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Explicit and Spontaneous Retrieval of Emotional Scenes: Electrophysiological Correlates

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When event-related potentials (ERP) are measured during a recognition task, items that have previously been presented typically elicit a larger late (400–800 ms) positive potential than new items. Recent data, however, suggest that emotional, but not neutral, pictures show ERP evidence of spontaneous retrieval when presented in a free-viewing task (Ferrari, Bradley, Codispoti, Karlsson, & Lang, 2012). In two experiments, we further investigated the brain dynamics of implicit and explicit retrieval. In Experiment 1, brain potentials were measured during a semantic categorization task, which did not explicitly probe episodic memory, but which, like a recognition task, required an active decision and a button press, and were compared to those elicited during recognition and free viewing. Explicit recognition prompted a late enhanced positivity for previously presented, compared with new, pictures regardless of hedonic content. In contrast, only emotional pictures showed an old-new difference when the task did not explicitly probe episodic memory, either when making an active categorization decision regarding picture content, or when simply viewing pictures. In Experiment 2, however, neutral pictures did prompt a significant old-new ERP difference during subsequent free viewing when emotionally arousing pictures were not included in the encoding set. These data suggest that spontaneous retrieval is heightened for salient cues, perhaps reflecting heightened attention and elaborative processing at encoding.

Keywords: emotion, recognition, pictures, explicit, implicit

There is abundant evidence from memory research using event-related potentials (ERPs) that items that have been experienced before elicit a larger late (500–800 ms) centro-parietal positive potential than new items when presented in the context of a recognition test (for reviews see Friedman & Johnson, 2000; Rugg & Curran, 2007). Whether stimuli are emotionally arousing or neutral, differences in ERP positivity between old and new items has been reliably found during explicit recognition for words (Windmann & Kutas, 2001), faces (Johansson, Mecklinger, & Treese, 2004), and scenes (Koenig & Mecklinger, 2008; Versace, Bradley, & Lang, 2010; Weymar, Löw, Schwabe, & Hamm, 2010). The amplitude of the difference, however, is often affected by whether the postencoding task explicitly probes episodic memory or not (e.g., Rugg & Wilding, 2000).

For instance, old-new ERP differences are attenuated when old and new words are presented in the context of a semantic categorization task (Düzel et al., 1999; Rugg & Wilding, 2000). Using natural scenes, a robust old/new ERP difference was found during explicit recognition, but when old and new exemplars were simply viewed with no task, a significant old-new ERP difference was found only for emotional scenes (Ferrari et al., 2012). Assuming the late old-new ERP difference reflects retrieval from episodic memory (Rugg & Curran, 2007), these data suggest that not all postencoding tasks prompt episodic retrieval, and that emotional stimuli may be more likely to be spontaneously retrieved in the absence of explicit recognition.

In two experiments, we further investigated the brain dynamics of implicit and explicit retrieval. In Experiment 1, old and new pictures were presented in different instructional contexts following encoding: One group performed a semantic categorization task, in which the participant decided whether each picture included one person or more than one person and pressed a button indicating their decision. This task, like explicit recognition (and unlike free viewing), requires both an active decision and a motor response. Old-new ERPs measured during semantic categorization were compared to ERPs elicited in a group of participants who either made an explicit recognition decision (i.e., old/new) or simply viewed old and new pictures; both of these conditions are identical to those used by Ferrari et al. (2012). Including the new semantic categorization task allowed us to contrast old/new ERPs to those elicited during active retrieval and during free viewing.

Differences in ERP timing and topography have previously been suggested to index different mnemonic processes (Rugg & Curran, 2007). An early (300–500 ms) difference that is maximal over frontal sensors is often attributed to decisions that are based on familiarity (Rugg & Curran, 2007), while a later (>500 ms)

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difference that is maximal over central sensors has been attributed to explicit recollection, as it is enhanced by depth of processing, correct source judgments (e.g., Curran, Tepe, & Piatt, 2006; Rugg & Curran, 2007) and confidence ratings (Weymar, Löw, Melzig, & Hamm, 2009). Previous ERP studies have reported similar old/new differences in the late ERP for both emotional and neutral pictures on an immediate recognition test (Ferrari et al., 2012; Koenig & Mecklinger, 2008; Versace, Bradley, & Lang, 2006; Versace et al., 2010), whereas a larger old/new difference for emotional, compared to neutral, pictures has been reported after longer retention intervals (e.g., Schaefer, Pottage, & Rickart, 2011; Weymar et al., 2009). In Experiment 1, we assessed effects of task context on both early and late components of the ERP.

