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Emotion impairs extrinsic source memory—An ERP study

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ABSTRACT

Substantial advancements in understanding emotional modulation of item memory notwithstanding, controversies remain as to how emotion influences source memory. Using an emotional extrinsic source memory paradigm combined with remember/know judgments and two key event-related potentials (ERPs)—the FN400 (a frontal potential at 300–500 ms related to *familiarity*) and the LPC (a later parietal potential at 500–700 ms related to *recollection*), our research investigated the impact of emotion on extrinsic source memory and the underlying processes. We varied a semantic prompt (either "people" or "scene") preceding a study item to manipulate the extrinsic source. Behavioral data indicated a significant effect of emotion on "remember" responses to extrinsic source details, suggesting impaired recollection-based source memory in emotional (both positive and negative) relative to neutral conditions. In parallel, differential FN400 and LPC amplitudes (correctly remembered — incorrectly remembered sources) revealed emotion-related interference, suggesting impaired familiarity and recollection memory of extrinsic sources associated with positive or negative items. These findings thus lend support to the notion of emotion-induced memory trade off: while enhancing memory of central items and intrinsic/integral source details, emotion nevertheless disrupts memory of peripheral contextual details, potentially impairing both familiarity and recollection. Importantly, that positive and negative items result in comparable memory impairment suggests that arousal (vs. affective valence) plays a critical role in modulating dynamic interactions among automatic and elaborate processes involved in memory.

1. Introduction

Emotionally charged events—weddings, graduation ceremonies or painful breakups—are often remembered vividly after a long time. However, certain details (e.g., color of the napkin at the reception) of such emotional episodes can fade quickly or be remembered mistakenly. Distinctions have been drawn between memory for central items of an event (i.e., *item memory*) and memory for contextual details of the event (i.e., *source memory*). While convergent evidence indicates that emotion enhances item memory (Christianson, 1992; Hamann, 2001; Neisser & Libby, 2000), controversies arise concerning whether source memory could be similarly enhanced (Cook, Hicks, & Marsh, 2007; D'Argembeau & Van der Linden, 2004; Madan, Caplan, Lau, & Fujiwara, 2012). Some researchers propose that emotion enhances source memory by increasing overall attention and prioritizing binding of emotional items to their contexts (Hadley & MacKay, 2006; Revelle & Loftus, 1992). However, others suggest attentional trade-off between central emotional items and peripheral contextual details (Easterbrook, 1959; Laney, Campbell, Heuer, & Reisberg, 2004), which could compromise memory encoding and binding in emotional situations (Payne, Nadel, Britton, & Jacobs, 2004; Waring & Kensinger, 2011), resulting in impaired source memory.

Nevertheless, this controversy may be reconciled when the type of source details involved (i.e., *intrinsic* vs. *extrinsic*) is taken into account. Intrinsic source details refer to features that are integral parts of an item (i.e., *within-item* features), such as perceptual properties (e.g., shape of a car; color of a phone). Extrinsic source details consist largely of *external* features, involving between-item associations (e.g., the context in which the car or phone was seen). It is proposed that emotion boosts intrinsic (but not extrinsic) source memory by facilitating encoding and information binding of intrinsic source details (Hadley & MacKay, 2006; Kensinger, 2007, 2009; Mather, 2007; Revelle & Loftus, 1992); and indeed, evidence

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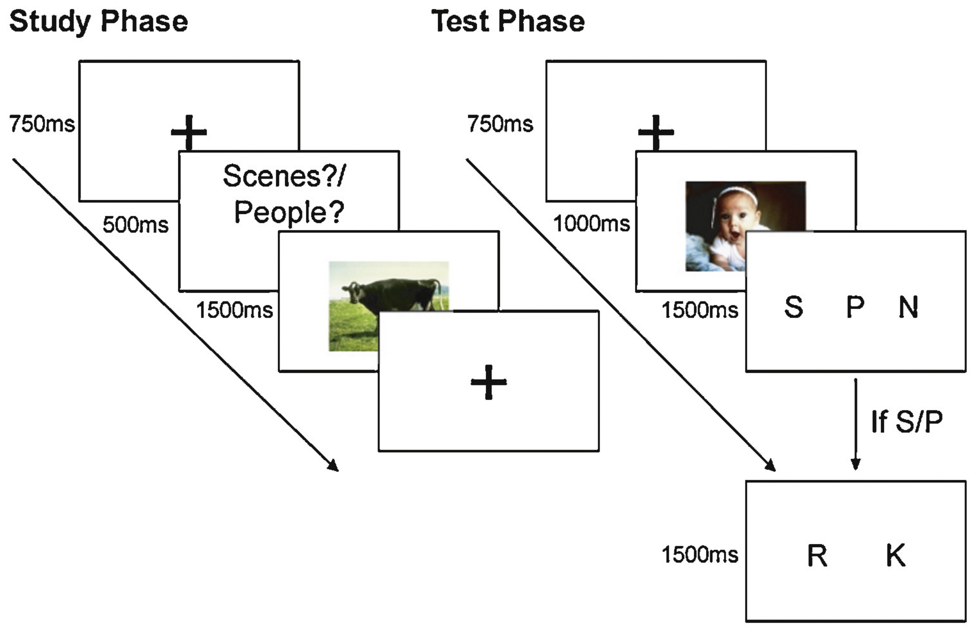

