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Recognition memory for valenced and arousing materials under conditions of divided attention

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Two experiments are reported that examined the effect of both valence and arousal on recognition memory performance. Each experiment used two classes of negative items that differed in arousal, as well as a neutral and non-arousing set of items. In Experiment 1 a difficult divided attention task was crossed with the learning and test phases of the experiment. In Experiment 2 encoding time was manipulated and remember–know judgements were collected. The emotional enhancement effect often found with verbal materials survived the depletion of cognitive resources, as did the extra benefit accruing from high arousal. Although we found that arousal led to more recollection, the general conclusion that we draw is that the effect of emotion on recognition memory can be attributed to relatively automatic influences.

Everyone knows that life brings with it a variety of experiences, some of which are pleasant and other ones that we would rather avoid. In terms of their memorability, valenced experiences tend to be better remembered than otherwise comparable neutral ones (for reviews see Buchanan & Adolphs, 2002; Dolan, 2002; Hamann, 2001). This emotional enhancement effect is a rather general property of our memory system because it occurs with any manner of stimulus types (e.g., words, pictures, stories, etc.). It also generally occurs when memory is tested using a wide range of assessment techniques (e.g., recognition, free recall, cued recall, etc.). The exact mechanisms underlying the memorial benefit to emotional materials have been debated over the years. For example, some argue that emotional items receive more rehearsal or more elaborate processing at the time that they are encountered (e.g., Christianson & Engelberg, 1999). These accounts usually posit further that such elaboration can result in idiosyncratic personal relevance of the material, which further increases measures of memory (in particular, recollection; Kensinger & Corkin, 2003). Others argue that the cognitive system is wired in a fashion to preattentively detect valenced materials against the fabric of everyday experiences, and this may be especially true for negative or aversive material (e.g., Anderson, 2005; Christianson, 1992; Williams, Matthews, & MacLeod, 1996). Of course, there are many biological and pharmacological theories for the emotional enhancement effect (Anderson & Phelps, 2001; Cain, Kapp, & Puryear, 2002). These theories align themselves with either the more controlled processing explanations or the ones positing more automatic benefits to memory.

In recent years, investigators have become increasingly aware of the fact that emotional information does not vary along one underlying dimension (Bradley, Greenwald, Petry, & Lang, 1992). Rather, emotional material has two underlying dimensions: valence and arousal. Valence refers to the dimension of how a stimulus evokes positive versus negative affect. By contrast, arousal

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is the degree to which a stimulus evokes an exciting versus a calming reaction. The psychophysiological evidence suggests that valence exerts its influence on more controlled processes such as elaboration and rehearsal. Consequently, when valenced items are experienced that are not arousing, then prefrontal cortical areas are more activated as compared with neutral materials that lack a valenced component (e.g., Kensinger & Corkin, 2004). But when items are presented that are both valenced and arousing, then amygdalar and hippocampal regions become activated thereby implicating the effect of arousal as a more automatic influence on memory (Cahill & McGaugh, 1990; Kensinger & Corkin, 2004; McGaugh et al., 1992). Thus there appear to be two routes by which the emotional enhancement effect can occur: one through controlled processing distinguishing between neutral versus valenced items, and one through more automatic processing distinguishing between arousing valenced materials and non-arousing valenced materials.

Supporting this view of the duality inherent in the emotional enhancement effect, Kensinger and Corkin (2004) conducted a behavioural study in which they presented neutral and two classes of negative items that differed in their level of arousal (arousing and non-arousing). Under conditions of full attention at encoding, both classes of negative items were recognised better than neutral items. However, under divided attention during learning, the negative and arousing items continued to be recognised more frequently, but the negative and non-arousing items no longer held any advantage over neutral words in their rate of subsequent recognition. Therefore the effect of divided attention during learning eliminated the emotional enhancement effect due to valence because it presumably interfered with more controlled processes. However, the arousing materials continued to display their advantage, implying that the effect of arousal on memory is a relatively automatic process that survives division of attention.