Of critical interest are ERP old/new differences for emotional and neutral pictures presented in the context of a semantic categorization (one or more people?) task, which does not explicitly probe episodic memory. Because a number of studies have reported old-new differences in implicit (or indirect) tasks (e.g., Guillem, Bicu, & Debruille, 2000; Kazmerski & Friedman, 1997), one hypothesis is that an old-new ERP difference will be found for both emotional and neutral pictures during categorization. If so, the previous null effect for neutral pictures during free viewing may simply reflect the lack of a requirement to process the picture. On the other hand, if spontaneous retrieval is more likely for affectively arousing cues when memory retrieval is not explicitly required, enhanced ERP positivity for old, compared to new, pictures will again be found for emotional, but not neutral, pictures in the semantic categorization task, paralleling the effects reported by Ferrari et al. (2012) during free viewing.

Experiment 1

Method

Participants. Participants were 76 healthy students (29 men, 47 women; mean age = 19.9 years; 8 left-handed) from a General Psychology course at the University of Florida (UF) who participated for course credit with normal or corrected-to-normal vision. All participants provided informed written consent for a protocol approved by the UF Institutional Review Board.

Materials and procedure. Overall, 72[1] photographs depicting people were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) consisting of 48 emotional pictures that included 24 unpleasant (violence); mean pleasure = 2.1, arousal = 6.3 and 24 pleasant (erotica; mean pleasure = 6.4; mean arousal = 6.1), and 24 neutral pictures that depicted people in everyday contexts (mean pleasure = 4.8; mean arousal = 3.4). Two sets of 36 pictures were matched based on pleasure and arousal ratings as well as semantic content and number of people in the picture (one or more). All pictures were presented in grayscale. During encoding, each of the two picture sets was shown to approximately half of the participants. Each picture was presented for 3,000 ms and followed by an intertrial interval (intertrial interval [ITI]) of 5,500, 6,000, or 6,500 ms. A fixation cross was present in all picture trials and ITIs to ensure that participants fixated the center of the screen.

Following encoding, one group of participants (6 men, 19 women) was instructed to decide if the picture depicted one person or more than one person, and, at picture offset, to press a button marked "one" or "more." A second group of participants (15 men, 10 women) was instructed to decide whether each picture has been presented earlier in the study, and, at picture offset, to press a button marked "yes" or "no." The assignment of left and right button presses to yes/no responses was counterbalanced across participants. A third group of participants (8 men, 18 women) was instructed to simply view each picture while it was on the screen.

Procedure. The participant was seated in a comfortable chair in a sound-attenuated, dimly lit room. After the geodesic net was placed on the head, each participant was instructed to view each picture while it was displayed on the monitor. No mention of a memory test was made (incidental encoding). Following a 5-min retention interval, in which the scalp impedance for each electrode was rechecked, old and new pictures were presented in the context of either semantic categorization, explicit recognition, or free viewing, depending upon group assignment.

EEG recording. EEG signals were recorded continuously from 128 electrodes using an Electrical Geodesic system and digitized at a rate of 250 Hz, using the vertex sensor (Cz) as recording reference. Scalp impedance for each sensor was kept below 50 kΩ, as recommended by the manufacturer guidelines. All channels were bandpass filtered online from 0.1 to 48 Hz. Offline, stimulus-synchronized epochs were extracted from 100 ms before to 1200 ms after picture onset and low-pass filtered (Butterworth filter) at 40 Hz and then submitted to the algorithm proposed by Junghöfer, Elbert, Tucker, and Rockstroh (2000) which is implemented in EMEGS software (Peyk, De Cesarei, & Junghöfer, 2011). Briefly, this procedure uses statistical parameters of the data to determine excluded channels and trials that are contaminated with artifacts (e.g., noise, movement or electrode artifacts). Specific sensors from specific epochs are removed based on three parameters of the distribution of measured voltages at each sensor including its absolute value, *SD*, and the maximum of the change gradient. Data for rejected sensors are replaced with a statistically weighted spherical spline interpolation from the full channel set (see Junghöfer et al., 2000).