Fig. 1. Experimental paradigm.
In an emotional extrinsic source memory task, participants completed a study phase immediately followed by a test phase. During the study phase, participants were instructed to make yes/no response to indicate whether the image contained content consistent with the prompt (a scene or people) and to remember both the image and the extrinsic source (the prompt). During the test phase, participants were asked to make a response of scene (S), people (P) or new (N). With an S/P response, participants were asked further to indicate whether they remembered (R) or knew (K) the source.

has accrued in support of emotion-induced memory enhancement for intrinsic source details (D'Argembeau & Van der Linden, 2004; Kensinger & Corkin, 2003; Mather & Nesmith, 2008), while showing no or impairing effects of emotion on extrinsic source details (Cook et al., 2007; Davidson, McFarland, & Glisky, 2006; Kesinger & Schacter, 2006; Madan et al., 2012). Therefore, emotion can shift source memories in opposing directions (improving intrinsic and impairing extrinsic source memory), accounting for the seemingly controversial findings in the literature.

Compromised source memory of extrinsic details under emotional or stressful situations (Payne et al., 2004) can have significant real life implications. For instance, crime eyewitness testimonies concerning extrinsic contextual details are often inaccurate and unreliable (Christianson & Loftus, 1991; Loftus, 1979), causing serious or even tragic problems in the court. Nevertheless, studies that systematically investigate extrinsic source memory of emotional events are scarce, and so remain unclear the psychological processes and neural mechanisms underlying emotional modulation of extrinsic source memory.

Therefore, we examined emotional modulation of extrinsic source memory using a modified extrinsic source memory task (Mollison & Curran, 2012) along with scalp electrophysiological recording. In particular, we assessed how emotion interacts with two key processes involved in recognition memory—familiarity (a fast and automatic process underpinning a general feeling of prior occurrence) and recollection (a slower process supporting conscious retrieval of specific episodic details; Yonelinas, 2002). Recollection and familiarity processes were measured using well-established remember/know (R/K) judgments, respectively, (Duarte, Ranganath, Winward, Hayward, & Knight, 2004; Mollison & Curran, 2012; Vilberg, Moosavi, & Rugg, 2006) in combination with two important event-related potential (ERP) correlates. The FN400 (a positive shift or reduction in negativity in frontal regions around 400 ms) was used to index familiarity, and the late positive complex (LPC; a positive component over posterior regions at a later window) to index recollection (Curran, 2000; Diana, Yonelinas, & Ranganath, 2007; Rugg & Curran, 2007). Briefly, at study, a picture (study item containing positive, negative or neutral emotion) was presented after a semantic prompt ("scene" or "people", serving as extrinsic source), and at test, participants made "scene", "people" or "new" responses to test items, followed by R/K judgments.

To the extent that recognition of source details (i.e., source memory) is a defining feature of recollection, recent evidence suggests that familiarity can also contribute to source memory (Addante, Ranganath, & Yonelinas, 2012; Bastin, Van der Linden, Schnakers, Montaldi, & Mayes, 2010; Cansino, Maquet, Dolan, & Rugg, 2002; Diana, Yonelinas, & Ranganath, 2008; Mayes, Montaldi, & Migo, 2007; Speer & Curran, 2007; Zimmer & Ecker, 2010). While most of this work concerns intrinsic source memory, behavioral and ERP evidence also exists in support of familiarity in extrinsic source memory (Mollison & Curran, 2012; Peters, Daum, Gizewski, Forsting, & Suchan, 2009; Speer & Curran, 2007, but also see Ecker, Zimmer, & Groh-Bordin, 2007). We thus interrogated the possibility that emotional items would interfere with familiarity and recollection in extrinsic source memory, resulting in reduced source accuracy and diminished source-correct (vs. -incorrect) ERP amplitudes.

2. Material and methods

2.1. Participants

Twenty right-handed college students from Capital Normal University (Beijing, China) with normal or corrected-to-normal vision participated in the experiment and received monetary compensation. Participants denied a history of psychiatric or neurological disorders, head injury, or psychotropic drug use. Data from three participants were excluded due to poor performance (i.e., minimal correct ERP trials <20), excessive eye movements or EEG artifacts (e.g., alpha), resulting in a final sample of 17 participants (mean age, 23.4 years; 7 men). All participants provided informed consent to participate in this study, which was approved by the Capital Normal University Human Research Committee.

2.2. Materials

One thousand and eighty color images (360 each for positive, negative, and neutral conditions) were selected from the International Affective Picture Set (IAPS; Lang, Bradley, & Cuthbert, 2008) and the Chinese Affective Picture Set (CAPS; Bai, Ma, & Huang, 2005), depicting artifacts, animals, and people. All images were matched on luminance, contrast, and visual complexity. An independent sample ($N = 10$) provided valence and arousal ratings of the images. Valence ratings (ranging from 1/extremely pleasant to 5/extremely unpleasant) confirmed the intended affective valence of the three emotion image sets [positive set: mean (SD) = 2.12 (0.15); neutral set: 2.84 (0.22); and negative set: 3.90 (0.22)]. All pairwise comparisons across the sets were significant ($t(16) > 16.27$, $p < 0.001$). Arousal ratings (ranging from 1/not at all arousing to 5/extremely arousing) indicated that the negative images had the highest arousal ratings [3.52 (0.25)], followed by positive images [3.04 (0.35)], and then neutral images [2.62 (0.40)]. All pair-wise t-tests between these image sets were significant, $t(16) > 5.00$, $p < 0.01$.

