Journal of Memory and Language 107 (2019) 54–68

Contents lists available at ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

The effects of arousal and attention on emotional false memory formation

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ARTICLE INFO

Keywords:
Arousal
Automatic processing
Controlled processing
False memory
Valence
Attention

ABSTRACT

Previous research has shown that with reduced attention at encoding, false recognition of critical lures for negative arousing DRM lists were higher than positive arousing lists. The current study extends this research to examine the role of attention for both arousing and non-arousing valenced false memory formation. Further, due to contradictory findings in past research, we examined attention at encoding using both within- (Experiment 1) and between- (Experiment 2) participants design. Participants were exposed to high and low arousing, valenced DRM lists under full and reduced attention conditions. Experiment 1 revealed that only negative arousing false memories were not affected by reduced attention at study, all other false memories decreased. In Experiment 2, although recognition of negative high arousing critical lures was higher, false memories increased in the reduced attention condition for all list types. Differences in attention during encoding affect the retrieval of emotional stimuli dependent on arousal and valence, however, our decision strategies can override the impact of this when it comes to retrieval.

Research has shown that, compared to non-emotional stimuli, emotional stimuli are preferentially attended to and processed, increasing the likelihood of successful memory retrieval (Kaestner, Wixted, & Mednick, 2013; Kensinger, 2009). Understanding this effect is not only theoretically important but also has more applied implications in clinical and forensic psychological literatures (Brown, Lloyd-Jones, & Robinson, 2008; Christianson & Loftus, 1987; Watts, Buratto, Brotherhood, Barnacle, & Schaefer, 2014).

Research has shown that emotion-enhanced memory is driven by both the valence and arousal intensity of stimuli. In this context, valence can either be a pleasant appetitive/approach reaction or an unpleasant aversive/withdrawal reaction to stimuli. Arousal reflects the intensity (low, high) with which these two motivational systems are activated by stimuli (Kaestner et al., 2013; Lang & Bradley, 2010). Differences between both components of emotional experience are reflected in behavioral data showing that arousing (in particular negative) stimuli typically show mnemonic advantages over non-arousing and neutral stimuli. In contrast, positively and negatively valenced stimuli tend to be better remembered than neutral stimuli, even when the arousal intensity of the emotional stimuli is relatively low (Kang, Wang, Surina, & Lü, 2014; Kensinger & Corkin, 2004; Kensinger & Schacter, 2006; Talmi, Schimmack et al., 2007).

For false memories, it seems reasonable to assume that emotion-enhanced veridical memories would be accompanied by a decrease in memory errors for emotional stimuli. However, we have now seen several studies that indicate the opposite trend. For instance, using an adapted version of the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), researchers have examined spontaneously generated false memories for emotional stimuli (e.g., Brainerd, Holliday, Reyna, Yang, & Toglia, 2010; Budson et al., 2006; Howe, Candel, Otgaar, Malone, & Wimmer, 2010). In this paradigm, participants are presented with word lists (e.g., *table, sit, seat, couch, desk…*) that are highly associated with nonpresented words or critical lures (e.g., *chair*). In a subsequent memory test, critical lures are often falsely recalled or recognized as being part of the originally presented lists. *Remember* judgements are often reported alongside recognition responses, indicating a strong recollective experience for the nonpresented word (e.g., Roediger & McDermott, 1995). Lists are adapted such that critical lures and list words are manipulated for valence and arousal (e.g., *harm, pain, wound, punish, insult* [critical lure = hurt]; *hug, embrace, lips, peck, affection* [critical lure = kiss]). Although results can vary depending on level of arousal and valence, it appears that negative high arousing DRM lists increase false memory rates, producing the familiar emotion-enhanced false memory effect (e.g., Brainerd et al., 2010; Howe et al., 2010).

There are two main theories that can account for these findings. According to spreading activation models [e.g., Associative-activation Theory (Howe, Wimmer, Gagnon, & Plumpton, 2009 and Activation-monitoring Theory (e.g., Roediger & McDermott, 1995; Roediger, Watson, McDermott, & Gallo, 2001), with the latter model including a

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https://doi.org/10.1016/j.jml.2019.03.010
Received 5 July 2018; Received in revised form 13 January 2019
Available online 13 April 2019

source monitoring process at retrieval], activation spreads from studied items to related items in an associative network in memory. The activation of related but nonpresented items at encoding can contribute to source monitoring difficulties, which lead adult participants to falsely identify the remembered critical lures as being part of the original word list. Higher false memories rates for negatively valenced, compared to neutral, DRM lists has been attributed to the dense and highly salient associative connections for negatively valenced information (Howe et al., 2009, 2010; Otgaar, Howe, Brackmann, & Smeets, 2016). The more connections and the fewer the number of theme nodes in a network, the faster the spread and activation to the critical lure. Further, when the stimuli also evoke arousal, it attracts attention which enhances memory binding (Talmi & McGarry, 2012) and increases activations to the nonpresented critical lure (Howe et al., 2010; Otgaar et al., 2016). Such activation spreads rapidly and automatically through this network, leading to enhanced levels of false memories.

Fuzzy-trace Theory (Brainerd & Reyna, 2005) in contrast, draws on the idea that there exist dual-opponent processes. It postulates that individuals encode and store in parallel verbatim and gist representations for a list item and that these traces are held independently of one another. Verbatim representations refer to surface-level aspects of a word (e.g., font) and is believed to drive accurate memories. Gist representations, which are more schematic in nature (fuzzy traces), represent the meaning of an item and are said to drive false memory production, especially in the absence of verbatim information (Steffens & Mecklenbräuker, 2007). Brainerd and Boofkbinder (in press) have recently argued that valenced stimuli is associated with memory properties that increase gist and formant false memories. However, they argue that false memory is more strongly influenced by negative than positive stimuli. This is because, whilst valence drives up gist processing, it is only negative valence that simultaneously drives down semantic properties that increase item-specific processing. Based on their findings, they argued that arousal did not affect false memory formation, but concluded that extreme levels of arousal may inoculate against memory distortion. Even high Levels of arousal elicited from word stimuli could only be considered moderate compared to some affect-laden situations in everyday life. Thus, based on the theoretical position put forward by Brainerd and Bookbinder, the semantic properties of negative valence stimuli should increase gist at the expense of item-specific processing due to their memory properties, but if negative valence were equal, arousal would not affect the formation of false memories.

For emotional stimuli, it appears that the role of relatedness is key, but recent behavioral research has also made reference to the role of distinct encoding processes in the production of false memories in this paradigm. Justification for this research comes from neuroimaging studies that found distinct neural processes associated with the effect of valence and arousal on memory (Kensinger & Corkin, 2004; Kensinger & Schacter, 2006). These studies showed that immediate emotion-enhanced memory for arousing (especially negative) stimuli is driven by amygdala-hippocampus interactions, brain areas related to memory that are less dependent on attentional resources at encoding. In contrast, mnemonic benefits for non-arousing stimuli are due in part to frontally mediated semantic and strategic processes that benefit retention without the key involvement of the amygdala (LaBar & Cabeza, 2006). Further, it appears that positive stimuli are underpinned by different processes compared to negative stimuli. For instance, Mickley Steinmetz, Addis, and Kensinger (2010) reported that amygdala efferents weakened as arousal increased for positive stimuli.

Several behavioral studies have supported these findings, showing that attention mediation (i.e., attention is necessary for the enhanced effects on memory) can account for neutral, positive, and negative non-arousing as well as positive arousing emotion but not for the effects of negative high arousing emotion on memory. That is, for negative arousing stimuli, the enhanced effects persist with little attention at encoding (Kang et al., 2014; Kensinger & Corkin, 2004; Talmi, Schimmack et al., 2007). These findings, although they are not based on the direct measurement of neural activity, do provide behavioral data that fit with the neurocognitive findings outlined by Kensinger and Corkin (2004). Taken together, the neuroimaging and behavioral studies suggest that memory for negatively-valenced high-arousing information persists because of the relatively automatic effects of emotion on memory via the automatic capture of attention. In comparison, memory for positive (high and low arousing), negative non-arousing, as well as neutral stimuli is dependent on the intentionality to encode the information and thus, is reliant on more controlled self-generated encoding processes (Kensinger & Corkin, 2004).

Knott et al. (2018) and Knott and Shah (in press) used a similar design to collect behavioral data to examine the role of attention in the formation of emotion enhanced false memories. They exposed participants to neutral and emotionally arousing negative and positive DRM lists under full and reduced attention conditions (random number generation in Experiment 1 and speeded word presentation in Experiment 2). Importantly, although these manipulations differ in that one is a concurrent task and the other is a change in presentation, both methods have been shown to limit associative activations from reaching conscious awareness in the divided attention and DRM literature (Dewhurst, Barry, Swannell, Holmes, & Bathurst, 2007; although see more later), and both have been used in the enhanced-emotion literature to show the effect of reduced attention and role of automatic encoding of negative arousing stimuli. They found that under limited attention conditions, false memory rates for negative stimuli were still higher compared to those for positive as well as neutral stimuli. Hence, their results were in line with past findings from the neuroimaging and behavioral studies and the relatively automatic capture of attention when processing negatively arousing stimuli. That is, enhanced false memories for negative high arousing stimuli survived limited attentional resources at encoding. Although, unlike previous behavioral studies, they did not examine the role of attention for non-arousing negative and non-arousing positive false memory formation, negative arousing items could still be encoded and associates in the network could still be activated under reduced attentional resources. In comparison, reduced attention hindered successful encoding and reduced the activation of nodes within the positive arousing and neutral associative networks. Similar inferences can be made that encoding of arousing positive (and neutral) stimuli require more elaborate and controlled processing.

The study by Knott et al. (2018) was the first to manipulate emotion when encoding DRM lists, but it was not the first to investigate the role of attention using the DRM paradigm. In fact, there has been some debate over the impact reduced attention has on false memory production. For example, Dewhurst et al. (2007) similarly argued that if attentional resources are sufficiently reduced to prevent the generation of associations, critical lures will not be activated and thus, not recognized as often at test. And indeed, the results of Knott et al. (2018) and several other studies (e.g., Dewhurst et al., 2007; Knott & Dewhurst, 2007) are in line with these predictions and show that false memory rates are generally lowered under reduced, compared to full, attention conditions. However not all studies that have manipulated attention at study have shown a reduction in false memory. Otgaar, Peters, and Howe (2012, for adults), Pérez-Mata, Read, and Diges (2002) and Peters et al. (2008) all found that various divided attention tasks at study increased false memory using the DRM paradigm. Here, it has been argued that divided attention undermines the encoding of distinctive perceptual and contextual features of semantic-related words at encoding, reducing the ability to successfully monitor and reject critical lures.

How can we reconcile these findings? First, Dewhurst et al. (2007) argued that if a task, although cognitively demanding, does not divide attention throughout the entirety of the presentation, it will not prevent the generation of associates. For example, Seamon, Luo, and Gallo (1998) found that a digit monitoring task (rehearsing a digit sequence shown before the list items for a subsequent test) did not reduce false recognition. Although this was cognitively demanding, spontaneous generation of associates could still occur during presentation.

Second, there is a relatively consistent difference in outcome due to experimental design. That is, from the research we have reviewed that manipulates attention using the DRM paradigm, false recognition rates are lower when attention is manipulated with-participant, but it seems, higher when attention is manipulated between-participants. For example, Seamon et al. (1998) found that false recognition of critical lures in the DRM paradigm was only lowered by a reduction in attentional resources when their reduced attention condition (presentation speed of words at encoding: fast vs. slow) was manipulated within-participant (Experiment 2). When attention/speed was manipulated between-participants (Experiment 1), levels of false recognition did not differ between reduced and full attention conditions. Further, Otgaar et al. (2012, for adults), Pérez-Mata et al. (2002) and Peters et al. (2008) all used a between-participants manipulation of attention and found an increase in false memory formation. Dewhurst et al. (2007), Knott and Dewhurst (2007) and Knott et al. (2018), by comparison, manipulated attention within-participant and found the reduction in false memories discussed earlier. Although Seamon et al. (1998) argued methodological differences in their study (number of lists per condition), it could be that the difference lies in the decision strategies adopted at test. In a between-participants design, participants may set a low threshold for accepting an item as old after a divided attention condition because they know words would be less familiar to them. In order to increase the probability of accurately recognizing a word, they adopt a more liberal criterion. In a repeated measures design, where participants are tested on items that were presented in full and divided attention conditions, their decision criteria remain the same for all items and fewer critical lures are considered familiar because they do not meet the more conservative threshold for recognition. Dewhurst et al. (2007) used a criterion effect to also explain the difference in false recall and recognition when using a divided attention task. All things being equal, they found that false responses to critical lures increased when participants completed a recall task, but decreased when they completed a recognition task. The recall task was conducted after each list presentation and they argued that participants had the opportunity to change their criterion threshold in what they perceived as more difficult conditions.