Data analysis. ERPs were computed for each sensor and participant. Based on visual inspection of the waveforms as well as previous studies (Ferrari et al., 2012; Rugg & Curran, 2007), mean ERP amplitudes were analyzed in a 300–500 ms window over frontal brain sensors and a 500–700 ms window over central sensors. ERP data were analyzed in a mixed analysis of variance (ANOVA) involving task (3: recognition, categorization, viewing) as a between subject factor, and hedonic *content* (3: unpleasant, neutral, pleasant), and *memory* (2: old, new) as repeated measures. For effects involving repeated measures, the Greenhouse-Geisser procedure was used to correct violations of sphericity.

Hit rate (H), false alarm rate (FA) and recognition accuracy (Pr = H – FA) were analyzed in the recognition task. For ERPs in the explicit memory group, only trials with correct behavioral

[1] IAPS numbers: Unpleasant: 3000, 3001, 3010, 3051, 3059, 3060, 3068, 3069, 3120, 3191, 3225, 3261, 3530, 6313, 6315, 6350, 6561, 6571, 6838, 9420, 9421, 9433, 9900, 9921; Pleasant: 4007, 4085, 4180, 4210, 4220, 4290, 4490, 4505, 4520, 4525, 4530, 4559, 4647, 4658, 4659, 4660, 4668, 4669, 4687, 4693, 4695, 4697, 4698, 4800; Neutral: 2038, 2101, 2102, 2104, 2190, 2200, 2210, 2215, 2305, 2308, 2312, 2359, 2390, 2393, 2396, 2397, 2400, 2411, 2441, 2579, 2590, 2595, 2890, 9210.

responses (hits and correct rejections) were used in the averaged ERP data.[2]

Results

Performance. During explicit recognition, correct recognition of pictures was high when recognizing emotional (unpleasant: $M = .91$; pleasant: $M = .92$) and neutral scenes ($M = .90$), $F(1, 24)<1$. False alarms were few, with a slightly higher false alarm rate for emotional (unpleasant: .08; pleasant: .06) compared with neutral (.03) pictures, $F(1, 24) = 12.25$, $p < .01$. Nonetheless, consistent with the hit rate, correct discrimination (Pr) did not differ for emotional (.84) and neutral (.87) pictures.

During semantic categorization, in which participants reported whether there was one or more than one person in the picture, accuracy was near perfect (97%).

Event-related potentials. Figure 1 illustrates grand average ERPs for old and new pictures during semantic categorization, explicit recognition, and free viewing.

Early (300–500 ms) window. Overall, no significant difference in frontal positivity in the 300–500 ms window was found when viewing old and new pictures, $F(1, 73) = 2.42$, $p = .12$, and there were no other significant main effects or interactions. When tested separately, however, old pictures showed slightly less negativity over frontal sensors than new pictures during explicit recognition, $F(1, 24) = 3.36$, $p < .05$ (one-tailed), as illustrated in Figure 1 (top left) but not during categorization or free viewing (both Fs < 1).

Late (500–700 ms) window. In the later time window (500–700 ms), a significant main effect of memory was found over central brain regions, in which old pictures prompted enhanced positivity, compared to new, pictures, $F(1, 73) = 22.3$, $p < .001$. This main effect was qualified by a significant three-way interaction between Memory, Hedonic Content and Task, $F(4, 146) = 2.51$, $p < .05$ (Table 1). Figure 2 illustrates grand average ERP waveforms for emotional and neutral content when viewing old and new pictures during semantic categorization, explicit recognition, and picture viewing. Significant differences in centro-parietal positivity were found when viewing old, compared with new, pictures, for both pleasant $F(1, 73) = 18.15$, $p < .000$ or unpleasant content, $F(1, 73) = 10.47$, $p < .01$, which did not differ as a function of postencoding task (explicit recognition: $F(1, 24) = 8.45$, $p < .001$; categorization: $F(1, 24) = 4.05$, $p = .05$; picture viewing: $F(1, 25) = 14.78$, $p < .001$). Despite the nonsignificant interaction, however, when ERPs for old and new items in the semantic categorization task were tested separately, the old/new difference was reliable for pleasant, $F(1, 24) = 8.84$, $p < .001$, but not unpleasant pictures, $F(1, 24) = 1.40$, $p = .53$. For neutral pictures, the interaction of memory and task did not reach significance, $F(1, 73) = 2.17$, $p = .12$, but separate tests showed a significant old/new ERP difference for neutral pictures only in the context of explicit recognition, $F(1, 24) = 4.78$, $p < .05$ (Figure 2).

