Can False Memories Prime Problem Solutions?

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Abstract

Previous research has suggested that false memories can prime performance on related implicit and explicit memory tasks. The present research examined whether false memories can also be used to prime higher order cognitive processes, namely, insight-based problem solving. Participants were asked to solve a number of compound remote associate task (CRAT) problems, half of which had been primed by the presentation of Deese/Roediger-McDermott (DRM) lists whose critical lure was also the solution to the problem. The results showed that when the critical lure (a) *was* falsely recalled, CRAT problems were solved more often and significantly faster than problems that were not primed by a DRM list and (b) *was not* falsely recalled, CRAT problem solution rates and times were no different than when there was no DRM priming. A second experiment demonstrated that these outcomes were not a simple artifact of the inclusion of a recall test prior to the problem-solving task. The implications of these results are discussed with regard to the previous literature on priming and the adaptive function of false memories.

Keywords: False memory; Problem solving; Adaptive memory

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Research has established that memory is error-prone and that these errors frequently lead to false memory illusions (Deese, 1959; Roediger & McDermott, 1995). Such errors of commission can be studied using the Deese/Roediger-McDermott (DRM) paradigm where participants are given word lists (e.g., *truck, bus, train, vehicle*) whose members are all associates of an unpresented item or critical lure (e.g., *car*). Despite never having been presented, participants often falsely remember the critical lure as being presented in the list.

There is considerable evidence showing that true and false memories most often behave in very different ways (for reviews, see Brainerd, Reyna, & Ceci, 2008; Gallo, 2006). Although these differences are many, including differences in patterns of neural activation for true and false memories (e.g., Paz-Alonso, Ghetti, Donohue, Goodman, & Bunge, 2008; Wiese & Donahue, 2006), there is a growing literature that also shows some similarities, at least at the behavioral level. Indeed, recent research has found that in a number of important ways false memories behave in a manner very similar to that of true memories. For example, Roediger and McDermott (1995) showed that not only do participants report a high level of confidence in their recognition of critical lures they also claim to have specifically "remembered" the act of studying such items. Indeed, Roediger and McDermott (1995) found that participants were just as likely to give remember responses for false memories as they are for true memories. Research by Payne, Lampinen, and Cordero (1996) has also suggested that false memories show similarities to true memories, providing evidence that both true and false recall decrease under divided attention conditions.

Based on findings such as these, it might be expected that false memories exhibit other parallels with true memories. One avenue that has recently been explored concerns whether false memories can prime implicit tests of memory in the same way that true memories can. If one accepts that false memories are caused by a spreading activation mechanism (see Howe, Wimmer, Gagnon, & Plumpton, 2009; Roediger & McDermott, 1995), then priming becomes an ideal area of investigation (Anderson, 1983). In true memory, priming can be understood as an enhanced speed and tendency to complete tasks, such as stem completion tasks, when their completion involves the use of a word previously studied (e.g. Graf, Shimamura, & Squire, 1985). McDermott (1997) examined whether the critical lures produced by the DRM paradigm could be used to prime word-stem and fragment-completion tasks in the same way. She found that although priming occurred at a level lower than if the items had actually been studied, priming of the critical lures did occur on both the stem- and fragment-completion tasks. Finally, research by McKone and Murphy (2000) managed to successfully prime critical lures on both implicit (stem-completion) and explicit (stem-cued recall) memory tasks.

A logical next step, and one which the present article is concerned with, is to investigate whether false memories can be used to prime more complex cognitive tasks, such as insight-based problem solving. Insight-based problem solving can be defined as the moment when a solver gains clear and sudden understanding of how to solve a problem (Bowden, Jung-Beeman, Fleck, & Kounios, 2005). Problems requiring a high level of insight may be aided by the spreading activation of concepts in memory, a process similar to the mechanisms proposed in spreading activation models of false memory effects (e.g., Associative-activation theory, or AAT, Howe et al., 2009; Activation-monitoring theory, or AMT, Roediger & McDermott, 1995). For example, Kershaw and Ohlsson (2004) found that insight problem solving initially involves searching through related concepts in memory for relevant information. Bowden et al. (2005) have also suggested that insight related problem solving initially involves the activation of concepts in memory that are unrelated to the solution, followed by the weak activation of concepts that are critical to the solution. Research has already suggested that true memories can be used to prime problem solving and reasoning tasks successfully (e.g., Kokinov, 1990). The present research is concerned with whether false memories can be used in the same manner.