When examining the effects of reduced or divided attention at encoding, one should consider the impact of experimental design. Of course, Seamon et al. (1998) and other similar research did not manipulate emotion in their list sets and because Knott et al. (2018) only used a repeated measures design, it raises the question of whether emotion-enhanced false memories would survive a criterion shift at test in a between-participants design and whether any shift would supersede the contributions of possible distinct neural processing in the encoding of emotional stimuli in the production of false memories.

To summarize, our study has two aims. First and foremost, we aimed to replicate the enhanced-emotional false memory effect first demonstrated by Knott et al. (2018). Based on the findings of previous neuroimaging studies, Kensinger and Corkin (2004) proposed that arousal and valence might play different roles in encoding processes via distinct neural routes. However, Knott et al. did not examine the role of non-arousing valenced stimuli and the impact of reduced attention on encoding. Although we do not propose to study these encoding processes using neuroimaging methodology, we can use behavioral data to make inferences similar to those who have manipulated attention in the emotion enhanced memory literature. Second, we aimed to explore some of the contradictory findings in relation to the effect of attention manipulation (and the role of experimental design) on false memory formation and the possibility that a change in decision strategy within a single test causes the increase or decrease in false recognition responses that we have seen in the literature. Therefore, in Experiment 1, in line with Knott et al., we used a repeated measures design to manipulate attention. In Experiment 2, attention was treated as a between-participants variable.

In line with Experiment 2 of Knott et al. (2018) and several emotion enhanced memory studies (e.g., Kang et al., 2014; Kensinger & Corkin, 2004) in both experiments of this study, list type was manipulated as a repeated measures variable. However, to prevent distinctiveness of emotional items from driving the enhanced memory effect in this study (see Knott et al., 2018; Talmi, Luk et al., 2007; Watts et al., 2014), we blocked encoding and retrieval by list type; that is, list learning and memory retrieval of a specific emotion type occurred in separate study and test blocks. Finally, previous research has used both secondary task procedures (e.g., random number generation or auditory tasks) to divide attention resources at encoding, and speeded presentation to reduce attentional resources (see Clark-Foos & Marsh, 2008; Knott et al., 2018; Knott & Shah, in press; Seamon et al., 1998). We used this latter method because it reduces variation in attentional resources at encoding (not dependent on individual performance on the secondary task) and it was used in Experiment 2 of Knott et al.'s study with very similar effects to those observed in the secondary task condition.

Experiment 1

Method

Participants

Fifty members of City, University of London (36% male) aged 18–25 ($M = 19.74$, $SD = 1.69$) individually participated in this study for course credit or remuneration. All participants were fluent-English-proficient (86% were English native speakers). Written informed consent was obtained from each participant. A priori power analysis with a medium effect size (0.25) and Power (1 − err prob) of 0.80 resulted in a sample size of 22.

Design & stimuli

This study followed a 2(Presentation Speed: 2000-ms vs. 20-ms) × 5(List Emotion: positive high arousal vs. positive low arousal vs. negative high arousal vs. negative low arousal vs. neutral) repeated measures design.

DRM lists. A set of 60 DRM lists (12 negative, high in arousal; 12 negative, low in arousal; 12 positive, high in arousal; 12 positive, low in arousal; and 12 neutral, non-emotional) was created by using the University of South Florida free association norms (Nelson, McEvoy, & Schreiber, 1998). The lists were constructed by selecting an emotional or neutral target word (the critical lure) and then choosing 12 emotion-congruent words in order of their backward associative strength to that target word. Valence and arousal scores for the critical lures and list words were obtained from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999). A list was only selected/created if the following conditions were met: (1) it had at least 12 emotion-congruent associates to the critical lure, (2) it had a mean backward associative strength value of 0.10 or above, and (3) it had available valence and arousal information for the critical lure. As backward associative strength between list items and the critical lure has been shown to be a key predictor for false memory production (e.g., Roediger et al., 2001), the mean backward associative strength values of lists were matched between the five different List Emotion types (negative high arousal lists: $M = 0.19$; negative low arousal lists: $M = 0.21$; positive high arousal lists: $M = 0.21$; positive low arousal lists: $M = 0.20$; neutral lists: $M = 0.21$). A one-way independent samples ANOVA (using post-hoc Bonferroni comparisons [$p < .05$]) showed that the lists did not differ significantly on backward associative strength, $F(4, 55) = 0.20$, $p = .94$.

In addition, valence and arousal scores of lists as well as critical lures were matched according to their List Emotion condition. Analyses confirmed that high arousal lists and critical lures (positive and

Table 1
Overall mean values and 95% Confidence Intervals for list emotion conditions as a function of list variables.

	Valence						Arousal						BAS			Connectivity		
	List items			Critical lures			List items			Critical lures			List items			List items		
		95% CI			95% CI			95% CI			95% CI			95% CI			95% CI	
	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB
Negative/high	3.08	2.77	3.40	2.74	2.33	3.14	5.95	5.69	6.21	6.89	6.58	7.19	0.19	0.14	0.24	0.48	0.17	0.79
Negative/low	3.44	3.08	3.80	2.71	2.26	3.16	4.48	4.26	4.70	4.36	3.84	4.87	0.21	0.17	0.25	0.24	0.02	0.46
Positive/high	7.35	7.07	7.62	7.93	7.63	8.23	5.92	5.63	6.20	6.33	5.90	6.76	0.21	0.17	0.26	0.52	0.25	0.79
Positive/low	6.32	6.11	6.53	7.06	6.80	7.32	4.29	4.05	4.53	4.10	3.66	4.55	0.21	0.14	0.28	0.44	0.26	0.62
Neutral	5.18	5.04	5.32	5.34	5.12	5.56	4.38	4.09	4.67	3.81	3.39	4.23	0.21	0.18	0.24	0.35	0.11	0.60

Note: M, LB, and UB refers to Mean, Lower Bound, and Upper Bound for 95% confidence intervals (CI) respectively. BAS refers to Backward Associative Strength.

negative) differed in arousal from the valenced low arousal and the neutral lists and critical lures, $F(4, 55) = 52.35$, $p < .001$, $F(4, 55) = 52.76$, $p < .001$, with no difference in arousal between valenced low arousal and neutral lists and critical lures. Valence was significantly lower for the negative lists and critical lures (high and low in arousal) compared to the positive and the neutral lists and critical lures and the positive lists and critical lures were higher in valence compared to the neutral lists and critical lures, $F(4, 55) = 220.22$, $p < .001$, $F(4, 55) = 243.70$, $p < .001$. Valence was significantly higher in the positive high arousal compared to the positive low arousal lists and critical lures (lists: $M = 7.35$ vs. 6.32, $p < .001$; critical lures: $M = 7.93$ vs. 7.06, $p = .002$). However, both positive valenced lists were significantly higher in valence than neutral (and negative) list types. The means for all negative, positive, and neutral study items and critical lures are shown in Table 1. Last, as interitem connectivity (how related items are to each other) has been shown to affect the production of false memories in the DRM paradigm (McEvoy, Nelson, & Komatsu, 1999), interitem connectivity between the five different List Emotion types was analysed using connectivity matrices (where values were available; see McEvoy et al., 1999). There were no differences in connectivity, and although it was lower for negative lists low in arousal (see Table 1), this was not significant, $F(4, 55) = 1.00$, $p = .42$.

The first 10 words per list were shown individually in descending strength of association to the non-presented critical lure on a computer screen (centrally in black, 80-point Arial Rounded MT font, white background). However, words in half of the 12 lists of each List Emotion condition were presented at a speed of two seconds (2000-ms) where the other half were presented at a speed of 20 ms (20-ms) per word. To accomplish this, the 12 lists of each List Emotion condition were divided into two sets of six lists, labelled List Set A and List Set B. For both sets, the average backward associative strength, valence, and arousal values between the List Emotion conditions were equated (the backward associative strength for each list as well as valence and arousal scores for lists and critical lures separated by List Set A and B can be found in Appendix A). The lists were shown blocked by List Emotion and Presentation Speed (i.e., List Set A and B) in superordinate blocks that not only included the presentation of a particular List Emotion type (e.g., exposure to the positive high arousal lists at 2000-ms and at 20-ms) but also the recognition test for the words presented in that block (e.g., for positive high arousal words presented at 2000-ms and at 20-ms). Whereas the order of the five List Emotion blocks, as well as the order of the lists within their Presentation Speed condition, was randomized, the order of the two Presentation Speed conditions (i.e., List Set A and B) was kept constant for a participant throughout the study. More specifically, half of the participants viewed the lists at 2000-ms first followed by the lists at 20-ms and the other half of the participants viewed the lists at 20-ms first followed by the lists at 2000-ms. Further, the use of List Set A and List Set B was counterbalanced between the 20 ms and 2000-ms conditions to reduce the risk of list effects.

Recognition test. Participants completed five different recognition tests (one in each List Emotion block), each consisting of 72 items. More specifically, each test consisted of: 12 critical lures, 36 list items [3 items from each of the 12 presented lists (1 item randomly chosen from positions 1–3, 1 item from positions 4–6, and 1 item from positions 7–10)], 12 non-presented but weakly related filler items (1 low associate for each of the 12 critical lures) and 12 non-presented and unrelated filler items. The non-presented but semantically related items were randomly chosen from the last two items of a list that were not presented at encoding. The unrelated filler items were matched for valence and arousal depending on the List Emotion condition. All test items (both those encoded at 2000-ms and at 20-ms) appeared on the computer screen one at a time and were presented in random order. E-Prime was used for presentation and data collection.

Procedure

Participants were exposed to the five different List Emotion blocks (five separate study and test phases) in one session lasting approximately 90 min. The blocks were separated by a 1-minute forced break to prevent fatigue. Within each of the blocks, the presentation of the lists was preceded by on-screen instructions announcing the Presentation Speed condition (e.g. "Lists 1–6 will be presented slowly", lasting 5 s) followed by an announcement of each individual list (List 1, List 2, List 3, etc., lasting 2 s). Then the 10 associates appeared individually on the screen, followed by an "End of list" slide (lasting 2 s in the 2000-ms condition and 5 s in the 20-ms condition). Half of the lists in each block were shown at 2000-ms, with each word separated by a 1 s interval, and the other half was shown at 20-ms, with each word separated by a 100 ms interval.

After the presentation of all 12 lists of a block, a 5-minute distractor task (a Sudoku or Maze puzzle) preceded the self-paced recognition test of that block. By pressing labelled keys on their keyboard, participants were instructed to press *old* if a word was presented on one of the lists that they had studied in that block or to press *new* if it had not. For *old* responses participants were ask to press *remember* only if they were able to consciously recollect vivid contextual details of the word's study presentation (i.e. recollecting some detail or context, such as an image or thought), to press *know* if the word felt familiar but if they could not remember it (i.e. if they had the sensation that the word was presented but if they could not remember any specific details) and to press *guess* when they were not sure whether or not the word was presented in that block but if they could not definitely reject it. In each block these instructions were repeated on-screen and they were provided verbally by the researcher preceding the memory test in Block 1.

Results and discussion

To analyze participants' recognition responses (*old* judgments to list items, critical lures and related filler items) separate 2 (Presentation Speed: 2000-ms [slow] vs. 20-ms [speeded]) × 5 (List Emotion:

negative/high vs. negative/low vs. positive/high vs. positive/low vs. neutral) repeated measure ANOVAs were used. Because responses to the unrelated filler items were not manipulated by Presentation Speed, *old* judgements to these items were analyzed by List Emotion only using one-way repeated measure ANOVAs. The analysis of *remember, know*, and *guess* responses did not reveal a pattern of significance that deviated from the findings in the old responses, however they are reported in a footnote for completeness.[1] To correct for participant's response bias, next to the analysis of participants' recognition scores, correct old responses to list items and false old responses to the critical lure words were further analyzed using Signal Detection Analysis. For this, signal detection parameters *d'* (discrimination ability) and *C* (response bias) were computed using the emotion specific list items/critical lures and the emotion corresponding unrelated filler items (Snodgrass and Corwin (1988) correction). A Greenhouse-Geisser correction was used where necessary. Significant interactions were explored using simple main effects and Bonferroni pairwise-comparisons (alpha set at 0.05). Mean proportions and 95% confidence intervals for old responses are presented in Table 2.