For each emotion condition, 240 images were used as study (old) items, and the other 120 images were used as test (new) items. Study and test items were carefully chosen to have equivalent low-level visual properties (i.e., luminance and contrast), valence and arousal. Lastly, we note that although we did not counterbalance the old and new pictures across participants (due to an uneven, 2:1 ratio of old and new trials that was adopted to save trials), we randomly selected the old and new pictures, which were matched on valence and arousal ratings [valence: old (2.95/0.18) and new (2.91/0.18); arousal: old (3.06/0.29) and new (3.05/0.17); $t(16) < 1.50$, $p > 0.10$]. More importantly, as the focus of the study was source memory (involving comparison between source correct and source incorrect trials among the *old* items), this issue would not cause significant bias in our hypothesis testing.

2.3. Experimental procedure

Participants were seated 70 cm from a Dell monitor in an electrically shielded room and performed an extrinsic source memory task (Fig. 1). After a short practice block, participants undertook the experiment, which included 12 study-test blocks (720 old and 360 new items in total), with each study phase followed by test phase after a 2-min gap. To prevent fatigue in participants, we split the 12 blocks over two consecutive days (6 study-test blocks on each day with the order of the two sessions counterbalanced across participants). EEG was recorded throughout the sessions.

Each block consisted of a study and a test phase. During the study phase, each trial began with a fixation cross (750 ms), followed by a visual prompt (“Scene?” or “People?”) for 500 ms, before a study item (extending a $9^{\circ} \times 8^{\circ}$ visual area) was centrally presented for 1500 ms. Participants then responded whether the item belonged to the scene or people category. Assignment of right or left index fingers to “yes” or “no” response keys was counterbalanced across participants. Participants were explicitly instructed to remember both the image and the extrinsic source. A total of 60 images (20 per each emotion condition), half containing scenes (scenic background with coherent animal/artifact in the foreground) and half people (a central face image in a plain background), were randomly presented during each block, proceeded by either a scene or a people prompt (probability = 0.5). To the extent that these prompts may activate anticipatory processes and thus impact subsequent memory, our data excluded this potential issue. Namely, among all responses, yes-responses and no-responses were statistically and practically comparable (50% yes-response and 50% no-response). Moreover, correctly cued (yes-response) and incorrectly cued (no-response) conditions were associated with comparable memory [yes source accuracy: 0.68 (0.08), no source accuracy: 0.67 (0.09), $t(16) = 0.9$, $p > 0.3$].

Immediately after the study phase, participants' memory was tested. In each block, test stimuli consisted of 60 old items (presented in the study phase) and 30 new items (10 per each emotion condition). All 90 images were randomly intermixed. Two additional new images were presented at the beginning and end of each block, respectively, to serve as filler items to orient subjects to the task. In each trial, after a fixation cross (750 ms), an image was presented for 1000 ms. At the offset of the image, participants were asked to make a response of scene (S), people (P) or new (N), indicating whether the image was preceded by a scene or a person prompt, or whether the image was never presented. Following an S or P response to a test item, a screen with prompts of “R” and “K” was displayed, to which participants pressed the R key to indicate remember judgment or the K key to indicate know judgment about the test item. We instructed participants to respond “Remember” when they were certain about an item picture presented previously and were able to recall details associated with the item. We instructed them to respond “Know” when they believed the picture was previously presented but could not recall any details (e.g., feeling familiar). With an N response, the next trial ensued. Five out of the six letter keys on a standard English keyboard (i.e., “S”, “D”, “F”, “J”, “K” and “L”) were chosen as response keys for the five possible responses (i.e., S/P/N and R/K). The S/P/N response keys were assigned to one hand, and the R/K keys to the other. Response hand assignment was counterbalanced across participants.

2.4. Behavioral analysis

Old items given S/P responses and assigned to correct sources were deemed to be “source-correct” (SC) responses; old items given S/P responses but assigned to incorrect sources were considered “source-incorrect” (SI) responses; and new items given N (new) responses were considered “correct rejections” (CR). Source accuracy for remember response and know response was calculated as the ratio of the number of source correct items with remember and know responses, respectively, over its number of item hits (Mollison & Curran, 2012). Two-way repeated-measures analyses of variance (ANOVA; with Greenhouse–Geisser corrections) were performed on source accuracy with independent variables of Emotion (positive, neutral and negative) and R/K judgment (“remember” and “know”). Significant main and interaction effects were followed by pair-wise comparisons.

