Published in final edited form as:
J Exp Psychol Learn Mem Cogn. 2010 September ; 36(5): 1331–1338. doi:10.1037/a0019903.

False memories seconds later: The rapid and compelling onset of illusory recognition

Kristin E. Flegal, **Alexandra S. Atkins**, and **Patricia A. Reuter-Lorenz**
Department of Psychology, University of Michigan

Abstract

Distortions of long-term memory (LTM) in the converging associates task are thought to arise from semantic associative processes and monitoring failures due to degraded verbatim and/or contextual memory. Traditionally, sensory-based coding is considered more prevalent than meaning-based coding in short-term memory (STM), whereas the converse characterizes LTM, leading to the expectation that false memory phenomena should be less robust in a canonical STM task. These expectations were violated in two experiments in which participants viewed lists of four semantically-related words and were probed immediately following a filled 3–4 second retention interval or approximately 20 minutes later in a surprise recognition test. Corrected false recognition rates, confidence ratings, and Remember/Know judgments reveal similar false memory effects across STM and LTM conditions. These results indicate that compelling false memory illusions can be rapidly instantiated, and originate from processes that are not specific to LTM tasks, consistent with unitary models of memory.

False memories refer to distortions of the source, details, or meaning of past experiences. In the laboratory, false long-term memories (LTM) are reliably produced with the converging associates or DRM paradigm (Deese, 1959; Roediger & McDermott, 1995), in which unstudied semantic associates ("related lure" words) are misremembered as studied items (see Gallo, 2006 for a comprehensive review). Moreover, false memories can be accompanied by high confidence ratings or strong feelings of recollection. Participants in DRM studies will avow qualitative memories of having studied lure words, and may feel equally confident in their recognition of lure and studied words (e.g., Anastasi, Rhodes, & Burns, 2000; Roediger & McDermott, 1995). Theoretical explanations of false memory are typically framed in terms of LTM processes, invoking associative activation and source monitoring failures (Gallo & Roediger, 2002; Robinson & Roediger, 1997; Roediger, McDermott, & Robinson, 1998), and further implicating variable strengths of verbatim memory traces and gist memory for semantic content (Brainerd, et al., 2008; Reyna & Brainerd, 1995).

Recently, however, false memory effects have been reported in the domain of short-term memory (STM). Findings of false recognition and false recall from lists of four semantically-related words occurring after mere seconds (Atkins & Reuter-Lorenz, 2008; Coane, et al., 2007) suggest that the processes responsible for false memories may be relatively delay-invariant. The vulnerability of STM to such distortion contrasts with conventional models of

---

Correspondence concerning this article should be addressed to P. A. Reuter-Lorenz, Department of Psychology, University of Michigan, 530 Church St., Ann Arbor, MI 48109 (parl@umich.edu).

multiple memory systems which characterize semantic codes as the province of LTM (Baddeley, 1986), but converges with evidence for a unitary memory system with delay-invariant storage and retrieval processes (Jonides, et al., 2008). Testing the dissociability of false memories at short and long delays is thus pertinent to elucidating the architecture of memory.

The present report directly compares false memories in the same participants under STM and LTM conditions. We used a novel experimental procedure that minimizes encoding differences and honors the limited capacity and brief storage demands of canonical STM tasks, while exploiting the large capacity and longer delays that characterize LTM. Unlike previous DRM studies (using lists of 12–15 items) that manipulated retention interval (e.g., Colbert & McBride, 2007; Lampinen & Schwartz, 2000; Seamon, et al., 2002; Thapar & McDermott, 2001), our approach probes four-item lists individually after 3–4 seconds, or with continuous recognition after all lists are encoded (on average 20 minutes later). Therefore, we can compare both quantity (the relative incidence of false recognition) and quality (the accompanying phenomenology) of memory distortions in the context of two putatively separate memory domains.

Several considerations predict semantic distortions to be more prevalent and compelling in LTM than STM. First, proactive and retroactive interference in LTM should contribute to greater decline of verbatim traces compared to STM, where retroactive interference, in particular, is minimal. Thus verbatim memory, used to monitor and oppose false memory, should have an advantage in STM. Second, context and source information are salient in the short term because each probe is assessed exclusively in relation to the immediately prior memory set. Consequently, STM conditions provide more cues for monitoring recognition decisions compared to LTM. Third, according to traditional models of separable memory systems, semantic coding that engenders false memories in the DRM paradigm should predominate perceptual coding in LTM, whereas the opposite prevails in STM. Relatedly, despite recent imaging evidence challenging separable memory systems (Ranganath & Blumenfeld, 2005), studies continue to find more robust meaning-based encoding effects in LTM than STM (Rose, et al., 2010). At minimum, semantic processing might be expected to exert measurably greater influence under LTM than STM conditions.

Similar considerations predict the phenomenology of false memories to differ in the short versus long term. The availability of verbatim traces in STM should permit diagnostic monitoring with the relative absence of detail-rich memories for lure probes supporting their correct rejection, or at minimum their endorsement with low confidence or a context-free sense of familiarity. If memory distortions are not found to be more prevalent or compelling in LTM than STM, however, process constancy would be implicated across memory domains.