Correct recognition of list items

For participants' correct old responses to list items, analysis yielded a significant main effect of Presentation Speed, $F(1,\ 49) = 205.29$, $MSE = 0.031$, $p < .001$, $\eta_p^2 = 0.81$, with more *old* responses in the slow ($M = 0.70$, *95% CI* [0.65, 0.74]) compared to the speeded word presentation condition ($M = 0.47$, *95% CI* [0.42, 0.52]). In addition,

[1] Recollective judgements made for list items and critical lures for Experiment 1 are reported in Table 4. For participants' correct *remember* responses to list items, analysis yielded a significant main effect of Presentation Speed, $F(1,\ 49) = 191.34$, $p < .001$, $\eta_p^2 = 0.80$, with more *remember* responses in the slow ($M = 0.45$, *95% CI* [0.40, 0.51]) compared to the speedy word presentation condition ($M = 0.19$, *95% CI* [0.15, 0.23]). The main effect of List Emotion was not significant, $F(4,\ 196) = 2.29$, $p = .061$, $\eta_p^2 = 0.50$, but there was a significant Presentation Speed × List Emotion interaction, $F(4,\ 196) = 2.80$, $p = .027$, $\eta_p^2 = 0.05$. Analysis of the simple main effects using one-way ANOVAs showed that the main effect of List Emotion was significant in the speeded, $F(3.36, 164.49) = 4.09$, $p = .006$, $\eta_p^2 = 0.08$, but not in the slow word presentation condition, $F(4,\ 196) = 1.74$, $p = .143$, $\eta_p^2 = 0.03$. Bonferroni pairwise comparisons in the speeded condition showed that there were more *remember* responses in the negative/high condition ($M = 0.24$, *95% CI* [0.18, 0.31]) compared to the positive/low ($M = 0.16$, *95% CI* [0.12, 0.20], $p = .015$) and the neutral condition ($M = 0.18$, *95% CI* [0.14, 0.22], $p = 0.023$), with no further differences (all $ps > .07$). Analysis of simple main effects using paired sample *t*-tests supported the main effect of Presentation Speed. (all List comparisons $ps < .001$). For *know* judgements, there was a significant main effect of List Emotion, $F(4,\ 196) = 2.47$, $p = .046$, $\eta_p^2 = 0.50$. However, Bonferroni pairwise comparisons did not yield significant differences between any of the List Emotion conditions (all $ps > .22$). There was no significant main effect of Presentation Speed ($F < 1$) and no interaction, $F(3.31,\ 162.32) = 2.07$, $p = .10$, $\eta_p^2 = 0.04$. Last, for *guess* responses, there was a significant main effect of Presentation Speed, $F(1,\ 49) = 11.02$, $p = .002$, $\eta_p^2 = 0.18$, with more guess responses in the speeded ($M = 0.11$, *95% CI* [0.09, 0.14]) compared to the slow word presentation condition ($M = 0.09$, *95% CI* [0.07, 0.11]). There was no main effect of List Emotion, $F(4,\ 196) = 2.00$, $p = .10$, $\eta_p^2 = 0.04$, and no significant Presentation Speed × List Emotion interaction, $F(4,\ 196) = 1.11$, $p = .358$, $\eta_p^2 = 0.02$.For participants' false *remember* responses to the critical lures, analysis revealed a significant main effect of Presentation Speed, $F(1,\ 49) = 12.42$, $p = .001$, $\eta_p^2 = 0.20$, showing that there were more remember judgements in the slow ($M = 0.27$, *95% CI* [0.21, 0.32]) compared to the speeded word presentation condition ($M = 0.20$, *95% CI* [0.15, 0.25]). In addition, there was a main effect of List Emotion, $F(4,\ 196) = 5.18$, $p = .001$, $\eta_p^2 = 0.10$, with more remember responses in the negative/high condition ($M = 0.30$, *95% CI* [0.24, 0.37]) compared to all other lists ($ps > .05$). The interaction between Presentation Speed and List Emotion was not significant ($F < 1$). Last, for *know* as well as *guess* judgments, no significant main effects or interactions were found (main effect of List Emotion for *know* responses: $F(4,\ 196) = 1.67$, $p = .16$, $\eta_p^2 = 0.03$, all other $Fs < 1$).

Table 2
Mean proportions and 95% Confidence Intervals for recognition test responses to list items, critical lures, weak-related fillers, and unrelated fillers for Experiment 1 and 2.

Speed	Slow Presentation												Fast Presentation											
Test Items	List Item			Critical Lure			Weak-Rel. Filler			Unrelated Filler			List Item			Critical Lure			Weak-Rel. Filler			Unrelated Filler*		
		95% CI			95% CI			95% CI			95% CI			95% CI			95% CI			95% CI			95% CI	
Responses	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB
											Experiment 1													
Old																								
Negative/high	0.72	0.67	0.78	0.67	0.60	0.74	0.32	0.24	0.40				0.54	0.48	0.60	0.68	0.61	0.75	0.32	0.26	0.38	0.15	0.11	0.20
Negative/low	0.71	0.66	0.77	0.63	0.56	0.70	0.31	0.23	0.40				0.46	0.40	0.52	0.54	0.47	0.61	0.28	0.22	0.34	0.18	0.13	0.24
Positive/high	0.70	0.64	0.76	0.60	0.53	0.67	0.32	0.25	0.39				0.49	0.43	0.56	0.49	0.41	0.57	0.28	0.21	0.34	0.16	0.12	0.21
Positive/low	0.70	0.63	0.76	0.63	0.56	0.70	0.30	0.23	0.37				0.42	0.36	0.48	0.53	0.44	0.61	0.29	0.22	0.35	0.17	0.12	0.22
Neutral	0.64	0.58	0.70	0.58	0.51	0.66	0.39	0.31	0.46				0.43	0.38	0.48	0.43	0.35	0.51	0.38	0.30	0.46	0.25	0.20	0.30
											Experiment 2													
Old																								
Negative/high	0.79	0.75	0.84	0.71	0.63	0.79	0.29	0.22	0.36	0.11	0.07	0.15	0.66	0.61	0.71	0.80	0.75	0.86	0.43	0.35	0.51	0.16	0.12	0.21
Negative/low	0.80	0.75	0.84	0.60	0.51	0.69	0.24	0.17	0.30	0.15	0.10	0.20	0.64	0.58	0.69	0.73	0.66	0.80	0.38	0.31	0.45	0.19	0.15	0.24
Positive/high	0.78	0.73	0.84	0.63	0.55	0.71	0.29	0.22	0.36	0.14	0.09	0.20	0.66	0.61	0.72	0.74	0.68	0.81	0.46	0.39	0.53	0.11	0.07	0.15
Positive/low	0.77	0.73	0.82	0.56	0.48	0.64	0.30	0.23	0.36	0.14	0.09	0.20	0.63	0.58	0.69	0.68	0.61	0.76	0.40	0.33	0.48	0.20	0.15	0.25
Neutral	0.75	0.69	0.80	0.59	0.50	0.68	0.39	0.31	0.47	0.18	0.12	0.24	0.59	0.54	0.64	0.73	0.67	0.80	0.51	0.44	0.59	0.22	0.17	0.27

Note. M, LB, and UB refers to Mean, Lower Bound, and Upper Bound for 95% confidence intervals (CI) respectively.
* For Experiment 1, unrelated fillers were not manipulated by presented speed due to the repeated measures design but are reported in the final column of this table as responses to unrelated fillers for each emotion type.

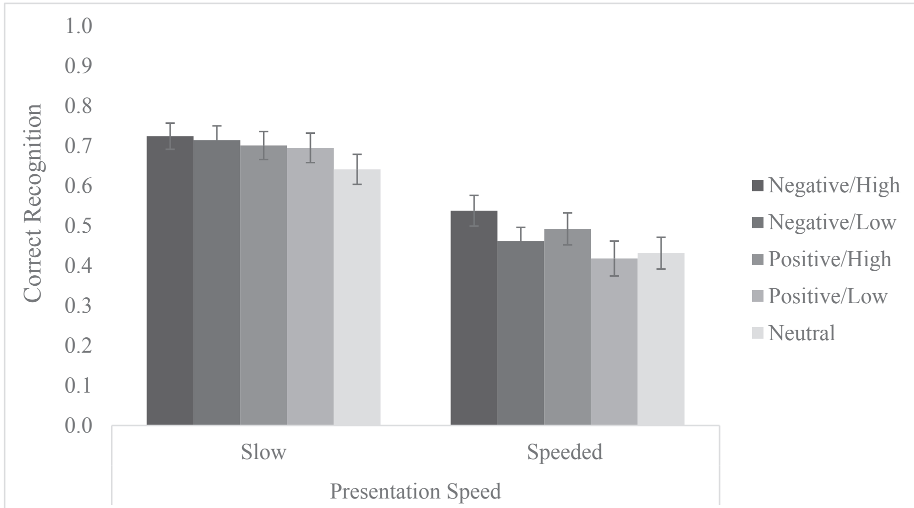

Fig. 1. Mean proportions of old responses for the correct recognition of list items as a function of List Emotion and Presentation Speed (Error bars represent standard error) for Experiment 1.

there was a significant main effect of List Emotion, $F(4, 196) = 5.66$, $MSE = 0.024$, $p < .001$, $\eta_p^2 = 0.10$, showing more *old* responses in the negative/high condition ($M = 0.63$, *95% CI* [0.58, 0.69]) compared to the positive/low ($M = 0.56$, *95% CI* [0.50, 0.61], $p = .019$) and the neutral condition ($M = 0.54$, *95% CI* [0.49, 0.59], $p < .001$), with no further differences between the other List Emotion conditions (all *ps* > .10). There was no interaction, $F(4, 196) = 1.90$, $MSE = 0.018$, $p = .112$, $\eta_p^2 = 0.04$ (see Fig. 1).

False recognition of critical lures

For false old responses to the critical lure words, there was a significant main effect of Presentation Speed, $F(1, 49) = 25.64$, $MSE = 0.038$, $p < .001$, $\eta_p^2 = 0.34$, with more false old responses in the slow ($M = 0.62$, *95% CI* [0.57, 0.68]) compared to the speeded word presentation condition ($M = 0.53$, *95% CI* [0.48, 0.59]). In addition, there was a main effect of List Emotion, $F(4, 196) = 9.17$, $MSE = 0.044$, $p < .001$, $\eta_p^2 = 0.16$, and a significant Presentation Speed × List Emotion interaction, $F(4, 196) = 2.44$, $MSE = 0.037$, $p = .048$, $\eta_p^2 = 0.05$. Analysis of SMEs using one-way ANOVAs showed that the main effect of List Emotion was significant in the speeded, $F(4, 196) = 9.63$, $MSE = 0.045$, $p < .001$, $\eta_p^2 = 0.16$, but not in the slow word presentation condition, $F(4, 196) = 1.63$, $MSE = 0.036$, $p = .169$, $\eta_p^2 = 0.03$. Bonferroni pairwise comparisons in the speeded condition revealed more false old responses in the negative/high condition ($M = 0.68$, *95% CI* [0.61, 0.76]) compared to any of the other List Emotion conditions (positive/high: $M = 0.49$, *95% CI* [0.41, 0.57], $p < .001$; positive/low: $M = 0.53$, *95% CI* [0.44, 0.61], $p = .015$; negative/low: $M = 0.54$, *95% CI* [0.47, 0.61], $p = .006$; neutral: $M = 0.43$, *95% CI* [0.35, 0.51], $p < .001$; see Fig. 2). There were no further differences between the other List Emotion conditions (all *ps* > .14). Alternatively, simple main effects analysis using paired sample *t*-tests showed a significant reduction in false recognition between the slow compared to the speeded word presentation condition in the positive/high condition, $t(49) = 3.04$, $p = .004$, $d = 0.43$, the positive/low condition, $t(49) = 2.63$, $p = .011$, $d = 0.37$, the negative/low condition, $t(49) = 2.37$, $p = .022$, $d = 0.34$, as well as in the neutral condition, $t(49) = 3.75$, $p < .001$, $d = 0.53$. However, there was no difference in the negative/high condition, $t(49) = -0.32$, $p = .754$, $d = -0.04$.

