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BRIEF REPORT

Influence of Emotion on Memory for Temporal Information

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Abstract

Contextual information such as color and spatial location has been found to be better remembered for emotional than for neutral items. The current study examined whether the influence of emotion extends to memory for another fundamental feature of episodic memory: temporal information. Results from a list discrimination paradigm showed that (a) item memory was enhanced for both negative and positive pictures compared to neutral ones, and was better for negative than for positive pictures; and (b) temporal information was better remembered for negative than for positive and neutral pictures, whereas positive and neutral pictures did not differ from each other. These findings are discussed in relation to the processes involved in memory for temporal information.

Influence of Emotion on Memory for Temporal Information

There is now abundant evidence that memory for emotional events tends to be better than memory for neutral events (Reisberg & Hertel, 2004). In laboratory studies, individuals typically recall or recognize more emotional than neutral stimuli, whether they be words or pictures (see, e.g., Ochsner & Schacter, 2003; Phelps, 2004, for reviews). In addition, some studies using the Remember-Know procedure (Gardiner & Richardson-Klavehn, 2000; Tulving, 1985) suggest that the probability of being able to bring to mind some recollection of what occurred at the time an item was encoded is enhanced for emotional words (Dewhurst & Parry, 2000; Kensinger & Corkin, 2003) and pictures (Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004; Ochsner, 2000), as compared to neutral ones. One does not know what participants in these studies actually remember about emotional stimuli, however. Memory for an item can include many kinds of information such as semantic features of the stimulus, information about the time and place at which it was acquired, its modality of presentation, associated thoughts and emotions, item parameters such as size and color, and so forth (Johnson, Hashtroudi, & Lindsay, 1993).

A handful of recent studies have begun to investigate the effect of emotion on memory for some specific stimulus attributes. These studies show that features such as color information and spatial location are better remembered for emotional than for neutral items (D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003). However, the influence of emotion on memory for other stimulus attributes is currently unknown. In this study, we investigated the influence of emotion on memory for an essential characteristic of episodic memory: temporal information. A defining feature of episodic memory is indeed that events seem to belong to particular times in our past (Wheeler, Stuss, & Tulving, 1997). As is the case for other stimulus attributes, memory for temporal information seems to be more or less precise depending on the retrieved item: we are able to recall the time of certain past events with great accuracy (e.g., one's own wedding), whereas other events can be recalled but are difficult to locate precisely (e.g., the date when you bought a particular book). The purpose of this study was to investigate whether the emotional salience of an item affects our ability to localize the time at which it was previously encountered.

To this end, a list discrimination paradigm (see, e.g., Parkin, Walter, & Hunkin, 1995) was used, in which participants were successively presented with three study lists, each containing positive, negative, and neutral pictures. For each study list, participants were asked to learn the pictures but were not informed that their memory for the list in which the item occurred would subsequently be tested (i.e., temporal information was encoded incidentally). This was done because previous findings suggest that the influence of emotion on memory for contextual information may in some cases be superseded by effortful encoding strategies (i.e., when participants voluntarily try to learn this information), at least for some types of contextual details such as color information (D'Argembeau & Van der Linden, 2004). Item memory and memory for temporal information were then assessed by asking participants to recognize the pictures among new ones and, contingent on recognition, to indicate whether they appeared in the first, second or third study list. Finally, as some studies have reported gender differences both in emotional response (e.g., Bradley, Codispoti, Sabatinelli, & Lang, 2001) and memory (e.g., Canli, Desmond, Zhao, & Gabrieli, 2002) for emotional pictures, we examined potential gender differences in the influence of emotion on item memory and memory for temporal information.

Method

Participants

The participants were 49 students from the University of Geneva. Data from one female participant had to be discarded because she failed to follow the procedure properly. The reported results are for the remaining 48 participants (24 women, 24 men; mean age of 23.7 years, SD = 3.1 years). All participants gave their informed consent and were free to withdraw from the experiment at any time.

