images on the scales of valence and arousal. In the test phase, ERPs were recorded while participants viewed again the images, put together with 120 new, and were asked to make old/new decisions and remember/know judgements on them. A clear arousal bias was obtained for remember/know judgements, which revealed that correctly recognised arousing images (negative and positive) received more remember judgements than nonarousing images (neutral and relaxing). Moreover, a Late Positive Component (LPC) activation revealed an old/new effect enhanced by arousing images. The LPC activation was located in parietal areas (precuneus), which appears to be mostly related to successful retrieval based on recollection. The results obtained through different indices supported the emotional bias found in previous studies for arousing material, but do not clarify the effect of the emotional valence on recognition.

Keywords: Emotional pictures; Late positive component; Old/new recognition; Phenomenological judgements.

In the context of current systematic research on the relationships between memory and emotion, it is expected that, in adaptive terms, events and contexts which involve relevant consequences (either positive or negative) for the individual would have privileged access to memory. If this is the case, the individual can cope better with such relevant situations, which are by definition associated with emotional feelings, whenever they reappear. In general, findings show memory performance tends to be better for emotionally arousing stimuli (negative and/or positive) than for low-arousing (neutral and relaxing) stimuli, that is, the former use to be more accurately and faster recognised than the latter (e.g., Bradley, Greenwald, Petry, & Lang, 1992; Ochsner, 2000. For reviews, see Christianson, 1992b; Kensinger, 2004; LaBar & Cabeza, 2006). This differential performance for stimuli as a function of their emotional arousal is called emotional bias, which has been observed in neuropsychological (e.g., Adolphs, Cahill, Schul, & Babinsky, 1997; LaBar...
& Phelps, 1998), behavioural (e.g., Burke, Heuer, & Reisberg, 1992; Cahill & McGaugh, 1995; Christianson & Loftus, 1991; Coles & Crawford, 2003; Crawford, Carlton, & Ahrens, 2003; Heuer & Reisberg, 1990; Kern, Libkuman, & Otani, 2002; Ochsner, 2000; Phelps & Anderson, 1997; Taylor & John, 2004), and neuroimaging studies (e.g., Gläscher, Rose, & Büchel, 2007; Hamann, Ely, Grafton, & Kilts, 1999; Taylor et al., 1998).

Traditionally, the emotional bias has been separately obtained from very different types of measures, stimuli and procedures. Thus, one of the main goals of our study was to bring together various kinds of recognition memory measures (electrophysiological and behavioural) for images that varied in valence and arousal dimensions. In this regard, we were interested in obtaining a consistent emotional bias for our recognition measures, although it should not be discarded that measures with a very different nature may be differently sensitive to the bias. For this purpose, we recorded event-related brain potentials (ERPs) during a recognition old/new test of images, but we also collected different behavioural recognition memory indices, namely, accuracy and speed of recognition, which have been traditionally analysed, and phenomenological judgements associated with previously recognised images, which have been less explored.

Regarding the electrophysiological measures, one well-established finding is the ERP old/new effect, consisting in “old” items eliciting more positive ERPs in a recognition memory test than “new” items (for reviews, see Allan, Wilding, & Rugg, 1998; Johnson, 1995; Rugg, 1995; Rugg & Allan, 2000). This effect typically occurs between 300 and 1000 ms post-stimulus onset, and has been identified in two components: the early (300–500 ms) frontal old/new effect, which has been interpreted as a representation of recognition process based on familiarity, implicit memory, priming effects, and stimulus familiarity/fluency due to mere stimulus repetition (Johnson, 1995; Paller, Kutas, & McIsaac, 1995; Rugg, 1995; Rugg, Mark, et al., 1998; Tapia, Carretié, Sierra, & Mercado, 2008); and the later portion (usually called late positive component or LPC, 500–1000 ms), often occurring over parietal areas, which is involved in participants’ ability to explicitly, consciously, and intentionally recollect and discriminate old from new items (Allan et al., 1998; Düssel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Paller & Kutas, 1992; Rugg, Mark, et al., 1998; Rugg & Nagy, 1989; Rugg, Schloerscheidt, Dayle, Cox, & Patching, 1996).

With regard to the emotional bias, furthermore, there are differentiated effects of emotional items, compared to neutral items, on the ERP old/new waveform with various materials, such as words (e.g., Dietrich et al., 2001; Friedman, 1990b; Inaba, Nomura, & Ohira, 2005, Rugg & Nagy, 1989; Windman & Kutas, 2001), pictures (e.g., Friedman, 1990a; Koenig & Mecklinger, 2008; Weymar, Löw, Melzig, & Hamm, 2009; Zhang, Begleiter, Porjesz, Wang, & Litke, 1995), faces (e.g., Guillem, Bicu, & Debruille, 2001; Johansson, Mecklinger, & Treese, 2004; Schweinberger, Pfütze, & Sommer, 1995), or other kinds of stimuli (e.g., nonwords and geometric figures, Beisteiner et al., 1996; object form and spatial location, Mecklinger, 1998), and with different types of sample (e.g., young vs. old adults: Langeslag & van Strien, 2008. For a recent review, see Kensinger, 2009). Even more, results appear to indicate that recognition memory performance based on recollection and controlled processes is enhanced by emotionally arousing stimuli, being more frequently associated with a late ERP activity than nonarousing ones. However, there are inconsistent findings in relation to the specific valence of stimuli promoting electrophysiological activity linked to a recognition memory based on recollection. Sometimes, this pattern is only revealed by negative stimuli (e.g., Inaba et al., 2005), sometimes by positive stimuli only (e.g., Koenig & Mecklinger, 2008), and sometimes by both negative and positive stimuli (e.g., Weymar et al., 2009). Clearly, although some methodological aspects could be responsible for these mixed results, such as the memory task employed (e.g., old/new recognition test, continuous recognition test), the time intervals manipulated (from a few minutes up to 1 year), and the kind of material presented (e.g., images, words, faces), the most important factor seems to be the manipulation carried out in the emotional dimensions of stimuli.