False recognition of related and unrelated filler items

For false old responses to the related filler items, there was no main effect of Presentation Speed, $F(1, 49) = 1.51$, $MSE = 0.028$, $p = .23$, $\eta_p^2 = 0.03$. However, there was a significant main effect of List Emotion, $F(4, 196) = 3.85$, $MSE = 0.037$, $p = .005$, $\eta_p^2 = 0.07$. Pairwise comparisons showed that participants made more false old judgements in the neutral condition ($M = 0.38$, *95% CI* [0.32, 0.45]) compared to the positive/high ($M = 0.30$, *95% CI* [0.24, 0.36], $p = .027$) and the positive/low condition ($M = 0.29$, *95% CI* [0.23, 0.36], $p = .007$), with no further differences (all *ps* > .15). There was no Presentation Speed × List Emotion interaction ($F < 1$).

For false old responses to the unrelated filler items (see Table 3), a one-way repeated ANOVA (see explanation for this analysis at the beginning of the results section) revealed a significant main effect of List Emotion, $F(4, 196) = 5.06$, $MSE = 0.015$, $p = .001$, $\eta_p^2 = 0.09$. Pairwise comparisons showed that there were more false old responses in the neutral condition ($M = 0.25$, *95% CI* [0.20, 0.30]) compared to the positive/high ($M = 0.17$, *95% CI* [0.12, 0.21], $p = .007$), the positive/low ($M = 0.17$, *95% CI* [0.12, 0.22], $p = .006$) as well as the negative/high condition ($M = 0.15$, *95% CI* [0.11, 0.20], $p = .003$).

Signal detection analysis for list items

Signal detection parameters *d'* and *C* were analysed separately using the same repeated measure ANOVAs as above. The analysis of *d'* allows use to examine the discriminability of the participant. Larger values equal better memory performance. Criterion value *C* allows us to separately distinguish the decision criterion used by the participant. Values of 0 represent no decision bias. The higher the value above 0, the more conservative the bias (criterion favors no responses). The lower the value, the more liberal the bias towards a 'yes' response. The results of *d'* and *C* are summarized in Table 3. For discrimination ability *d'* of participants' correct old responses to the list items, there was a significant main effect of Presentation Speed, $F(1, 49) = 210.73$, $MSE = 0.261$, $p < .001$, $\eta_p^2 = 0.81$, with better discrimination ability in the slow ($M = 1.51$, *95% CI* [1.37, 1.66]) compared to the speeded word presentation condition ($M = 0.85$, *95% CI* [0.74, 0.97]). In addition, there was a main effect of List Emotion, $F(4, 196) = 9.64$, $MSE = 0.582$, $p < .001$, $\eta_p^2 = 0.16$, with better discrimination ability in all four emotional list conditions (positive/high: [$M = 1.27$, *95% CI* (1.07, 1.47)]; positive/low: [$M = 1.18$, *95% CI* (0.99, 1.36)]; negative/high: [$M = 1.45$, *95% CI* (1.25, 1.64)]; negative/low: [$M = 1.22$, *95% CI* (1.05, 1.40) compared to the neutral condition ($M = 0.80$, *95% CI* [0.63, 0.97], $p = .001$, $p = .010$, $p < .001$, and $p = .003$), with no further differences between the List Emotion conditions (all *ps* > .15). There was no significant Presentation Speed × List Emotion interaction $F(4, 196) = 1.59$, $MSE = 0.165$, $p = .179$, $\eta_p^2 = 0.03$.

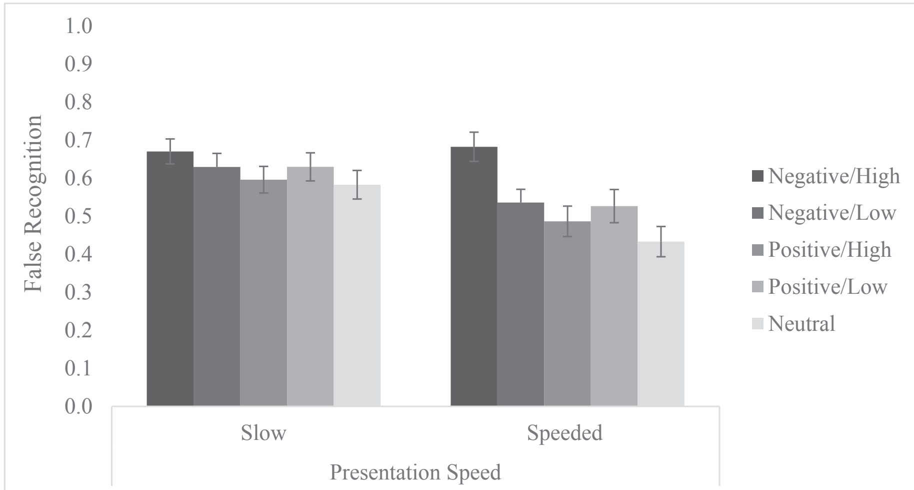

Fig. 2. Mean proportions of old responses for the false recognition of critical lures as a function of List Emotion and Presentation Speed (Error bars represent standard error) for Experiment 1.

For response bias C, there was a significant main effect of Presentation Speed, $F(1, 49) = 210.73$, $MSE = 0.065$, $p < .001$, $\eta_p^2 = 0.81$, showing a relatively liberal bias in the slow ($M = 0.19$, *95% CI* [0.08, 0.30]) compared to the speeded condition ($M = 0.52$, *95% CI* [0.40, 0.64]). There was no significant main effect of List Emotion, $F(4, 196) = 1.61$, $MSE = 0.142$, $p = .173$, $\eta_p^2 = 0.03$, and no significant Presentation Speed × List Emotion interaction, $F(4, 196) = 1.59$, $MSE = 0.041$, $p = .179$, $\eta_p^2 = 0.03$.

Signal detection analysis for critical lures

For discrimination ability *d'* of participants' false old responses to the lures, analysis yielded a significant main effect of Presentation Speed, $F(1, 49) = 25.68$, $MSE = 0.268$, $p < .001$, $\eta_p^2 = 0.34$, showing better discrimination ability in the slow ($M = 1.27$, *95% CI* [1.11, 1.43]) compared to the speeded condition ($M = 1.03$, *95% CI* [0.88, 1.19]). In addition, there was a main effect of List Emotion, $F(4, 196) = 11.13$, $MSE = 0.741$, $p < .001$, $\eta_p^2 = 0.19$, and, similar to the main analysis above, a significant Presentation Speed × List Emotion interaction, $F(4, 196) = 2.58$, $MSE = 0.261$, $p = .038$, $\eta_p^2 = 0.50$. Analysis of simple main effects using one-way ANOVAs showed that the main effect of List Emotion was significant in both, the slow, $F(4, 196) = 4.72$, $MSE = 0.494$, $p = .001$, $\eta_p^2 = 0.09$, as well as the speeded word presentation condition, $F(4, 196) = 12.99$, $MSE = 0.507$, $p < .001$, $\eta_p^2 = 0.21$. Bonferroni pairwise comparisons in the slow condition revealed better discrimination ability in the negative/high ($M = 1.51$, *95% CI* [1.28, 1.73]) and the positive/low condition ($M = 1.35$, *95% CI* [1.11, 1.59]) compared to the neutral condition ($M = 0.92$, *95% CI* [0.67, 1.17], $p = .003$ and $p = .044$), with no further differences (all *ps* $> .08$). In the speeded condition, analysis revealed better discrimination ability in the negative/high condition ($M = 1.55$, *95% CI* [1.30, 1.80]) compared to all other List Emotion conditions (positive/high: $M = 0.98$, *95% CI* [0.73, 1.22], $p = .003$; positive/low: $M = 1.06$, *95% CI* [0.82, 1.31], $p = .028$; negative/low: $M = 1.06$, *95% CI* [0.82, 1.29], $p = .017$; neutral: $M = 0.53$, *95% CI* [0.31, 0.74], $p < .001$). In addition, discrimination ability was better for all other emotional conditions compared to the neutral condition (positive/high: $p = .015$, positive/low: $p = .001$, negative/low: $p = .007$), with no further differences (all *ps* $> .90$). Alternatively, simple main effects analysis using paired sample *t*-tests showed better discrimination ability in the slow compared to the speeded condition in the positive/high condition, $t(49) = 2.95$, $p = .005$, $d = 0.42$, the positive/low condition, $t(49) = 2.77$, $p = .008$, $d = 0.39$, the negative/low condition, $t(49) = 2.48$, $p = .017$, $d = 0.35$, as well as in the neutral condition, $t(49) = 3.77$, $p < .001$, $d = 0.53$. However, there was no difference in discrimination ability in the negative/high condition, $t(49) = -0.42$, $p = .679$, $d = -0.06$.

For response bias *C*, analysis yielded a significant main effect of Presentation Speed, $F(1, 49) = 25.68$, $MSE = 0.067$, $p < .001$, $\eta_p^2 = 0.34$, showing a relatively liberal bias in the slow ($M = 0.31$, *95% CI* [0.20, 0.42]) compared to the speeded condition ($M = 0.43$, *95% CI* [0.31, 0.55]). Whereas the main effect of List Emotion was not significant, $F(4, 196) = 2.26$, $MSE = 0.156$, $p = .064$, $\eta_p^2 = 0.044$, the Presentation Speed × List emotion interaction was, $F(4, 196) = 2.58$, $MSE = 0.065$, $p = .038$, $\eta_p^2 = 0.05$. Analysis of simple main effects using one-way ANOVAs showed that the main effect of List Emotion was significant in the speeded, $F(4, 196) = 2.85$, $MSE = 0.129$, $p = .025$, $\eta_p^2 = 0.06$, but not in the slow word presentation condition, $F(4, 196) = 1.65$, $MSE = 0.092$, $p = .16$, $\eta_p^2 = 0.03$. However, further comparisons in the speeded condition only revealed a relatively liberal bias in the negative/high ($M = 0.29$, *95% CI* [0.14, 0.44]) compared to the positive/high condition ($M = 0.52$, *95% CI* [0.38, 0.66], $p = .037$), with no other differences (all *ps* $> .16$). Alternatively, simple main effects analysis using paired sample *t*-tests showed a more liberal bias in the slow compared to the speeded condition in the positive/high condition, $t(49) = -2.95$, $p = .005$, $d = -0.42$, the positive/low condition, $t(49) = -2.77$, $p = .008$, $d = -0.39$, the negative/low condition, $t(49) = -2.48$, $p = .017$, $d = -0.35$, as well as in the neutral condition, $t(49) = -3.77$, $p < .001$, $d = -0.53$. However, there was no difference in response bias in the negative/high condition, $t(49) = .42$, $p = .679$, $d = 0.06$.

The aim of Experiment 1 was to replicate and extend the findings of Knott et al. (2018) who found higher false memory rates for high arousing negative compared to positive and neutral critical lures when attentional resources were reduced at DRM encoding. We aimed to extend these findings by adding non-arousing valenced stimuli to examine whether emotion enhanced memories that depended on arousal and valence are associated with automatic or controlled processing. As outlined in the introduction and shown in previous emotion enhanced memory research (e.g., Clark-Foos & Marsh, 2008; Kang et al., 2014), we predicted that non-arousing valenced, neutral, as well as positive high arousing false memory production should be mediated by attention and hence reflect controlled cognitive processing. However, negative arousing false memories should persist because, consistent with neurocognitive findings, such stimuli may benefit from more automatic processing and can rely on relatively automatic capture of attention at encoding.

Analyses showed that speeded word presentation reduced old responses to the critical lures for the positive (high and low arousal),

Table 3
Signal detection measures of Discriminability (d′) and Criterion Bias (C) for list items and critical lures for Experiments 1 and 2.