Materials

The stimuli were 42 positive, 42 negative, and 42 neutral pictures taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). These pictures were selected on the basis of normative ratings of valence and arousal provided by Lang et al. (1999). The mean valence was 2.73 (SD = 0.69) for negative pictures, 4.98 (SD = 0.36) for neutral pictures, and 7.40 (SD = 0.49) for positive pictures, $F(2, 123) = 814.94$, $p < .001$. When selecting the pictures, care was taken to match positive and negative pictures with regard to arousal ratings (M = 5.39, SD = 0.87 and M = 5.69, SD = 0.76, for positive and negative pictures, respectively), $t(82) = 1.67$, $p > .05$; both positive and negative pictures had higher arousal values than neutral pictures (M = 3.15, SD = 0.76), $t(82) = 12.52$, $p < .001$, and $t(82) = 15.24$, $p < .001$, respectively. The IAPS numbers for the pictures that were included in the study are shown in the Appendix.

The pictures were divided into two sets (A and B), each containing 21 positive, 21 negative, and 21 neutral pictures. The two sets were matched for valence and arousal, and the use of set A or set B as studied or non-studied items was counterbalanced across participants. Within each set, the pictures were further divided into three lists (each containing 7 positive, 7 negative, and 7 neutral pictures) matched for valence and arousal. The order of presentation of the three lists during the study phase was counterbalanced across participants, and pictures within each list were presented randomly. For the test phase, pictures of sets A and B were presented randomly.

Procedure

Participants were tested individually. During the study phase, they were successively presented with three lists of positive, negative, and neutral pictures. Each picture was presented for 2 s on a computer screen, with a 750-ms inter-stimulus interval. Presentation of each list was separated by a 3-min delay during which participants had to perform some arithmetic operations. For each list, participants were asked to look carefully at each picture so that they would be able to recognize it later; they were not informed that their memory for temporal information would be tested. After presentation of the third list, participants performed some arithmetic operations for 1 min and were then presented with the memory test. For each picture, participants had to indicate whether it has been presented during the study phase or whether it was a new picture by pressing either the 1 or the 2 key, respectively (item memory). In addition, when participants claimed to recognize a picture, they then had to decide whether it had been presented in the first, second or third study list by pressing the corresponding key (memory for temporal information). The memory task was self-paced. At the end of the experiment, participants were asked whether they had suspected that memory for temporal information would be assessed. None of them reported such suspicions.

Results

Item memory

Mean proportions of hits and false alarms are presented in Table 1 as a function of gender and picture type. Item memory was assessed by means of corrected recognition scores (hits minus false alarms). A 2 (gender) X 2 (picture type) analysis of variance (ANOVA) indicated a significant main effect of picture type, $F(2, 92) = 20.60$, $p < .001$, $\eta^2 = .44$. Subsequent *t*-tests indicated that item memory was better for both negative and positive pictures than for neutral pictures, $t(47) = 5.68$, $p < .001$, $d = .83$, and $t(47) = 2.92$, $p = .005$, $d = .43$, respectively. In addition, item memory was better for negative than for positive pictures, $t(47) = 4.22$, $p < .001$, $d = .62$. The ANOVA also revealed a significant main effect of gender, $F(1, 46) = 4.44$, $p = .04$, $\eta^2 = .10$, with item memory being better for women than for men. However, the gender by picture type interaction was not significant, $F(2, 92) = 0.72$, $p = .49$.

Memory for temporal information

As item memory differed between positive, negative, and neutral pictures, memory for temporal information was determined with a measure that corrects for the change in the probability of obtaining a given score by chance as a function of the number of correct item recognition responses made (see Parkin et al., 1995), and this is expressed as a *z* score.[1] These data are presented in Table 1 as a function of gender and picture type. A 2 (gender) X 2 (picture type) ANOVA indicated a significant effect of picture type, $F(2, 92) = 7.80$, $p < .001$, $\eta^2 = .17$. Subsequent *t*-tests indicated that memory for temporal information was better for negative than for positive, $t(47) = 2.61$, $p = .01$, $d = .38$, and neutral, $t(47) = 3.98$, $p < .001$, $d = .58$, pictures. Memory for temporal information did not differ significantly between positive and neutral pictures, $t(47) = 1.12$, $p = .27$, $d = .16$. [2] The main effect of gender approached statistical significance, $F(1, 46) = 3.44$, $p = .07$, $\eta^2 = .07$, but the gender by picture type interaction was not significant, $F(2, 92) = 0.48$, $p = .62$.