Overall, a heightened late positive potential (centro-parietal, 500–700 ms) was found when viewing emotional, compared with neutral, pictures regardless of whether old or new, $F(2, 146) = 84.96$, $p < .0001$.

Experiment 2

When a semantic categorization followed encoding, neutral pictures did not prompt an old-new difference in either early or late windows, and, replicating Ferrari et al. (2012), no old/new ERP differences were found when neutral pictures were simply viewed following encoding. Some studies, however, have reported ERP old/new differences for neutral stimuli presented in implicit memory tasks. For instance, using a postencoding task that required a decision whether an item depicted a natural or artificial object, old/new ERP differences have been reported for both words (e.g., Kazmerski & Friedman, 1997) and pictures (Küper, Groh-Bordin, Zimmer, & Ecker, 2012). One hypothesis is that the presence of emotional pictures in the encoding array may distract processing from the (less engaging) neutral scenes, affecting the probability of later spontaneous retrieval. For instance, many studies have found that emotional, compared to neutral, pictures prompt heightened attention, orienting, and arousal during encoding, as indexed by pronounced cardiac orienting, enhanced pupil dilation, slower probe reaction time (RT), better free recall, and so forth (e.g., Bradley, 1994, 2009; Lang & Bradley, 2010, for an overview). If spontaneous retrieval profits from elaboration at encoding, neutral stimuli may show evidence of spontaneous retrieval when not intermixed with emotional scenes during encoding.

Therefore, in Experiment 2, we tested whether neutral pictures show an old/new ERP difference during an implicit postencoding task (free viewing) when no emotionally engaging pictures are present in the encoding array. The same set of neutral pictures used in Experiment 1, which depicted people in everyday situations, were presented in the context of (potentially less interesting) pictures of everyday objects (e.g., plate, basket, etc.). Consistent with enhanced processing, larger late positive potentials have been reported when participants view neutral scenes depicting people, compared to objects (Ferri, Weinberg, & Hajcak, 2012; Weinberg & Hajcak, 2010).

We also tested whether the lack of an old/new ERP difference for neutral pictures during implicit retrieval might be due to less similarity among the exemplars in this set, compared to pictures of erotica or violence, in which individual exemplars shared more perceptual features. Greater similarity among exemplars could lead to a higher probability of spontaneously matching an encoded item, and could also prompt the slightly higher false alarm rate found for emotional pictures in Experiment 1. To assess this hypothesis, we included a third set of neutral pictures that depicted vegetation, in which exemplars shared similar features of leaves and branches. Thus, in Experiment 2, pictures of neutral people, objects, and vegetation (Figure 3 for sample pictures) were presented during encoding and ERPs measured during subsequent free viewing.

Method

Participants. Participants were 22 healthy students (9 men, 13 women; mean age = 19.1 years; one left-handed) from a

[2] Because ERP data for the explicit recognition group were analyzed using trials with correct performance (e.g., hits/correct rejections), we also analyzed ERPs for this group using all trials (irrespective of performance) to insure differences were not because of this factor. Because memory performance was quite high (i.e., >90%), however, results were identical to the differences found using correct trials only. Thus, old pictures prompted an enhanced late (500–700 ms) ERP positivity than new pictures, $F(1, 24) = 11.86$, $p < .01$, which was not modulated by emotional content, $F(1, 24) < 1$.