Speed	Slow Presentation												Fast Presentation											
	d′						C						d′						C					
Test Item	List Items			Critical Lure			List Items			Critical Lure			List Items			Critical Lure			List Items			Critical Lure		
		95% CI			95% CI			95% CI			95% CI			95% CI			95% CI			95% CI			95% CI	
List Emotion	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB
	Experiment 1																							
Negative/high	1.73	1.51	1.95	1.50	1.28	1.73	0.20	0.06	0.34	0.31	0.18	0.44	1.16	0.97	1.36	1.55	1.30	1.79	0.48	0.35	0.62	0.29	0.14	0.44
Negative/low	1.59	1.36	1.82	1.31	1.09	1.54	0.17	0.03	0.31	0.31	0.16	0.46	0.85	0.70	1.01	1.06	0.82	1.29	0.54	0.38	0.70	0.44	0.30	0.58
Positive/high	1.58	1.34	1.81	1.25	1.01	1.50	0.22	0.10	0.34	0.38	0.26	0.50	0.97	0.75	1.18	0.97	0.73	1.22	0.52	0.38	0.66	0.52	0.38	0.66
Positive/low	1.58	1.35	1.80	1.35	1.11	1.59	0.22	0.08	0.35	0.33	0.19	0.47	0.77	0.59	0.96	1.06	0.82	1.31	0.62	0.47	0.77	0.47	0.31	0.64
Neutral	1.10	0.88	1.32	0.92	0.67	1.17	0.14	0.01	0.26	0.23	0.11	0.35	0.50	0.35	0.65	0.53	0.31	0.74	0.43	0.32	0.55	0.42	0.28	0.57
	Experiment 2																							
Negative/high	2.11	1.89	2.34	1.81	1.58	2.03	0.17	0.05	0.28	0.32	0.17	0.47	1.46	1.26	1.67	1.82	1.59	2.04	0.29	0.17	0.41	0.11	−0.00	0.23
Negative/low	1.98	1.75	2.21	1.33	1.07	1.59	0.08	−0.05	0.20	0.40	0.24	0.57	1.25	1.06	1.43	1.50	1.26	1.74	0.26	0.13	0.40	0.14	−0.00	0.28
Positive/high	2.01	1.72	2.30	1.48	1.21	1.76	0.14	0.02	0.26	0.40	0.25	0.55	1.71	1.48	1.94	1.90	1.66	2.14	0.39	0.27	0.50	0.29	0.16	0.42
Positive/low	1.98	1.71	2.25	1.31	1.07	1.55	0.16	0.04	0.28	0.49	0.33	0.66	1.20	1.00	1.41	1.34	1.09	1.58	0.26	0.13	0.38	0.19	0.06	0.31
Neutral	1.75	1.47	2.03	1.24	0.97	1.50	0.12	−0.01	0.25	0.38	0.21	0.55	1.07	0.87	1,27	1.44	1.19	1.69	0.28	0.17	0.40	0.19	−0.03	0.22

Note. M, LB, and UB refers to Mean, Lower Bound, and Upper Bound for 95% confidence intervals (CI) respectively.

negative low arousal and neutral lists. In contrast, false alarms for the negative high arousal critical lures did not significantly differ across speed presentation conditions. Further, analysis showed that under reduced attention conditions, the amount of false alarms for the high arousal negative critical lures exceeded the false alarms for any other list type. Signal detection analysis in the speeded condition confirmed these findings and showed that discrimination ability (more false memories to critical lures and fewer false alarms to unrelated fillers) was higher for high arousal negative lures compared to any of the other valenced and neutral critical lures. Thus, it appears that the speeded presentation condition had less influence on the recognition of negative arousing stimuli. In line with the findings of Knott et al. (2018) our analyses indicated that participants were still able to produce false memories for negative high arousal stimuli that appear to require less controlled attentional resources. This finding is consistent with past neurocognitive and behavioral research that has demonstrated that negative arousing items can be encoded using automatic processing and thus associates in the network can still be activated under reduced attentional resources. Extending their findings, the encoding of positive (arousing/non-arousing) and non-arousing negative stimuli require more elaborate and controlled processing, thus reduced attention hindered successful encoding and reduced the activation of nodes within the positive, negative non-arousing and neutral associative networks.

It should be noted that the emotion enhanced false memory effect was not present, or not as pronounced, in the slow word presentation condition. Although the pattern of the means reflected a trend comparable to that in the speeded condition (see Fig. 2), only signal detection analysis in the slow condition provided some evidence for higher discriminability of negative high arousal critical lures compared to the neutral critical lures. However, these findings are in line Knott et al. (2018) as well as with other studies who observed more striking influence of emotion on memory performance under divided attention compared to full attention conditions (e.g., Talmi, Schimmack et al., 2007). If emotionally arousing stimuli automatically capture more attention than neutral stimuli, and if emotional enhanced memory is mediated by attention, emotion-enhanced false memories would be more pronounced after reduced attention at encoding (see also, Sava, Paquet, Dumurgier, Hugon, & Chainay, 2016).

We hypothesized from the outset that if attention was treated as a repeated measures factor we would expect a reduction in false memories for lists that were encoded under reduced attention conditions. We have seen that this is true for all but negative arousing lists and we have argued that this is a result of distinct neural processes involved in the encoding of negative-arousing stimuli. Interestingly, for these lists, we also found no change in response bias between fast and slow presentation speeds. The strength of the critical lure and the decision set to make a response was the same in both conditions because the critical lure was similarly activated in both conditions. Thus, discrimination and measured bias did not differ. However, for all other emotion conditions, discrimination between target and distractor was better, and measured bias (Criterion Bias) was more liberal for items encoded with a slow presentation speed. With such an explicit impact on the required controlled attentional processes to encode list items, participants appeared to be more conservative in their decision strategy for items that were encoded in the speeded condition. We return to this point in the General Discussion.

Last, with regard to participants correct old responses, although there was a memory advantage for negative high arousal over neutral and positive low arousal list items there were no further differences no interaction between List Emotion and Presentation Speed. Signal detection analysis provided some evidence for the presence of an emotion enhanced memory effect with better discrimination ability in all four emotional list conditions compared to the neutral condition. We return to the findings for correct recognition in the General Discussion.

Table 4
Mean proportions and 95% Confidence Intervals for remember, know, guess responses to list items, critical lures, weak-related fillers, and unrelated fillers for Experiment 1 and 2.

Speed	Slow Presentation												Fast Presentation											
Test Items	List Item			Critical Lure			Weak-Rel. Filler			Unrelated Filler			List Item			Critical Lure			Weak-Rel. Filler			Unrelated Filler		
		95% CI			95% CI			95% CI			95% CI			95% CI			95% CI			95% CI			95% CI	
Responses	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB	M	LB	UB
Experiment 1																								
Remember																								
Negative/high	0.47	0.40	0.53	0.31	0.24	0.39	0.07	0.03	0.11				0.24	0.18	0.31	0.29	0.21	0.38	0.07	0.04	0.10	0.02	0.00	0.04
Negative/low	0.46	0.38	0.53	0.27	0.20	0.34	0.08	0.04	0.12				0.18	0.14	0.23	0.18	0.12	0.25	0.05	0.02	0.08	0.03	0.01	0.05
Positive/high	0.44	0.37	0.50	0.26	0.19	0.33	0.04	0.01	0.07				0.18	0.14	0.22	0.17	0.11	0.23	0.06	0.03	0.10	0.03	0.01	0.04
Positive/low	0.49	0.42	0.55	0.26	0.19	0.32	0.08	0.05	0.12				0.16	0.12	0.20	0.20	0.13	0.26	0.09	0.06	0.12	0.03	0.01	0.04
Neutral	0.41	0.34	0.48	0.23	0.16	0.30	0.10	0.05	0.15				0.18	0.14	0.22	0.14	0.08	0.19	0.09	0.05	0.14	0.05	0.02	0.07
Know																								
Negative/high	0.18	0.14	0.22	0.22	0.16	0.27	0.12	0.07	0.17				0.17	0.14	0.21	0.26	0.19	0.33	0.11	0.08	0.15	0.07	0.03	0.10
Negative/low	0.18	0.14	0.22	0.24	0.18	0.29	0.11	0.07	0.15				0.15	0.12	0.19	0.24	0.18	0.29	0.11	0.07	0.16	0.07	0.05	0.10
Positive/high	0.16	0.12	0.19	0.21	0.16	0.26	0.14	0.08	0.19				0.19	0.15	0.22	0.17	0.13	0.22	0.09	0.05	0.13	0.07	0.04	0.10
Positive/low	0.13	0.09	0.16	0.23	0.17	0.29	0.13	0.08	0.18				0.17	0.13	0.21	0.21	0.15	0.27	0.11	0.07	0.15	0.06	0.04	0.08
Neutral	0.14	0.11	0.18	0.21	0.15	0.27	0.12	0.08	0.16				0.14	0.11	0.18	0.18	0.12	0.24	0.14	0.09	0.19	0.09	0.05	0.12
Guess																								
Negative/high	0.08	0.05	0.11	0.14	0.09	0.19	0.13	0.09	0.17				0.12	0.09	0.15	0.13	0.08	0.18	0.14	0.10	0.18	0.07	0.04	0.09
Negative/low	0.08	0.06	0.10	0.12	0.08	0.17	0.13	0.09	0.17				0.12	0.10	0.15	0.12	0.08	0.16	0.11	0.07	0.16	0.08	0.05	0.11
Positive/high	0.11	0.08	0.13	0.13	0.08	0.17	0.14	0.09	0.19				0.13	0.09	0.16	0.14	0.10	0.19	0.12	0.08	0.16	0.07	0.04	0.09
Positive/low	0.08	0.05	0.11	0.14	0.10	0.19	0.09	0.05	0.13				0.09	0.07	0.11	0.12	0.08	0.16	0.09	0.05	0.12	0.08	0.05	0.11
Neutral	0.09	0.07	0.12	0.15	0.10	0.20	0.17	0.12	0.22				0.11	0.09	0.14	0.12	0.08	0.16	0.15	0.09	0.21	0.12	0.09	0.15
Experiment 2																								
Remember																								
Negative/high	0.52	0.46	0.59	0.33	0.25	0.40	0.06	0.02	0.10	0.02	0.01	0.03	0.29	0.24	0.34	0.37	0.30	0.44	0.07	0.03	0.11	0.02	0.01	0.04
Negative/low	0.55	0.49	0.61	0.24	0.17	0.30	0.05	0.01	0.10	0.04	0.01	0.06	0.29	0.23	0.34	0.35	0.28	0.43	0.06	0.02	0.09	0.04	0.01	0.07
Positive/high	0.53	0.46	0.60	0.24	0.17	0.31	0.06	0.03	0.10	0.03	0.00	0.05	0.28	0.22	0.34	0.33	0.24	0.41	0.11	0.06	0.15	0.02	−0.00	0.03
Positive/low	0.54	0.48	0.61	0.25	0.18	0.33	0.06	0.03	0.09	0.03	0.00	0.06	0.27	0.22	0.32	0.33	0.25	0.41	0.12	0.07	0.17	0.03	0.01	0.05
Neutral	0.51	0.44	0.57	0.25	0.18	0.33	0.10	0.05	0.14	0.04	0.01	0.06	0.25	0.21	0.30	0.33	0.25	0.41	0.13	0.09	0.18	0.04	0.01	0.07
Know																								
Negative/high	0.17	0.13	0.20	0.23	0.17	0.29	0.11	0.06	0.16	0.03	0.01	0.05	0.20	0.17	0.24	0.25	0.20	0.31	0.16	0.11	0.21	0.04	0.01	0.06
Negative/low	0.15	0.12	0.19	0.21	0.16	0.27	0.09	0.05	0.13	0.04	0.02	0.06	0.20	0.17	0.23	0.23	0.18	0.29	0.11	0.08	0.15	0.06	0.03	0.08
Positive/high	0.16	0.12	0.20	0.22	0.17	0.28	0.11	0.07	0.15	0.04	0.02	0.06	0.20	0.17	0.24	0.24	0.18	0.30	0.16	0.12	0.21	0.04	0.02	0.06
Positive/low	0.15	0.12	0.19	0.18	0.12	0.24	0.12	0.07	0.16	0.04	0.02	0.06	0.20	0.16	0.23	0.20	0.15	0.25	0.11	0.07	0.16	0.07	0.04	0.10
Neutral	0.14	0.11	0.18	0.17	0.13	0.22	0.13	0.09	0.18	0.06	0.03	0.09	0.17	0.14	0.20	0.24	0.18	0.29	0.16	0.10	0.21	0.05	0.03	0.08
Guess																								
Negative/high	0.10	0.07	0.14	0.16	0.10	0.22	0.13	0.08	0.17	0.06	0.04	0.09	0.16	0.12	0.20	0.18	0.12	0.24	0.19	0.14	0.15	0.10	0.07	0.13
Negative/low	0.10	0.07	0.13	0.15	0.09	0.20	0.10	0.06	0.13	0.08	0.05	0.11	0.16	0.12	0.19	0.14	0.10	0.18	0.21	0.15	0.27	0.10	0.07	0.13
Positive/high	0.10	0.07	0.13	0.17	0.11	0.22	0.12	0.07	0.16	0.08	0.05	0.11	0.18	0.14	0.22	0.18	0.12	0.24	0.19	0.14	0.24	0.06	0.03	0.08
Positive/low	0.08	0.05	0.11	0.13	0.08	0.18	0.12	0.08	0.16	0.07	0.03	0.10	0.17	0.13	0.21	0.16	0.12	0.20	0.17	0.11	0.22	0.10	0.07	0.14
Neutral	0.10	0.07	0.12	0.17	0.12	0.21	0.17	0.11	0.22	0.08	0.05	0.12	0.17	0.13	0.21	0.17	0.12	0.22	0.22	0.17	0.28	0.12	0.09	0.16

Note. M, LB, and UB refers to Mean, Lower Bound, and Upper Bound for 95% confidence intervals (CI) respectively.
*For Experiment 1, unrelated fillers were not manipulated by presented speed due to the repeated measures design but are reported in the final column of this table.

