The Effect of Limited Attention and Delay on Negative Arousing False Memories

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Abstract

Previous research has shown that, in comparison to neutral stimuli, false memories for high arousing negative stimuli are greater after very fast presentation and limited attention at study. However, full compared to limited attention conditions still produce comparably more false memories for all stimuli types. Research has also shown that emotional stimuli benefit from a period of consolidation. What effect would such consolidation have on false memory formation even when attention is limited at study? The aim of the present study was to investigate the effect of fast presentation on false memory production for negatively-arousing and neutral items over time using the DRM paradigm. Sixty-Eight participants studied Negative and neutral DRM lists with fast or slow presentation conditions. Half completed a recognition test immediately and half completed a recognition test after one-week. Results revealed that, for fast presentation, negative critical lures increased after one week and were comparable to negative critical lures in the slow presentation encoding conditions. Neutral critical lures in the fast presentation condition did not change and remained lower compared to the slow presentation condition. These findings are the first demonstration that arousing negative false memories can increase over time when attention at encoding is limited.

Keywords: DRM Paradigm; Attention; False Memory; Emotion; Delay

Negative Arousing False Memories Develop with Limited Attentional Resources and Increase Over Time

Research has shown that emotionally arousing events are better remembered than comparable neutral ones (Talmi, Schimack, Paterson, & Moscovitch, 2007). This has been demonstrated in the lab using a variety of stimuli type including stories, (e.g., Cahill & McGaugh), pictorial stimuli, (e.g., Bradley, Greenwald, Petry, & Lang); and taboo words, (e.g., LaBar & Phelps, 1998). Research has shown this enhancement effect to occur immediately and after a period of delay. Immediate effects of emotion have been attributed to enhanced relatedness of emotional items (LaBar & Phelps, 1998), the influence of emotion on attention (Talmi et al., 2007), and enhanced binding of items with their encoding context (Doerksen & Shimamura, 2001). The delay effects have been attributed to the influence of emotion on the modulation of neurobiological processes involved in the consolidation of memory (see McGaugh 2004).

Neuroimaging studies have also shown that different types of emotion might be modulated by different encoding processes that enhance memory via distinct neural routes. For example, using functional MRI, Kensinger and Corkin (2004) demonstrated that the enhanced memory of a negative arousing stimulus (e.g., rape, slaughter) was mediated by the amygdala-hippocampal network, and associated with relatively automatic encoding processes, whereas, the enhanced memory of a negative nonarousing stimulus (e.g., sorrow, mourning) was supported by a PFC-hippocampal network, and associated with more controlled encoding processes. In a companion behavioural study, Kensinger and Corkin, found that a secondary task presented at study (divided attention) significantly reduced recognition for negative nonarousing (71% remembered) and neutral stimuli (68%), compared to arousing negative stimuli (84%). This differed from a full attention condition, where there was a benefit for negative arousing (88%) and nonarousing words (83%) compared to neutral words (75%).

Emotion can enhance accurate memory, but research has also shown that it can, rather counterintuitively, increase memory errors. Evidence comes from research using emotive materials within standard false memory paradigms. For example, the Deese/Roediger-McDermott (DRM; Deese, 1959; Roediger & McDermott 1995) paradigm (also referred to as the Deese-Roediger-McDermott-Read-Solso: DRMRS; see McKelvie, 2001) is a popular list-based paradigm used to measure the production of, so called, spontaneous false memories. Here, semantically related lists (e.g., *bed, rest, wake, tired*) are presented at encoding, but a highly associated critical lure is not included (e.g., *sleep*). A false memory is recorded when the critical lure is incorrectly recalled or recognised at test. When studying the impact of emotion on false memory production, emotive lists (e.g., *harm, pain, wound, punish, insult; critical lure - hurt*) are often compared to non-emotive neutral lists. Findings using emotive lists have varied depending on valence and arousal levels but a common theme is that when arousal is matched, negative stimuli produce higher false memory rates compared to positive and neutral stimuli (e.g. Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008; Howe, Candel, Otgaar, Malone, & Wimmer, 2010, although note, increases in false memory rates for emotional stimuli in the aforementioned studies often relate to increases in recognition, and not recall).