In fact, studies typically include positive, negative, and neutral stimuli (Inaba et al., 2005; Johansson et al., 2004; Koenig & Mecklinger, 2008; Langeslag & van Strien, 2008; Ochsner, 2000; Weymar et al., 2009), so that images with emotional valence (positive and negative) are also high-arousing, whereas the neutral ones are characterised by their low-arousal level. However, when the valence and arousal dimensions of stimuli have been more systematically taken into
account, differential effects of those dimensions have been observed on several memory measures. Thus, Bradley et al. (1992, Exp. 1) found that high-arousing images were more likely recalled than low-arousing ones, both in immediate and delayed memory tests. In contrast, valence only affected immediate tests. Fernández-Rey and Redondo (2007), with respect to the valence dimension, obtained a more conservative recognition bias for pleasant than unpleasant images; and with respect to the arousal dimension, the conservative bias was higher for nonarousing than arousing images. In this vein, van Strien, Lange-slag, Strekalova, Gootjes, and Franken (2009), including electrophysiological measures associated with memory, found that valence influenced rapid recognition memory and showed up its effect in the 200–300 ms and 300–400 ms time windows at right anterior sites; specifically, pleasant pictures elicited a larger positive-going deflection than unpleasant pictures (see too, Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006). However, arousal influenced sustained encoding; in fact, its effect was absent in the 200–300 ms time window, but was located posteriorly in the 300–400 ms time window, with midline maximal spreading from a more posterior location to a more central location (see too, Cuthbert et al., 2000; Schupp et al., 2004; for recent reviews of the effects of these dimensions on memory and attention, see Kensinger, 2009, and Olofsson, Nordin, Sequeira, & Polish, 2008).

Considering the relevance of clearly distinguish valence and arousal dimensions for a more appropriate methodological treatment of relationships between emotion and memory, in the present study we used both dimensions: valence (positive vs. negative pictures) and arousal (arousing vs. relaxing pictures; Osgood, Suci, & Tannenbaum, 1957), in order to examine their potential effects on ERP activity. Therefore, we had four types of stimuli, the three typically used (positive, negative, and neutral) and a fourth, the relaxing one, which represents the lowest end of the arousal dimension. Furthermore, we incorporated a methodological improve with respect to ERP analyses. A not widely used but frequently recommended strategy to detect and quantify the ERP components—Principal Components Analyses (PCA)—was employed in the present study. This strategy permit to avoid several types of misinterpretation that the exclusive use of traditional visual inspection of grand averages and voltage computation may entail (e.g., Chapman & McCrory, 1995; Coles, Gratton, Kramer, & Miller, 1986; Dien, Beal, & Berg, 2005; Donchin & Heffley, 1978; Fabiani, Gratton, Karis, & Donchin, 1987), as will be explained in detail in the Methods section.

On the other hand, regarding behavioural indices, research on emotional bias in memory has mainly focused on recognition memory performance (recognition accuracy and speed), but it has devoted quite less attention to how a person experiences the items recognised. Thus, another main objective of the present research was to investigate how the emotional bias in phenomenological judgements could be revealed. In particular, two different qualities of subjective experience can contribute to a recognition decision (Tulving, 1985): Participants can simply “know” (K) that an old item has been previously studied, or they can “remember” (R) its previous occurrence. Specifically, K judgements indicate that although the individual clearly recognises the “old” status of the item (it is familiar), he/she is unable to recover any specific information (contextual, affective, etc.) about the previous encounter with it. In contrast, R responses indicate that the recognised item triggers the conscious recollection of some specific aspect of the episode (e.g., some image-based, affective or contextual association with its original presentation). Moreover, different variables have revealed interesting dissociations between R/K judgements assigned to retrieved items. Thus, variables that usually trigger conceptual, more elaborative processing tend to result in R judgements, whereas K judgements tend to be mainly associated with more perceptual, data-driven processing (e.g., Dewhurst & Conway, 1994; Gardiner, 1988; Gardiner, Gawlik, & Richardson-Klavehn, 1994; Gregg & Gardiner, 1994; Mäntylä, 1993, 1994; Perfect, Williams, & Anderson-Brown, 1995; Rajaram, 1993, 1996; Wippich, 1992).

However, few studies have been interested in exploring the impact of emotions on R/K judgements (e.g., using faces, Johansson et al., 2004; using images, Dolcos, LaBar, & Cabeza, 2005; Humphreys, Underwood, & Chapman, 2010; Ochsner, 2000; Sharot, Delgado, & Phelps, 2004). Ochsner (2000) found that recollection and R judgements were mainly enhanced by negative affect, whereas K responses increased for positive and decreased for negative images. Likewise, Humphreys et al.’s (2010) results indicated that negative pictures were more likely recollected than positive and neutral ones; and Sharot et al.
(2004) observed more \( R \) than \( K \) judgements for negative images, whereas neutral ones did not differ on \( R \) and \( K \) decisions (they did not use positive images). Also, Johansson et al. (2004) found that accurate recognition of negative faces was higher based on recollection and more frequently associated with \( R \) judgements, than positive and neutral faces, which were predominantly based on a feeling of familiarity. In contrast, Dolcos et al. (2005), including a long delay (1 year), found that the relevant variable for recollection was the arousal because arousing images were more frequently recollected than neutral ones, regardless of their valence content. Taking into account this variety of methods and results, we included in our experimental procedure the assessment of our participants’ \( R/K \) judgements associated with recognised images.

Summarising, the primary goal of our study was to examine the emotional bias of images, which varied in valence and arousal dimensions (negative, positive, neutral, and relaxing), in relation to both behavioural (accuracy and speed of recognition memory, and phenomenological \( R/K \) judgements) and electrophysiological (ERP) indices of recognition memory. Thereby, we examined temporally and spatially the ERP correlates of the old/new effect; in this regard, we predicted the effect to be reflected as enhanced ERP late positivities for “old” stimuli, since previous evidence appears to indicate that late activation is involved in the conscious and intentional discrimination of old from new items. More specifically, in line with the previously mentioned emotional bias observed in previous studies, we expected an effect of emotional arousal of “old” stimuli in the amplitudes of the old/new effect, reflecting better recognition memory for arousing than for nonarousing images. Also, we examined whether there was a differential recognition memory for positive and/or negative images, reflected as well in higher positivities in the amplitudes of the old/new effect either for positive or negative stimuli. On the other hand, we also expected a similar emotional bias for behavioural indices. That is, we anticipated a higher recognition accuracy (better discrimination) and faster speed (lower reaction times) for arousing images (positive and/or negative) than for nonarousing ones (neutral and relaxing) and, in turn, a higher assignation of \( R \) judgements to arousing recognised images than to nonarousing images, being the former more likely associated with recognition based on recollection (i.e., \( R \) judgements), whereas being the latter more likely related to recognition based on familiarity (i.e., \( K \) judgements).