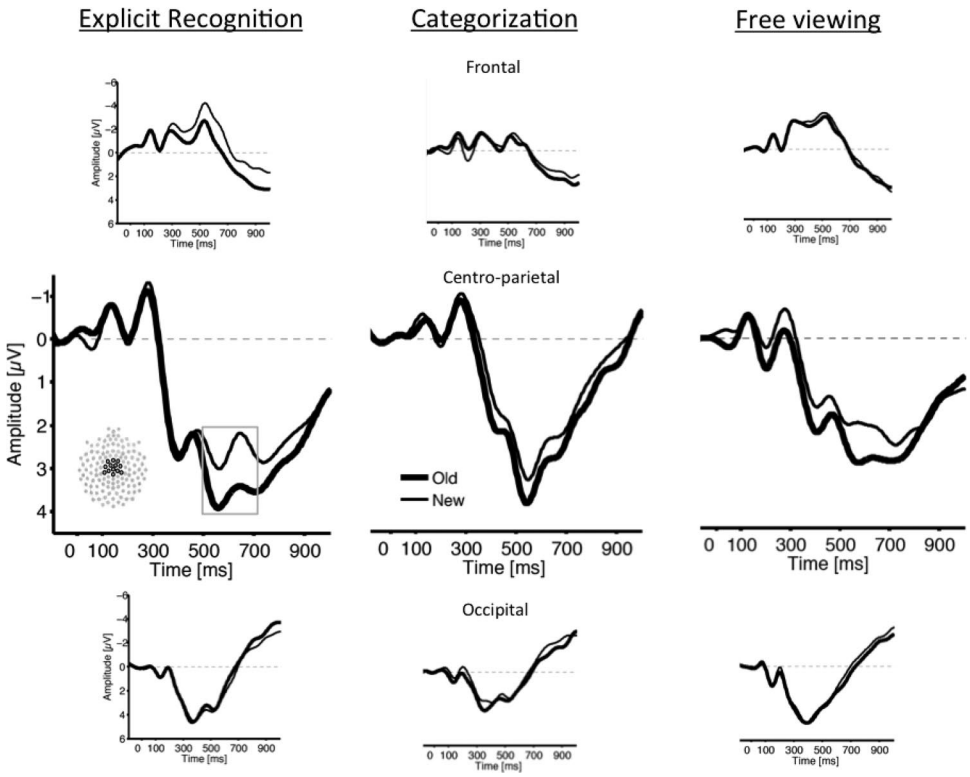

Figure 1. Grand average event-related potential (ERP) waveforms averaged over representative sensor clusters (midline frontal, centro-parietal, and occipital) for old (thick line) and new (thin line) pictures during explicit recognition (left), semantic categorization (middle) and free viewing (right). The inset in the left center figure illustrates the sensors in which differences in positivity when viewing old and new pictures was maximal; the time window (500–700 ms) used in the analyses is indicated by a box.

General Psychology course at the UF who participated for course credit, with normal or corrected-to normal vision. All participants provided informed written consent for the protocol approved by the UF Institutional Review Board.

Materials and procedure. Stimuli consisted of 72 neutral pictures taken from the International Affective Picture Series (IAPS; Lang et al., 2008) and the Emotional Picture Set (EmoPicS; Wessa et al., 2010) and included the same 24 pictures of neutral people in everyday contexts used in Experiment 1 (mean pleasure, arousal = 4.8, 3.4), as well as 24 pictures of objects (mean pleasure, arousal = 5.1, 3.3), and 24 pictures of vegetation (mean pleasure, arousal = 5.4, 2.7). Two sets of 36 pictures were matched based on category and mean pleasure and arousal ratings.

Procedure. The encoding procedure was identical to that described in Experiment I. Following encoding, old and new pictures were presented for free viewing in which the participant was instructed to simply view each picture while it was on the screen, and to maintain fixation at the center of the screen.

Results

Event-related potentials. Figure 4 illustrates grand average ERPs for old and new pictures depicting neutral people, objects, and vegetation.

Early (300–500 m) window: Overall, no significant main effect of memory was found over frontal sensors (300–500 ms), $F(1, 21)<1$ (see Figure 3, insets) and the interaction between picture content (people, objects, plants) and memory was not significant, $F(2, 42) < 1$.

Late (500–700 ms) window. A significant main effect of memory (old/new) was found for centro-parietal sensors in which old

Table 1
Mean Change (in μv) in a 500–700 ms Window for Centro-Parietal Sensors as a Function of Hedonic Content for Old and New Pictures During Explicit Recognition, Categorization, and Free Viewing (SEM)

	Explicit recognition	Semantic categorization	Free viewing
Old pictures			
Emotional	4.5 (.6)	3.8 (.4)	4.0 (.5)
Pleasant	5.1 (.7)	5.0 (.5)	4.9 (.6)
Unpleasant	3.9 (.6)	2.5 (.4)	3.0 (.4)
Neutral	1.8 (.5)	2.1 (.4)	.6 (.4)
New Pictures			
Emotional	3.5 (.6)	3.0 (.4)	2.9 (.4)
Pleasant	4.6 (.7)	3.8 (.5)	3.5 (.5)
Unpleasant	2.4 (.5)	2.2 (.4)	2.4 (.5)
Neutral	.7 (.5)	2.2 (.4)	.5 (.6)