As the results from two experiments reported here indicate, dissociations predicted by models of multiple memory systems were not observed. The absolute incidence of false memories was greater under LTM than STM conditions, but when corrected for the increased frequency of false alarms to unrelated probes, false recognition rates did not significantly differ. Moreover, our findings indicate the phenomenology of false memory errors is equally compelling in STM or LTM trials, suggesting a rapid breakdown of monitoring processes.

Experiment 1

Method

Participants—27 individuals (18–20 yrs old) participated for course credit. Three participants were excluded for recognition accuracy scores > 2.5 standard deviations from the mean. Research protocols were approved by the University of Michigan Institutional Review Board, and all participants provided written informed consent.

Materials—The memory sets were 128 lists of four semantically-related words, all associates of a common theme word. Forty-eight lists were created from published lists used in the DRM paradigm (Roediger, et al., 2001), as previously described (Atkins & Reuter-Lorenz, 2008). Eighty new lists were constructed by selecting theme words from the University of South Florida (USF) Free Association Norms (Nelson, McEvoy, & Schreiber, 1998) with the following constraints: Each new theme word (1) had frequency and concreteness values within the range of the original 55 DRM lists; (2) had at least four semantic associates; (3) shared no associates with any other theme word. List items were cross-checked across associative matrices from the USF norms to minimize semantic associations between lists. Pilot testing confirmed that the new lists induced false recognition in the Atkins and Reuter-Lorenz (2008) STM task.

The 128 lists were divided into four groups of 32 four-word lists (Groups A–D) equated in mean backward associative strength ($\underline{M} = 0.35$), and containing an even distribution of old (i.e., derived from DRM) and new lists. Each group was further divided into two subgroups of 16 four-word lists, following the same parameters, to balance the status of each list as short-term versus long-term memoranda across participants.

The four semantically-related words in each list converged upon a theme word (e.g., SLEEP for the associates nap, doze, bed, awake) which served as the probe on all trials. The three probe types were: *related lure*, the unstudied theme word associated with a studied list; *unrelated lure*, an unstudied theme word associated with a nonpresented list; and *target*, the theme word associated with, and present in, a studied list (replacing one of the four associates; ordinal position of the replaced item balanced across trials). Probe type was counterbalanced with word lists across participants, so that for one quarter of all participants, lists in Group A were paired with related lures, B with unrelated lures, and C with target probes. Theme words associated with nonpresented Group D lists served as the unrelated lure probes. For half of the participants in each of these four counterbalanced orders, the first subgroup of lists from each group (e.g., A1) was probed during the STM trials, and the second subgroup of lists (e.g., A2) during the LTM trials; the assignment was reversed for the other half of the participants. This procedure ensured that all participants encountered the same probes–all theme words, but in different contexts–as related lure, unrelated lure, or target probes, and as STM or LTM probes. Theme words appeared only once during the experiment; no list was probed in both STM and LTM trials.

Design and procedure—The STM task used by Atkins and Reuter-Lorenz (2008) was modified to test recognition at both short and long delays (see Figure 1). Four-word lists were probed either within the same trial (i.e., STM) or in a surprise recognition test following completion of all STM trials (i.e., LTM), to compare performance across equivalent lists without confounding long-term recognition with intervening short-term recognition of the same lists. STM trial parameters were those used by Atkins and Reuter-Lorenz, with two exceptions: (1) a confidence rating followed the response to every probe word; (2) two trial types were randomly interspersed: half of the trials ended with a probe word and confidence rating, and the other half ended with cues for arbitrary button presses with corresponding response mappings; these memory sets were subsequently probed at LTM.

STM trials: Each STM trial began with a four-item memory set presented for 1,200 msec. During the 3,000–4,000 msec retention interval, participants completed a math verification problem based on the operation span task (Turner & Engle, 1989) by making a left-handed response to indicate whether or not an equation was solved correctly[1]. Next, the probe word appeared for 3,000 msec, and participants indicated whether it was in the memory set with a left-handed response (*yes* or *no*). Lastly, a four-point confidence scale appeared for 3,000 msec, and participants used their right hand to indicate their confidence in the response they just made: *very low, somewhat low, somewhat high,* or *very high*. On trials not probed at STM, a display of two boxes replaced the probe word, to prompt an arbitrary left-handed response, and then a display of four boxes replaced the confidence scale, to prompt an arbitrary right-handed response. Each participant completed 96 STM trials presented in random order. Of the 48 trials probed at STM, 16 were of each probe type (related lure, unrelated lure, target).

LTM trials: A 2-min break followed completion of the STM trials, then participants were informed about, and given instructions for, the LTM recognition test. Each participant completed 96 LTM trials, 48 of which tested the memory sets that were not probed at STM (16 of each probe type). Additionally, there were 18 trials of studied associates from memory sets that were probed at STM (never including theme words from target probe trials), and 30 trials of unstudied, unrelated foils, matched for frequency and word length with the corpus of theme words used in the experiment.

In each LTM trial, a probe word first appeared for 3,000 msec, and participants made a left-handed response to indicate whether or not it was present during the STM trials. A four-point confidence scale (as before) then appeared for 3,000 msec, and participants used their right hand to indicate their confidence in their preceding response.