2.5. EEG recording and analysis

EEG was recorded from a 62-channel Neuroscan system at 500 Hz sampling rate with a 0.05–100 Hz bandpass filter. Electrooculogram (EOG) was recorded at two eye electrodes at the outer canthi of each eye and one infraorbital to the left eye. EEG signals were referenced to the left mastoid during recording and re-referenced offline to the average of the left and right mastoid recordings. EEG/EOG signals (impedance <5 kΩ) were digital bandpass filtered from 0.05 to 40 Hz, segmented around image onset (−200–1600 ms) and corrected to a 200 ms pre-stimulus baseline. Trials with EEG voltages exceeding $\pm 75\,\mu V$ were excluded from analysis. EOG blink artifacts were corrected using a linear regression estimate (Gratton, Coles, & Donchin, 1983). Experiment presentation was executed using presentation (Neurobehavioral Systems, Inc.). Data collection was performed using Neuroscan acquisition software, and statistical analysis was performed in SPSS 20.0.

Mean ERP amplitudes were extracted from two time windows (300–500, 500–700 ms after test item onset) to estimate the old–new effect as indexed by the FN400 and LPC. The time windows were selected based on both visual inspection of the grand average ERP waveform and previous ERP literature on familiarity (FN400) and recollection (LPC; Rugg & Curran, 2007; Voss & Paller, 2008). Electrodes were selected a priori to form two regions of interest (ROIs) centered around midline frontal and parietal sites that best capture FN400 and LPC old-new effects (anterior site: F1, F2, Fz, FC1, FC2 and FCz; posterior site: P1, P2, Pz, PO3, PO4 and POz). Using the vector normalization approach (McCarthy and Wood, 1985), we conducted topographic analyses across time windows and electrode sites to examine the scalp distribution of FN400 and LPC old-new effects, respectively. We computed differential FN400 and LPC amplitudes between source correct and source incorrect trials (SC–SI) to index extrinsic source memory (Guo, Duan, Li, & Paller, 2006; Addante et al., 2012).

A repeated-measures ANOVA of emotion was conducted on differential (SC–SI) amplitudes of the FN400 and LPC components, separately. As the numbers of "remember" trials within the SI category and of "know" trials within the SC category were very low, we combined the "remember" and "know" responses in the ERP analysis (for SC and SI trials separately) and used the FN400 and LPC components to index familiarity and recollection, respectively. Significant ANOVA effects were followed by *t*-tests to contrast the effects of individual conditions (using the least significant difference test; LSD).

3. Results

3.1. Behavior

Two-way ANOVA of emotion and R/K judgment on source accuracy revealed a main effect of R/K judgment [$F(1,16) = 52.58$, $p < 0.001$, $\eta_p^2 = 0.77$]: recollection-based ("remember") source accuracy was significantly higher than familiarity-based ("know") source accuracy ["remember" mean(SD): 0.73 (0.12); "know": 0.55 (0.04)]. There was also a significant emotion-by-R/K-judgment interaction [$F(2,32) = 3.93$, $p < 0.05$, $\eta_p^2 = 0.20$; Fig. 2]. Recollection-based source accuracy was significantly modulated by emotion [$F(1.74, 27.83) = 5.22$, $p < 0.05$, $\eta_p^2 = 0.25$]. Paired comparisons indicated that this type of source accuracy was reduced in both positive [0.73 (0.12)] and negative conditions [0.72 (0.12)], compared with the neutral [0.75 (0.12)] condition [positive vs. neutral: $t(16) = 2.34$, $p < 0.05$; negative vs. neutral: $t(16) = 2.72$, $p < 0.05$]. Notably, there was no significant difference between positive and negative conditions ($p = 0.23$). In contrast, no emotion effect was observed for familiarity-based source accuracy [$F(1.70, 27.18) = 2.47$, $p = 0.11$].

3.2. ERPs

To ensure FN400 and LPC old-new effects were reliably elicited, topographic analyses (according to the vector normalization approach, McCarthy and Wood, 1985) were conducted on mean amplitude differences between old and new items (collapsed across source accuracy and emotion conditions), revealing a significant time window (300–500 ms vs. 500–700 ms) *electrode site (anterior vs. posterior) interaction [$F(1,16) = 15.82$, $p < 0.001$, $\eta_p^2 = 0.50$; Fig. 3], in support of the distinction between FN400 and LPC markers of old-new effects. That is, at 300–500 ms, the anterior (frontal) site showed significantly larger old–new effect than the posterior (parietal) site [$F(1,16) = 83.32$, $p < 0.001$, $\eta_p^2 = 0.84$]; however, at 500–700 ms, the anterior site was not significantly different from the posterior site [$F(1, 16) < 1$, $p = 0.88$], with both sites exhibiting equally large old–new effects. Also, pair-wise comparisons of FN400 showed significant differences between old and new pictures in all 3 emotion conditions [neutral: old–new = 1.36 (0.38); positive: 1.92 (0.27); negative: 2.08 (0.23), $t(16) > 3.55$, $p < 0.01$]. Pair-wise comparisons of LPC also showed significant differences between old and new pictures in all 3 emotion conditions [neutral: old–new = 1.74 (0.43); positive: 2.04 (0.37); negative: 1.82 (0.42), $t(16) > 4.01$, $p < 0.01$].