The purpose of the present study was to explore these effects further. More specifically, our goal was to compare the effects of dividing attention at both encoding and retrieval. Obviously, with division of attention at encoding we would expect to find that negative and arousing items are better recognised, thereby replicating Kensinger and Corkin (2004). Hicks and Marsh (2000) have claimed that division of attention during a recognition test reduces memory for well-learned, recollective information but leaves intact information that would have been recognised based on vaguer feelings of familiarity (cf. Jacoby, 1999; Jennings & Jacoby, 1993, 1997). Therefore if the difference between arousing and non-arousing items persists under divided attention at test, then the difference is likely owing to average differences in more vague feelings of familiarity between the two classes of negative information. If the difference does not persist, then that outcome would suggest that arousal and amygdalar projections confer their memorial advantage through more disruption-prone recollective details. Alternatively, automatic processes akin to post-stimulus elaboration may be able to engender recollective details without being affected by a reduction in resources. In addition, the division of attention at both encoding and retrieval forces participants to rely solely on familiarity for their recognition judgements and has been known to have the ironic effect of resulting in better memory than, say, dividing attention only during encoding (Hicks & Marsh, 2000; Jacoby, 1991). To our knowledge, whether valence and arousal still confer memorial advantages has not been tested under divided attention at both study and test. Theoretically, finding either a valence advantage and/or an additional arousal advantage would help to specify the type of information conferring that advantage (i.e., recollection or familiarity).

EXPERIMENT 1

The goal of Experiment 1 was to orthogonally cross division of attention with the phase (encoding vs test) in which it was applied. The result was four conditions: one with full attention at both encoding and retrieval, another with divided attention during both phases, and two additional conditions with divided attention only during learning or test but not both.

Method

Participants. Undergraduate students from the University of Georgia volunteered in exchange for credit towards a research appreciation requirement. Each participant was tested individually in sessions that lasted approximately 30 minutes. We tested 25 volunteers in each of the four between-participants conditions. Two people with at-chance performance were replaced, under the assumption that they were not cognitively engaged in the tasks that we asked them to perform.

Materials and procedure. The materials were words selected from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999). Each of the three classes of items comprised 48 words that were equated on both ANEW word frequency and Kučera and Francis (1967) measures. Obviously, the neutral and both negative classes of items differed significantly in valence (5.78 vs 2.43, respectively, in ANEW values), but the neutral and negative non-arousing items were of the same low level of arousal (4.38 in ANEW values). Only the two negative classes of items differed in arousal (4.38 vs 6.84 in ANEW values). For a given participant, the software controlling the experiment randomly chose anew 24 items from each of the three classes to be studied and reserved the remaining 24 items in each class to serve as distractors on the recognition test. In this way, the encoding phase was 72 trials long and the test phase was 144 items long. Each item was studied for 2 s in the centre of the computer monitor during encoding; and the test phase was self-paced. All instructions to participants were first read from the computer monitor and then they were reiterated in the experimenter's own words. No participant was allowed to continue with any task unless the experimenter was confident that the participant had complete understanding of what was being requested. The presentations of all stimuli were preceded by a 250-ms warning tone and fixation point at both study and test. The intertrial interval during testing was 700 ms.

Participants who were asked to perform random number generation (RNG) as the divided attention task were given detailed instructions on how to be random (see Hicks & Marsh, 2000). They were asked to call out a number between 1 and 10 (inclusive) for every beep of an electronic metronome programmed to issue a beep at 1-s intervals. This pacing is quite fast and the task is quite difficult. Participants were given approximately 1.5 minutes to practice the task unencumbered by either learning or testing, during which the experimenter recorded the digits, missed beats, etc. to serve as a baseline measure of randomness to compare with performance when the task was performed concurrently. After practice, either the learning phase or test phase was administered. In all cases where the baseline did not need to be taken (or had already been taken earlier in the case of dividing attention at both study and test) all other participants were given a mathematical distractor task to equate the timing and retention intervals across all four between-participants conditions.

Results and discussion

In this and the following experiment, unless a *p* value is reported with a statistical test, the probability of a Type I error does not exceed the conventional 5%. We begin by reporting the results of the RNG task. A measure of randomness was computed using the first 100 digits at both baseline and when the task was performed concurrently. Numerically lower values of RNG indicate more random sequences and higher values indicate less random performance. For the conditions where the task was performed while studying words, baseline performance was 0.29 and it was 0.33 when performed concurrently during encoding, $t(59) = 5.65$. For the conditions where the task was performed during testing, baseline performance was 0.30 and it was 0.34 when performed concurrently during testing, $t(59) = 4.57$. Consequently, there were no dual task trade-offs in which participants sacrificed performance on one task to perform well on the other because, as we will show shortly, memory performance also suffered when performed concurrently as well. In short, performance deficits were shown on both tasks (cf. Marsh & Hicks, 1998).

