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BRIEF REPORT

The role of attention in the associative binding of emotionally arousing words

Geoffrey B. Maddox · Moshe Naveh-Benjamin · Susan Old · Angela Kilb

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Abstract In the present study, we examined the role of attention in modulating the memory benefit of emotional arousal for same-valence word pair associations. To assess the role of attention either at encoding or at retrieval, participants studied lists of positive, neutral, and negative words pairs under full attention, divided attention at encoding, or divided attention at retrieval, and then were tested on the single words and on the associations between words. Consistent with past studies, memory accuracy was higher for emotional items than for neutral items, and no memory difference was observed across emotional arousal conditions for associations when encoding occurred under full attention. In contrast, memory accuracy was higher for emotionally arousing items and associations relative to neutral items when encoding occurred under divided attention. Finally, dividing attention at retrieval revealed similar effects across emotion conditions, suggesting that retrieval of emotional stimuli relative to neutral stimuli, unlike encoding, does not benefit from automatic processing. The discussion emphasizes the role of automatic processing during encoding in producing the benefit of emotionally enhanced memory, as well as the extent to which controlled attention is responsible for eliminating or reversing (relative to neutral materials) emotionally enhanced memory for associations. Additionally, the implications of the divided-attention-at-retrieval manipulation include consideration of the way in which emotional items may be consciously processed during encoding.

Keywords Episodic memory · Divided attention · Emotion · Associative memory

G. B. Maddox
Department of Psychology, Washington University,
St. Louis, MO, USA

M. Naveh-Benjamin (✉)
Department of Psychological Sciences, University of Missouri, Columbia,
106 McAlester Hall,
Columbia, MO 65211, USA
e-mail: navehbenjaminm@missouri.edu

S. Old
Missouri Southern State University,
Joplin, MO, USA

A. Kilb
Plymouth State University,
Plymouth, NH, USA

Evidence suggests that memory is often better for emotionally arousing than for neutral stimuli (see Kensinger, 2009, for review). This finding is termed *emotionally enhanced memory* (EEM; Talmi, Schimmack, Paterson, & Moscovitch, 2007) and has been observed across numerous experimental manipulations (see Kensinger, 2009, for a review). Although robust, EEM is sometimes eliminated or reversed in situations that demand associative binding between two emotional items (e.g., Naveh-Benjamin, Maddox, Jones, Old, & Kilb, 2012; Pierce & Kensinger, 2011) or between emotional and neutral items (e.g., Nashiro & Mather, 2011).

To account for the trade-off in memory between emotional items and associations, Mather (2007) suggested that controlled attention benefits and disrupts EEM for intraitem and interitem associations, respectively. When binding occurs within an item (e.g., a person's face and expression), attention directed toward one component will also be directed toward the entire object, which enhances encoding of the intraitem association. When binding occurs between items (e.g., two faces), emotionally arousing items may capture attention, and in turn, the association between items is not encoded as well as is the association between two neutral items. Similarly, Christianson (1992) suggested that controlled attention contributes to positive and negative EEM and that negative EEM also benefits from automatic processing. In this sense, controlled processing is more demanding of attentional resources but can be directed toward specific tasks or objects, whereas automatic processing is relatively less demanding of resources but occurs without the individual's direction. We next consider the roles of controlled and automatic processing in producing EEM.

Divided attention during encoding of emotional stimuli

One way to assess controlled and automatic processes in memory performance is to divide a participant's attention (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Gavrilescu, & Anderson, 2000). When attention is divided, effects obtained under full attention that are due primarily to effortful processes should be reduced, whereas effects due to automatic processes should be relatively unaffected. Moreover, reduced secondary-task performance within a condition may also indicate that controlled processes are critical for the primary memory task effect.