Therefore, based on previous evidence, we were betting on a consistent emotional bias for the electrophysiological and behavioural indices measured.

**METHODS**

**Participants**

Thirty-two students from the Universidad Autónoma de Madrid voluntarily took part in the present study. The data from eight participants were excluded from the analyses, as will be explained later in the Recording section, the final number of participants thus being 24 (four men and 20 women). These 24 participants were aged between 20 and 35 years (\( M = 22.75, SD = 3.40 \)), and provided written informed consent to participate, reporting normal or corrected-to-normal visual acuity.\(^1\)

**Stimuli and procedure**

The stimuli consisted of 240 digitised colour photographs. Sixty of them were arousing-negative (\( A^- \)), 60 arousing-positive (\( A^+ \)), 60 neutral (\( N \)), and 60 relaxing (\( R \)). All the photographs were taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005) according to their reported scores on the valence and arousal dimensions. Serial numbers and descriptions of the selection of IAPS slides are included in Appendix 1.

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\(^1\) The nonhomogeneity between genders was due to the participants’ availability. It is true that there is evidence, although not always consistent, indicating relevant gender differences in neuroscience when emotional material is processed by participants (for a review, see Cahill, 2006). Nevertheless, our encoding task was very constrained (valence and arousal assessments for each presented image), the delay between study and test phases was not too long (20 min), and the demand of the retrieval test (old/new recognition) was not high. All these factors (constrained encoding instructions, short delays, and nondemanding retrieval tasks) seem scarcely sensitive to potential gender differences on emotional memory for discrete stimulus (for a review, see Kensinger, 2009). Nevertheless, we ran analyses eliminating the four men from the sample, and the resulting pattern was the same as when they were included; for that reason we decided to keep them in order to have a bigger sample.
The study phase of the experiment took place in a silent room. The subject sat alone in front of a computer screen, in which 120 of the 240 pictures were presented. Presentation time of each picture was 500 ms. The incidental task consisted of filling out a bidimensional scaling test for each of these 120 pictures, assessing their valence and arousal level, two affective dimensions that are widely considered to explain the principal variance of emotional meaning (Lang, Greenwald, Bradley, & Hamm, 1993; Osgood et al., 1957; Smith & Ellsworth, 1985). In order to facilitate the participants’ assessments, valence and arousal scale levels used ranged from 1 to 5, with 1 = “very negative” and 5 = “very positive” (valence), and 1 = “very relaxing” and 5 = “very arousing” (arousal). This task was not explicitly related to memory, what allowed the incidental encoding of the images and, at the same time, permitted to validate the previous IAPS ratings of the images for our sample, so that we would count with our participants’ particular assessments on the selection of images we made from IAPS. These 120 pictures were used as “old” stimuli in the test phase of the experiment, and the 120 nonrated pictures were the “new” stimuli. Therefore, eight different types of stimuli were established: −new, A + new, R new, N new, A − old, A + old, N old, and R old. In order to avoid possible differential effects on incidental encoding due to the physical characteristics of the images, the two blocks of 120 stimuli were counterbalanced, so that each one of them was new for one half of the sample, and old for the other half. Average duration of this part of the experiment was 30 min.

Immediately after the study phase, participants were placed in an electrically shielded, sound-attenuated room. Once the electrodes had been placed on the participant’s scalp, the experimenter read aloud the instructions for this test phase of the experiment. Participants were told that for each item they first had to make a recognition decision and then a phenomenological judgement (R/K), and they should make those decisions as fast as they were able but, at the same time, being as accurate as they were able. R/K instructions were based on those used by Gardiner, Java, and Richardson-Klavehn (1996); Pérez-Mata, Read, & Díges, 2002; Read, 1996).\(^2\) Average duration of this part of the procedure was 20 min, this being the time interval between the study phase and the test phase.

Next, a block of eight training trials was presented. Though the pictures were all new in this training phase, participants were told to respond as though some of the trials were new and some were old-R and old-K. After the block of training trials, the 240 pictures (120 already seen in the study phase and 120 new ones) were presented, in six blocks of 40. Each picture was shown for 220 ms, the interstimulus interval being 3500 ms. The order in which the images were presented was set by means of semirandom criteria, in such a way that more than two consecutive pictures of the same emotional category or new/old condition were never presented. Blocks were presented with a 1-min rest period between them. Subjects were told to stare at the centre of the screen and to blink only after they heard the beep (1050 ms after stimulus onset), in order to control eye-movement interference. The assignment of left- and right-hand buttonpresses to new and old responses was counterbalanced across participants. Likewise, one half of the sample pushed once to make R judgements and twice to make K judgements, whereas the other half pushed once for K judgements and twice for R judgements. Once the recording phase was finished, subjects were asked to assess, with the same procedure as in the study phase, the 120 new pictures (i.e., those not seen in the study phase). Therefore, each subject rated all 240 stimuli. The IAPS normative ratings and our

\(^2\) Participants were read the following instructions: “You are going to see some pictures. Some of them are old (you saw them in the previous phase) and some are new (you didn’t see them in the previous phase). As soon as the picture is presented, if you recognize it as old, please press the right button of the keypad you are holding (recognition decision). If you consider that the picture is new, push the left button on the keypad. After that, when the picture disappears you will hear a beep, and then, only if the picture is old, you must push the button again, once if you remember the image or twice if you know you have seen the picture before. Assign an R (remember) judgement to a specific image if you can recollect information associated with it, such as the approximate moment in which it was presented or what you thought or felt when you saw it. However, if you have a strong feeling that the image has appeared on the screen before, but you cannot recall any of these associated data, then assign a K (know) judgement.” Also, it was emphasized that these judgements were not related to confidence estimates.
participants’ ratings distinguishing men and women are included in Appendix 2.