Discussion

Using a list discrimination paradigm, we found that negative pictures were better recognized than positive pictures, and that both positive and negative pictures were better recognized than neutral ones. These findings are consistent with previous studies that investigated the influence of emotion on the recall or recognition of pictures similar to those used in the present study (e.g., Bradley, Greenwald, Petry, & Lang, 1992; Comblain et al., 2004; Dolcos, LaBar, & Cabeza, 2004; Hamann, Ely, Grafton, & Kilts, 1999; Ochsner, 2000). This difference in item memory between emotional and neutral pictures may involve mechanisms such as enhanced attention to, and hence encoding of, emotional items as well as enhanced consolidation or storage of emotional items, mechanisms that are thought to be underlain by a specific neuro-hormonal system (McGaugh & Cahill, 2003; Phelps, 2004). The specific purpose of our study was to investigate whether emotion affects not only item memory but also memory for *when* an item has been previously encountered. We found that participants were better at discriminating the list in which a picture had been presented for negative than for positive and neutral pictures, whereas performances did not differ between positive and neutral pictures. These results extend previous findings that memory for contextual information such as color and spatial location is better remembered for emotional than for neutral items (D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003), showing that negative emotion enhances memory for another fundamental feature of episodic memory, that is, temporal information.

What might the mechanisms be that underlie this influence of negative emotion on memory for temporal information? According to Friedman (1993, 2001), we may remember the times of past events by relying on different types of processes. Distance-based processes involve evaluating the amount of time that has elapsed between the event and the present. Most theories that have been proposed to describe how this amount of time is assessed contend that changes in the characteristics of memories with the passage of time (e.g., the strength, accessibility, or elaborateness of memory traces) provide cues to their age (see Friedman, 1993, 2001, for review). For instance, if a memory is vivid, the event is assigned to the recent past; if it is dim, the event is judged to be old. A second class of processes, location-based processes, involve reconstructing the time of occurrence by relating events to particular time patterns, such as conventional patterns (e.g., parts of a day), personal patterns (e.g., when I was at university), or patterns produced in experiments (e.g., List 1, 2, etc.). The reconstruction is done by retrieving contextual information encoded with the event, linking this information to some time pattern, and inferring when the event probably occurred. In some cases, memory for the times of past events may also rely on order codes. Specifically, if the presentation of an item causes the retrieval of an item that has been previously presented, the before-after relation between the two may be stored in memory and later used to reconstruct their times of occurrence.

Our findings are difficult to explain in terms of distance-based processes. First, given that negative pictures are typically more richly recollected than positive and neutral ones (Comblain et al., 2004; Ochsner, 2000), if participants relied only on strength or vividness to judge when they occurred, they should have systematically judged negative pictures to be more recent—that is, to have been part of a more recently presented list—than neutral ones (an error called "forward telescoping"; see e.g., Loftus & Marburger, 1983), rather than placing them more accurately in time. In addition, it has been argued that, as the paradigms traditionally used to assess memory for temporal information in the laboratory, including list discrimination, often run over a relatively short period of time (usually less than one hour), distance-based processes are probably difficult to use and performance depends mostly on location-based processes (Bastin, Van der Linden, Michel, & Friedman, 2004). It is thus more plausible that memory for temporal information is enhanced because negative pictures facilitate location-based processes. Ochsner (2000) argued that, as they are more relevant to one's goals, negative pictures elicit physiological and evaluative responses not evoked by neutral pictures, and they also tend to capture and hold one’s attention to a greater extent. This leads negative pictures to be encoded more distinctively than neutral ones, and hence more richly recollected. Accordingly, in the present study, people may have encoded more contextual information for negative than for neutral pictures (e.g., the thoughts or emotions they have while viewing the pictures), thereby increasing the amount of information available for reconstructing the time of occurrence. For instance, when viewing a negative picture during the test phase, participants may remember what they thought or felt when they were presented with this picture in the study phase and this contextual information might help them to link the item information to the time pattern in which it occurred (i.e., list 1, list 2, and list 3). Another possibility, which is not incompatible with the previous one, would be that order codes were more frequently formed for negative than for neutral pictures. A particular negative picture may have caused participants to recall a previous negative picture (because of the similarity of their emotional reactions to both pictures, for instance), thereby creating an order code for these two pictures. This order information may then help participants reconstruct the location of the pictures in time. However, order codes are of limited use on a list-discrimination task (Friedman, 1993) and furthermore it is very unlikely that order codes were formed for each possible pair of negative pictures, so it is probably not the only mechanism by which negative emotion affected memory for temporal information.