Trials without responses, with non-allowable responses or with response times under 200 msec were excluded from all subsequent analyses. Trimming retained 93% of STM trials and 99% of LTM trials, and did not change the pattern of results.

Results and Discussion

To assess the effects of probe type and delay on recognition accuracy and confidence, we conducted 2×2 within-subjects ANOVAs, and paired t tests for subsequent analyses. Effect sizes were computed using original standard deviations for each condition mean (Dunlap, et al., 1996). Unless otherwise stated, statistical tests are significant at $p < .01$.

Accuracy—Mean math task accuracy during the STM trial retention interval was 0.89. The key comparison between *yes* responses to unstudied, related lure probes and unstudied, unrelated lure probes revealed a false memory effect at both STM ($t(23) = 4.81$, $d = 1.43$) and LTM ($t(23) = 5.13$, $d = 1.07$; Table 1A). The lure type (related, unrelated) × delay (STM, LTM) interaction was not significant ($F(1,23) = 1.08$, $p = .31$, $\eta_p^2 = .05$). Surprisingly, this result indicates that the rate of false recognition did not increase from short-term to long-term testing. Thus, while false alarms overall were more frequent for LTM than STM, as veridical memory dropped over time, corrected false memory rates (i.e., corrected rates of false alarms to related lures) were statistically indistinguishable in the short and long term. At LTM, the related lure false alarm rate approached, but remained reliably lower than, the hit rate for target probes ($t(23) = -3.82$, $d = .72$).

We used two approaches to obtain comparable measures of memory performance across delay (see also Colbert & McBride, 2007; Seamon, et al., 2002): (1) true and false recognition accuracy conditionalized by subtracting the baseline (unrelated lure) false alarm rate from target hits and related lure "hits" (producing the discriminability index *Pr*), and (2) estimates

---

[1] The filled retention interval parallels the additional "processing" demands that characterize working memory measures (e.g., Turner & Engle, 1989). Atkins and Reuter-Lorenz (2008) tested both filled and unfilled intervals in the STM paradigm and verified that false memory errors occurred reliably in both conditions. In the present paper we use the terms short-term memory and working memory interchangeably.

of recognition sensitivity (*d′*) computed for item-specific memory (target hits vs. unrelated lure false alarms) and gist memory (related lure "hits", i.e., false alarms, vs. unrelated lure false alarms), as proposed by Koutstaal and Schacter (1997). As shown in Table 1B, both adjusted measures of true recognition were significantly higher at STM than LTM, while both adjusted measures of false recognition indicate that susceptibility to gist did not change significantly from short-term to long-term testing.

Phenomenological experience—Confidence levels were predictably higher at STM than LTM, but critically, confidence in false alarms to related lures was equivalent across delay ($t(18) = 0.01$, $p = .99$, $d < .01$; Figure 2), suggesting that the illusory experience of false recognition widely documented in LTM may in fact be established within seconds of encoding. At STM, confidence in correct responses to all probe types was higher than confidence in all error types. At LTM, however, confidence in related lure false alarms approached confidence for target hits ($t(23) = -1.39$, $p = .18$, d =..20), and actually exceeded the level of confidence in correct rejection of related lures, as shown by a significant response (*yes*, *no*) × delay (STM, LTM) crossover interaction ($F(1,18) = 30.24$, $\eta_p^2 = .63$).

Although confidence in false recognition of related lures did not change over time, the calibration of subjective ratings may have differed when rendered in the context of other recognition judgments at STM and LTM. Experiment 2 thus employed Remember/Know judgments as an alternative way to assess false recognition phenomenology (Lampinen, Neuschatz, & Payne, 1998). Remember/Know judgments specify different states of subjective awareness during memory retrieval (Gardiner, 1988; Tulving, 1985): either remembering vivid, specific details from the experience of a previous event (*remember*) or "just knowing" with certainty that an event occurred without access to any particular details (*know*).

In the DRM paradigm, high rates of *remember* responses to related lures attest to the robustness, and apparent realism, of false memories (Payne, et al., 1996; Roediger & McDermott, 1995; Yonelinas, 2002). Although the rate of *remember* judgments for lures can be selectively attenuated with warnings or modified instructions (Anastasi, et al., 2000; Geraci & McCabe, 2006; McDermott & Roediger, 1998; Neuschatz, et al., 2001), a sizable measure of "illusory recollection" persists. Evidence in line with dual-process theories of memory suggests that the Remember/Know distinction and self-reports of confidence represent independent constructs (Gardiner & Java, 1991; Rajaram, 1993). Therefore, using Remember/Know methodology to demonstrate similar phenomenology of short-term and long-term false memories would confirm and extend the findings from Experiment 1, implicating a common processing basis for these forms of illusory recognition.

Experiment 2

Method

Participants—32 individuals (18–27 yrs old) participated for course credit or payment. Two participants were excluded for recognition accuracy scores > 2.5 standard deviations from the mean. Three others were excluded for post-experiment questionnaire responses indicating they failed to understand the Remember/Know distinction.