One of the original studies that first introduced the DRM paradigm, referred to an activation-monitoring theory to explain the false memory effect (Roediger & McDermott, 1995; also see Bookbinder & Brainerd, 2016, for a review of current false memory theories). As participants view the associative items, activation spreads through the semantic network to related but nonstudied words. A false memory occurs when participants fail to monitor the source of the activated item. To explain the enhanced emotional false memory effect, research has shown that semantic relatedness is higher for emotional relative to neutral items. Indeed, evidence has shown that when semantic relatedness is controlled in memory studies for word recall, the enhanced effect for emotional stimuli disappears (see Talmi & Moscovitch, 2004). Based on associative activation theories, if negative stimuli activate networks of more strongly interrelated nodes, where thematic relationships overlap, the spread of activation within the semantic network to the critical lure will be easier (Otgaar, Howe, Brackmann, & Smeets, 2016).

For emotional stimuli, it appears that the role of relatedness is key, but recent research has also examined the role of encoding processes in the production of false memories in the DRM paradigm. In a modified version of the behavioural study by Kensinger and Corkin (2004), Knott, Howe, Toffalini, Shah, and Humphreys (2018) found that, although false recognition for all stimuli was higher in full attention, higher false recognition rates to critical lures associated with negative high arousing compared to neutral (and positive valenced) DRM lists were found when attention at study was interrupted (by dividing attention or reducing presentation time). Knott et al. (2018) argued that the encoding of negative arousing items seemed to benefit from automatic processing and thus could still be encoded and associates in the network could still be activated under limited attentional resources. In comparison, the encoding of neutral (and positive) stimuli required more elaborate and controlled processing, thus limited attention hindered successful encoding and reduced the activation of nodes within the more neutral (but also positive) associative networks.

Although these findings show an enhanced negative false memory effect compared to positive and neutral false memories during limited attention conditions, there was still an overall reduction in false recognition compared to full attention conditions after an immediate recognition test. But after a significant delay between encoding and retrieval, would this finding continue? We pose this question due to the influence of emotion in the consolidation of memory as shown in the emotion enhanced memory literature. The modulation hypothesis states that the activation of the amygdala during encoding leads to better consolidation after a period of delay (for reviews see Cahill & McGaugh, 1998; Hamann, Ely, Grafton & Kilts, 1999; McGaugh, 2004).

If the consolidation process only enhances memory for emotional rather than neutral information, then after a delay, false memories for negative but not neutral stimuli should increase (if they have been successfully encoded). Indeed, this hypothesis is supported from previous findings. For example, Howe et al., (2010) manipulated a delay interval between study and test and found that false memories for negative stimuli increased over a one-week period compared to immediate testing, whereas false memories for neutral stimuli remained the same over the same period. Going back to our hypothesis, if stimuli have been successfully encoded due to the more automatic processes involving the amygdala, this should support modulation of the long-term consolidation of emotional stimuli and subsequent false memory production. Thus, after a period of delay, false memories for negative stimuli encoded under limited attention should be higher compared to immediate recognition and possibly similar to levels of false recognition compared to items that were encoded with full attention conditions. Since the enhanced emotion memory effect is often diluted by effects of list organisation for correct recognition in the DRM paradigm (Knott et al., 2018), we make no directional hypothesis regarding the outcome for correct recognition. The current study aimed to examine the role of delay and the effects of consolidation for the development of emotional false memories when attention has been manipulated during encoding. We will conduct an extended replication of experiment two from the Knott et al's (2018) study, whereby attention was manipulated using fast and slow presentation speeds at encoding whilst presenting negative arousing and neutral DRM lists. In addition, we will measure recognition either immediately after study or after a one-week delay.

Method

Participants

Sixty-eight participants (47 females and 21 males) aged 18-56 (*M* = 23.97, *SD* = 8.30) took part in the study, and received either course credits or £5 for their participation. A priori power analysis indicated a required total sample size of 68, with an effect size of 0.30 and Power of 0.80. All participants gave written informed consent and were fully debriefed at the end of the experiment. The study was ethically approved by City, University of London's Psychology Research Ethics Committee.

Design and stimuli

The experiment followed a 2 (Presentation Speed: 20ms vs. 2s) x 2 (List Valence: Neutral vs. Negative) x 2 (Time of Test: Immediate vs. one-week) mixed factorial design, with repeated measures on all but the final factor. All participants were presented with 20 word-lists in total (10 negative and 10 neutral). Negative and neutral DRM lists were taken from Knott et al. (2018; see for full details) and were matched for backward associative strength (BAS) and inter-item connectivity (see Nelson, McEvoy, & Schreiber, 1998), but significantly different for ratings of valence and arousal. Each negative list consisted of 12 associates to the following critical lures: *devil, sick, hurt, dead, thief, cry, hate, lie, fear* and *alone,* while each neutral list consisted of 12 associates to the following critical lures: *car, chair, foot, mountain, smell, window, pen, shirt, cup,* and *high* (see Appendix A for all word lists).