**Recording**

Behavioural activity was recorded using a two-button keypad whose electrical output was continuously digitised at a sampling rate of 800 Hz. Electroencephalographic (EEG) activity was recorded using an electrode cap (ElectroCap International) with tin electrodes. The software employed for registering and analysing the EEG was programmed with Visual Basic in our laboratory (this software has been successfully employed in previous studies: e.g., Albert, López-Martín, & Carretié, 2010; Carretié, Hinojosa, López-Martín, & Tapia, 2007; Carretié, Hinojosa, Mercado, & Tapia, 2005; Tapia et al., 2008). Thirty electrodes were placed at the scalp following the International 10-20 system homogeneous distribution. All scalp electrodes were referenced to the nosetip. Electrooculographic (EOG) data were recorded supra and infraorbitally (vertical EOG), as well as from the left versus right orbital rim (horizontal EOG), in order to detect and control the ocular interferences. Electrode impedances were always kept below 5 kΩ. A bandpass filter of 0.3 to 40 Hz was applied. Recordings were continuously digitised at a sampling rate of 200 Hz throughout the recording session. The continuous recording was divided into 1000 ms epochs for each trial, beginning 200 ms before stimulus onset. Visual inspection was carried out in order to delete epochs containing eye movements or blinks. Trials for which subjects responded either out of time (2500 ms) or erroneously were also eliminated. Data from eight participants had to be removed from the final analysis because the number of accepted trials was under 25 in at least one of the emotional categories. The mean number of accepted trials for each of these categories was 40.29 \((A-; SD = 2.87)\), 49.46 \((N; SD = 2.76)\), 50.54 \((R; SD = 2.61)\), and 51.46 \((A+; SD = 2.67)\).

**Data analyses**

**Valence and arousal ratings.** First, in the Results section, we present our participants’ valence and arousal assessments of the IAPS images used in the study. Two-way repeated-measures analyses of variance (ANOVAs) were computed for valence and arousal assessments, using emotion (four levels: \(A-, A+, R, \text{ and } N\)) and type of item (two levels: new and old) as factors. The Huynh-Feldt (HF) correction was applied to adjust the degrees of freedom of the \(F\)-ratios. Post hoc comparisons were also made to determine the significance of pairwise contrasts, using the Bonferroni procedure \((alpha = .05)\).

**Behavioural data.** One-way repeated measures analyses of variance (ANOVAs) on accuracy recognition (discrimination and response bias statistics), reaction time, and \(R/K\) judgement measures with respect to emotion (four levels: \(A-, A+, R, \text{ and } N\)) were carried out. Specifically, a signal-detection approach based on Green and Swets (1966/1974) was applied. We employed the TDS-EXPER software for Windows (Reales & Ballesteros, 2006), specifically developed for calculating the TDS statistics (discrimination and \(c\)) in typical scores. Thus, we analysed discrimination \(d' = Z(\text{false alarm}) - Z(\text{hit})\) and response bias \([c = -0.5 (Z(\text{false alarm}) + Z(\text{hit}))]\) measures based on a parametric model. The greater the separation between the noise distribution and the signal distribution, the better the discrimination between the two and a higher \(d'\) value will be obtained. However, the closer were together the two distributions, the more difficult the discrimination and the lower the \(d'\) value. Thus, this measure can vary between 0 and infinity. On the other hand, when false alarm proportion and miss proportion are equal, the \(c\) value will be 0; when false alarm proportion exceeds the miss proportion, the \(c\) value will be negative; and when false alarm proportion is lower than miss proportion, the \(c\) value will be positive. Thus, the \(c\) values can vary like those of \(d'\), but they have 0 at the midpoint of the two distributions. The Huynh-Feldt (HF) epsilon correction was applied to adjust the degrees of freedom of the \(F\)-ratios where necessary, and post hoc comparisons to determine the significance of pairwise contrast were performed using the Bonferroni procedure \((alpha = .05)\).

**ERP data**

**Detection and quantification of ERP components.** In the present study, components explaining most ERP variance were detected and quantified through covariance-matrix-based temporal principal component analysis (tPCA).
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 subjacent components (traditional grand averages often show components in a distorted way, and may even fail to show some of them). In brief, tPCA computes the covariance between all ERP time points, which tends to be high between those time points involved in the same component, and low between those belonging to different components. The solution is therefore a set of independent factors made up of highly covarying time points, which ideally correspond to ERP components. Temporal factor score, the tPCA-derived parameter in which extracted temporal factors may be quantified, is equivalent to amplitude. In this study, the decision of the number of factors to select was based on the Scree test (Cliff, 1987). Extracted factors were submitted to Varimax rotation.

Analyses of the experimental effects on ERP measures. Repeated-measures ANOVAs on temporal factors scores with respect to emotion (four levels: A-, A+, R, and N), type of item (two levels: new and old), and electrode location (30 levels) were carried out. The Huynh-Feldt (HF) epsilon correction was applied to adjust the degrees of freedom of the F-ratios where necessary, and post hoc comparisons to determine the significance of pairwise contrast were performed using the Bonferroni procedure (alpha = .05).

Source-location data. In order to three-dimensionally locate the cortical regions that were sensitive to the experimental effects, standardised low-resolution brain electromagnetic tomography (sLORETA; Pascual-Marqui, 2002) was applied to temporal factor scores. sLORETA is a three-dimensional, discrete linear solution for the EEG inverse problem. Although, in general, solutions provided by EEG-based source-location algorithms should be interpreted with caution due to their potential error margins, LORETA solutions have shown significant correspondence with those provided by haemodynamic procedures in the same tasks (Dierks et al., 2000; Vitacco, Brandeis, Pasqual-Marqui, & Martin, 2002). Moreover, the use of tPCA-derived factor scores instead of direct voltages (which leads to more accurate source-localisation analyses: Carretié et al., 2004) contributes to reducing this error margin. Solutions were projected on the Montreal Neurological Institute (MNI) standard brain.

RESULTS

Valence and arousal ratings

Table 1 shows the means and standard error of means on valence and arousal dimensions for each type of image assessed by participants. The two-way repeated measures ANOVAs with emotion (A-, A+, R, and N) and type of item (new and old) yielded no significant effects for type of item factor or for the Emotion × Type of item interaction in either of the emotional dimensions (valence and arousal). Significant differences for the emotion factor were observed in both valence, $F(3, 69) = 146.32$, HF corrected $p < .001$, and arousal, $F(3, 69) = 100.40$, HF corrected $p < .001$. Post hoc contrasts indicated that, among new and old images, valence levels showed A+ to be equal to R, while these two were significantly higher than N and A-, and, in turn, N were significantly higher than A- [i.e., $(A+ = R) > N > A-]$; on the other hand, there was a continuum for arousal levels from $-A$ to R, whereby A- were significantly higher than A+, A+ were significantly higher than N, and the latter were significantly higher than R [that is, $A- > A+ > N > R$].