With respect to divided attention and EEM, past research has typically focused on negative EEM, but it is important to consider negative and positive EEM separately, given Christianson's (1992) proposal that negative and positive EEM may be differentially supported by controlled and automatic processes. Indeed, Talmi et al. (2007; see also Clark-Foos & Marsh, 2008; Kern, Libkuman, Otani, & Holmes, 2005) reported a study in which participants studied positive, neutral, and negative pictures under full or divided attention during encoding (i.e., a tone discrimination task). Although recall results revealed EEM under both full and divided attention for positive and negative pictures, there was a significant cost to memory performance for positive but not for negative stimuli when the stimuli were encoded under divided attention. Importantly, positive EEM was completely mediated by secondary-task performance (i.e., controlled attention), and negative EEM was due to automatic processing during encoding.

Other studies, however, have demonstrated that controlled attention also contributes to negative EEM. For example, Pottage and Schaefer (2012) asked participants to encode negative and neutral pictures under full and divided attention. When attention was divided during encoding, participants viewed a series of single digits superimposed on each picture and determined whether an even or odd number of digits was presented. Recall results revealed main effects of attention and emotion but no interaction, which suggested that negative EEM was due to automatic processing during encoding. However, a mediation analysis revealed that secondary-task performance partially mediated negative EEM (see also Talmi & McGarry, 2012). Pottage and Schaefer attributed the difference between their results and Talmi et al.'s (2007) results to the use of a more strenuous secondary task. Thus, automatic and controlled attention may both contribute to negative EEM. These mixed findings in the literature suggest the need for further investigation of emotion and attention (see Pessoa, 2010, for a similar argument when using fMRI and EEG).

Present study

Past research is unclear regarding the contributions of automatic and controlled attentional processes to positive and negative EEM. Moreover, these studies have several limitations worthy of consideration. First, as Talmi and McGarry (2012) noted, the use of picture stimuli and free recall (typical in many studies) addresses the influence of emotion and divided attention on gist memory but may not fully address verbatim memory, because free recall of picture stimuli may capture an image's theme or central object without capturing its details. Second, the role of attention in producing the trade-off in EEM between items and interitem associations has not been examined. Thus, in the present study we examined divided attention during encoding of emotional and neutral items and of interitem associations when using recognition testing. Moreover, we also examined divided attention during retrieval of emotional stimuli.

It was predicted that a trade-off in memory for emotional items and associations would be observed and that it would reflect a benefit of emotional over neutral item memory but no difference (or a trade-off) between neutral and emotional associations when encoding and retrieval occurred under full attention (e.g., Naveh-Benjamin et al., 2012; Pierce & Kensinger, 2011). Furthermore, if memory for negative stimuli benefits in part from automatic processing (e.g., Pottage & Schaefer, 2012), negative EEM may be preserved under divided attention during encoding, but positive EEM may be reduced or eliminated for items and associations. Finally, if retrieval of emotional items is relatively automatic, the trade-off between memory for emotional items and associations should be observed even under divided attention at retrieval. Alternatively, if retrieval of emotional stimuli is as effortful and demanding of controlled processes as retrieval of neutral stimuli, then dividing attention during retrieval may eliminate or reduce positive and negative EEM.

Method

Participants

A group of 36 undergraduates at the University of Missouri participated in exchange for course credit (mean age = 19.11 years, *SD* = .82 years). Of the total sample, 14 were men and 22 were women.

Design and materials

Three variables were manipulated as within-subjects factors. These variables included test type (item, association), attention during encoding and retrieval (full–full, F-F; divided–full, DA-F; and full–divided, F-DA; the first entry refers to encoding, and the second one to retrieval), and valence (positive, neutral, negative).