Full counterbalancing procedures were applied for Presentation Speed and List Valence. The order of Presentation Speed and List valence condition was counterbalanced such that half of the participants were presented with Negative followed by Neutral lists and half Neutral followed by Negative lists. Within each List Valence condition, for half of the participants, lists were encoded with the fast presentation first, and half with the slow presentation first. Also, within each List Valence condition, the lists were subdivided into two groups (totalling four groups across List Valence conditions), with each group of lists being used equally often in each counterbalancing condition. The order of list-presentation within each group was randomised for each participant. Words within the lists were presented in BAS order. The presentation speeds were taken from Knott et al. (2018) and based on the study by Seamon, Luo, and Gallo (1998). List Valence was blocked to eliminate a possible distinctiveness effect from driving the emotional enhanced memory effect (see Talmi et al., 2007 for a review).

The recognition test consisted of 120 words: 20 critical lures (associated with all the negative and neutral lists), 60 list items (3 items from each list), 20 weak-related fillers and 20 unrelated fillers. The filler items were used to ensure that the responses (i.e. Old/New) are used approximately equally. This can help avoid response bias, where participants may decide to use one response predominantly throughout. The weak-related fillers were connected to the critical lures and were taken from the bottom of the Nelson et al. (1998) normed lists associated with the critical lures, a procedure similarly used by Roediger and McDermott (1995). Unrelated fillers were matched in valence and arousal with equal neutral and negative words and were not connected to the list items or critical lures. E-prime (Version 2.0) was used for presenting the words and completing the recognition test.

Procedure

Opportunity sampling was used such that participants signed up to either an immediate (N = 34) or delayed (N = 34) testing condition. The number of males and females were matched between these two conditions (females: $24_{Immediate}$ vs. 23_{Delay}; males: $10_{Immediate}$ vs. 11_{Delay}). The study phase consisted of two main blocks. Participants either studied negative lists in the first block followed by neutral lists in the second block, or this negative and neutral blocked-list order was reversed for other participants. A 5-minute break was inserted between the two main blocks during which participants completed Sudoku puzzles. Within each main block, the presentation of the lists was broken into two further blocks with a 1-minute break in-between. The first block consisted of 5 lists with words presented at a speed of 20ms (fast), and the second block consisted of 5 lists with words presented at a speed of 2s (slow). The order of these Presentation Speed blocks was counterbalanced. Before the start of each block, participants were either instructed to silently read and memorise the words (2s condition) or were told that the word presentation will be quite fast, so they must pay very close attention when reading the words (20ms condition). These instructions remained on-screen until the participants pressed the Spacebar on the keyboard. Then, the 12 associates from each list was presented. List items were presented from strongest to weakest in associative strength. An on-screen instruction (List 1, List 2, List 3, etc.) lasting 2 seconds was shown to announce each individual list.

After the presentation of all 20 lists, participants completed the test phase either immediately (following another 5-minute non-verbal distractor task) or in exactly one-week. Participants were given clear verbal instructions on how to complete the recognition task. Participants made an *old/new* followed by a recollective experience judgement of *remember/know/guess* (only if an *old* response was made). See Knott et al. (2018) for a full description.

Results

All statistical analyses were performed using SPSS (Version 24.0). Correct recognition to studied items and false old recognition responses[1] to critical lures and weak-related filler items were analyzed separately using a 2(Presentation Speed: 20*ms* vs. 2*s*) x 2(List Valence: negative vs. neutral) x 2(Time of Test: immediate vs one-week) mixed factor ANOVA with repeated measures on the first two factors. Any significant interactions were further analyzed using either paired-samples or independent-samples t-tests with Bonferroni corrections (alpha set at .025). False old recognition responses to unrelated distractor items were analyzed using a List Valence x Time of Test mixed factor ANOVA with repeated measures on the first factor. Mean proportions and 95% confidence intervals for the dependent measures are reported in Table 1. [2]