To confirm the well-established effects of familiarity and recollection on R and K judgments, we analyzed ERPs associated with R and K judgments (collapsed across 3 emotional conditions). The FN400 amplitude was significantly higher for R than K judgment [R–K = 1.58(0.33) μV; $t(16) = 4.82$, $p < 0.001$], and was significantly higher for K than CR (new) judgment [K–CR = 0.86 (0.30) μV; $t(16) = 2.83$, $p < 0.05$]. The LPC amplitude was higher for R judgment than both K [R–K = 1.37 (0.39) μV; $t(16) = 3.50$, $p < 0.01$] and CR judgment [R–CR = 2.18 (0.39) μV; $t(16) = 5.54$, $p < 0.001$]. LPC for K judgment was somewhat higher than LPC for CR judgment, but the difference was only marginally significant, $t(16) = 2.02$, $p = 0.06$. These results thus confirmed that R judgment engaged both familiarity and recollection, but K judgment involves largely familiarity. Overall, these old–new effects and their respective topographic distributions were largely consistent with FN400 and LPC old-new effects indicated by previous ERP studies (Curran, 2000; Curran & Cleary, 2003; Woodruff, Hayama, & Rugg, 2006), confirming the validity of our a priori selection of time window, electrode sites, and extrinsic source memory paradigm.

We then analyzed ERP (FN400 and LPC) amplitudes as critical neural indices of successful source retrieval. For FN400 amplitudes at the anterior site, a repeated-measures ANOVA with factors of response (SC vs. SI vs. CR) and emotion (neutral vs. positive vs. negative pictures) revealed significant main effects of response [$F(2,32) = 50.89$, $p < 0.001$, $\eta_p^2 = 0.76$] and emotion[$F(2,32) = 4.36$, $p < 0.05$, $\eta_p^2 = 0.21$], and a significant interaction between the two variables [$F(4,64) = 2.70$, $p < 0.05$, $\eta_p^2 = 0.14$; Fig. 4].

The emotion effect was related to more positive FN400 for positive than neutral trials [positive–neutral = 0.85 (0.29) μV; $t(16) = 3.35$, $p < 0.01$], but there was no difference between positive and negative trials or between negative and neutral trials [positive–negative = 0.40 (0.29) μV; negative–neutral = 0.45 (0.32) μV; $t(16) < 1.50$, $p > 0.1$]. In terms of the response main effect, SC trials evoked the highest amplitude [1.57 (0.65)], followed by SI trials [0.85 (0.74)], and then CR trials [−0.58 (0.77)]. All pairwise *t*-tests between these conditions were significant, $t(16) > 3.00$, $p < 0.01$. Particularly relevant to our hypothesis, the interaction effect between emotion and response was substantiated by a significantly more positive FN400 for SC than SI trials in the neutral condition [neutral = 1.42 (0.30) μV > 0; $t(16) = 4.79$, $p < 0.001$], which was absent in the other two emotion conditions [negative = 0.30 (0.44) μV, positive = 0.45 (0.23) μV, $t(16) < 1.90$; $p > 0.07$]. These results suggest that emotion impeded familiarity process in source memory. Interestingly, we observed an amplitude difference between SI and CR trials in the emotional conditions [negative = 1.93 (0.28) μV, positive = 1.70 (0.33) μV, $t(16) > 5.00$; $p < 0.001$], but not in the neutral condition [neutral = 0.65 (0.41) μV; $t(16) = 1.57$, $p = 0.14$], suggesting that emotion enhanced familiarity of old items but not familiarity of their extrinsic source details.

For LPC amplitudes at the posterior site, the repeated ANOVA with factors of response (SC vs. SI vs. CR) and emotion (neutral vs. positive vs. negative pictures) revealed significant main effects of response [$F(2,32) = 25.09$, $p < 0.001$, $\eta_p^2 = 0.61$] and emotion [$F(2,32) = 28.31$, $p < 0.001$, $\eta_p^2 = 0.64$], but no significant interaction [$F(4,64) = 1.36$, $p = 0.26$, $\eta_p^2 = 0.08$: Fig. 4]. Emotion augmented LPC amplitudes: negative images evoked the highest amplitude [5.14 (3.49) μV], followed by positive images [4.10 (3.48) μV], and then neutral images [3.46 (3.43) μV]. All pairwise *t*-tests between these conditions were significant, $t(16) > 2.84$, $p < 0.05$. These results confirmed the well-established effect of emotion on late positive potentials in the literature (cf. Olofsson, Nordin, Sequeira, & Polich, 2008).