Design and procedure—The method was the same as Experiment 1 except that remember/know/guess judgments replaced confidence ratings. Following each *yes* response to a probe word, participants used their right hand to indicate whether they *remember* the probe word was in the memory set (recollecting something distinctive about studying the word), they *know* the probe word was present (recognizing the word without retrieving specific details of its study), or their response had been a *guess*. Detailed instructions explaining the Remember/Know distinction were adapted from Rajaram (1993). To equate the number of responses on each trial, a display of three boxes appeared following each *no* response to a probe word, prompting an arbitrary right-handed response.

Trimming (see Experiment 1) retained 92% of STM trials and 98% of LTM trials and did not change the pattern of results.

Results and Discussion

Accuracy—Mean math task accuracy during the STM trial retention interval was 0.87. As in Experiment 1, participants made significantly more false alarms to unstudied, related lure probes than to unstudied, unrelated lure probes, at STM ($t(26) = 5.55$, $d = 1.26$) and LTM ($t(26) = 5.87$, $d = 1.13$; Table 1A). Again the lure type (related, unrelated) × delay (STM, LTM) interaction was not significant, showing consistency in the false memory effect from short-term to long-term testing ($F(1,26) = 1.55$, $p = .22$, $\eta_p^2 = .06$). Notably, this interaction remains unreliable even when the error data from Experiments 1 and 2 are combined ($F(1,50) = 2.59$, $p = 0.11$, $\eta_p^2 = .05$). The relative time-invariance in susceptibility to gist was corroborated by both adjusted measures of overall false recognition for Experiment 2 (Table 1B).

Phenomenological experience—An overall ANOVA on the proportion of *remember* responses (out of all responses) revealed a main effect of probe type ($F(2,52) = 98.14$, $\eta_p^2 = .79$), reflecting higher rates of “remembering” target probes than related or unrelated lure probes. We also found a main effect of delay ($F(1,26) = 12.69$, $\eta_p^2 = .33$), indicating more *remember* responses were made at STM than LTM, and a significant lure type × delay interaction ($F(2,52) = 29.63$, $\eta_p^2 = .53$). As shown in Table 1A, the proportion of *remember* responses is significantly higher for related than unrelated lures at both STM ($t(26) = 2.95$, $d = .85$) and LTM ($t(26) = 4.62$, $d = .98$). This difference shows that the overall false memory effect observed in *yes* responses (related lure false alarms - unrelated lure false alarms) is not due solely to *know* responses for which verbatim memory is absent.

The rate of *remember* responses to related lures actually increased at later delays, although this shift was confounded with a rising baseline (unrelated lure) false alarm rate. Normalized estimates of false recollection, expressed as the proportion of *remember* responses to related lures out of the total proportion of *yes* responses to related lures, did not significantly differ from short-term to long-term testing ($t(22) = 0.99$, $p = .33$, $d = .21$; Table 2). In other words, the quality of the memory illusion appears equally robust at STM and LTM, indicating that the subjective feeling of certainty which characterizes some instances of false recognition may be relatively time-invariant, consistent with the stable confidence in related lure false alarms in Experiment 1.

As shown in Table 2, while the normalized incidence of *remember* responses to related lures is relatively stable over time, it is lower than that for *remember* responses to target probes at both STM ($t(22) = -2.80$, $d = .65$) and LTM ($t(26) = -2.65$, $d = .65$). Unlike the confidence judgments in *yes* responses from Experiment 1, which did not differentiate between related lures and targets at LTM, here a significant difference persists for *remember* responses to these two probe types, suggesting that participants could still use the presence or absence of verbatim detail to distinguish true from false memories at LTM.

In contrast to the selectivity of *remember* responses based in recollective experience, the normalized incidence of *know* responses was equivalent for related lures and target probes at STM ($t(22) = -1.27$, $p = .22$, $d = .27$), and LTM ($t(26) = 1.42$, $p = .17$, $d = .33$). Thus, while *remember* responses comprised a smaller proportion of false recognition than true recognition at both STM and LTM, *know* responses suggest the contribution of familiarity did not differentiate between related lures and targets at either delay. These results indicate that gist memory exerts equivalent influences in STM and at LTM when context information is inaccessible.

Experiment 2 replicated key similarities between memory distortions under STM and LTM conditions, and further characterized the phenomenology of illusory recognition. As in Experiment 1, the corrected false memory rate was stable across delay. Critically, despite higher absolute numbers of false memory errors at LTM, the proportion of false memories associated with “remember” phenomenology was statistically equivalent in the short and long term. Nevertheless, while LTM confidence ratings in Experiment 1 were equivalent for falsely recognized related lures and correctly recognized target probes, differing proportions of LTM *remember* responses in Experiment 2 imply subtle qualitative differences in the content of true and false memories that persist over time.

General Discussion

Our results extend recent findings of rapid semantic distortions (Atkins & Reuter-Lorenz, 2008; Coane, et al., 2007) and directly connect their occurrence to the well-established phenomenon of false long-term memories (Brainerd & Reyna, 2005; Gallo, 2006). In an STM task, we observed illusory effects that characterize LTM errors: Unstudied theme words are falsely recognized, “remembered” as studied, and endorsed with considerable confidence.

Critically, the normalized incidence of these errors did not change from short-term to long-term testing. The expectation that illusory recognition of semantic associates would be more robust in LTM than STM, based on differential effects of interference, monitoring processes, semantic codes, and access to verbatim traces, was not supported. Instead, false memory rates and phenomenological measurements were found to be relatively stable, suggesting that processes responsible for semantic memory errors are not unique to LTM conditions. These commonalities favor the operation of unitary memory processes across delay..