Experiment 2

The aim of Experiment 2 was to replicate the first experiment but test presentation speed as a between-participants factor. The rationale for the second experiment is a methodological one and comes from contradictory findings in the DRM literature regarding the effects of divided/reduced attention on false memory production. If, as we hypothesize, decision strategies will be more liberal when all words are encoded with limited attention, then we would expect more false memories in the reduced compared to full attention condition when attention is manipulated between-participants. That is, if participants have only been presented with items in a limited attention condition, they are likely to set a lower threshold for accepting an item as old because they know words would be less familiar to them. In order to increase the probability of accurately recognizing a word, they are likely to adopt a more liberal criterion. We expect this to be the case for all list types, however, given that negative arousing stimuli appear to be processed with less attentional resources, critical lures associated with negative arousing lists should still produce better discrimination (distinguish critical lures from new items), and greater false memories rates than all other list types.

Method

Participants

Ninety-seven participants from City University (27% male) aged 18–58 (M = 23.91*,* SD = 8.66) individually took part in this study for course credit or remuneration. All participants were fluent-English-proficient (75% were English native speakers). Written informed consent was obtained from each participant. A priori power analysis with a medium effect size (0.25) and Power of 0.8 resulted in a sample size of 78.

Design and stimuli

Experiment 2 used a 2(Presentation Speed: 2000-ms vs. 20-ms) × 5(List Emotion: negative/high vs. negative/low vs. positive/high vs. positive/low vs. neutral) mixed factor design with Presentation Speed as the between-participants factor. Participants were randomly allocated to either the 2000-ms (N = 49) or the 20-ms (N = 48) Presentation Speed condition. The same 60 DRM lists as those in Experiment 1 were used. Again, participants completed five List Emotion blocks (study and test phases). For list counterbalancing purposes, in both Presentation Speed conditions, half of the participants were exposed to List Set A while the other half of the participants were exposed to List Set B.

All other study and test conditions were the same as in the first experiment with the following exceptions. A 48 item recognition test was used with 6 critical lures, 24 list items, 6 non-presented but weakly related filler items and 12 non-presented and unrelated filler items. The study was completed in one session lasting approximately 75 min in the 2000 ms condition and 65 min in the 20 ms condition (although the interval between the study-test phases remained identical, the faster completion rate was due to the presentation rate of the stimuli).

Results and discussion

To analyze participants' recognition responses (*old*, judgments to list items, critical lures, related and unrelated filler items) separate 2 (Presentation Speed: 2000-ms [slow] vs. 20-ms [speeded]) × 5 (List Emotion: negative/high vs. negative/low vs. positive/high vs. positive/low vs. neutral) mixed factor ANOVAs were conducted with repeated measures on the last factor (note that in Experiment 2, the unrelated filler items were analyzed in the same way as the other items types because, in contrast to Experiment 1, here they were manipulated by presentation speed). Again, Similar to Experiment 1, the analysis of *remember, know*, and *guess* responses did not reveal a pattern of significance that deviated from the findings in the old responses, however they are reported in a footnote for completeness.[2] To examine participant's response bias, as in Experiment 1, correct old responses to the list items and false old responses to the critical lure words were further analyzed using Signal Detection Analysis. For this, signal detection parameters d' (discrimination ability) and C (response bias) were computed using the emotion specific list items/critical lures and the emotion and presentation speed corresponding unrelated filler items (Snodgrass and Corwin (1988) correction). Where Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated ($p < .05$), a Greenhouse-Geisser correction was used. Also, significant interactions were explored using Bonferroni pairwise-comparisons (alpha set at .05). Mean proportions and 95% confidence intervals for old responses are reported in Table 2.

Correct recognition of list items

For participants' correct old responses to list items, analysis yielded a significant main effect of List Emotion, $F(4, 380) = 3.51$, $MSE = 0.014$, $p = .008$, $\eta_p^2 = 0.04$, with more *old* responses in the negative/high (M = 0.73*, 95% CI* [0.69, 0.76]), the positive/high (M = 0.73*, 95% CI* [0.69, 0.76]) and the negative/low condition (M = 0.72*, 95% CI* [0.68, 0.75]) compared to the neutral condition (M = 0.67*, 95% CI* [0.64, 0.71], $p = .006$, $p = .029$ and $p = .045$). There were no further differences (all $ps > .75$). There was a main effect of Presentation Speed as well, $F(1, 95) = 23.10$, $MSE = 0.105$, $p < .001$, $\eta_p^2 = 0.20$, with more *old* responses in the slow (M = 0.78*, 95% CI* [0.74, 0.82]) compared to the speeded word presentation condition (M = 0.64*, 95% CI* [0.60, 0.68]). There was no Emotion × Presentation Speed interaction ($F < 1$; see Fig. 3).

False recognition of critical lures

For false old responses to the critical lures, there was a significant main effect of List Emotion, $F(4, 380) = 6.31$, $MSE = 0.038$, $p < .001$, $\eta_p^2 = 0.06$, showing more false old responses in the negative/high condition (M = 0.76*, 95% CI* [0.71, 0.80]) compared to the positive/low (M = 0.62*, 95% CI* [0.57, 0.68], $p < .001$), the negative/low (M = 0.66*, 95% CI* [0.61, 0.72], $p = .010$) and the neutral condition (M = 0.66*, 95% CI* [0.61, 0.72], $p = .017$), with no further differences (all $ps > .28$). Analysis yielded a significant main effect of Presentation

[2] Participants *remember, know,* and *guess responses to list items and critical lures* in Experiment 2 are reported in Table 4. Analysis of participants' correct *remember* responses to list items revealed no main effect of List Emotion, $F(4, 380) = 1.37$, $p = .24$, $\eta_p^2 = 0.01$, and no significant List Emotion × Presentation Speed interaction ($F < 1$). However, there was a main effect of Presentation Speed, $F(1, 95) = 49.90$, $p < .001$, $\eta_p^2 = 0.34$, with more *remember* responses in the slow (M = 0.53*, 95% CI* [0.48, 0.58]) compared to the speeded condition (M =0 .28*, 95% CI* [0.22, 0.33]). For know judgements, there was no main effect of List Emotion, $F[3.60, 341.92] = 1.64$, $p = .17$, $\eta_p^2 = 0.02$, and no List Emotion × Presentation Speed interaction either ($F < 1$). However, there was a significant main effect of Presentation Speed as well*,* $F(1, 95) = 4.49$, $p = .037$, $\eta_p^2 = 0.05$, with more know responses in the speeded (M =0 .19*, 95% CI* [0.17, 0.22]) relative to the slow condition (M =0 .16*, 95% CI* [0.13, 0.18]). Last, the effect of Presentation Speed was found for guess judgements as well, $F(1, 95) = 14.18$, $p < .001$, $\eta_p^2 = 0.13$, with more guess responses in the speeded (M =0 .17*, 95% CI* [0.14, 0.20]) compared to the slow condition (M =0 .10*, 95% CI* [0.07, 0.12]; all other $Fs < 1$).For participants' false *remember* responses to the critical lures, analysis revealed no main effect of List Emotion, $F(4, 380) = 2.14$, $p = .075$, $\eta_p^2 = 0.02$, and no significant List Emotion × Presentation Speed interaction ($F < 1$). However, there was a trend for the main effect of Presentation Speed, $F(1, 95) = 3.68$, $p = .058$, $\eta_p^2 = 0.04$, with more *remember* responses in the speeded (M =0 .34*, 95% CI* [0.28, 0.40]) compared to the slow condition (M =0 .26*, 95% CI* [0.20, 0.32]). For participants' *know* and *guess* responses no significant main effects or interactions were found (*know* responses: List Emotion [$F(4, 380) = 1.46$, $p = .215$, $\eta_p^2 = 0.02$], Presentation Speed: [$F(1, 95) = 1.27$, $p = .262$, $\eta_p^2 = 0.01$; *guess* responses: List Emotion [$F(4, 380) = 1.01$, $p = .376$, $\eta_p^2 = 0.01$]; all other $Fs < 1$).

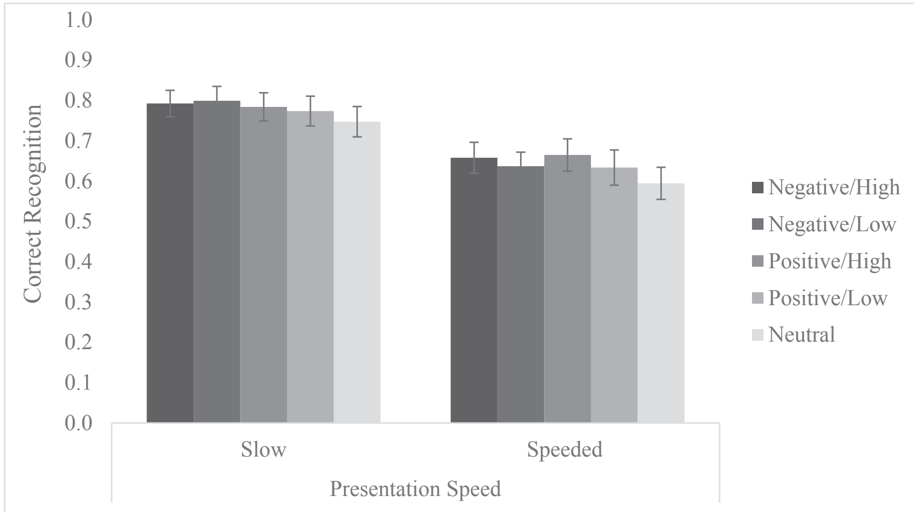

Fig. 3. Mean proportions of old responses for the correct recognition of list items as a function of List Emotion and Presentation Speed (Error bars represent standard error) for Experiment 2.

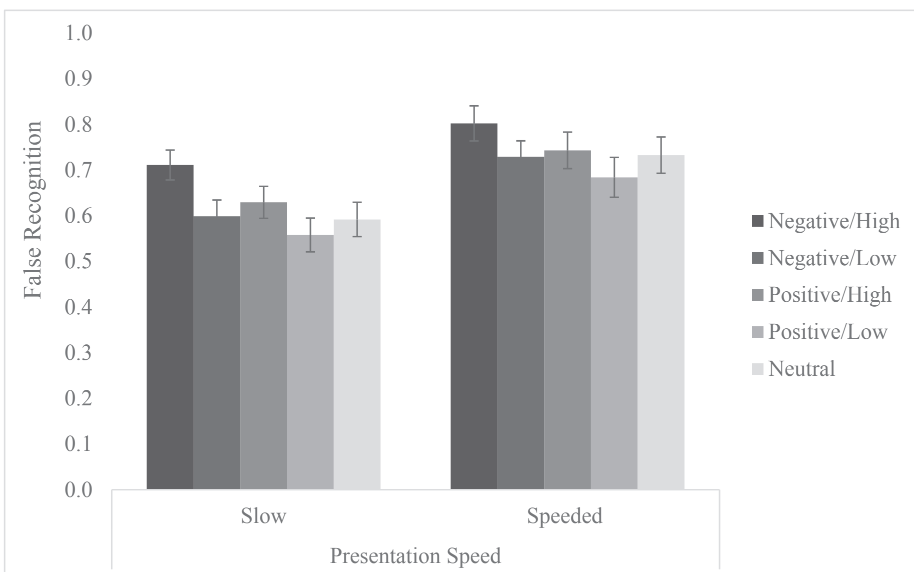

Fig. 4. Mean proportions of old responses for the false recognition of critical lures as a function of List Emotion and Presentation Speed (Error bars represent standard error) for Experiment 2.