The hit rates and false alarm rates are reported in Table 1 for each of the three classes of items across the four between-participants conditions. These metrics have also been combined by subtracting the false alarm rate from the hit rate within a given class of items to arrive at measures of corrected recognition. Only the last three columns of Table 1 were analysed statistically. We conducted a 2 (full vs divided attention at encoding) × 2 (full vs divided attention at test) × 3 (item type) Analysis of Variance (ANOVA). As the reader can see, negative items were recognised more often than their neutral counterparts, $F(2, 192) = 27.81$, $\eta_p^2 = 0.23$. Thus, the emotional enhancement effect was obtained. In simple effects tests that contrasted the negative arousing items against the negative non-arousing items, there were significant differences when attention was divided at study alone and test alone, smaller

TABLE 1
Recognition accuracy in Experiment 1

		Memory measure and item type								
		Hits			*False alarms*			*Corrected recognition*		
Study manipulation		*NegNA*	*NegA*	*NeuNA*	*NegNA*	*NegA*	*NeuNA*	*NegNA*	*NegA*	*NeuNA*
Full Attention	*M*	.76	.79	.68	.23	.20	.31	.54	.59	.36
	SE	(.03)	(.03)	(.04)	(.04)	(.03)	(.04)	(.07)	(.06)	(.07)
DA @ Study	*M*	.61	.66	.50	.40	.34	.50	.21	.31	.01
	SE	(.03)	(.03)	(.03)	(.03)	(.03)	(.03)	(.06)	(.06)	(.07)
DA @ Test	*M*	.73	.78	.69	.27	.22	.31	.46	.55	.39
	SE	(.02)	(.02)	(.03)	(.02)	(.02)	(.03)	(.05)	(.04)	(.05)
DA @ Both	*M*	.64	.67	.59	.36	.33	.41	.28	.33	.17
	SE	(.03)	(.03)	(.04)	(.03)	(.03)	(.04)	(.07)	(.06)	(.07)

Standard errors are in parentheses.
Corrected recognition = Hits – False alarms.

of the two *t*s(24) = 2.15. However, there was only a nominal effect favouring the arousing negative items over the non-arousing in the remaining two conditions. Most critically, the evidence appears to converge on the idea that the emotional enhancement effect for negative items over neutral items is not necessarily eliminated by division of attention at either study or test (cf. Kensinger & Corkin, 2004). In addition, the benefit of arousing over non-arousing items was numerically present in two of the four conditions, and statistically present in the other two conditions, so it too appears to generally survive the depletion of cognitive resources. This claim can be further bolstered by running a reduced ANOVA model without the full attention condition and without the neutral items that shows the difference between the two classes of negative items is statistically significant, $F(1, 72) = 8.26$, $\eta_p^2 = 0.10$.

Not surprisingly, performance was much lower when attention was divided during study as compared with full attention, $F(1, 96) = 25.03$, $\eta_p^2 = 0.21$. That outcome replicates the extensive work that Naveh-Benjamin and his colleagues have performed to show that almost inevitably depletion of resources during study has a deleterious effect on memory (e.g., Naveh-Benjamin, Guez, & Marom, 2003; Naveh-Benjamin, Kilb, & Fisher, 2006). In the omnibus test the main effect of divided (versus full) attention at test did not reach significance and none of the interactions was significant. The absence of this test effect in contrast to Hicks and Marsh's (2000) significant effect is likely owing to the fact that two-thirds of the entire set of materials were protected by the emotional enhancement effect. In addition, participants assigned to the condition with both divided attention at study and test performed numerically better than those in the condition with only divided attention during study. Participants in the former condition are forced to rely almost exclusively on familiarity and in doing so adjust their decision criteria to maximally capture studied items.