One reasonable interpretation of our findings that is consistent with memory-based (versus decision-based; see Gallo, 2006) accounts is that false memory errors stem from heightened familiarity of the related lure due to semantic activation from the memory set. Indeed, we found equivalence in the normalized incidence of *know* responses (associated with feelings of familiarity that lack verbatim detail) to related lures and to target probes at both short and long delays. As documented in LTM, the vivid yet illusory qualities of false *remember* responses may result from the process of “content borrowing” (Lampinen, et al., 2005), whereby veridical details from studied items are attributed to related but unstudied items. If so, the present results would constitute a demonstration of this effect at the lower temporal boundary of a recognition task (cf. Lampinen, Ryals, & Smith, 2008). Moreover, the present results indicate that illusory recognition can be independent of the declining availability of verbatim traces: the level of confidence and the proportion of *remember* judgments assigned to related lure false alarms are equivalent at STM and LTM.

The immediate vulnerability of memory to distortion indicates the rapid activation of semantic associations (Roediger, et al., 1998; Underwood, 1965) along with an immediate breakdown of monitoring processes, thereby minimizing the potential contributions of decay or other time-dependent processes as sources for these illusory phenomena. Semantic priming may contribute to the effects we observed, as suggested by previous investigations of false memories in implicit memory tests (Cotel, Gallo, & Seamon, 2008; McDermott, 1997; Tse & Neely, 2007); however, nonconscious processes alone offer an insufficient explanation of the phenomenological qualities of false recognition. Furthermore, if conscious generation of the related lure word were occurring at encoding and producing memory traces which could then support false *remember* or high-confidence responses, we might expect a greater proportion of illusory recognition at STM than LTM. However, our results were not in this direction. An alternative possibility is that both associative activation and monitoring operations may be strong under STM conditions, yet counteract each other so that the false memory effect is the same as under LTM conditions when different processes are engaged (Gallo, 2004)[2]. Careful investigations varying activation and monitoring levels independently would be required to test this hypothesis. However, the stability of false memory phenomenology across delay supports a semantic rather than associative explanation, because the vividness of a related lure brought to mind by associative processes during encoding, like that of an actually studied item, would be expected to quickly decline (Brainerd, et al., 2008).

Theoretical accounts of false memories have been largely confined to LTM processes, because even when testing is immediate, the length of studied lists typically exceeds working memory span. Likewise, STM is rarely mentioned in theoretical discussions of false memories, suggesting that generally, STM processes are not considered relevant to these effects (however, see Kimball, Smith, & Kahana, 2007). The present results suggest otherwise by demonstrating that false memory errors and associated phenomenology can arise within seconds, indicating that explanations of false memory need not be confined to episodic long-term remembering and should be extended to include short-term effects as well. Our findings are thus consistent with the interpretation that false memories occurring over varying delays may emerge as a consequence of semantic processes that can operate under STM and LTM conditions, and are compatible with unitary models of memory.

Acknowledgments

This research was supported by the National Institutes of Health (R01AG18286), the National Institute of Mental Health (F31MH079536) and an APF/COGDOP Graduate Research Scholarship.

We are grateful to John Jonides and Cindy Lustig for helpful discussions and advice, and we thank Halle Zucker, Megan Walsh, Laura Zahodne, and Fred Upton for their assistance with stimulus preparation and data collection. Thoughtful comments from Reed Hunt, Charles Brainerd, and an anonymous reviewer improved an earlier version of this manuscript. We also thank the International Max Planck Research School "The Life Course: Evolutionary and Ontogenetic Dynamics" (LIFE) for valuable feedback on this work. Portions of this article were presented at the Annual Meeting of the Cognitive Neuroscience Society, April 2008, in San Francisco.

References

Anastasi JS, Rhodes MG, Burns MC. Distinguishing between memory illusions and actual memories using phenomenological measurements and explicit warnings. Am J Psychol 2000;113(1):1. [PubMed: 10742841]

Atkins AS, Reuter-Lorenz PA. False working memories? Semantic distortion in a mere 4 seconds. Mem Cognit 2008;36(1):74–81.

Baddeley, AD. Working Memory. Oxford: Clarendon Press; 1986.

Brainerd, CJ.; Reyna, VF. The Science of False Memory. New York: Oxford University Press; 2005.

Brainerd CJ, Yang Y, Reyna VF, Howe ML, Mills BA. Semantic processing in "associative" false memory. Psychon Bull Rev 2008;15(6):1035–1053. [PubMed: 19001566]

Coane JH, McBride DM, Raulerson BA, Jordan JS. False memory in a short-term memory task. Exp Psychol 2007;54(1):62–70. [PubMed: 17341016]

Colbert JM, McBride DM. Comparing decay rates for accurate and false memories in the DRM paradigm. Mem Cognit 2007;35(7):1600–1609.

Cotel SC, Gallo DA, Seamon JG. Evidence that nonconscious processes are sufficient to produce false memories. Conscious Cogn 2008;17(1):210–218. [PubMed: 17368912]

Deese J. On the prediction of occurrence of particular verbal intrusions in immediate recall. J Exp Psychol 1959;58(1):17–22. [PubMed: 13664879]

---

[2] We thank an anonymous reviewer for this suggestion.