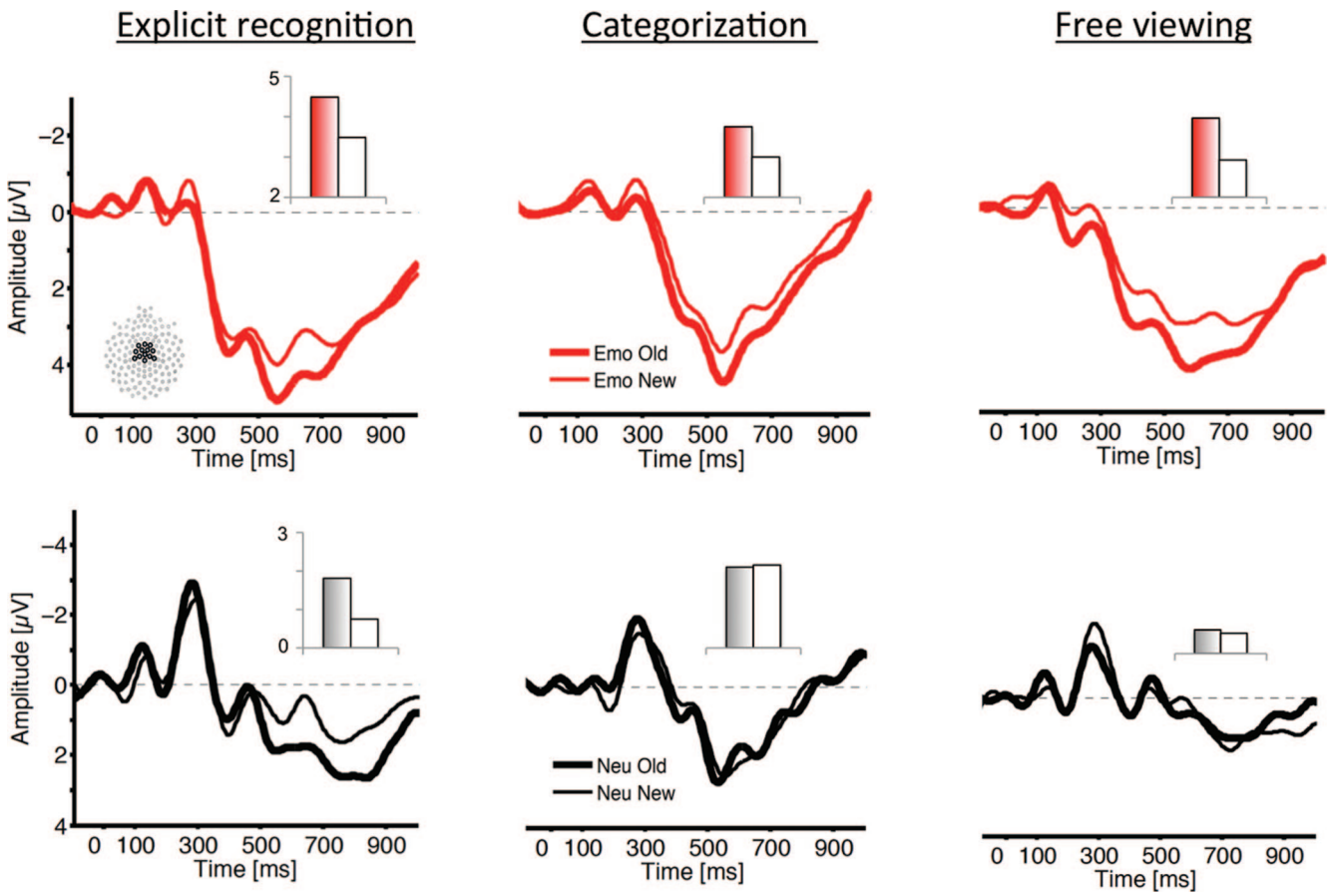

Figure 2. Grand average event-related potential (ERP) waveforms over central-parietal sensors when viewing old (thick line) and new (thin line) emotional (red) and neutral (black) pictures during explicit recognition (left), semantic categorization (middle) and free viewing (right). The inset in each figure illustrates the mean ERP (500–700 ms) when viewing old (filled) and new (empty) pictures.

pictures prompted enhanced positivity, compared to new, pictures, $F(1, 21) = 6.55$, $p = .02$. A priori comparisons indicated that neutral pictures depicting people in everyday contexts now showed a significant centro-parietal ERP old/new difference, $F(1, 21) = 6.55$, $p = .02$, unlike in Experiment 1. On the other hand, neither pictures of objects nor plants resulted in a difference in ERP amplitude for old and new stimuli (Figure 4).