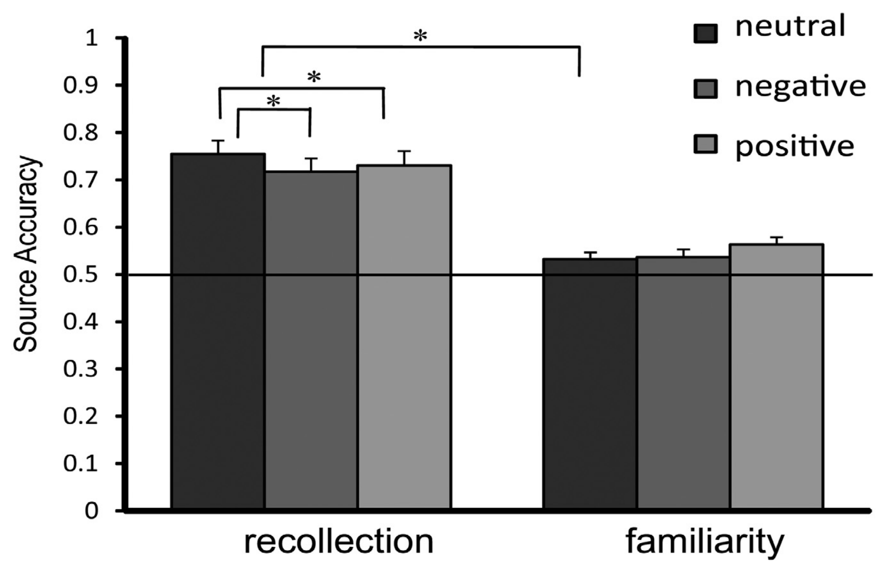

Fig. 2. Behavioral results.
Recollection-based source accuracy was reduced in both positive and negative conditions. Familiarity-based source accuracy was unaffected by emotion (* $p < 0.05$). The horizontal black line indicates chance-level performance (0.5).

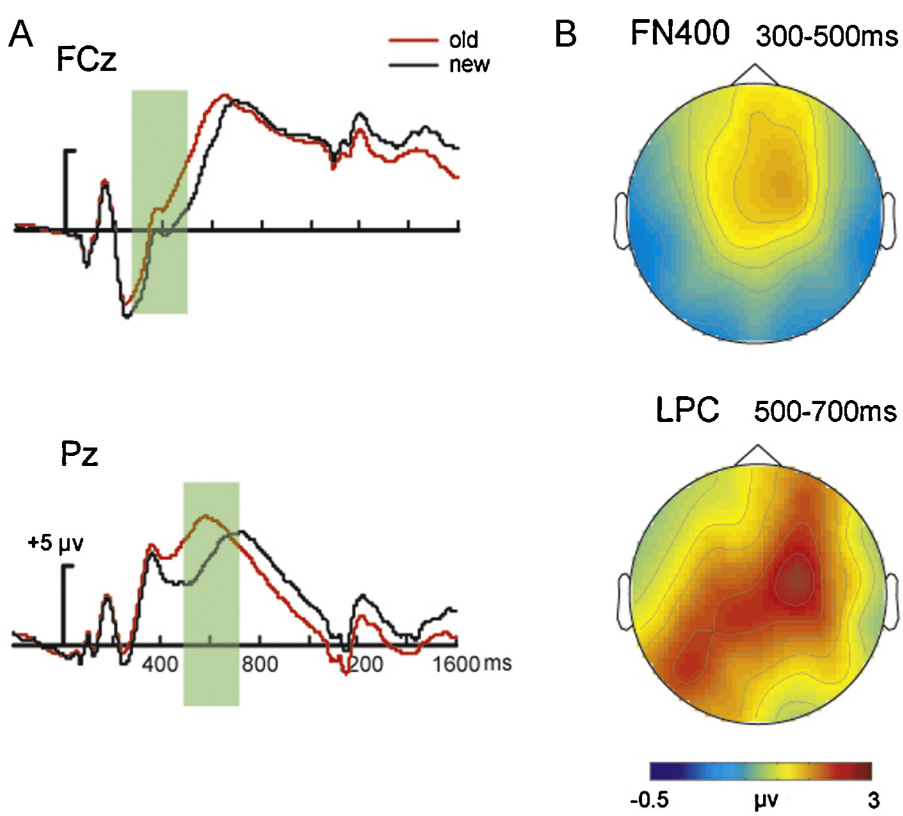

Fig. 3. ERP results: FN400 and LPC old/new effects.
(A) Grand average ERP waveforms (collapsed across source accuracy and emotion conditions) and (B) topographic maps showed reliable FN400 (300–500 ms) and LPC (500–700 ms) old/new effects, respectively.

For the response main effect, SC items elicited the highest amplitude [5.78 (0.86)], followed by SI trials [5.17 (0.85)], and then CR trials [3.61 (0.84)]. All pairwise *t*-tests between these conditions were significant, $t(16) > 3.11$, $p < 0.01$. The higher LPC amplitudes for SC/SI trials than CR trials would reflect recollection of item memory (potentially including both criterial and non-criterial source memory; illustrated in Fig. 3). Although, the emotion-by-response interaction was not significant, to test our hypotheses further, we performed a set of post hoc contrasts (using Bonferroni correction for multiple comparisons), testing item memory and source memory in each emotion condition. Our results indicated that the old/new effect was seen for all three emotion levels, $t(16) > 2.68$, $p < 0.05$. By contrast, reflecting recollection of criterial, extrinsic source memory (people vs. scene), the augmentation of LPC for SC versus SI trials was observed in the neutral condition only [SC–SI = 1.14(0.32) μV; $t(16) = 3.52$, $p < 0.01$]. The difference