In sum, although the depletion of resources at study and test did negatively impact memory, it generally left both the emotional enhancement effect and the advantage to arousing over non-arousing items intact. One cannot claim that the RNG task was too easy because Hicks and Marsh (2000) used the very same task at a slower pace and found a significant reduction in recognition memory for neutral materials. Therefore, these results suggest that there are tasks and conditions where the benefits to emotional material survive even a severe depletion of resources.

EXPERIMENT 2

Our goal in this next experiment was to ascertain just how early in the processing sequence the emotional advantage to arousing items occurs. Although dividing attention during study hurt performance in Experiment 1, participants still had a full 2 s at encoding to process the items. Because shortening the study time acts like divided attention, we expected worse performance when items were studied for 250 ms as compared with 2000 ms of encoding time. The question was whether the emotional enhancement effect would be observed with such short processing time, and over and above that, whether the arousing items were still better recognised. If our conclusions from Experiment 1 are accurate, that these effects are largely due to automatic processes, then the effect may indeed survive very fast presentation rates. To provide a larger window into memory performance, we also took remember–know judgements in this experiment. Valenced materials will often be recognised to greater degree with remember responses than more neutral material (e.g., Kensinger & Corkin, 2003; Ochsner, 2000).

Method

Participants. Undergraduates from the University of Georgia volunteered in exchange for partial credit towards a research appreciation requirement. Each of the 30 participants was tested individually in sessions that lasted approximately 30 minutes.

Materials and procedure. The materials used in Experiment 1 were used again, as was the core of the procedures. The main difference was that half of each class of items were studied for 250 ms whereas the other half were studied for 2000 ms. Study duration in the study sequence appeared random to the participant, but they were informed that different study times were being manipulated. At test, detailed instructions on the distinction between remembering and knowing were read initially from the computer monitor. These were followed by a detailed restatement from the experimenter in his or her own words. Finally, the participant had to repeat back to the experimenter their understanding of this distinction. Because this was a fairly involved process requiring approximately 6 minutes, no distractor task was administered. During the test itself, participants decided for each item whether they recollected it, knew that it had been studied, or it was brand new (i.e., three response options).

Results and discussion

We analysed the remember responses separately from the know responses; and these proportions can found in Table 2. In the omnibus 2 (encoding time) × 3 (item type) ANOVA, there was a main effect of encoding time on remember responses, $F(1, 29) = 38.31$, $\eta_p^2 = 0.57$. Greater encoding time resulted in more recollection. There was also a main effect of item type, $F(2, 58) = 7.08$, $\eta_p^2 = 0.20$, but no interaction. As the reader can see, arousing items received more remember responses than negative non-arousing or neutral items did. The specific contrast between the two negative classes of items was statistically significant at both short, $t(29) = 2.09$, and long, $t(29) = 1.98$, $p = .05$, encoding durations. Thus, in recollection we did not find a general emotional enhancement effect, but rather found only an effect of arousal that was present even at the very short encoding duration.

In know responses, only the main effect of item type was statistically significant, $F(2, 58) = 3.17$, $\eta_p^2 = 0.10$. As often happens with the remember–know procedures, Rs and Ks will trade-off with one another. This outcome appears to have happened here because negative non-arousing items received the most know responses. None of the other terms in the model was statistically

TABLE 2
Proportion of remember, know, & new responses in Experiment 2

	Study duration and item type					
	Short (250 ms)			*Long (2000 ms)*		
Response type	*NegNA*	*NegA*	*NeuNA*	*NegNA*	*NegA*	*NeuNA*
Remember	.33 (.03)	.39 (.04)	.30 (.03)	.45 (.04)	.54 (.05)	.45 (.04)
Know	.35 (.03)	.32 (.04)	.30 (.03)	.34 (.03)	.30 (.03)	.28 (.03)
New	.32 (.03)	.29 (.03)	.40 (.03)	.21 (.02)	.16 (.03)	.28 (.03)

Standard errors are in parentheses.

significant. Taken together, the remember and know responses demonstrate that the advantage to longer encoding times and the effects of arousal are both localised to better recollection, with neither of these effects necessarily strongly emerging in the know (familiarity) responses.