Discussion

Enhanced centro-parietal positivity was found for both emotional and neutral pictures when presented in the context of an explicit recognition task (e.g., Koenig & Mecklinger, 2008; Versace et al., 2006, 2010; Weymar et al., 2009; Weymar, Löw, Modess, et al., 2010). In contrast, during semantic categorization, only previously presented emotional scenes were associated with greater ERP positivity than new scenes, and the difference was similar in time and scalp distribution to that found during explicit recognition. Replicating Ferrari et al. (2012), only emotional scenes also prompted a significant old-new ERP difference when the postencoding task involved free viewing, with the current data confirming that this is not merely due to the lack of a task, but persists when an active decision (i.e., categorization) and motor response is required. Taken together, the data are consistent with Ferrari et al.'s (2012) interpretation that at least some of the previously presented emotional scenes spontaneously trigger episodic memory retrieval in the absence of an explicit memory search.

When neutral pictures were presented in the context of affectively engaging scenes during encoding, there was no evidence of prior occurrence in the ERP when the task did not explicitly probe episodic memory. Thus, in Experiment 1, neutral scenes did not prompt a significant difference in late ERP positivity as a function of previous occurrence during either a semantic categorization task or during free viewing. It is important, however, the same neutral pictures, which depicted people in everyday contexts, did prompt a significant old/new ERP difference in Experiment 2 when encoded in the absence of emotionally engaging stimuli, and in a context of neutral objects and vegetation, neither of which elicited significant old-new ERP difference during subsequent viewing. Taken together, the data are not only consistent with previous studies that have reported finding late old-new ERP differences for neutral stimuli on implicit memory tasks (Kazmerski & Friedman,

Figure 3. Images available in the public domain illustrate the picture contents used in Experiment 2, depicting (1) people, (2) objects, and (3) vegetation.

1997; Küper, Groh-Bordin, Zimmer, & Ecker, 2012) but also indicate that spontaneous retrieval may be reflect differences in encoding processes such as depth of processing, degree of rehearsal, or other cognitive processes that result in a more elaborated memory representation.

Hintzman (2011) has proposed that spontaneous retrieval—what he calls "reminding"—is a routine occurrence in which cues spontaneously activate prior memory representations, grounding judgments of frequency, duration, temporal distance, and so forth. In their attention-to-memory account, Cabeza, Ciaramelli, Olson, and Moscovitch (2008) theorize that this type of bottom-up memory processing may involve specific activation of ventral, rather than dorsal, parietal cortex, a hypothesis they address using functional MRI (fMRI) methodology. Consistent with our theorizing, however, deeper processing at encoding has been found to prompt more frequent spontaneous retrieval of previously presented words in word association tasks (e.g., Ramponi, Richardson-Klavehn, & Gardiner, 2007; Richardson-Klavehn & Gardiner, 1998), and, when ERPs were measured during a repetition priming test, evidence of spontaneous retrieval was stronger for words with more semantic features (Rabovsky, Sommer, & Abdel Rahman, 2012). And, supporting the idea that emotional cues may naturally elicit more spontaneous retrieval are data showing that people report a higher number of spontaneous recollections after viewing emotionally engaging, compared to neutral, films when asked a few days later (Ferree & Cahill, 2009).

On the immediate recognition test in Experiment 1, memory performance was near the ceiling and did not differ for emotional and neutral pictures on this immediate test, as found previously (Versace et al., 2006, 2010). When memory is delayed (i.e., 1 week to 1 year), however, previous studies suggest that both memory performance and the late old-new ERP difference are enhanced for emotional, compared with neutral, pictures (Weymar et al., 2009, 2010; Weymar, Löw, & Hamm, 2011). Whether spontaneous retrieval of emotionally evocative cues will continue to be found on a delayed test is not clear. One hypothesis is that, following a delay, the categorization decision might overshadow implicit retrieval, reducing the old-new ERP difference for emotional pictures. On the other hand, because emotional pictures are both recalled and recognized better than neutral pictures even a year later (Bradley, Greenwald, Petry, & Lang, 1992; Dolcos, LaBar, & Cabeza, 2005; Weymar et al., 2011), and consistent with the adaptive advantage presumably conferred by involuntary reminding of motivationally relevant events (c.f., Berntsen, 2010), evidence of spontaneous retrieval during implicit tasks may continue to be found for emotional scenes even on a delayed test.