Six lists from Naveh-Benjamin et al. (2012, Exp. 1) were used, which each consisted of 39 word pairs of the same valence (e.g., positive–positive). Each list consisted of equal numbers of positive, neutral, and negative pairs. Across valence conditions, stimuli were controlled for length and HAL frequency (Balota et al., 2007), as well as for imageability, meaningfulness, concreteness, and part of speech (Toglia & Battig, 1978). An independent sample (N = 12) provided valence and arousal ratings for all words. Valence ratings were different across conditions (ps < .001; Ms = 2.80, 5.38, and 6.89 on a 1–9 scale, with 1 being *extremely negative*). Arousal ratings were equivalent between positive and negative stimuli (p = .73; Ms = 5.17 and 4.93, respectively, on a 1–9 scale, with 1 being *not arousing*), both of which had more arousing ratings than neutral stimuli (M = 3.51; ps < .05). Additionally, a latent semantic analysis of co-occurrence failed to reveal an effect of valence, p > .05 (Landauer, Foltz, & Laham, 1998). Lists were counterbalanced across attention conditions, and word pairs were presented randomly within each list. Finally, a concurrent continuous auditory response time (CRT) task required responses to a series of three different pitches of tones. The tones sounded for 200 ms each and were played through headphones. Responses were made by pressing one of three adjacent keys on a keyboard, which were labeled "L," "M," and "H," corresponding respectively to the low-, medium-, and high-pitched tones.

Procedure

Participants were tested individually and first completed a practice session in which short lists of word pairs were encoded and retrieved under full attention; the tone discrimination task was then practiced in isolation, and finally the memory and tone discrimination tasks were combined. Participants received practice with both divided-attention conditions (DA-F and F-DA). In all practice conditions, participants completed both item and association recognition tests.

For the experimental phase, the participants completed three cycles of testing, each consisting of two blocks of the memory task. Between cycles, participants completed the auditory tone discrimination task for 1 min to serve as a baseline measure. Across cycles, participants completed two lists in each of the three attention conditions (F-F, DA-F, and F-DA). The order of the attention conditions was counterbalanced across cycles and participants.

Stimuli were presented individually at a rate of 6 s per pair, and participants were instructed to learn the items and associations. Following encoding, participants completed a backward-counting task for 30 s before proceeding with recognition testing. The order of tests was counterbalanced across participants, and word pairs were counterbalanced across test types (item test, intact associations, and recombined associations). Traditional old–new item tests consisted of 30 items (ten from each valence condition). Half of the items in each valence condition had been previously studied, and half were unstudied lure items. The association tests consisted of 30 word pairs (ten from each valence condition). Participants were informed that all items had been previously studied and were told to say "yes" if the word pair was intact (i.e., the first and second words of the pair had been presented together during learning) and "no" if the word pair was recombined (i.e., the first and second words of the pair had been presented with different words during learning). Half of the pairs in each valence condition appeared intact and half were recombined. All recombined associations consisted of two words of the same valence condition. No stimulus appeared on both the item and association tests for a given participant.

When encoding occurred under divided attention, participants were told to divide their attention equally between responding to the tone task and learning the items and associations. Unlike previous studies, in which secondary-task tones occurred at prespecified time points (e.g., primary task stimulus onset), the tone discrimination task in the present study was participant-paced, such that a tone's onset did not occur until participants had responded to the previously presented tone. In addition to accuracy, this procedure provided a measure of rate (i.e., how many tone discrimination trials did a participant complete within a given condition?). When retrieval occurred under divided attention, participants were told to divide their attention equally between responding to the tone task and to the recognition test. Finally, the baseline tone-task condition required that participants complete the tone task as quickly and accurately as possible.

Results

Since we had specific hypotheses regarding differences in processing under full and divided attention at encoding and retrieval, we will report separate comparisons between the DA-F and F-F conditions and the F-DA and F-F conditions.