Behavioural data

Memory performance. Table 2 shows an overview of participants’ recognition memory perfor-

<table>
<thead>
<tr>
<th></th>
<th>A - new</th>
<th>N new</th>
<th>R new</th>
<th>A + new</th>
<th>A - old</th>
<th>N old</th>
<th>R old</th>
<th>A + old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence</td>
<td>1.86 (0.11)</td>
<td>3.08 (0.03)</td>
<td>3.81 (0.09)</td>
<td>4.02 (0.07)</td>
<td>1.82 (0.10)</td>
<td>3.08 (0.03)</td>
<td>3.91 (0.07)</td>
<td>4.06 (0.09)</td>
</tr>
<tr>
<td>Arousal</td>
<td>4.22 (0.07)</td>
<td>3.09 (0.03)</td>
<td>2.53 (0.11)</td>
<td>3.83 (0.09)</td>
<td>4.28 (0.08)</td>
<td>3.15 (0.05)</td>
<td>2.59 (0.11)</td>
<td>3.89 (0.09)</td>
</tr>
</tbody>
</table>
Recall. The one-way repeated-measures ANOVA with emotion as the factor (A - , A + , R, and N) revealed its main effect for $d'$, $F(3, 69) = 3.34$, $p < .05$. Bonferroni post hoc tests showed a better discrimination for A - stimuli than for R stimuli, but the remaining comparisons were not significant ($p > .05$). Moreover, the analysis of $c$ revealed no significant effect involving the factor emotion ($F < 1$).

Reaction times. Table 3 shows the reaction time for old items (hits and misses) and for new items (correct rejections and false alarms). Outliers, defined as responses above 2500 ms or below 200 ms, were ignored in the analyses. The one-way repeated measures ANOVA (emotion: A - , A + , R, and N) on reaction-time measures showed the emotion effect only for hits, $F(2.8, 65.1) = 4.88$, $p < .01$, and correct rejections, $F(2.7, 62.5) = 5.24$, $p < .01$. Bonferroni post hoc tests pointed to faster hits for A + than N stimuli ($p < .05$), and marginally faster for A + than A - stimuli as well ($p = .08$); in contrast, the correct rejections were slower for A + images than for the remaining images ($ps < .01$). No other comparisons were significant.

R/K judgements. Table 4 shows mean proportions (and SD) of remember (R) and know (K) judgements assigned to hits in the memory performance test. On R judgements, the one-way repeated measures ANOVA showed significant effects of emotion, $F(2.9, 66.3) = 9.95$, HF corrected, $p < .001$. Bonferroni post hoc tests revealed that arousing stimuli (A - and A +) received more R judgements than nonarousing ones (N and R stimuli) ($ps < .05$). Complementarily, for K judgements, the effect of emotion, $F(2.6, 60.2) = 9.87$, HF corrected, $p < .001$, indicated that nonarousing images (N and R) were associated more frequently with K judgements than arousing images (A - and A +) ($p < .05$). Thus, at first sight, there were more R judgements assigned to nonarousing images than to arousing ones. However, the probability of making K responses on the basis of familiarity, which can be calculated by the formula 

$$
R/K = \frac{R}{R + K}
$$

(where $K$ are the “know judgements” and $R$ are the “remember judgements”; Yonelinas & Jacoby, 1995), did not differ across emotional charges of stimuli ($ps > .05$, see Table 4).

ERP data

Figure 1 shows three grand averages once the baseline value (prestimulus recording) had been subtracted from each ERP (baseline correction). These grand averages correspond to frontal, central, and parietal scalp areas (Fz, Cz, and Pz, respectively). As a consequence of the application of the tPCA (see Method section for details), six temporal factors (TFs) were extracted from the ERPs (Figure 2).

**Table 2**

Mean (and SD) of correct recognition to: old items or hits (H) and new items or correct rejections (CR); mean (and SD) of recognition errors to: old items or misses (M) and new items or false alarms (FA); and measures of discrimination ($d'$) and response bias ($c$)

<table>
<thead>
<tr>
<th>Emotion</th>
<th>H</th>
<th>CR</th>
<th>M</th>
<th>FA</th>
<th>$d'$</th>
<th>$c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>27.04 (6.64)</td>
<td>26.79 (5.93)</td>
<td>3.17 (2.71)</td>
<td>1.08 (0.88)</td>
<td>3.48 (0.89)</td>
<td>0.34 (0.48)</td>
</tr>
<tr>
<td>Neutral</td>
<td>24.54 (10.52)</td>
<td>29.38 (11.77)</td>
<td>2.79 (2.34)</td>
<td>1.50 (1.45)</td>
<td>3.50 (1.07)</td>
<td>0.26 (0.55)</td>
</tr>
<tr>
<td>Relaxing</td>
<td>24.88 (6.02)</td>
<td>26.00 (5.52)</td>
<td>5.63 (3.13)</td>
<td>2.25 (2.36)</td>
<td>2.67 (0.94)</td>
<td>0.26 (0.44)</td>
</tr>
<tr>
<td>Positive</td>
<td>26.17 (2.50)</td>
<td>26.83 (2.24)</td>
<td>2.88 (2.49)</td>
<td>2.25 (2.05)</td>
<td>3.28 (1.15)</td>
<td>0.16 (0.47)</td>
</tr>
</tbody>
</table>

**Table 3**

Mean reaction times (and SD) for old items: hits (H) and misses (M); and for new items: correct rejections (CR) and false alarms (FA) on recognition test