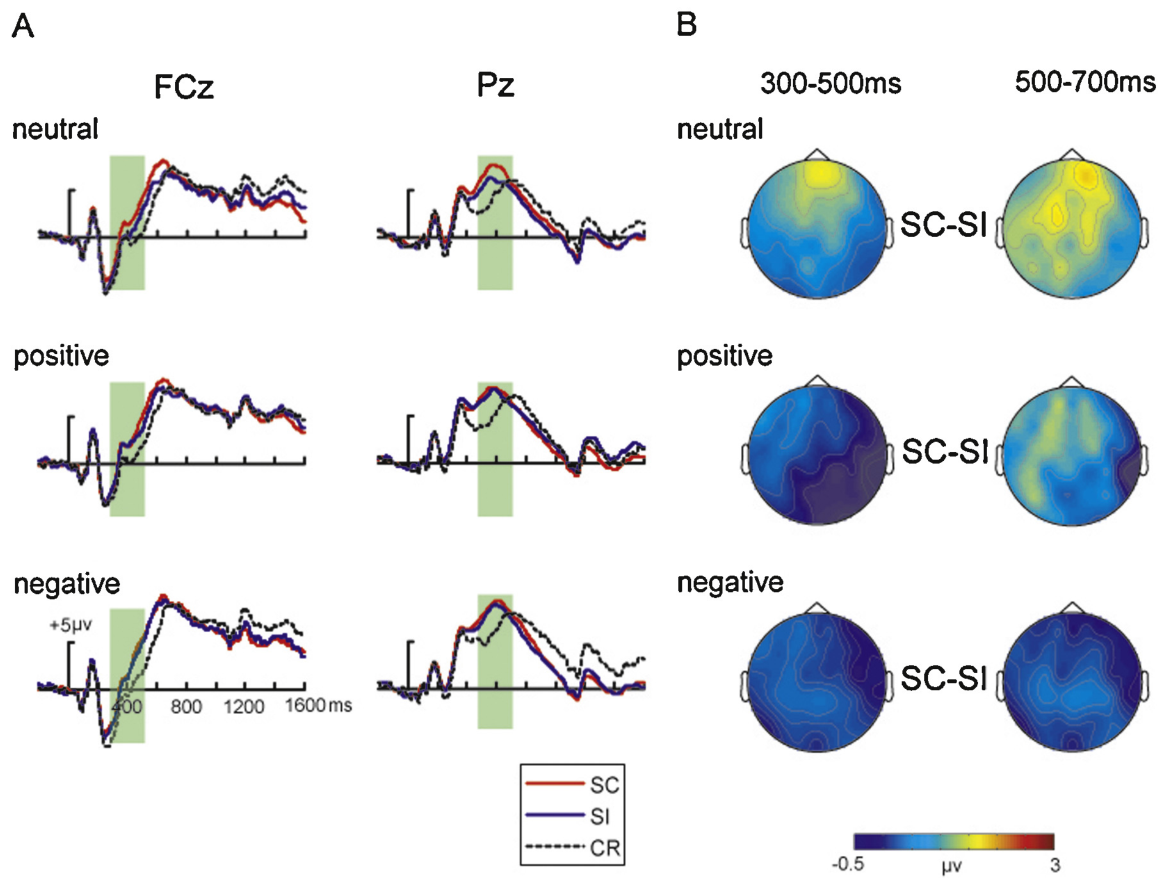

Fig. 4. Source memory ERPs across emotions.
(A) Grand average ERP waveforms of source-correct (SC), source-incorrect (SI) and new (CR) trials, and (B) topographic maps of differential (SC–SI) ERPs showed diminished amplitudes in SC (relative to SI) trials in emotion (positive and negative) vs. neutral conditions during both FN400 (300–500 ms) and LPC (500–700 ms) time windows.

between SC and SI trials in the emotional conditions did not survive corrected or uncorrected tests, $t(16) < 1.80$, $p > 0.27$.

4. Discussion

Combining an extrinsic source memory paradigm with EEG recordings, the present study examines emotional modulation of extrinsic source memory (targeting both familiarity and recollection). Our behavioral data reveal reduced recollection-based ("remember") source accuracy for both positive and negative (relative to neutral) items. ERP (FN400 and LPC) correlates of source memory (SC–SI) further indicate significant source effects for neutral items but not for positive or negative items. Therefore, behavioral and neural evidence converges on weakened source memory associated with emotional items, lending support to the hypothesis that emotion impairs extrinsic source memory and highlighting its impact on both familiarity and recollection processes.

Using R/K judgments as behavioral indices of recollection and familiarity, respectively, we demonstrated significantly higher recollection-based than familiarity-based source accuracy, consistent with the notion of recollection being the primary memory process associated with conscious recall of episodic details (Yonelinas, 2002). Nevertheless, familiarity-based source accuracy was still significantly above chance [0.55 (0.04), $p < 0.001$], and the differential FN400 amplitude between remembered and unremembered trials (SC–SI), a neural index of familiarity (Addante et al., 2012; Guo et al., 2006), showed a significant source effect in the neutral condition. Therefore, our findings align with recent reports in the literature, arguing that familiarity process can also contribute to source memory, not only intrinsic (Addante et al., 2012; Cansino et al., 2002; Diana et al., 2008; Zimmer & Ecker, 2010), but also extrinsic source memory (Mollison & Curran, 2012; Peters, Daum, Gizewski, Forsting, & Suchan, 2009; Speer & Curran, 2007). Taken together, neural and behavioral effects in the neutral condition replicate previous findings concerning non-emotional source memory. Furthermore, we also observed significant ERP effects of familiarity and recollection in item memory. These significant effects thus validate our ERP measures and help to rule out the possibility that the diminished effects in the emotion (vs. neutral) conditions were due to insufficient statistical power (especially in the presence of a significant emotion effect on these behavioral and neural measures).