To provide a touchstone to the previous experiment we summed over the claims of remember and know. The reader can see that these proportions will be the complement to unity of the claims that old items were new in Table 2. There were main effects of emotional enhancement in these hit rates, $F(2, 58) = 10.94$, $\eta_p^2 = 0.27$, as well as encoding duration, $F(1, 29) = 27.55$, $\eta_p^2 = 0.49$. Thus, although the effect of arousal is mainly localised to recollection, there is an emotional enhancement effect in the overall hit rates.

GENERAL DISCUSSION

The empirical outcomes of this study demonstrate that both the emotional enhancement effect due to valence and the additional benefit of arousal on memory survive divided attention at both encoding and test. Moreover, the additional benefit of arousal appears to occur very early in the information-processing stream because it can occur with study conditions as rapid as 250 ms. Although others have found the benefit of valence to be localised to remember responses (i.e., recollection; Dewhurst & Parry, 2000; Kensinger & Corkin, 2003) we found that only the arousing items showed heightened remember responses. Although it is easy to say that the materials might be responsible for this effect, we believe that a more likely candidate is the direct contrast between arousing and non-arousing items. Dewhurst and Parry found a remember response advantage to valenced materials when they were learned alongside neutral materials. When the lists were made pure (i.e., separate neutral and valenced lists), the recollective advantage for valenced items disappeared. In the present case, the non-arousing items might not be receiving recollective responses because the arousing items are viewed as the more memorable class of items. Obviously, pure lists of arousing and non-arousing items would need to be tested to assess the viability of this idea.

Because both the emotional enhancement effect and the arousal effect survive divided attention, we believe that it is relatively unlikely that the memorial benefit of processing valenced items is due to more elaborate encoding or additional processing resources being devoted to them. The pace of the RNG task was quite rapid and many of our participants expressed frustration over the difficulty of the task. Although it is tempting to say that the effect of valence is owing to conscious resources and the effect of arousal is due to more automatic amgydalar activation (Kensinger & Corkin, 2004), the present results argue quite strongly that there is a strong automatic component to both the effect of arousal and valence on subsequent memory. This point is important because it shows that there are tasks and conditions where an emotional enhancement effect can be obtained even when more elaborative encoding and assessment cannot reasonably be applied. Therefore, although we do not disagree that there are indeed two routes for emotion to affect memory, even when the more conscious route is severely constrained the more automatic route can occur as a consequence of both valence and arousal.

In dual-process theories of memory, the reduction of conscious resources at either encoding or test leave familiarity as the primary basis for responding (e.g., Jacoby, 1999; Kelley & Jacoby, 1998). Thus, in all but the full attention condition in Experiment 1, the memorial advantages accruing to valence and arousal had to be based primarily on familiarity. In Experiment 2, recollection dominated the arousal effect, and know judgements contributed to an overall emotional enhancement in the hit rates. Together the experiments demonstrate that valence can confer its memorial advantage by either recollection or familiarity. Consequently, finding greater remember responses for valence materials, as many others have reported, does not mean that the enhancement effect cannot in some situations be due primarily to familiarity as we found in Experiment 1. In other words, we do not believe that there is necessarily any lawful relationship that allows one to claim that emotionality effects are due primarily to a recollective process or to a familiarity process—rather, which process confers the emotional enhancement effect is likely to depend on the particulars of the learning episode and the conditions under which memory is tested.

To place our findings in the broader fabric of work on emotion and memory, the reader should understand that our materials were relatively tame and the sizes of our effects mainly modest. With some stimuli such as the International

Affective Picture System (Lang, Bradley, & Cuthbert, 1999), the emotional reactions can be quite extreme. In these cases, researchers can observe memory decrements due to emotion such as not fully processing information that might be considered peripheral to the central subject (e.g., Loftus, Loftus, & Messo, 1987; Pickel, French, & Betts, 2003). Consequently, many of the effects of emotion depend on the severity of the emotional reaction that people have to the materials being used. The so-called weapon focus effect would be considered the loss of contextual information due to the narrowing of attention, but context memory for valenced words has been found to be improved in some cases (Doerksen & Shimamura, 2001) but not universally (Cook, Hicks, & Marsh, 2006). Our point is that what sort of effect will be found, and whether it will be found in recollection or familiarity, is going to be highly specific to the particular learning and retrieval episodes being studied. We are not saying that there are no lawful relationships to be found, only that they will often have to be strongly qualified by the particular contexts in which they occur.

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