Correct recognition of List Items. For *old* responses, there was a significant main effect of Presentation Speed, $F(1, 66) = 96.91$, $p < .001$, $\eta_p^2 = .60$, whereby correct recognition of studied items was higher for lists that were presented at 2*s* ($M = .62$, 95% CI [.57, .66]) compared to 20*ms* ($M = .42$, 95% CI [.38, .46]). There was also a significant main effect of List Valence, $F(1, 66) = 31.83$, $p < .001$, $\eta_p^2 = .33$, with a higher rate of correct recognition in the negative ($M = .58$, 95% CI [.54, .63]) compared to the neutral ($M = .45$, 95% CI [.41, .49]) condition. There was one significant two-way Presentation Speed x Time of Test interaction, $F(1, 66) = 25.32$, $p < .001$, $\eta_p^2 = .28$. There were still more correct responses for the slower, compared to fast, presentation at each time of test (Immediate: $M_{Slow} = .64$ vs. $M_{Fast} = .34$;Delay: $M_{Slow} = .60$ vs. $M_{Fast} =.50$). However, independent samples t-tests showed no significant difference in correct responses for lists presented for 2*s* between the Time of Test conditions, $t(66) = -1.00$, $p = .322$, $r = .12$, but there was an increase in correct responses for list items presented for just 20*ms* after 1 week, $t(66) = 4.19$, $p < .001$, $r = .46$. Alternatively, paired-samples t-tests revealed that correct responses to list items was higher in the slow compared to the fast presentation condition at both immediate, $t(33) = 8.86$, $p < .001$, $r = .84$, and delayed testing, $t(33) = 4.43$, $p < .001$, $r = .61$. There was no main effect of Time of Test and no further interactions (*F*s < 25.40, *p*s > .05).

False Recognition of Critical Lures. For false *old* responses, there was a significant main effect of Presentation Speed, $F(1, 66) = 28.36$, $p < .001$, $\eta_p^2 = .30$, with more false responses to critical lures with a 2*s* study presentation ($M = .67$, 95% CI [.62, .71]) compared to 20*ms* (*M* = .54, 95% CI [.49, .58]). There was also a significant main effect of List Valence, $F(1, 66) = 38.06$, $p < .001$, $\eta_p^2 = .37$, with negative lures receiving more false memories (*M* = .70, 95% CI [.65, .76]) compared to neutral lures (*M* = .50, 95% CI [.45, .55]). There was no significant main effect of Time of Test, $F(1, 66) = 1.88$, $p = .176$, $\eta_p^2 = .03$. However, the three-way Presentation Speed x List Valence x Time of Test interaction approached significance, $F(1, 66) = 3.84$, $p = .054$, $\eta_p^2 = .06$. We further investigated this trend in the interaction by conducting a two-way List Valence x Time of Test ANOVA separately on Fast and Slow Presentation conditions. For slow word presentation, there was a significant main effect of List Valence, $F(1, 66) = 22.33$, $p < .001$, $\eta_p^2 = .25$, indicating higher false memories for negative compared to neutral critical lures. However, there was no significant main effect of Time of Test, $F(1, 66) = .21$, $p = .651$, $\eta_p^2 = .003$, nor List Valence x Time of Test interaction, $F(1, 66) = .82$, $p = .823$, $\eta_p^2 = .001$. For fast word presentation, there were, once again, a significant main effect of List Valence $F(1, 66) = 26.00$, $p < .001$, $\eta_p^2 = .28$, with the pattern of result similar to slow presentation condition. There was a marginal main effect of Time of Test, $F(1, 66) = 3.28$, $p = .075$, $\eta_p^2 = .05$, with more false memories after one-week compared to immediate testing. The List Valence x Time of Test interaction was found to be significant, $F(1, 66) = 6.15$, $p = .016$, $\eta_p^2 = .09$. Decomposing this interaction using independent-samples t-tests revealed that there was no difference in false recognition between immediate and delayed testing conditions for neutral lures, $t(66) = -.27$, $p = .788$, $r = .03$, but false recognition was significantly higher in the delayed (*M* = .74, 95% CI [.66, .82]) compared to the immediate (*M* = .55, 95% CI [.44, .65]) testing condition for negative lures, $t(66) = 3.02$, $p = .004$, $r = .35$. Alternatively, paired samples t-tests showed that false memories between negative and neutral lures was not significantly different at immediate testing, $t(33) = 1.83$, $p = .076$, $r = .30$, but after one-week, false memories were higher for negative compared to neutral critical lures, $t(33) = 5.42$, $p < .001$, $r = .69$.