Importantly, we observe that these memory processes are susceptible to the influence of emotion. Our behavioral and ERP indices of recollection memory (i.e., "remember" responses and LPC amplitudes) converge, indicating that emotion impairs the recollection of extrinsic source details (which nevertheless remains intact in the neutral condition). Substantial evidence has accrued for emotional modulation of item memory and related LPC amplitudes (Dolcos, LaBar, & Cabeza, 2005; Inaba, Nomura, & Ohira, 2005; Kensinger, 2007; Langeslag & Van Strien, 2008; Mather & Sutherland, 2009; Schaefer, Pottage, & Rickart, 2011; Weymar, Löw, Melzig, Hamm, 2009). In addition, emotion also augments memory for inherent features (i.e., intrinsic source memory) of an emotional item (Burke, Heuer, & Reisberg, 1992; Kensinger & Schacter, 2006; Sharot & Yonelinas, 2008). Here, by targeting retrieval of not easily integrated, contextual details, we show that in contrast to effects on item memory and intrinsic source memory, emotion diminishes LPC effects and reduces recognition accuracy of extrinsic sources.

That this impairment is present for both positive and negative items and does not differ between the two emotions highlights the impact of the arousal (vs. affective valence) aspect of emotion on memory (Mather, 2007). This emphasis on arousal aligns with several previous reports of emotional memory (Kensinger & Schacter, 2006; Mather et al., 2006; Waring & Kensinger, 2009) while extending those findings by specifying arousal-related decrement in recollection memory of extrinsic details. As biologically salient information in emotional events (highly rewarding or greatly disturbing) would draw attention away from peripheral contextual information (i.e., extrinsic source details; Lang et al., 2008; Öhman, Flykt, & Esteves, 2001), encoding and retrieval of the contextual details can be weakened (Mather, 2007), trading off for strengthened memory for central items (Inaba et al., 2005; Kensinger, 2007; Langeslag & Van Strien, 2008; Weymar et al., 2009). Presumably, such attention interference could especially impact recollection given the involvement of conscious, attention-based encoding and retrieval in this memory process (Yonelinas, 2002).

In addition, emotion-induced "tradeoff" appears to affect familiarity-based source memory as well. The FN400 component reveals that emotion also disrupts the familiarity process in extrinsic source memory; differential FN400 amplitudes are present in the neutral condition while in neither the positive nor negative condition do FN400 amplitudes reliably differentiate correctly versus incorrectly remembered source trials. Notably, similar to the recollection effects above, this effect on familiarity appears to be driven primarily by arousal rather than valence given that the two emotion conditions showed comparable FN400 effects. This finding represents some first evidence of emotional modulation of familiarity in extrinsic source memory, highlighting an additional mechanism by which emotion can influence memory. Also notably, this disrupted familiarity process in the emotional conditions adds to prior data that the contribution of familiarity to extrinsic source memory could vary as a function of the characteristics of the item or the peripheral detail (e.g., Mollison & Curran, 2012), thus helping to clarify the controversy in the literature concerning the role of familiarity in extrinsic source memory (e.g., Diana et al., 2008; Yonelinas et al., 2002; Zimmer & Ecker, 2010).

It is possible that a tradeoff between item and extrinsic memory emerges as emotion augments familiarity-based memory (e.g., semantic memory; Yonelinas, 2002) for the central item (Buchanan & Adolphs, 2002; Hashtroudi, Johnson, Vnek, & Ferguson, 1994), detracting familiarity-related processing away from extrinsic sources details. Furthermore, just as emotion often evokes automatic information processing (Dolan & Vuilleumier, 2003; LeDoux, 1995), familiarity memory, an automatic process, can be particularly susceptible to emotion modulation. As such, by biasing automatic processing toward central items, emotion can further impair the familiarity process in extrinsic source memory. Nevertheless, it is worth noting that our behavioral responses failed to demonstrate an emotion effect on familiarity-based source recognition (based on "know" judgments). We suspect that this null effect could reflect the inadequate sensitivity of subjective judgments in indexing subtle automatic processes. Future research using indirect tasks targeting implicit memory and familiarity (e.g., stem completion task; Jacoby, 1991) could be more effective at detecting behavioral evidence of this effect.

Therefore, our neural findings largely concur with behavioral results, shedding new light on emotional modulation of extrinsic source memory, an area remaining understudied despite significant progress in other aspects of emotional memory (Buchanan, 2007; Dolan & Vuilleumier, 2003). Emotion-induced interference in extrinsic source memory (implicating both familiarity and recollection processes) contrasts with the growing evidence of memory enhancement due to emotion, highlighting the multifaceted effects of emotion on memory. To the extent that emotion can boost item memory and *intrinsic* source memory (Kensinger, 2009), it can nevertheless hamper memory of extrinsic peripheral details. Often, these details are tangential or negligible to pose a real threat to our cognitive function and general well-being if misremembered or forgotten. However, shocking and grave consequences may arise in emotional and stressful situations when a frightened eyewitness misremembers a contextual detail in a crime scene, or a stressed ER doctor forgets a patient's recent trip to a disease-inflected region in Africa.

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