Dunlap WP, Cortina JM, Vaslow JB, Burke MJ. Meta-analysis of experiments with matched groups or repeated measures designs. Psychological Methods 1996;1(2):170–177.

Gallo DA. Using recall to reduce false recognition: Diagnostic and disqualifying monitoring. J Exp Psychol Learn Mem Cogn 2004;30(1):120–128. [PubMed: 14736301]

Gallo, DA. False Memory Research in DRM and Related Tasks. New York: Psychology Press; 2006.

Gallo DA, Roediger HL. Variability among word lists in eliciting memory illusions: evidence for associative activation and monitoring. J Mem Lang 2002;47(3):469–497.

Gardiner JM. Functional Aspects Of Recollective Experience. Mem Cognit 1988;16(4):309–313.

Gardiner JM, Java RI. Forgetting In Recognition Memory With And Without Recollective Experience. Mem Cognit 1991;19(6):617–623.

Geraci L, McCabe DP. Examining the basis for illusory recollection: The role of remember/know instructions. Psychon Bull Rev 2006;13(3):466–473. [PubMed: 17048732]

Jonides J, Lewis RL, Nee DE, Lustig CA, Berman MG, Moore KS. The Mind and Brain of Short-Term Memory. Annu Rev Psychol 2008;59(1):193–224. [PubMed: 17854286]

Kimball DR, Smith TA, Kahana MJ. The fSAM model of false recall. Psychol Rev 2007;114(4):954–993. [PubMed: 17907869]

Koutstaal W, Schacter DL. Gist-based false recognition of pictures in older and younger adults. J Mem Lang 1997;37(4):555–583.

Lampinen JM, Meier CR, Arnal JD, Leding JK. Compelling untruths: Content borrowing and vivid false memories. J Exp Psychol Learn Mem Cogn 2005;31(5):954–963. [PubMed: 16248744]

Lampinen JM, Neuschatz JS, Payne DG. Memory illusions and consciousness: Examining the phenomenology of true and false memories. Curr Psychol 1998;16(3–4):181–224.

Lampinen JM, Ryals DB, Smith K. Compelling untruths: The effect of retention interval on content borrowing and vivid false memories. Memory 2008;16(2):149–156. [PubMed: 18286419]

Lampinen JM, Schwartz RM. The impersistence of false memory persistence. Memory 2000;8(6):393–400. [PubMed: 11145070]

McDermott KB. Priming on perceptual implicit memory tests can be achieved through presentation of associates. Psychon Bull Rev 1997;4(4):582–586.

McDermott KB, Roediger HL. Attempting to avoid illusory memories: Robust false recognition of associates persists under conditions of explicit warnings and immediate testing. J Mem Lang 1998;39 (3):508–520.

Nelson, DL.; McEvoy, CL.; Schreiber, TA. The University of South Florida word association, rhyme, and word fragment norms. 1998. from http://www.usf.edu/FreeAssociation/

Neuschatz JS, Payne DG, Lampinen JM, Toglia MP. Assessing the effectiveness of warnings and the phenomenological characteristics of false memories. Memory 2001;9(1):53–71. [PubMed: 11315661]

Payne DG, Elie CJ, Blackwell JM, Neuschatz JS. Memory illusions: Recalling, recognizing, and recollecting events that never occurred. J Mem Lang 1996;35(2):261–285.

Rajaram S. Remembering And Knowing: Two Means Of Access To The Personal Past. Mem Cognit 1993;21(1):89–102.

Ranganath C, Blumenfeld RS. Doubts about double dissociations between short- and long-term memory. Trends Cogn Sci 2005;9(8):374–380. [PubMed: 16002324]

Reyna VF, Brainerd CJ. Fuzzy-trace theory: An interim synthesis. Learn Individ Differ 1995;7(1):1–75.

Robinson KJ, Roediger HL. Associative processes in false recall and false recognition. Psychol Sci 1997;8 (3):231–237.

Roediger HL, McDermott KB. Creating false memories: Remembering words not presented in lists. J Exp Psychol Learn Mem Cogn 1995;21(4):803–814.

Roediger, HL.; McDermott, KB.; Robinson, KJ. The role of associative processes in producing false memories. In: Conway, M.; Gathercole, S.; Cornoldi, C., editors. Theories of memory. Vol. 2. Hove, England: Psychology Press; 1998. p. 187-245.

Roediger HL, Watson JM, McDermott KB, Gallo DA. Factors that determine false recall: A multiple regression analysis. Psychon Bull Rev 2001;8(3):385–405. [PubMed: 11700893]

Rose NS, Myerson J, Roediger HL, Hale S. Similarities and differences between working memory and long-term memory: Evidence from the levels-of-processing span task. J Exp Psychol Learn Mem Cogn 2010;36(2):471–483. [PubMed: 20192543]

Seamon JG, Luo CR, Kopecky JJ, Price CA, Rothschild L, Fung NS, et al. Are false memories more difficult to forget than accurate memories? The effect of retention interval on recall and recognition. Mem Cognit 2002;30(7):1054–1064.