See Figure 1 for a representation of the pattern within the three-way interaction using violin plots.

False Recognition of Weak-Related and Unrelated Distractors. For weak related items, there was a significant difference in List Valence for *old* responses, $F(1, 66) = 10.58$, $p = .002$, $\eta_p^2 = .14$, with higher false recognition rates for the neutral ($M = .25$, 95% CI [.21, .30]) compared to the negative ($M = .19$, 95% CI [.15, .23]) fillers. There was a marginal significant effect for Time of Test, $F(1, 66) = 3.58$, $p = .063$, $\eta_p^2 = .05$, whereby false recognition for weak fillers were marginally higher when tested after one-week ($M = .26$, 95% CI [.20, .31]) than when tested immediately ($M = .19$, 95% CI [.13, .24]) However, there was no significant main effect of Presentation Speed ($F = 2.23$, $p = .14$) or any interactions (Fs < 1.50, $p > .230$).

For *old* responses to unrelated fillers, false recognition increased over one-week, $F(1, 66) = 9.72$, $p = .003$, $\eta_p^2 = .13$. Although there was no main effect of list Valence ($F = .86$, $p = .357$), there was a significant List Valence x Time of Test interaction, $F(1, 66) = 4.90$, $p = .030$, $\eta_p^2 = .07$. Independent-samples t-tests showed that the increase in false responses after one-week was only significant for negative distractors, $t(66) = 3.67$, $p < .001$, $r = .41$, and not neutral distractors, $t(66) = 1.72$, $p = .090$, $r = .21$, although the latter was in the same direction. See Table 1 for Means and Confidence Intervals.

Discussion

The aim of the present study was to investigate the effect of limited attention at encoding and delay on false memory production for negative arousing and neutral items using the DRM paradigm. We hypothesized that negative emotional stimuli can be encoded automatically with limited attentional resources. Further, because the consolidation process only enhances memory for emotional rather than neutral information, then after a delay, even with fast presentation and limited attention, false memories for negative but not neutral stimuli should increase.

The typical emotion advantage was seen in the slow presentation condition with higher false memory rates for negative compared to neutral critical lures with immediate test and 1-week delay. For fast presentation, negative false memory rates increased after the delay and were at a level comparable to full attention encoding conditions. For neutral critical lures, encoded using the fast presentation condition, there was no difference over the delay, all rates were lower than those for negative critical lures. Based on our initial hypothesis, after a delay negative false memories increased and were at a comparable level across attention conditions because long-term consolidation of emotional stimuli into our knowledge base increased activation of the critical lure. The explanation for these findings are considered next.

Two lines of research can be combined to explain this finding: (1) the automatic processing of negatively arousing stimuli, and (2) the persistence of negative false memories over time. First, behavioural and neurocognitive research (e.g., Eimer, Kiss, & Holmes, 2008; Kensinger & Corkin, 2004; Talmi et al., 2007) have demonstrated that negatively-valenced arousing stimuli may benefit from rapid and automatic processing at encoding. Therefore, such stimuli are essentially less dependent on attentional resources. Kensinger and Corkin (2004) showed that this was achieved by the activation of the amygdala and hippocampal brain regions which mediates the enhanced memory for negative arousing stimuli. In contrast, neutral stimuli are thought to be dependent on controlled processing, with intentional encoding a necessity to achieve successful processing of neutral information. These findings have led behavioural research to further demonstrate that automatic processing is associated with the production of negative false memories. Knott et al. (2018) found that, when attention was reduced by presenting words for 20ms, false recognition was higher for negative compared to neutral critical lures. This indicates that negative lists were successfully processed during the study phase. As a result, and according to activation theories (e.g., AMT; Roediger & McDermott, 1995), semantically-related negative concepts/nodes are activated within one's knowledge-base due to a spread of activation. In comparison, neutral stimuli require elaborative and controlled processing, therefore limited attentional resources disrupted the activation of related nodes within one's neutral associative memory networks.