Full versus divided attention at encoding

Overall memory accuracy A corrected recognition score was calculated for each participant by subtracting the proportion of false alarms (responding "old" to a lure or recombined pair on the item or association test, respectively) from the proportion of hits (responding "old" to a studied item or intact pair on the item or association test, respectively). Accuracy is presented in Table 1 and was submitted to a 2 (Attention) × 2 (Test) × 3 (Valence) ANOVA. All main effects were significant, *p*s < .005. Moreover, the Attention × Valence interaction was significant, $F(2, 70) = 3.19$, $p = .047$, $\eta_p^2 = .08$, which reflected similar benefits for negative and positive stimuli over neutral stimuli when they were learned under full attention ($M = .04$ and $M = .07$, respectively), but a larger benefit for negative than for positive stimuli, relative to neutral stimuli, when encoding occurred under divided attention ($M = .16$ and $M = .10$, respectively). Finally, the three-way interaction was marginally significant, $F(2, 70) = 3.19$, $p = .076$, $\eta_p^2 = .07$.[1]

As can be seen in Fig. 1, the marginal three-way interaction reflects the benefit in memory performance for emotional *items* over neutral items when encoding occurred under full and divided attention. However, a benefit for both positive and negative *associations* over neutral associations was only observed when encoding occurred under divided attention. Separate 2 (Attention) × 3 (Valence) ANOVAs were conducted for each test. Regarding item recognition, the results revealed main effects of attention, $F(1, 35) = 22.44$, $p < .001$, $\eta_p^2 = .39$, and valence, $F(2, 70) = 10.53$, $p < .001$, $\eta_p^2 = .23$. Furthermore, the Attention × Valence interaction was marginally significant, $F(2, 70) = 2.66$, $p = .077$, $\eta_p^2 = .10$, which reflected significant differences between attention conditions for positive and neutral stimuli (*p*s < .005), but no difference for negative stimuli ($p = .153$). Importantly, significant negative EEM ($p < .001$) and marginal positive EEM ($p = .078$) were obtained when attention was divided at encoding.

Regarding associative recognition, the results revealed an effect of attention, $F(1, 35) = 29.48$, $p < .001$, $\eta_p^2 = .46$, but no effect of valence, $p > .15$. The Attention × Valence interaction was significant, $F(2, 70) = 3.35$, $p = .041$, $\eta_p^2 = .09$, which reflected similar performance across valence conditions under full attention but significant benefits for both positive and negative association recognition relative to the neutral condition under divided attention (*p*s < .05). There was no difference between positive and negative association recognition ($p = .454$).

Tone-task performance Although reaction times and tone identification accuracy (percentage of correct responses) were improved when the secondary task was completed in isolation (i.e., baseline; see Table 2) relative to when the task was completed during encoding (*p*s < .005), there were no differences in reaction times, accuracy, or number of trials completed across valence conditions when the secondary task was completed during encoding (*p*s > .45).

Full versus divided attention at retrieval

Overall memory accuracy Accuracy is presented in Table 1 and was submitted to a 2 (Attention) × 2 (Test) × 3 (Valence) ANOVA. The results revealed a significant effect of attention, $F(1, 35) = 5.19$, $p = .029$, $\eta_p^2 = .13$, and a marginal effect of test, $F(1, 35) = 2.99$, $p = .093$, $\eta_p^2 = .079$. Additionally, the Test × Valence interaction was significant, $F(2, 70) = 3.77$, $p = .028$, $\eta_p^2 = .10$. As can be seen in Fig. 2, performance was higher for positive and negative items than for neutral items (*p*s < .05), but was equivalent across valence conditions for associations (*p*s > .20).[2] This interaction, however, was driven entirely by the full–full condition and was not significant when performance in the full–divided attention was analyzed separately ($p > .50$). No other interactions involving valence were significant (*p*s > .20).

Tone-task performance Accuracy was reduced and reaction times increased on the auditory tone task when it was completed during retrieval rather than completed alone (*p*s < .001). Reaction times were submitted to a 2 (Test) × 3 (Valence) ANOVA that yielded a main effect of test, $F(1, 66) = 28.75$, $p < .001$, $\eta_p^2 = .47$, reflecting slower reaction times during the association test ($M = 2,089$ ms) than during the item test ($M = 1,830$ ms).