Whatever the mechanisms involved, the present findings, together with earlier ones (D’Argembeau & Van der Linden, 2004), indicate that negative emotion affects two fundamental properties of episodic memory, that is, memory for the place and time at which a piece of information was acquired, both of which may increase the probability of having a “recollective experience” (Gardiner & Richardson-Klavehn, 2000; Wheeler et al., 1997) when retrieving emotional events. It should be noted, however, that this study showed an enhanced memory for temporal information for negative pictures, as compared to neutral ones, but not for positive pictures. In addition, memory for temporal information was better for negative than for positive pictures. Earlier studies that used stimuli from the IAPS found that negative pictures were richly recollected (as assessed by “remember” responses) more often than positive ones (Comblain et al., 2004; Ochsner, 2000), which is consistent with our findings. However, using words as stimuli, we found in a previous study that memory for color information and spatial location was enhanced for both positive and negative words compared to neutral ones (D’Argembeau & Van der Linden, 2004), and there was no difference between positive and negative words. This divergence in results concerning the effects of the positive versus negative valence of the items may be related to the type of stimuli used, that is, words versus pictures. Emotional pictures such as those included in the IAPS are known to elicit significant levels of emotional arousal (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001), which may in turn enhance memory (McGaugh & Cahill, 2003), whereas emotional words typically do not elicit much emotional arousal (except for specific types of words such as “taboo words”; LaBar & Phelps, 1998) and may instead influence memory because their affective meaning makes them more semantically related (e.g., Maratos, Allan, & Rugg, 2000; Phelps et al., 1998) or more distinctive (Dewhurst & Parry, 2000) relative to neutral words. However, in the present study, positive and negative pictures were matched for arousal, so the differences between their effects on item memory and memory for temporal information are probably related to their positive versus negative valence rather than to differences in arousal. As Ochsner (2000) noted, the scenes depicted in the negative pictures of the IAPS may, on average, be more relevant to important goals (e.g., to identify threatening stimuli) than those depicted in the positive pictures; consequently, the negative pictures may be encoded more distinctively and hence more recollectable. Nevertheless, as Ochsner further remarked, the difference in item memory for negative and positive stimuli might well disappear if both kinds of stimuli were matched for personal significance. Similarly, the difference in memory for temporal information between positive and negative items might disappear if the two kinds of stimuli were matched for importance to subjects' goals and concerns because, if this were the case, people might encode similar amounts of contextual information for both positive and negative items, information that would later help them reconstruct their times of occurrence. This is an intriguing possibility that would be worth addressing in future studies.

Finally, concerning gender differences, we found that item memory was better for women than for men and that memory for temporal information also tended to be better for women than for men, which is consistent with previous studies showing that women outperform men on episodic memory tasks (Herlitz, Nilsson, & Baeckman, 1997). However, the effect of emotion on both item memory and memory for temporal information was not influenced by gender. Cahill, Gorski, Belcher, and Huynh (2005) recently found that memory for the central and peripheral details of an emotional story was influenced by masculine and feminine traits, and not by the actual gender of the participants. Therefore, in future studies, it might be interesting to examine whether the influence of negative emotion on memory for temporal information differs as a function of gender-related traits rather than actual gender per se.