This automatic processing of negative stimuli supports the modulation of the long-term consolidation of negative information, and this constitutes the second line of research to explain the present study's main finding. Information that is of an emotional nature have been shown to be better remembered over time compared to neutral information (e.g., LaBar & Cabeza, 2006), and one explanation for this may be the possible existence of different consolidation trajectories for positive and negative emotional and neutral information. According to the modulation hypothesis, adrenal stress hormones are released during emotional experiences, which subsequently activates the amygdala. This activity then modulates memory consolidation and consequently influences long-term memory (McGaugh, 2004). There is evidence that the long-term consolidation is specific to negative arousing information (e.g., Sharot & Yonelinas, 2008). Therefore, the modulation theory ultimately leads to the hypothesis that memory for arousing negative stimuli will persist, while memory for neutral stimuli will either decline or remain unchanged, over time (Wang, 2014). Furthermore, consistent with previous research (e.g., Howe et al., 2010), the present study found that false recognition of negative arousing critical lures were higher than neutral critical lures after a one week delay. Although negative critical lures overall, increased over time, this was only evident after fast presentation at encoding. After slow presentation, false recognition of both negative and neutral lists remained consistent. Although this differs to the increase in false recognition of negative critical lures found by Howe et al., our proportionate scores after immediate recognition were higher and could already be at ceiling, not to mention various methodology differences, including negative lists that were both low and high in arousal, that prevent direct comparisons. Overall, however, it seems that both true and false memories for negative information benefits from these consolidation differences.

Like previous research, correct recognition rates were higher for negative compared to neutral stimuli (e.g., Kensinger & Corkin, 2004), demonstrating an enhanced emotional memory effect. However, we did not find a consolidation effect for emotional list items and there was no interaction with presentation speed. Whilst this does not support previous findings examining the role of automatic processes at encoding and consolidation effects, we have to be cautious when interrupting any effects related to correct recognition using the DRM lists. Research has shown that the effects of list organisation in the emotion enhanced memory literature eliminates the enhanced effect, that is when both neutral and emotive stimuli are presented categorically, the emotion effect disappears (Talmi & Moscovitch 2004). Given that DRM lists, are by nature, categorical, such results should be interpreted with caution.

We conclude from our findings that the higher rates of negative compared to neutral false memories at immediate test is consistent with the automatic processing hypothesis, whereby negative high arousing stimuli can be encoded using more automatic processes at study. Although recognition responses are lower in the fast, compared to slow presentation condition after immediate testing, this disadvantage disappears after delay because long-term consolidation of emotional stimuli into our knowledge base increases activation of the critical lure. Is this a worrying finding? When you consider the forensic implications and increases in memory errors for negative arousing stimuli over a period of delay, then we may well answer, yes, to this question. However, we acknowledge that DRM lists may not be representative of “real life” forensic situations, and future research should continue to investigate the mechanisms underlying false memory formation for negative arousing events, using more ecologically valid paradigms.

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Footnote

1. The analysis of *remember (R), know (K),* and *guess (G)* responses, and the signal detection measures, discrimination (d') and response bias (C) were calculated and analysed to measure recognition decision accuracy. As this is a brief report, they are not summarised in this article. The analyses of RKG responses and signal detection measures did not significantly deviate from the findings in the old responses. For those interested in these findings, see the supplementary materials that contains a summary of the RKG results and Signal Detection analysis.
2. Due to the small male participant sample in this study, an exploratory analysis which included Gender as a between-subjects factor was conducted on old responses to corrects items, critical lures, weak-related and unrelated filler items. This analysis confirmed that there were no significant main effects of Gender and no significant interactions with this factor. There were approximately equal number of males and females in the Time of Test conditions. That is, there were 24 and 23 females in the immediate and 1-week conditions respectively, and 10 and 11 males in the immediate and 1-week conditions respectively.

Table 1

Mean proportions and 95% Confidence Intervals for recognition responses to correct items, critical lures, weak-related and unrelated fillers

	Immediate recognition test				Delayed recognition test			
	Fast presentation		Slow presentation		Fast presentation		Slow presentation	
	Negative	Neutral	Negative	Neutral	Negative	Neutral	Negative	Neutral
Word type								
Correct items	.38	.29	.68	.59	.59	.40	.68	.51
	(.30, .45)	(.23, .36)	(.61, .75)	(.52, .66)	(.52, .67)	(.34, .47)	(.61, .74)	(.44, .58)
Critical lures	.55	.44	.75	.57	.74	.42	.78	.58
	(.44, .65)	(.34, .53)	(.66, .83)	(.48, .66)	(.66, .82)	(.32, .51)	(.70, .86)	(.49, .68)
Weak related fillers	.16	.21	.15	.22	.19	.26	.26	.31
	(.09, .22)	(.14, .27)	(.10, .21)	(.15, .30)	(.12, .27)	(.19, .34)	(.19, .33)	(.22, .41)
	Negative List – Immediate test		Neutral List – Immediate test		Negative List – Delayed test		Neutral List – Delayed test	
Unrelated fillers	.13		.15		.29		.22	
	(.08, .17)		(.09, .21)		(.21, .37)		(.16, .28)	