Accuracy was submitted to a 2 (Test) × 3 (Valence) ANOVA that yielded a main effect of valence, $F(2, 66) = 7.49$, $p = .001$, $\eta_p^2 = .19$; a marginal effect of test type, $F(1, 33) = 3.65$, $p = .065$, $\eta_p^2 = .10$; and a significant Test × Valence interaction, $F(2, 66) = 5.78$, $p = .005$, $\eta_p^2 = .15$. This interaction reflected equivalent performance during the association test for the positive ($M = .77$), neutral ($M = .76$), and negative ($M = .77$) conditions, but poorer secondary-task performance on the item test for the negative condition ($M = .62$), relative to the positive ($M = .79$) and neutral ($M = .76$) conditions.

Finally, there were no differences in the numbers of secondary-task trials (i.e., completion rate) across valences when completing the item test (*p*s > .40) or the association test (*p*s > .40).

Discussion

In the present study, we examined the influence of divided attention on EEM and extended on past research in two critical ways. First, the present study revealed the influence of divided attention during encoding for item and interitem

[1] Analysis of the signal detection *d′* measure revealed the same pattern of results as for overall accuracy, including a significant three-way interaction, $p = .019$.

[2] Again, analysis of the signal detection *d′* measure revealed the same pattern of results as for overall accuracy.

Table 1 Mean proportions (and standard errors) of hits and false alarms (FAs), with corrected recognition scores (hits minus FAs), as a function of attention and valence conditions for the item and association recognition tests

	Items			Associations		
	Positive	Neutral	Negative	Positive	Neutral	Negative
	Full–Full					
Hits	.76 (.03)	.61 (.03)	.69 (.03)	.67 (.03)	.62 (.04)	.69 (.03)
FAs	.16 (.02)	.16 (.02)	.15 (.02)	.22 (.03)	.14 (.03)	.22 (.03)
Hits – FAs	.60 (.04)	.45 (.04)	.54 (.04)	.45 (.04)	.48 (.04)	.47 (.04)
	Divided–Full					
Hits	.63 (.03)	.49 (.03)	.67 (.03)	.55 (.03)	.43 (.04)	.56 (.03)
FAs	.28 (.03)	.23 (.02)	.23 (.03)	.27 (.03)	.25 (.03)	.24 (.03)
Hits – FAs	.35 (.04)	.26 (.03)	.44 (.04)	.28 (.04)	.18 (.05)	.32 (.04)
	Full–Divided					
Hits	.67 (.03)	.59 (.03)	.69 (.03)	.64 (.03)	.61 (.04)	.65 (.04)
FAs	.22 (.03)	.16 (.03)	.21 (.03)	.22 (.04)	.15 (.03)	.20 (.03)
Hits – FAs	.45 (.04)	.43 (.04)	.48 (.03)	.42 (.04)	.46 (.04)	.45 (.05)

associations when using recognition testing. The use of interitem associations and recognition testing allowed for an examination of the role of attention in producing EEM for verbatim versus gist memory (a concern noted by Talmi & McGarry, 2012), and also afforded the opportunity to examine the role of attention in producing the trade-off in EEM between items and interitem associations. Second, the present study revealed the influence of divided attention at retrieval.