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Footnotes

[1] *z*-score formula: $z = (r - x)/SD$, where r = number of correct list discrimination, n = number of correctly recognized items, p = probability of correctly discriminating the list of a recognized item by chance, $q = (1 - p)$, $x = n \,.\, p$, and SD = square root of $(n \,.\, p \,.\, q)$. For instance, as the probability of correctly discriminating the list of a recognized item by chance was .33 in the present study, a participant who correctly recognized 19 negative pictures and correctly identified the list (1, 2 or 3) for 13 of these negative pictures, received a *z*-score of 3.28 for negative pictures. An analysis performed with a more conventional measure of memory for temporal information (i.e., the proportion of correctly recognized pictures for which the associated study list was correctly identified) revealed identical results (mean proportions were $M = .652$, $SD = .115$, $M = .588$, $SD = .143$, and $M = .575$, SD = .130, for negative, positive, and neutral pictures, respectively), so we only report the analysis with the corrected measure.

[2] An anonymous reviewer raised the interesting possibility that memory for temporal information may differ as a function of the list in which the pictures were presented. We examined this hypothesis by computing temporal memory scores for the first, second, and third list separately. Data from one male participant had to be discarded because he did not recognize any neutral pictures from the second list. A 3 (picture type) X 3 (list of presentation) ANOVA indicated a main effect of picture type, $F(2, 92) = 7.31$, $p = .001$, and a main effect of list of presentation, $F(2, 92) = 9.53$, $p < .001$, revealing that memory for temporal information was better for pictures that belonged to the first and third lists than for pictures that belonged to the second list. This is consistent with previous studies and might be explained by the fact that the start and end of the study phase are salient landmarks to which the stimuli may be linked, thereby rendering temporal judgments to be more accurate for stimuli presented near these landmarks than for stimuli presented in the middle of the study phase (see e.g., Friedman, 2001).

Importantly for our purpose, however, the effect of picture type did not interact with the effect of list of presentation, $F(4, 184) = 1.39$, $p = .24$.

Table 1

Measures of Item Memory and Memory for Temporal Information for Negative, Positive, and Neutral Pictures

	Item memory				Memory for temporal information	
	Hits		False alarms			
	M	*SD*	*M*	*SD*	*M*	*SD*
Men						
Negative	.893	.103	.010	.020	2.70	1.11
Positive	.837	.111	.026	.034	2.09	1.32
Neutral	.770	.171	.026	.040	2.02	1.18
Women						
Negative	.938	.060	.010	.020	3.23	0.97
Positive	.885	.113	.010	.020	2.57	1.34
Neutral	.847	.168	.014	.022	2.14	1.03

Appendix
IAPS picture numbers

Negative: 1120, 1200, 1201, 1300, 1930, 2053, 2141, 2205, 2692, 2710, 2753, 2900, 3181, 3210, 3220, 3230, 3280, 3530, 6020, 6200, 6212, 6230, 6313, 6570, 9000, 9040, 9041, 9042, 9050, 9140, 9180, 9181, 9230, 9250, 9265, 9300, 9340, 9571, 9611, 9911, 9920, 9921

Positive: 1600, 1710, 1750, 1920, 2050, 2080, 2150, 2160, 2208, 2209, 2216, 2311, 2530, 2550, 2655, 4180, 4220, 4250, 4532, 4599, 4607, 4608, 4610, 4640, 4659, 4660, 5260, 5270, 5600, 5621, 5623, 5629, 5830, 5890, 5910, 7580, 8030, 8200, 8370, 8420, 8461, 8500

Neutral: 2214, 2220, 2230, 2271, 2280, 2383, 2440, 2480, 2485, 2495, 2570, 2840, 2850, 2870, 4605, 5534, 5740, 6150, 7000, 7002, 7004, 7006, 7010, 7030, 7035, 7050, 7080, 7100, 7130, 7150, 7190, 7207, 7217, 7233, 7235, 7491, 7496, 7500, 7550, 7560, 7595, 7705