Note. 95% confidence intervals are in parenthesis as follows: (lower limit, upper limit)

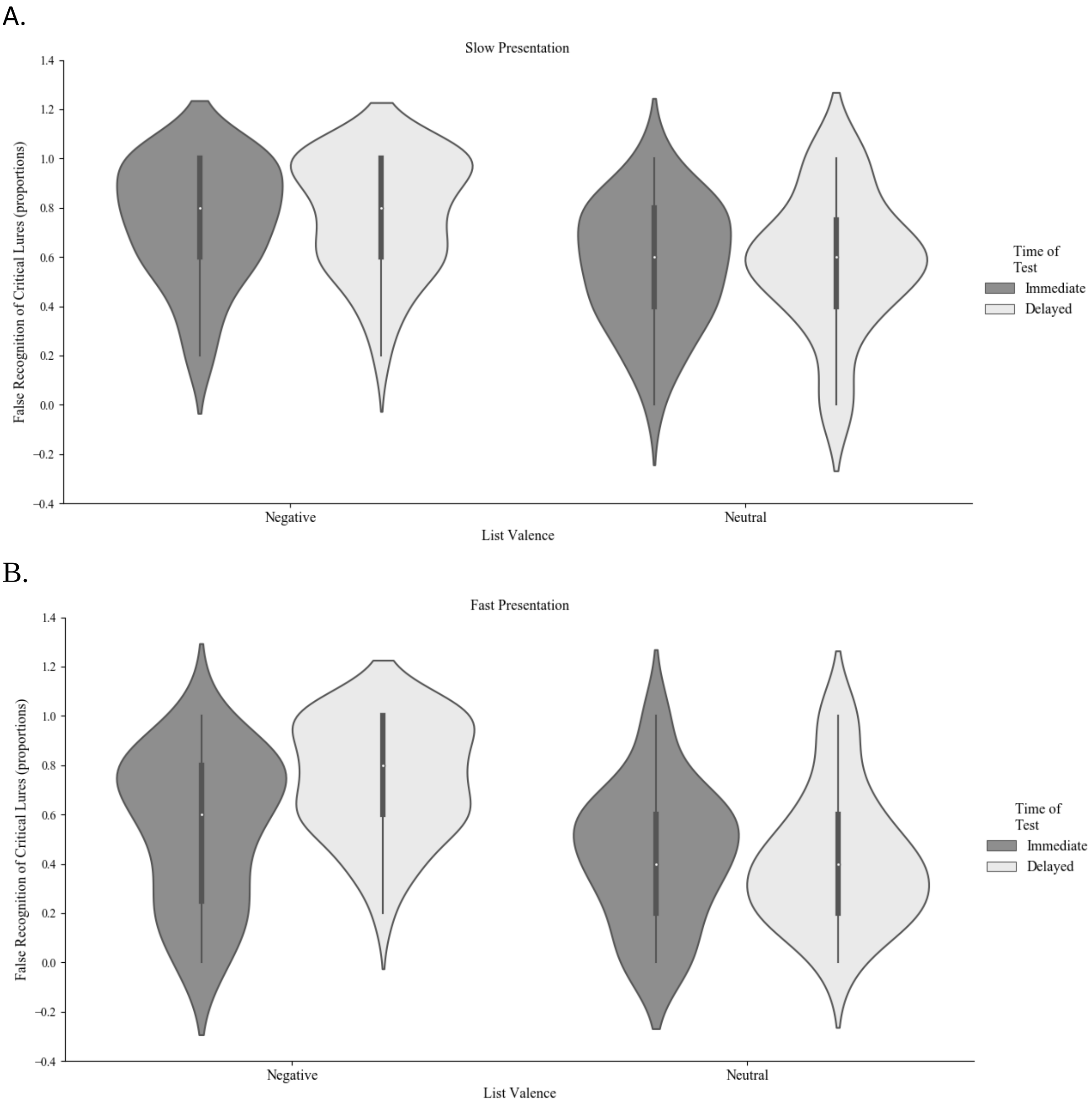

Figure 1. The violin plots above represent the proportion of false recognition responses to critical lures for slow and fast presentation conditions as a function of List Valence and Time of Test. Violin plots, a hybrid of a box plot and a kernel density estimation (KDE), were used to visualise the distribution of the data. The box plots provide basic information regarding the interquartile range (including the lower [25%] and upper [75%] quartiles; the grey bar at the centre), the median (the white dot), and the high and low extreme proportion values (the ends of the grey lines extending from the bar). On each side of the box plot is the kernel density estimation, which shows the distribution shape of the data. Wide sections indicate a high frequency of average false recognition responses at that value. As it can be seen in both A and B, false recognition was frequently higher for negative (than neutral) critical lures. For Time of Test conditions, in A, false recognition was generally higher for both testing conditions, whereas in B, delayed testing produced more false memories. Furthermore, in B, negative critical lures appear to be significantly higher after delayed testing compared to immediate testing. *Note*: two boxplots in A and one boxplot in B do not have top vertical lines. That is due to the 75%

quartile and the maximum proportion value being the same. Also, the average false recognition proportions were only between 0 and 1. However, in A and B, the KDE distribution extends outside of this range, and this is a consequence of the way KDE is performed.

Appendix A

Neutral lists

CAR	**CHAIR**	**FOOT**	**MOUNTAIN**	**SMELL**