<table>
<thead>
<tr>
<th>Emotion</th>
<th>H</th>
<th>CR</th>
<th>M</th>
<th>FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>1209.10 (155.30)</td>
<td>1202.95 (152.23)</td>
<td>1420.96 (281.93)</td>
<td>1345.76 (421.82)</td>
</tr>
<tr>
<td>Neutral</td>
<td>1235.90 (160.13)</td>
<td>1210.40 (153.99)</td>
<td>1345.28 (286.35)</td>
<td>1209.01 (303.48)</td>
</tr>
<tr>
<td>Relaxing</td>
<td>1210.93 (153.91)</td>
<td>1208.59 (156.38)</td>
<td>1408.71 (234.42)</td>
<td>1359.38 (361.09)</td>
</tr>
<tr>
<td>Positive</td>
<td>1183.84 (156.77)</td>
<td>1249.34 (149.74)</td>
<td>1408.56 (279.64)</td>
<td>1390.64 (328.40)</td>
</tr>
</tbody>
</table>
The next task was to detect any effect of emotion (A−, A+, R, and N) and/or type of item (new and old) on the six components extracted by tPCA. For this purpose, ANOVAs on temporal factor scores (directly related to amplitudes, as previously indicated) were carried out. The first relevant contrast concerned type of item, and set out to detect those ERP components sensitive to the old/new effects. Analyses yielded significant differences in Factor 1, $F(1, 23) = 7.83$, $p < .05$, and Factor 4, $F(1, 23) = 8.32$, $p < .01$, amplitudes to old stimuli being greater than those to new stimuli in both cases (Figure 2). The next step was to test whether this old/new effect was modulated by the emotional content in any of those factors. Factors were type of item (two levels: new and old), emotion (four levels: A−, A+, R, and N), and electrode location (30 levels). Significant results were only found for Factor 4 (peaking at 745 ms). Figure 3 shows mean factor scores of Factor 4 for each electrode location, in the form of a scalp map. Factor peak latency and topography characteristics (see Figures 2 and 3) associate Factor 4 (peaking at 745 ms) with the wave labelled LPC in grand averages (Figure 1).

Specifically, the Type of item × Emotion × Electrode location interaction was significant, $F(87, 2001) = 1.50$, HF corrected $p < .05$. Bonferroni post hoc tests on the interaction revealed greater positivities for old than for new items for both A− and A+ items (see Figure 4). This pattern was observed at frontal, central, and

![Figure 1](image-url)
parietal sites. Old/new differences for \( R \) and \( N \) items were not significant (\( p > .05 \) in all channels).

**Source-location data.** The next step was to locate three-dimensionally the cortical sources of LPC in order to determine the origin of the

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**Figure 2.** Factor loadings after Varimax rotation. Temporal Factor 4 (LPC), which is sensitive to the experimental effects, is drawn in black.

**Figure 3.** Mean factor scores of Temporal Factor 4 (LPC) for each condition in the form of scalp map. C1 = Negative new; C2 = Neutral new; C3 = Relaxing new; C4 = Positive new; C5 = Negative old; C6 = Neutral old; C7 = Relaxing old; C8 = Positive old. [To view this figure in colour, please visit the online version of this Journal.]
previously described experimental effects. To this end aim, sLORETA was applied to LPC amplitudes (see Method section for details). As can be seen in Figure 5, this analysis suggested the inferior parietal lobe/precuneus as the origin of the LPC.

### DISCUSSION

The main contribution of the present study was to investigate the effects of emotional valence and arousal of images on recognition memory through a variety of measures (electrophysiological and...
we obtained a ’’decisions (and others less explored as phenomenological and response bias) and speed (reaction times), assessed, as recognition accuracy (discrimination behavioural measures, some of those traditionally considered as the lowest extreme category in terms of arousal (i.e., relaxing stimuli) is included, people seem to be able to discriminate finely in the case of stimuli that tend to be at the endpoints of the arousal continuum, namely, better discrimination for negative images than for relaxing images, but they do not show differences of discrimination between these stimuli and others that could be located between the extremes of the continuum (e.g., neutral images). In our study, this result pattern is shown up when people are completing a recognition test, which may be a memory measure less sensitive to different grades of arousal. We will return to this point later when we discuss results for phenomenological judgements.

Other explanation for this lack of a clear emotional bias in our results could be the unbalanced sample—with regard to the gender—with only four male participants. Nevertheless, when we excluded these four participants from statistic analyses in order to test if there was some change in the result pattern, this pattern did not suffer any change. The IAPS normative ratings and our participants’ ratings are included in Appendix 2, showing that both groups, men and women, assessed emotional categories as expected. So, it does not look that the reduced number of male participants is responsible for the lack of emotional bias. To this empirical evidence from our data, we must add that constrained encoding instructions (task consisting in evaluating images in terms of valence and arousal dimensions), not too long delays (20 min), and nondemanding retrieval tasks (old/new recognition test) seem scarcely sensitive to potential gender differences on emotional memory for discrete stimulus (for a recent review, see Ken-
singer, 2009). However, we must be cautious and emphasise that female participants are the main contributors to our results and therefore the conclusions should be limited to the female population.

Other relevant factor is that the delay introduced between encoding and the memory test in the present study is not too long, but if we review the literature related, we observe a large diversity in the retention intervals used with discrete stimuli, which go from a few minutes (e.g., 2.5) until 1 year (in some exceptional case) (e.g., Dolcos et al., 2005; Fernández-Rey & Redondo, 2007; Humphreys et al., 2010; Inaba et al., 2005; Johansson et al., 2004; Koenig & Mecklinger, 2008; Langeslag & Van Strien, 2008; Maratos et al., 2000; Mackiewicz et al., 2006; Ochsner, 2000; Sharot et al., 2004; van Strien et al., 2009; Weymar et al., 2009). So, it is really difficult to compare studies and to assess the weight of this factor. Although we cannot discard the delay as an explanation, a 20-min delay should not be a problem for finding an emotional bias in the results, to the extent that with shorter delays the bias has been obtained for discrete stimuli. The characteristics of the experimental design we employed did not allow us to include this time interval as a variable that could affect the recognition of the emotional material. But the fact that memory for emotional material changes over time is indeed an important issue that should be taken into account in future researches through systematic manipulations of delays.

Finally, other alternative explanation for our findings could be attributable to the difference in the initial arousal assessments of the participants in the positive and negative categories of images (see valence and arousal ratings section). Unfortunately, discrepancies in ratings of positive and negative images are frequent when participants’ assessments are requested in order to form stimuli categories with the evaluations of the same people involved in experiments, instead of the IAPS normative ratings (Koenig & Mecklinger, 2008; Langeslag & van Strien, 2008; Weymar et al., 2009). Thus, in our study, insofar as participants’ response threshold is similar for the different stimuli presented, the initial difference in arousal between negative and positive images (assessed by our participants), together with the similar valence ratings in positive and relaxing stimuli (assessed by our participants as well), make us to be cautious in the interpretation of experimental effects observed. Therefore, future researches should try a finer selection of stimuli. Maybe, a way to resolve this problem is that, previous to the recollection of memory data, a separate sample of participants, with same socio-demographic characteristics of the experimental sample, assesses a large pool of IAPS images and, then, it could be possible to make a very rigorous selection of images for experiments. Obviously, this is not free of other problems (e.g., time, effort, human resources) but, likely, it would offer more guaranties about the stimuli nature and, thus, more reliable result interpretations.