Speed as well, $F(1, 95) = 9.25$, $MSE = 0.190$, $p = .003$, $\eta_p^2 = 0.90$. However, contrary to the pattern found in Experiment 1, there were more false old responses in the speeded ($M = 0.74$, *95% CI* [0.68, 0.79]) relative to the slow word presentation condition ($M = 0.62$, *95% CI* [0.56, 0.67]; see Fig. 4). There was no List Emotion × Presentation Speed interaction ($F < 1$).

False recognition of related and unrelated filler items

For false old responses to the related filler items, analysis revealed a significant main effect of List Emotion, $F(3.63, 344.60) = 7.31$, $MSE = 0.040$, $p < .001$, $\eta_p^2 = 0.07$, showing that participants made more false old judgements in the neutral ($M = 0.45$, *95% CI* [0.40, 0.51]) compared to any other of the other List Emotion conditions (positive/high: $M = 0.37$, *95% CI* [0.33, 0.42], $p = .008$, positive/low: $M = 0.35$, *95% CI* [0.30, 0.40], $p = .005$, negative/high: $M = 0.36$, *95% CI* [0.31, 0.41], $p = .021$ and negative/low: $M = 0.45$, *95% CI* [0.40, 0.51], $p < .001$). There were no further differences (all *ps* $>$ .08). There was also a main effect of Presentation Speed, $F(1, 95) = 13.38$, $MSE = 0.161$, $p < .001$, $\eta_p^2 = 0.12$, with more false old responses in the speeded ($M = 0.44$, *95% CI* [0.39, 0.49])

For false old responses to the unrelated filler items, analysis revealed no main effect of Presentation Speed, $F(1, 95) = 1.19$, $MSE = 0.094$, $p = .277$, $\eta_p^2 = 0.01$. However, there was a significant a main effect of List Emotion, $F(4, 380) = 6.63$, $MSE = 0.013$, $p < .001$, $\eta_p^2 = 0.07$, as well as a significant List Emotion × Presentation Speed interaction, $F(4, 380) = 2.74$, $p = .029$, $\eta_p^2 = 0.03$. Analysis of simple main effects using one-way ANOVAs showed that the differences in List Emotion type were more pronounced in the speeded, $F(4, 188) = 7.14$, $MSE = 0.012$, $p < .001$, $\eta_p^2 = 0.13$, compared to the slow condition, $F(4, 192) = 2.33$, $MSE = 0.013$, $p = .058$, $\eta_p^2 = 0.05$. Whereas pairwise comparisons did not reveal any differences in the slow condition (all *ps* $>$ .09), in the speeded condition, fewer old responses were found in the positive/high condition ($M = 0.11$, *95% CI* [0.07, 0.15]) compared to the positive/low ($M = 0.20$, *95% CI* [0.15, 0.25], $p < .001$), the negative/low ($M = 0.19$, *95% CI* [0.15, 0.24], $p = .004$) as well as the neutral condition ($M = 0.22$, *95% CI* [0.17, 0.27], $p < .001$, with no further differences (all *ps* $>$ .18).

Signal detection analysis for list items

The results of *d′* and *C* are summarized in Table 3. For discrimination ability *d′*, the same analysis as above revealed a main effect of Presentation Speed, $F(1, 95) = 24.51$, $MSE = 1.95$, $p < .001$, $\eta_p^2 = 0.21$ with better discrimination ability in the slow ($M = 1.97$, *95% CI* [1.79, 2.14]) compared to the speeded word presentation condition ($M = 1.34$, *95% CI* [1.16, 1.52]). Further, there was a main effect of List Emotion, $F(4, 380) = 8.99$, $MSE = 0.336$, $p < .001$, $\eta_p^2 = 0.09$, as well as a significant List Emotion × Presentation Speed interaction, $F(4, 380) = 2.64$, $p = .034$, $\eta_p^2 = 0.03$. Separate one-way ANOVAs, revealed a significant main effect of List Emotion in the slow condition, $F(4, 192) = 2.45$, $MSE = 0.352$, $p = .048$, $\eta_p^2 = 0.05$, showing better discrimination ability in the negative/high condition ($M = 2.11$, *95% CI* [1.89, 2.34]) compared to the neutral condition ($M = 1.75$, *95% CI* [1.47, 2.03], $p = .013$). In the speeded condition the main effect of List Emotion was significant as well, $F(4, 188) = 9.45$, $MSE = 0.320$, $p < .001$, $\eta_p^2 = 0.17$. Whereas discrimination ability was better in the negative/high ($M = 1.46$, *95% CI* [1.26, 1.67]) compared to the neutral condition here as well ($M = 1.07$, *95% CI* [0.87, 1.27], $p = .018$), discrimination was also better in the positive/high condition ($M = 1.71$, *95% CI* [1.48, 1.94]) compared to the positive/low ($M = 1.20$, *95% CI* [1.00, 1.41], $p < .001$), the negative/low ($M = 1.25$, *95% CI* [1.06, 1.43], $p = .007$), as well as the neutral condition ($p < .001$).

For response bias C, there was no main effect of List Emotion, $F(4, 380) = 1.63$, $MSE = 0.068$, $p = .165$, $\eta_p^2 = 0.02$, and no significant List Emotion × Presentation Speed Interaction, $F(4, 380) = 1.16$, $p = .329$, $\eta_p^2 = 0.01$. However there was a main effect of Presentation Speed, $F(1, 95) = 5.01$, $MSE = 0.631$, $p = .028$, $\eta_p^2 = 0.05$, showing a relative liberal response bias in the slow condition ($M = 0.13$, *95% CI* [0.03, 0.24]) compared to the speeded condition ($M = 0.30$, *95% CI* [0.19, 0.40]).

Signal detection analysis for critical lures

For discrimination ability d’, analysis yielded no main effect of Presentation Speed, $F(1, 95) = 1.95$, $MSE = 1.693$, $p = .17$, $\eta_p^2 = 0.02$, and no List Emotion × Presentation Speed interaction, $F(4, 380) = 1.30$, $p = .27$, $\eta_p^2 = 0.01$. However the main effect of List Emotion was significant, $F(4, 380) = 9.69$, $MSE = 0.491$, $p < .001$, $\eta_p^2 = 0.09$, with better discrimination ability in the negative/high ($M = 1.81$, *95% CI* [1.65, 1.97]) compared to the positive/low ($M = 1.33$, *95% CI* [1.16, 1.50], $p < .001$), the negative/low ($M = 1.42$, *95% CI* [1.24, 1.59], $p = .001$) and the neutral condition ($M = 1.34$, *95% CI* [1.16, 1.52], $p < .001$). In addition, discrimination was better in the positive/high condition ($M = 1.69$, *95% CI* [1.51, 1.87]) compared to the positive/low ($p = .012$), the neutral ($p = .009$) and in borderline significant form the negative/low condition ($p = .063$; all other $ps > 1.00$).

Last, for response bias C, analysis revealed a main effect of List Emotion, $F(4, 380) = 3.15$, $MSE = 0.108$, $p = .014$, $\eta_p^2 = 0.03$, however, pairwise comparisons did not reveal any differences between the five List Emotion conditions (all $ps > .12$). In addition, there was main effect of Presentation Speed, $F(1, 95) = 7.90$, $MSE = 0.848$, $p = .006$, $\eta_p^2 = 0.08$, showing a relative liberal bias in the speeded ($M = 0.17$, *95% CI* [0.05, 0.28]) compared to the slow word presentation condition ($M = 0.40$, 95% CI [0.28, 0.52]. There was no interaction between the variables, $F(4, 380) = 1.38$, $p = .24$, $\eta_p^2 = 0.01$.

The aim of Experiment 2 was to examine emotion enhanced false memories in a study design in which Presentation Speed was treated as a between-participants factor. In contrast to Experiment 1, analyses showed that the speeded presentation increased false recognition of the critical lures, but notably decreased correct recognition of list items. The analysis of signal detection parameters shed some light on this. For discriminability measures, participants were better able to distinguish between list items and distractors in the slow compared to fast presentation condition, but more likely to distinguish critical lures from distractors in the fast compared to slow condition. This was also accompanied by a decision-making process that differed for list items and critical lures. For the response bias measure, participants were more liberal in the speeded compared to slow presentation condition which reflected the fact that more old responses were made for critical lures in that condition. Participants were likely able to set a more conservative decision strategy for critical lures in the slow presentation condition because they could rely more successfully on source-monitoring strategies to accurately reject the critical lure items. Similar to Experiment 1, there was a more liberal bias measure for list items in the slow compared to fast presentation condition.

There was also a main effect of List Emotion for both critical lures and lists items, with both showing higher recognition rates for negative high arousing stimuli. We note that in this experiment, although there was a trend in the right direction, negative and positive arousing lists did not differ significantly in recognition across both speed conditions. This supports an enhanced emotion effect specific to arousing stimuli.

General discussion

The results from these two experiments address two aims of this study. First and foremost, can we provide additional behavioral data to support the neurocognitive finding that valence and arousal play different roles in encoding processes via distinct neural pathways, and make the inference that this leads to different rates of false memory formation when those pathways require more controlled processing. Second, does the manipulation of experimental design cause the contradictory increase or decrease in false memories rates due to changes in decision criteria? Regarding the former, from Experiment 1, negative arousing stimuli were less affected by the reduction in attentional resources compared to other stimuli and could therefore rely more on automatic, as opposed to controlled, processing. Indeed, all other valenced and neutral lists were affected by changes in attentional resources and thus appeared to be dependent on controlled processing. We argue that for these lists, the decrease in false recognition occurred because the speeded presentation reduced participants’ ability to encode the list and subsequently generate associates to the words. Regarding the latter aim, the changes in experimental design appeared to have significant subsequent impact on decision strategy with decreased false memory rates for repeated measures manipulation of attention and increased false memory rates for a between-participants manipulation of attention. These findings will be discussed in turn.

In Experiment 1, for all but negative high arousing lists, the overall false old responses to the critical lure words were significantly impaired by a reduction in stimulus presentation speed, a result in line with our predictions and prior research (e.g., Knott & Dewhurst, 2007; Knott et al., 2018; Seamon et al., 1998). Explanations for these findings come from theoretical models of false memory production, where stimuli have to be encoded to allow for spreading activation (e.g., associative activation theory, Howe et al., 2009; associative monitoring theory, Roediger & McDermott, 1995) or the extraction of gist (fuzzy-trace theory, Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008). The fast presentation times at DRM encoding in Experiment 1 sufficiently reduced stimulus processing, which in turn, hindered the generation of associations. However, this was not the case for high arousing negative associations, where false memories for critical lures persisted even with fast presentation time. Although not directly testing such theory, our results provide further support that emotion modulates (false) memory through an automatic route primarily consisting of the amygdala and brain regions related to memory, which are less dependent on attentional resources (Clark-Foos & Marsh, 2008; Kang et al., 2014; Kern, Libkuman, Otani, & Holmes, 2005; Talmi, Schimmack et al., 2007). Under conditions of limited attentional resources, high arousing negative stimuli that are automatically processed should then allow for the extraction of gist or the activation of associative connections when encoding negative high arousing DRM lists (Knott et al., 2018).

Regarding arousal, unlike negative information, memory for positive high arousal stimuli was adversely affected by the fast presentation times. Hence, positive stimuli high in arousal seemed to depend on the intentionality to encode the information, and thus, could be reliant on more controlled processing (Kern et al., 2005; Talmi et al., 2007).