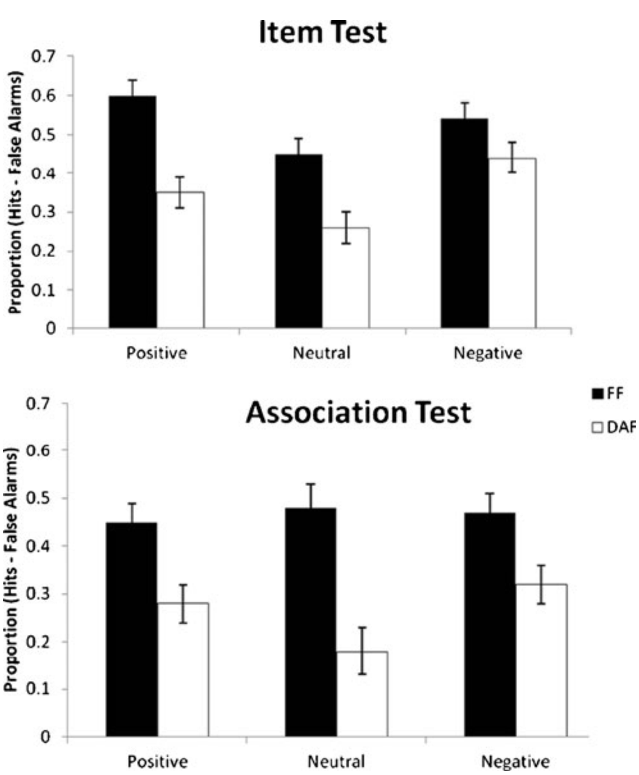

Fig. 1 Memory performance (mean proportions of hits minus false alarms ± 1 *SE*) as a function of valence condition and test type for the full–full (FF) and divided–full (DAF) attention conditions

Regarding the role of attention during the encoding of emotional and neutral word pairs, we replicated and extended past findings of EEM for items but no difference in performance across valence conditions for associations when materials were learned under full attention (e.g., Naveh-Benjamin et al., 2012). When encoding occurred under divided attention, relative to full attention, recognition accuracy was significantly reduced for positive and neutral item memory, but not for negative item memory. However, we did find evidence for both positive and negative item EEM under divided attention at encoding, even though secondary-task performance was equivalent across all conditions. This finding diverges from past findings that have suggested that positive EEM is fully mediated by controlled attention (e.g., Talmi et al., 2007), and instead suggests that positive memory may benefit in part from automatic processing. Critically, the differential decline in performance between positive and negative conditions when attention was divided suggests that negative stimuli may be preferentially processed over positive stimuli or may benefit more from automatic processing than do positive stimuli. Most importantly, EEM was observed for associations when encoding occurred under divided attention, which contrasts with the typical finding of an elimination or impairment of EEM for interitem associations when encoded under full attention (e.g., Madan, Caplan, Lau, & Fujiwara, 2012; Pierce & Kensinger, 2011). The preserved EEM for associations under divided attention reflected a larger decrease in memory for neutral associations than for emotional associations when attention was divided. This finding underscores the importance of controlled attention in the binding process for neutral interitem associations as a way of offsetting the benefit of the automatic

Table 2 Mean tone-task accuracy (percentage correct; top panel) and reaction times (in milliseconds; bottom panel), with standard errors in parentheses, as a function of attention and valence conditions

	Positive	Neutral	Negative	Baseline
	Accuracy			
Encoding	.87 (.02)	.87 (.03)	.87 (.02)	.93 (.02)
Item test	.79 (.02)	.76 (.02)	.62 (.05)	
Association test	.78 (.03)	.77 (.03)	.76 (.03)	
	Reaction Time			
Encoding	1,236 (76)	1,221 (83)	1,220 (72)	888 (18)
Item test	1,784 (115)	1,836 (117)	1,871 (113)	
Association test	2,134 (122)	2,024 (122)	2,107 (143)	

processing elicited by emotional stimuli. When the influence of controlled processing was limited during encoding, as it was in our divided-attention paradigm, the benefit of automatic processing for emotional stimuli was observed even for association memory.