Then, there are many factors that could be responsible for the unstable pattern shown in the emotional bias. As a matter of fact, an important methodological limitation of this area is the vast variability of designs, measures, materials, and procedures that make really difficult a direct comparison among studies and, in turn, it is very difficult to reliably track why on some occasions a clear emotional bias is found, whereas in other cases it is not observed. Actually, this variability makes very difficult to separate the weight of every singular relevant factor and establish a consistent pattern.

On the other hand, related to reaction time measure, it has been proposed that positive stimuli are usually associated with reliance on heuristics or schemas, whereas negative stimuli are linked to analytic and detailed processes, and these differences between stimuli could affect the type of information that people remember about positive and negative arousing experiences (Kensinger, 2009), and subsequently, how much time they might need for correct recognition of old positive-arousing stimuli. However, this explanation, though plausible because we observe a tendency to correctly recognise faster positive-arousing images than others, does not account for our results. First, because it seems that to correctly reject positive images is a slow process, however, and, second but not less relevant, since R judgements were attributed in equal measure to both types of arousing images (negative and positive), as we mention later.

Thus, regarding phenomenological measures, we found more R judgements associated with arousing stimuli (negative and positive) than nonarousing ones (relaxing and neutral). Thus, at first sight, the reduction of R responses for relaxing and neutral images seemed to be associated with an increase in K responses. However, when the familiarity contribution to K responses was considered by applying the formula suggested by Yonelinas and Jacoby (1995; see Table 4), the
emotional valence of stimuli did not affect the probability of making a $K$ judgement based on familiarity; that is, regardless of the arousal or valence nature of the stimuli, familiarity has the same weight for images judged as known.

However, an expected result is that arousal is mediating for $R$ judgement. Thus, arousing stimuli, as compared to nonarousing stimuli, are recognised with a “recollection taste”—the recognition responses are associated with retrieval of vivid and more or less specific information on the presentation time of images, which suggests that participants must be recollecting how they experienced those images. This result was expected, since it seems to us that arousing images are favoured at encoding insofar as these kinds of stimuli are more relevant to organisms than nonemotional or nonarousing ones. In one case, it is important to “remember” negative stimuli in order to execute avoidance behaviours when they are encountered again; in the other case, it is important to “remember” positive stimuli to execute approaching behaviours toward them.

In this vein, different recent researches are pointing out that sometimes emotional effects are only evident through qualitative responses, as phenomenological judgements, but not through quantitative responses, such as recognition performance (Dougal & Rotello, 2007; Humphreys et al., 2010; Ochsner, 2000; Sharot et al., 2004; for a review, see Kensinger, 2009). That is, phenomenological decisions look more sensitive to the emotional content of information than just old/new decisions and, then, for this measure we have obtained a clear emotional bias.

On the other hand, electrophysiological measures support our hypothesis for the LPC because this component has shown up the typical old/new effect and, at the same time, the effect was modulated by the emotional content of the pictures (it was enhanced for negative and positive images). More specifically, LPC indicates a late activation, which is associated more with retrieval based on recollection than that based on familiarity (Allan et al., 1998; Düzel et al., 1997; Paller & Kutas, 1992; Rugg & Nagy, 1989; Rugg et al., 1996; Rugg, Schloerscheidt, & Mark, 1998). For neutral and relaxing images, however, we do not clearly find the typical old/new effect. This absence of a significant effect for these categories could be attributed to the arousing emotional content of the other stimuli presented. In fact, previous studies have shown that the old/new effect seems to be reduced for neutral stimuli when emotional ones—whether they are pictures or words—are included in the experimental task (Dietrich et al., 2001; van Strien et al., 2009; Weymar et al., 2009). This fact could be due to a higher assignation of resources at encoding and/or to the distinctiveness of the resulting memory trace for stimuli that are considered biologically more relevant (positive and negative) than for neutral ones. The same could be applied in the case of relaxing stimuli, which are by definition nonarousing, and their recall can be considered less relevant in survival terms. On the other hand, the short display time at retrieval (220 ms) used in the present experiment could be another factor responsible for the divergence between our findings and the results from other experiments, where longer display times have been employed (e.g., 300 ms: Dietrich et al., 2001, and Düzel et al., 1997; 500 ms: van Strien et al., 2009; 3000 ms: Weymar et al., 2009), to the extent that during a longer display individuals more likely can make decisions based on controlled processes. Unfortunately, the 1000 ms time window employed in the experiment made not possible to explore the possible effects that could be found occurring 800 ms after the stimulus onset.

Additionally, source location analyses appear to indicate that the LPC presents a parietal source (precuneus). Curiously, the parietal cortex is frequently activated during episodic memory retrieval (for recent reviews, see Buchanan, 2007; Cabeza, Ciaramelli, Olson, & Moscovitch, 2008; Cavanna & Trimble, 2006; Vilberg & Rugg, 2008). Specifically, 11 functional imaging studies of episodic memory retrieval have shown significant activation of the precuneus (Cavanna & Trimble, 2006), and it has been established that one of the central roles for this region has to do with successful retrieval. As successful retrieval tends to be associated with recollection rather than familiarity (e.g., Henson, Rugg, Shallice, Josephs, & Dolan, 1999; using a source monitoring paradigm, Gilboa, Winocur, Grady, Hevenor & Moscovitch, 2004; and Lundstrom et al., 2003), it seems plausible to assume that the LPC is activated when people correctly recognise an old stimulus because they have some contextual information about its original presentation (but also see Henson et al., 1999; Yonelinas, Otten, Shaw, & Rugg, 2005). In this vein, event-related fMRI studies have found that some parietal regions, including the precuneus, show greater activity for recollection than for familiarity (Eldridge, Knowlton, Furmansky, Bookheimer,
Rajaram (1996) proposed a distinctiveness-fluency framework as an alternative to the conceptual-perceptual distinction, precisely because under some experimental conditions recollection and familiarity are sensitive in the same direction to manipulations (e.g., Gardiner et al., 1996; Wippich, 1992). From the perspective of this alternative framework, recollection is boosted by variables that enhance the distinctiveness of to-be-remembered items, such as generation and semantic processing (Gardiner, 1988), high imagery (Dewhurst & Conway, 1994), and low-frequency words (Dewhurst, Hitch, & Barry, 1998; Gardiner & Java, 1990), whereas other variables, such as masked recognition priming at test (Rajaram, 1993), and study–test modality matches (Gregg & Gardiner, 1994), enhance the fluency with which test items are processed. In this sense, the distinctiveness-fluency framework is consistent with the general pattern of findings so far observed using the R/K procedure (Dewhurst & Parry, 2000).