Last, our results extend the findings of Knott et al. (2018) and show that speeded word presentation and thus reduced attention, adversely impacted false memories for negative and positive non-arousing stimuli. For non-arousing valenced information, reduced attentional resources interferes with the rehearsal and elaboration process and thereby impacts false memory for the non-arousing emotional stimuli. That is, for a false memory for a critical lure to occur, the associative links between concepts/nodes need to be activated. If speeded presentation prevents the controlled encoding of non-arousing valenced stimuli, the associative links cannot be activated. These findings are consistent with the neuroimaging studies and previous behavioral studies, which have shown that, for non-arousing emotion-enhanced memories, whether negative or positive, rely on the PFC-hippocampal network associated with controlled processing (e.g., Kang et al., 2014).

In contrast, Experiment 2, the between-participants design, showed that while correct recognition of list items decreased, false memories increased with reduced attention. This finding is more in line with Pérez-Mata et al. (2002) and Seamon et al. (1998), who also found higher false memory rates in divided attention and speeded presentation conditions. We argue that these findings reflect a change in decision criteria whereby participants set a lower threshold for accepting an item as old because they know words will appear less familiar to them after studying items in a speeded presentation condition. This is supported by signal detection analysis with participants appearing to adopt a more liberal response criterion for accepting the critical lures as old. Of note, these findings are similar to those reported by Stretch and Wixted (1998; see also Wixted & Stretch, 2000), who investigated experimental design using a levels of processing task. When strength was manipulated between lists, false alarms were low for the strong list condition because participants used a high criterion (strong belief they could accurately recognize a word) and could avoid making false alarms without missing many targets. With the weak list condition, false alarms were high because the criterion was set low to maximize the probability of giving a correct answer in light of items not feeling as familiar. Stretch and Wixted (1998) argued that participants used a kind of metaknowledge to set their decision criterion. The results from Experiment 2 support this suggestion. Participants adopted a more liberal response in the fast presentation condition because words did not feel as familiar to them. In order to increase the probability of accurately recognizing a word, they adopted a more liberal criterion. The slow presentation condition allows for processing of the list items, and strategies for making old and new decisions can occur as normal. In contrast, for Experiment 1, where participants were tested on items at recognition that were presented both fast and slow at study, there was no shift in criterion and participants used the same response criterion for accepting old and new words for all recognition items (critical lures and list items) associated with each encoding condition. We see the pattern of results that we do for Experiment 1 because the decision for accepting an item as old is set high for items known to be encoded with comparatively less detail than those encoded with rich detail. This means that fewer critical lure items are considered as familiar (because they were not encoded) and thus do not meet the threshold for recognition. Negative high arousing items were automatically encoded so the level of familiarity is the same and thus, the threshold for accepting these as old words is similar.

We propose this explanation because our signal detection analysis showed a change in criterion *C* between the fast and slow presentation for critical lures and list items in each experimental design. Previous studies that have manipulated divided attention at encoding have varied in design, however, Dewhurst et al. (2007), and Knott et al. (2018) used a repeated measures design, similar to our first experiment, and found a reduction in false memory formation. Peters et al. (2008), Otgaar et al. (2012, for adults), and Pérez-Mata et al. (2002) used between-participants designs and found an increase in false memory formation. Only Peters et al. reported response bias with no significant difference in attention conditions. However, their recognition test was a final test that followed free recall tests after each list, thus, the recognition data and analysis is not directly comparable because the recognition test is confounded by the recollection of the items from the individual recall tasks. It should be noted here that our recognition tasks in Experiment 1 and 2, did differ in item length (72 vs 46 items respectively). Although it could be argued that fewer items on the recognition test would make the task easier, you would expect the opposite impact on criterion shift. That is, research has shown that when the recall/recognition task is harder, participants adopt a more liberal criterion to account for the difficult of recognizing list items. This is not what we found. Further, previous research has shown the effect with a wide variation in item length (Knott et al., 2018; Knott & Shah, in press, used a 60 and 120 item recognition test respectively) and found the same effect. Although future work may be needed to rectify this, we believe this demonstrates that recognition item length does not impact the effect found with regard to the attention and emotion manipulations used in this study.

As noted, in Experiment 2, participant's response bias in the speeded condition shifted to more liberal responses in all five list emotion conditions. However, in both speed conditions, the results suggest an emotional enhanced false memory effect that is driven by arousal. That is, higher false memories for negative-arousing lists compared to other list types. Several emotion enhanced memory theories attribute the effect largely to arousal (Adelman & Estes, 2013). The underlying assumption is that limited mnemonic resources are preferentially allocated to behaviorally significant stimuli (Nairne, 2010), with arousal acting as their primary index (McGaugh, 2000). In contrast, valence, independent of arousal, is believed to exert a lesser influence on memory (Mather & Sutherland, 2009). By this account, memory enhancement can occur for both negative and positive materials, provided they are sufficiently arousing (Adelman & Estes, 2013). Based on previous research, a theoretical explanation for the impact of valence and arousal on the formation of false memories will need further consideration. As mentioned earlier, Brainerd and Boofkbinder (in press), with reference to the Fuzzy-Trace theory, argue that arousal does not contribute substantially to valence effects found in the DRM paradigm. They argue that the differential effect of valence occurs because negative, in comparison to positive stimuli have fewer properties that support item-specific processing (known to enhance true memory). Their findings and conclusions contradict those found here. Overall, we find that arousing negative stimuli produce more false memories than nonarousing negative stimuli. Something that Brainerd and Bookbinder would not predict. Referring to associative activation theories (Howe et al., 2009), we argue that high arousing valenced lists have dense and highly salient semantic connections which allow the spread of activation to occur rapidly and automatically through a network. when the stimuli also evoke arousal, it attracts attention which enhances memory binding (Talmi, 2013) and increases activations to the nonpresented critical lure. We have seen here that this attention capture can be relatively automatic. Of course, we have not explicitly tested either theory, and how valence and arousal contribute to the formation of false memories will require further research.

To conclude, we had two main goals in this research. First and foremost, we wanted to extend the findings of Knott et al. (2018) and use behavioral data to make inferences about the role of automatic and controlled processing when encoding stimuli manipulated for valence and arousal. Second, we wanted to explore some of the contradictory findings in relation to the effect of reduced or divided attention on false memory formation and the possibility that this was a result of a reluctance to change decision criteria during the course of a single recognition test. In Experiment 1, where participants were tested on items at recognition that were presented both fast and slow at study, there was no shift in criterion and participants used the same response criterion for accepting old and new words for all recognition items. With all things being equal in this design, few attentional resources are needed for the activation of associative connections and the formation of false memories for high arousing negative stimuli. In contrast, speeded presentation prevented the encoding of non-arousing valenced stimuli and positive arousing stimuli and thus, hindered the activation of associative links and reduced false memory formation. In Experiment 2, participants adopted a more liberal response in the fast presentation condition because they knew words would be less familiar to them. In order to increase the probability of accurately recognizing a word, they adopted a more liberal criterion. Thus, although we saw the overall enhanced false memory effect for negative arousing stimuli, we saw an increase in false memories in the reduced attention encoding condition because the response bias set at retrieval superseded the role of encoding processes during study. This final conclusion draws out two important issues. First, the role of arousal in false memory formation. Overall it appears that false memory rates are higher for negative arousing compared to negative non-arousing stimuli. This conflicts with a recent finding and explanation outlined by Brainerd and Boofkbinder (in press) who argued that arousal does not affect false memory. Further research is needed to unpick these conflicting findings and the role of attention and automaticity of processing could be key. Finally, when it comes to attention, we should be mindful of the impact experimental design has on changes to our decision strategies.

Declarations of interest

The authors declared that there is no conflict of interest.

Acknowledgments

Funding: This work was supported by a project grant from the Economic and Social Research Council, ESRC [grant number ES/L00853X/1].

Appendix A. Overall mean values for lists and critical lures as a function of list set, list emotion and list variables.

	List set A						List set B				
	Valence		Arousal		BAS		Valence		Arousal		BAS
Lists	LI	CL	LI	CL		Lists	LI	CL	LI	CL	
Negative/high											
Anger	2.86	2.34	6.64	7.63	0.15	Hate	2.40	2.12	6.04	6.95	0.16
Bomb	3.56	2.10	6.50	7.15	0.16	Gun	3.15	3.47	5.93	7.02	0.30
Snake	2.99	3.31	5.97	6.82	0.26	Pain	2.67	2.13	5.62	6.50	0.30
Evil	2.44	3.23	5.72	6.39	0.10	Danger	4.01	2.95	5.83	7.32	0.12
Thief	2.74	2.13	5.81	6.89	0.14	Drugs	3.43	3.76	5.56	6.00	0.17
Bees	3.60	3.20	5.31	6.51	0.31	Stress	3.11	2.09	6.45	7.45	0.10
Grand means	**3.03**	**2.72**	**5.99**	**6.90**	**0.19**	**Grand means**	**3.13**	**2.75**	**5.90**	**6.87**	**0.19**
Negative/low											
Alone	2.56	2.41	3.67	4.83	0.17	Sad	2.55	1.61	4.31	4.13	0.26
Sick	3.22	1.90	5.00	4.29	0.32	Fat	3.99	2.28	4.29	4.81	0.16
Stupid	3.62	2.31	4.59	4.72	0.23	Smoke	3.86	3.39	4.76	4.48	0.20
Trash	3.14	2.67	4.53	4.16	0.17	Cold	4.00	4.02	4.65	5.19	0.26
Wrong	3.60	2.93	4.62	4.67	0.17	Boring	4.18	3.38	4.32	2.29	0.12
Old	3.72	3.31	4.20	3.50	0.28	Poor	2.83	2.28	4.78	5.21	0.18
Grand means	**3.31**	**2.59**	**4.43**	**4.36**	**0.22**	**Grand means**	**3.57**	**2.83**	**4.52**	**4.35**	**0.20**
Positive/high											
Laugh	7.96	8.36	6.35	7.39	0.28	Love	7.78	8.72	6.29	6.44	0.32
Win	7.78	8.38	6.09	7.72	0.17	Pretty	7.68	7.75	5.99	6.03	0.13
Beach	6.97	8.03	5.12	5.53	0.17	Gold	6.99	7.54	5.46	5.76	0.16
Sweet	6.59	7.64	5.16	5.96	0.19	Happy	7.68	8.21	6.35	6.49	0.32
Party	7.28	7.86	6.07	6.69	0.16	Trip	7.02	6.96	6.06	6.30	0.16
Money	7.47	7.59	6.33	5.70	0.29	God	6.95	8.15	5.76	5.95	0.17
Grand means	**7.34**	**7.98**	**5.85**	**6.50**	**0.21**	**Grand means**	**7.35**	**7.89**	**5.98**	**6.16**	**0.21**
Positive/low											
Sleep	6.40	7.20	3.66	2.80	0.35	Flower	6.44	6.64	4.15	4.00	0.37
Calm	6.70	6.73	3.70	3.60	0.10	Safe	6.89	7.07	3.91	3.86	0.10
Fruit	6.05	6.93	4.21	4.63	0.25	Bird	6.71	7.27	4.48	3.17	0.38
Blue	6.08	6.76	4.55	4.31	0.19	Girl	6.23	6.87	4.66	4.29	0.17
Art	5.91	6.68	4.25	4.86	0.17	Bath	5.89	7.33	4.73	4.16	0.10
Earth	6.18	7.15	4.61	4.24	0.13	Music	6.35	8.13	4.57	5.32	0.23
Grand means	**6.22**	**6.91**	**4.16**	**4.07**	**0.20**	**Grand means**	**6.42**	**7.22**	**4.42**	**4.13**	**0.22**
Neutral											
Cup	5.18	5.44	4.25	3.70	0.14	Window	4.70	5.91	4.27	3.97	0.20
Foot	5.53	5.02	4.24	3.27	0.23	Paper	4.99	5.20	3.77	2.50	0.25
Rock	5.05	5.56	4.36	4.52	0.25	Street	5.10	5.22	4.64	3.39	0.24
Chair	5.24	5.08	3.76	3.15	0.27	Hammer	5.22	4.88	4.62	4.58	0.16
Tire	5.44	4.97	4.89	4.00	0.12	Number	5.19	5.55	4.49	4.34	0.21
Milk	5.36	5.95	4.17	3.68	0.23	Time	5.15	5.31	4.09	4.64	0.21
Grand means	**5.30**	**5.34**	**4.44**	**3.72**	**0.21**	**Grand means**	**5.06**	**5.35**	**4.31**	**3.90**	**0.21**

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jml.2019.03.010.

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