Thapar A, McDermott KB. False recall and false recognition induced by presentation of associated words: Effects of retention interval and level of processing. Mem Cognit 2001;29(3):424–432.

Tse CS, Neely JH. Semantic and repetition priming effects for Deese/Roediger-McDermott (DRM) critical items and associates produced by DRM and unrelated study lists. Mem Cognit 2007;35(5): 1047–1066.

Tulving E. Memory and Consciousness. Can Psychol 1985;26(1):1–12.

Turner ML, Engle RW. Is working memory capacity task dependent? J Mem Lang 1989;28(2):127.

Underwood BJ. False Recognition Produced By Implicit Verbal Responses. J Exp Psychol 1965;70:122–129. [PubMed: 14315122]

Yonelinas AP. The nature of recollection and familiarity: A review of 30 years of research. J Mem Lang 2002;46(3):441–517.

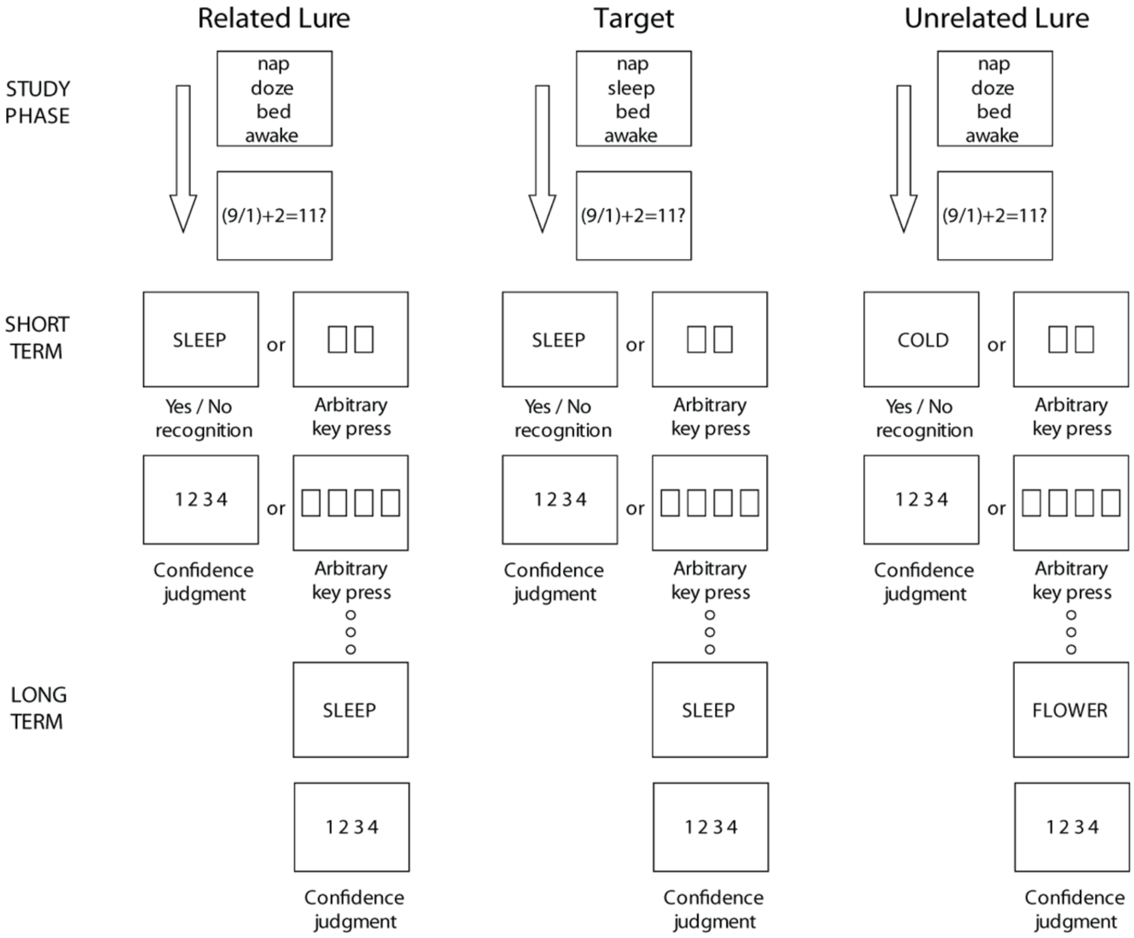

Figure 1.

Experiment 1 design. Each four-word list is probed only once; either immediately following a 3–4 second filled retention interval (short-term memory), or in a surprise recognition test after all lists are encoded (long-term memory).