Vehicle	Table	Toe	Climber	Aroma
Garage	Recliner	Ankle	Hill	Scent
Drive	Seat	Shoe	Climb	Whiff
Van	Stool	Sandals	Peak	Stench
Truck	Couch	Sock	Hike	Reek
Bus	Desk	Hand	Valley	Sniff
Jeep	Sit	Boot	Summit	Fragrance
Caravan	Sofa	Kick	Slope	Perfume
Taxi	Bench	Knee	Rocks	Sense
Bike	Sitting	Walk	Steep	Nose
Train	Cushion	Arm	Canyon	Hear
Race	Legs	Mouth	Cave	See
WINDOW	**PEN**	**SHIRT**	**CUP**	**HIGH**
Pane	Quill	Blouse	Saucer	Low
Sill	Pencil	Sleeves	Measuring	Elevate
Shutter	Bic	Collar	Mug	Tower
Curtain	Marker	Shorts	Lid	Jump
Door	Write	Button	Measure	Above
Ledge	Fountain	Cuffs	Glass	Up
Glass	Felt	Pants	Sip	Noon
View	Point	Polo	Coaster	Cliff
Screen	Scribble	Vest	Plastic	Dive
Shade	Blot	Tie	Coffee	Sky
Open	Crayon	Pocket	Handle	Tall
Frame	Cap	Belt	Drink	Building

Negative lists

DEVIL	**SICK**	**HURT**	**DEAD**	**THIEF**
Demon	Ill	Harm	Alive	Crook
Satan	Nauseous	Pain	Corpse	Robber
Evil	Flu	Injury	Coffin	Burglar

Angel	Virus	Offend	Grave	Stolen
Hell	Hospital	Wound	Bury	Steal
Pitchfork	Fever	Bruise	Cemetery	Rob
Dare	Disease	Punish	Funeral	Theft
Worship	Medicine	Ache	Coma	Criminal
Curse	Vomit	Abuse	Die	Crime
Voodoo	Cough	Fell	Stiff	Liar
Horn	Germ	Torture	Suicide	Convict
Red	Dizzy	Insult	Gone	Fraud
CRY	**HATE**	**LIE**	**FEAR**	**ALONE**
Weep	Despise	Fib	Terror	Isolated
Sob	Dislike	Deception	Doubt	Solo
Laugh	Love	Deceive	Panic	Secluded
Emotional	Prejudice	Untrue	Fright	Lonely
Tears	Revenge	Bluff	Anxiety	Single
Upset	Enemy	Truth	Afraid	Private
Sorrow	Disgust	Rumour	Scared	Individual
Sensitive	War	Dishonest	Monster	Withdrawn
Grief	Kill	Deny	Horror	Without
Sad	Shun	Cheat	Scream	Bored
Tissue	Insult	Betray	Coward	Together
Misery	Condemn	False	Hide	Empty

Note. All neutral and negative lists used in the experiment, with critical lures shown in bold.