Whereas late old/new ERP differences were found during both explicit and implicit memory tasks, early frontal old/new ERP differences were weak and only apparent during the explicit recognition task in Experiment 1. Thus, no early differences over frontal sensors were found during any of the implicit tasks in either Experiment 1 or 2. Some investigators have proposed that an early frontal difference in the ERP indexes recognition decisions based on familiarity (Curran, Tepe, & Piatt, 2006), whereas later centroparietal ERP differences index decisions based on explicit episodic retrieval (e.g., Voss & Paller, 2008). The current data suggest only that modulation of early (frontal) ERPs is, at least for relatively complex natural scenes, apparent only in the context of a task that directly probes episodic memory, requiring an explicit decision regarding recognition.

Taken together, the current data suggest that spontaneous retrieval of previously encountered cues, in the absence of an explicit

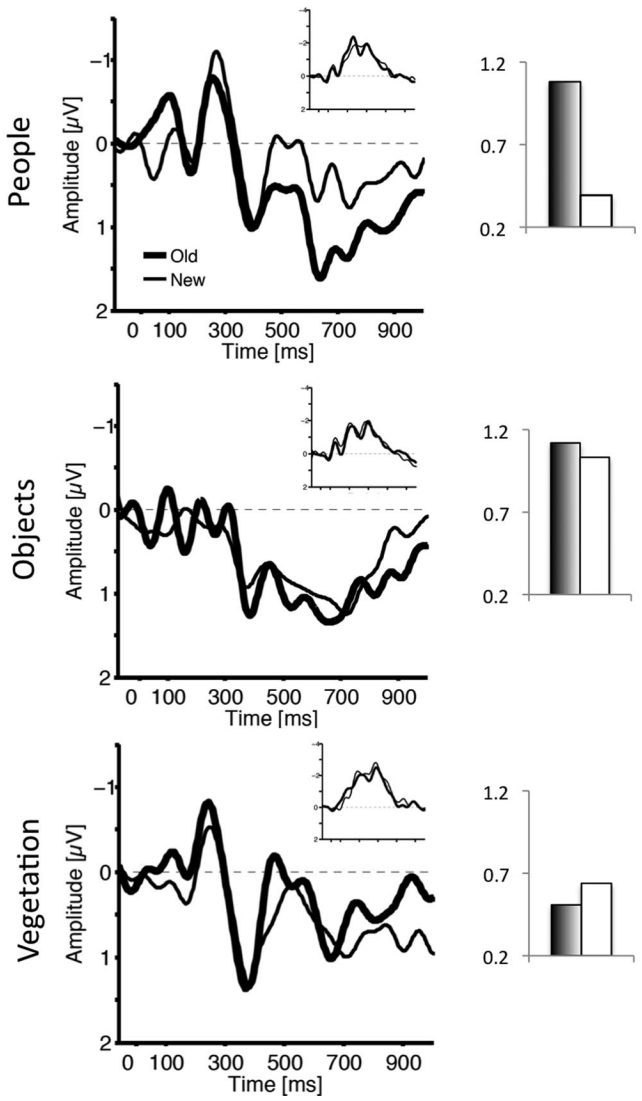

Figure 4. Grand average event-related potential (ERP) waveforms over centro-parietal sensors when viewing old (thick line) and new (thin line) neutral pictures of people, objects and plants during free viewing. The inset in each figure illustrates ERP waveforms for frontal sensors. The mean ERP (500–700 ms) over centro-parietal sensors when viewing old (filled) and new (white) pictures are displayed next to the waveforms.

episodic memory search, is more likely for stimuli that attract attention and deeper processing at encoding, which occurs "naturally" for affectively engaging scenes (Bradley, 2009). Involuntary reminding is indexed by a difference in late positivity (500–700 ms) in the ERP for old, compared with new, stimuli that is similar to that found during explicit recognition, and was apparent for emotional, particularly pleasant, pictures whether the implicit task involved semantic categorization or simply viewing the repeated items. For neutral pictures, on the other hand, evidence of spontaneous retrieval in the ERP during implicit retrieval was only apparent when no emotional scenes were present in the encoding array. Spontaneous retrieval of emotionally arousing cues, regardless of task context, is consistent with the hypothesis that both learning and memory processes have evolved to support the survival of the individual and the species.

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