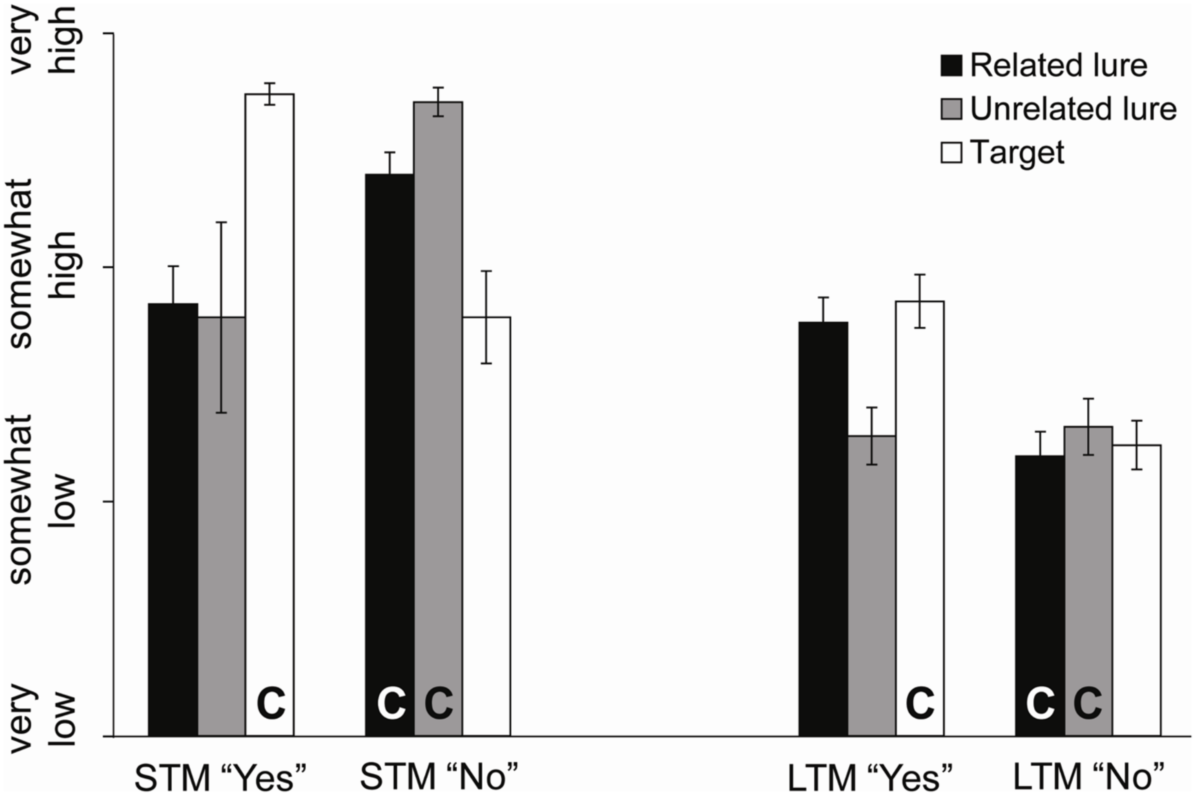

Figure 2.
Experiment 1 mean confidence ratings by probe type and delay (error bars = SEM; C = correct response). Note that confidence in related lure false alarms ("Yes" responses) is equivalent in short-term memory trials and long-term memory trials.

Table 1

Recognition performance in Experiments 1 and 2.

A. Mean recognition proportions				
	Experiment 1		**Experiment 2**	
	STM	**LTM**	**STM**	**LTM**
Probe type	“Yes”	“Yes”	“Yes” (R/K/G)	“Yes” (R/K/G)
Related lure	.18	.57	.17 (.05/.05/.06)	.46 (.12/.18/.15)
Unrelated lure	.01	.35	.04 (.01/.01/.02)	.28 (.03/.13/.11)
Target	.92	.69	.88 (.51/.32/.03)	.57 (.23/.19/.12)

B. Measures of recognition performance adjusted for a shifting baseline (unrelated lure) false alarm rate										
	Experiment 1					**Experiment 2**				
	STM		**LTM**			**STM**		**LTM**		
	M	**SEM**	**M**	**SEM**	**p-value**	**M**	**SEM**	**M**	**SEM**	**p-value**
True recognition										
Discriminability (*Pr*)	.90	.02	.34	.04	< .001	.84	.02	.29	.04	< .001
Item-specific memory sensitivity (*d*′)	3.10	.11	.91	.11	< .001	2.71	.10	.78	.13	< .001
False recognition										
Discriminability (*Pr*)	.17	.04	.23	.04	.31	.13	.02	.18	.03	.22
Gist memory sensitivity (*d*′)	.78	.14	.62	.11	.39	.61	.10	.52	.09	.49

Note: The signal detection measure *d*′ was used to estimate recognition sensitivity, following the recommendation of Seamon et al. (2002), who compared sensitivity measures in a DRM experiment and argued that *d*′ is superior to the nonparametric measure *A*′ for discriminating change in true recognition versus false recognition over time. The pattern of results reported above does not change if *A*′ is used.

Table 2

Experiment 2 proportion of “Remember”, “Know”, and “Guess” responses out of total proportion “Yes” responses.

	STM						**LTM**					
	“Remember”		**“Know”**		**“Guess”**		**“Remember”**		**“Know”**		**“Guess”**	
	M	**SEM**	**M**	**SEM**	**M**	**SEM**	**M**	**SEM**	**M**	**SEM**	**M**	**SEM**
Related lure	.36	.09	.29	.07	.35	.08	.27	.05	.39	.06	.34	.06
Unrelated lure	.32	.14	.23	.12	.45	.16	.13	.05	.51	.07	.36	.06
Target	.60	.06	.37	.06	.03	.01	.43	.04	.31	.04	.26	.04