The findings obtained in the present study suggest that Rajaram’s (1996) framework can account for the effects obtained. Specifically, arousing stimuli correctly recognised are more frequently associated with a recollection experience (R judgement) and are characterised by an enhanced LPC, compared with nonarousing stimuli. The latter receive fewer R responses and elicit smaller LPCs. In general, when an item is correctly recognised and receives an R judgement, it means that the individual has enough information about the presentation context to allow him/her to intentionally reexperience the past event on retrieval. Further, this correlates well with a high LPC activation, which is related to the individual’s ability to consciously, intentionally, discriminate old from new items. In this sense, we have two kinds of measure, one behavioural and another electrophysiological, which seem to go in the same direction when the arousal nature of stimuli is considered: Arousing stimuli are distinctive enough because they have associated sufficient contextual richness to discriminate their true origin, which allows to reexperience them at retrieval and, in turn, to bring with an enhanced LPC activation. However, nonarousing stimuli are not so distinctive, and they are recognised by a fluency process that simply allows people to establish that the event was experienced, but without any contextual richness or reexperience; that is, they are “known”, but do not lead to an enhanced LPC activation. As we have pointed out, this pattern of results has an adaptive function in
our life, insofar as it enables us to distinguish what is relevant (in terms of avoidance and approach) from what is not.

Our results seem quite clear with respect to a consistent arousal bias in phenomenological and electrophysiological measures, but not in the traditional measures of recognition tests (accuracy and reaction times). This result pattern appears pointing out a differential sensitiveness of the measures used in our study with respect to the emotional content of stimuli. So that, future studies should combine various indices (e.g., phenomenological decisions, accuracy and speed of recognition, and ERP activity) with a view to obtain a comprehensive picture of this research field, and to obtain direct empirical evidence about the roles played by the LPC and the precuneus in this situation. In fact, one limitation of our study is the lacking of ERP measures for R/K judgements due to a methodological problem (number of trials). For the moment, there is a gap in the episodic memory research on how phenomenological experiences associated with emotional events are correlated with electrophysiological activity because there are no many studies involving all these measures considered together (e.g., Curran, 2000; Düzel et al., 1997; Rugg, Mark, et al., 1998; Rugg et al., 1996; Rugg, Schloerscheidt, Mark, 1998; Schaefer, Pottage, & Rickart, 2011; Smith, 1993; Spencer, Vila Abad, & Donchin, 2000; Tendolkar, Ruhrmann, Brockhaus, Pukrop, & Klosterkötter, 2002; Troll, Friedman, Ritter, Fabiani, & Snodgrass, 1999). Results obtained so far seem to indicate that K judgements tend to be correlated with greater positivity for old stimuli than for new ones, which is maximal at mid-frontal scalp sites between approximately 300 and 500 ms latency (early portion of the old/new ERP effect). However, in the case of R judgements, this positivity has a left parietal maximum and onsets around 400–500 ms poststimulus (later portion or LPC; Düzel et al., 1997; Smith, 1993; Troll et al., 1999; but see Schaefer et al., 2011; and Spencer et al., 2000). This pattern is pointing out an earlier activation for know decisions than for remember decisions, that might denote more controlled processes associated with remember answers.

Research that is currently being carried out by our group has modified the experimental methods in order to obtain reliable ERP recordings for R/K judgements for both verbal and pictorial stimuli by increasing the number of stimuli so that we can count with enough trials belonging to each type of phenomenological responses to analyse. We are also carrying out a project through which we pursue to build up an emotional data base with pictures and words that will be assessed in valence and arousal by samples sociodemographically closer to experimental participants; these new materials will allow us to count with more reliable emotional stimulation to overcome some of the methodological limitations identified in this research area. Moreover, from an applied perspective, all of these relationships among emotional content of stimuli, behavioural (typical memory tests and phenomenological judgements) and electrophysiological measures are important for understanding clinical problems (e.g., Bremner et al., 1999; Carretié et al., 2005; Gorman, Kent, Sullivan, & Coplan, 2000; López-Martín, Albert, Fernández-Jaén, Pérez-Mata, & Carretié, 2008; Reiman, 1997; Tendolkar et al., 2002), and may also have relevant forensic implications (e.g., Christanson, 1992a; Kiehl, Hare, McDonald, & Brink, 1999; Raine et al., 1998).

Original manuscript received March 2011
Revised manuscript received July 2011
First published online November 2011

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**APPENDIX 1**

Serial numbers and descriptions from the IAPS of the sets of slides used in the experiment

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
<th>Relaxing</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kittens</td>
<td>1030 Snake</td>
<td>1602 Butterfly</td>
<td>2190 Man</td>
</tr>
<tr>
<td>Jaguars</td>
<td>1050 Snake</td>
<td>1603 Butterfly</td>
<td>2191 Farmer</td>
</tr>
<tr>
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<td>1111 Snakes</td>
<td>1620 Sprgbok</td>
<td>2214 NeutMan</td>
</tr>
<tr>
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<td>1120 Snake</td>
<td>1670 Cow</td>
<td>2372 Girl</td>
</tr>
<tr>
<td>Baby</td>
<td>1121 Lizard</td>
<td>1731 Lion</td>
<td>2381 Girl</td>
</tr>
<tr>
<td>Father</td>
<td>1201 Spider</td>
<td>1740 Owl</td>
<td>2383 Factoryworker</td>
</tr>
<tr>
<td>Children</td>
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<td>2393 Man</td>
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<td>1900 Fish</td>
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<td>2055 ManInPool</td>
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<td>6190 Aimedgun</td>
<td>5593 Sky</td>
<td>7030 Pole</td>
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APPENDIX 2

Mean (and sd) of valence (1, negative to 9, positive) and arousal (1, calming to 9, arousing) taken from the IAPS normative ratings and from the assessments given by the experimental subjects to the 4 emotional categories (A+ = Arousing Positive; A− = Arousing Negative; N = Neutral; R = Relaxing). Scores from our scale that ranged from 1 to 5, have been transformed to the IAPS scale (1–9).

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<th>Neutral</th>
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