In the present study, we also examined the role of attention during retrieval of emotional and neutral words and word pairs. Under divided attention at retrieval, no EEM emerged for item or association memory, which suggests that retrieval of emotional stimuli relies in part on controlled attention. The extent to which retrieval of positive, neutral, and negative materials relies on controlled processing is elucidated by secondary-task

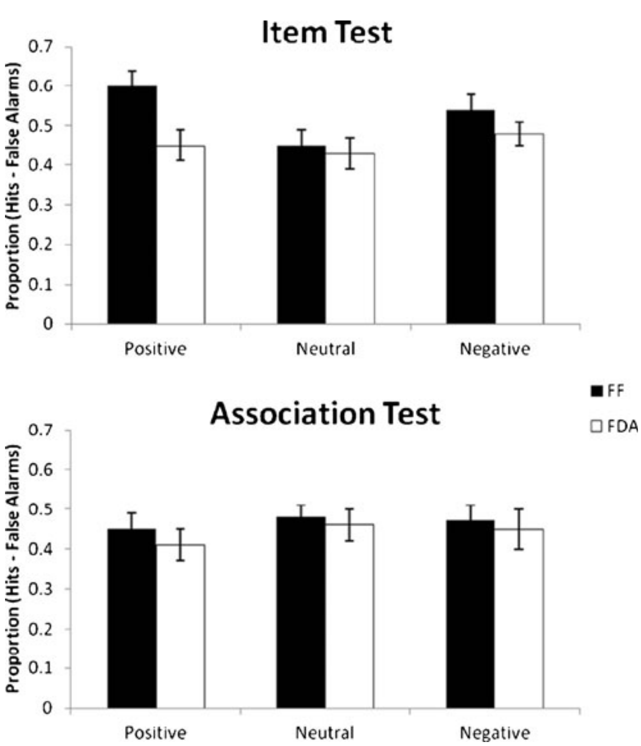

Fig. 2 Memory performance (mean proportions of hits minus false alarms ± 1 *SE*) as a function of valence condition and test type for the full–full (FF) and full–divided (FDA) attention conditions

performance. First, consider the association test. Equivalent secondary-task performance across emotion conditions suggests that discrimination between intact and rearranged word pairs is similarly demanding of controlled processes (e.g., inhibition or recollection) when all stimuli are familiar. This contrasts with secondary-task performance during item recognition (discriminating studied items from unstudied lures), which was poorer when the secondary task was completed during negative trials, relative to positive and neutral trials, suggesting that controlled processing may be relatively more important for recognition of negative than of positive and neutral items. This increased demand for controlled processing during recognition of negative items may be due to the greater contribution of automatic processing during encoding for negative stimuli than for positive or neutral stimuli. It may also be the case that controlled processing is required to inhibit the processing fluency of lure items, given past evidence suggesting that negative stimuli benefit more from semantic categorization than do positive or neutral stimuli (Talmi & McGarry, 2012). Such differential demands of controlled processing across emotion conditions may not be readily observed in association recognition tests, when all items are familiar and discrimination between intact and rearranged pairs is more reliant on recollection processes. Of course, future work will be required to examine this suggestion.

In sum, our results suggest that automatic processing contributes to positive EEM as well as negative EEM. Moreover, when controlled attention was limited during encoding, neutral association memory was reduced, such that EEM for positive and negative associations was observed. This finding suggests that controlled attentional processing of neutral associations may benefit both the individual components and the interitem associations between components, relative to controlled processing of emotional associations, in which attention may be directed toward the individual components at the cost of adequately binding these components. Importantly, emotional items and interitem associations benefited similarly from automatic attention and did not suffer from the item-level attentional capture that would otherwise disrupt automatic processing of the associations (cf. Mather, 2007). The use of recognition testing with intact versus recombined associations also addresses a limitation of past studies regarding gist-based memory in free recall of pictures. The results from the present study suggest that EEM is similarly obtained when relatively more detail-dependent memory (i.e., memory for associations) is assessed, but this was only true when controlled processing was limited during encoding. Finally, divided attention at retrieval suggested that demands on controlled processing were similar across valence conditions for association recognition, but were significantly greater for negative item recognition than for positive and neutral item recognition. When examining the contributions of automatic and controlled processing to positive and negative EEM, the relative demands of primary and secondary tasks during encoding and retrieval should be more fully considered.

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