One particular insight problem that has received much interest is the Compound Remote Associate Task (CRAT). Originally developed by Mednick (1962), these tasks involve the presentation of three words, for example, *apple, family, house*, all of which can be linked by the use of one word, in this case *tree.* In order to gain insight and solve this problem, theorists have suggested a process involving spreading activation, one that continues until the correct concept has been activated (e.g., Bowden et al., 2005). The possibility that false recall of a critical lure (one which is the same as the linking word in the CRAT) could prime, and therefore aid, the solution of these problems will be explored in the current experiment. To do this, we asked participants to solve CRAT problems, half of which had their solution primed by the prior presentation of a DRM list whose critical lure was also the solution to the problem, and half of which had not been primed. It was predicted that when participants are primed using DRM lists whose critical lure is also the solution to a subsequently presented CRAT problems, such problems would be solved more readily and more quickly than those that were not primed.

Experiment 1

Method

Participants

Forty-two students, aged between 21 and 42 (*M* = 24.6 years, *SD* = 5.4 years), participated in the experiment. All participants provided written informed consent prior to the study and were fully debriefed about the purpose of the study upon completion.

Design, Materials, and Procedure

A within-participant design was used where each participant was primed on half of the CRAT problems with a preceding DRM list whose critical lure was also the solution to one of the CRAT problems. Following study-test trials on four DRM lists, participants attempted to solve all eight CRAT problems. Each participant was randomly assigned four DRM lists, and both the order of the DRM lists and CRAT problems were carefully counterbalanced to eliminate order effects.

Eight CRAT problems were selected from the normative data produced by Bowden and Jung-Beeman (2003). Each CRAT consisted of three words, all of which could be solved by a single linking word. Eight DRM lists were used, consisting of 15 associates of the critical lure. Lists were selected because their critical lure was the same as the solution word used in the selected CRAT problem. DRM lists were taken from the normed associates created by Nelson, McEvoy, and Schreiber (1998) and were randomly divided into two groups of four. Participants were primed on half the DRM lists first and then completed all eight CRAT problems. The two sets of four DRM lists were equated on backward associative strength (BAS) List set 1 BAS = .189; List set 2 BAS = .186).

Participants were given four out of the eight DRM lists in a randomized order. Each list was presented verbally, followed by a distractor task (counting backwards by threes for 30 seconds), and were then asked to verbally recall as many words as they could remember from the list. Once this had been repeated for each of the four lists, participants completed all eight CRAT problems. Participants were first given an example, followed by two practice CRAT problems before they began. Each CRAT was presented on a computer screen, in random order, and participants were asked to provide a verbal solution. If participants failed to correctly solve a CRAT, they were given feedback as to the correct answer after each problem. Solution times were measured from the problem onset to the time the participant gave their response, with participants having a maximum of one minute to complete the problem before they were considered to have failed to solve the problem.

Results and Discussion

False memory rates were comparable to other studies using recall measures (e.g., Howe et al., 2009) with participants falsely recalling the critical lure an average of 56% of the time. The mean CRAT solution rates (proportions) and the mean CRAT solution times (seconds) were calculated for each participant and analyzed separately in a series of analyses of variance (ANOVAs). For primed CRAT problems, solution rates and solution times were further conditionalized on whether the participant had produced the critical lure during recall (i.e., primed/FM = critical lure produced and primed/No-FM = no critical lure produced). Thus, both solution rates and solution times were subjected to separate ANOVAs where the only factor was solution type (unprimed vs. primed/No-FM vs. primed/FM).

Concerning solution rates, there was a main effect for solution type, $F(2, 82) = 4.09$, $p = .02$, $(^{2}_{p} = .09$, where post-hoc tests (Tukey's LSD) showed that solution rates were highest for primed/FM problems (*M* = .65) than primed/No-FM (*M* = .45; $p < .02$) and unprimed (*M* = .48;

$p < .02$) problems, and the latter two did not differ. Concerning solution times, there was also a main effect for solution type, $F(2, 82) = 7.51$, $p = .001$, ($^{2}_{p}$ = .16, where post-hoc tests (Tukey's LSD) showed that solution times were fastest for primed/FM problems ($M = 31.14$) than primed/No-FM ($M = 45.15$; $p < .002$) and unprimed ($M = 43.74$; $p < .006$) problems, and the latter two did not differ.

The findings from this study are the first to demonstrate that false memories can prime insight-based problem solving. It was clear that when problem solutions were primed by the prior presentation of DRM lists whose critical lures were the solution to that problem, both the probability of, and speed with which, such problems were solved improved significantly. Key to this finding is that it is not simply the priming of the problem solution given the presentation of a DRM list whose critical lure is the problem solution, but rather, the participant must also falsely remember that item as one having been presented in the list. That is, the false memory must, for all intents and purposes, become part of the "presented" list and be recalled along with the items that were actually presented.

It could be argued that the very act of falsely remembering the critical lure changes this item from a false memory into something analogous to a memory for something that was actually presented. That is, recalling a false memory makes it now something that was actually remembered, in effect, rendering it no different from a true memory. However, we argue that there is a fundamental difference between remembering an item that was actually presented (a true memory) and one that was not presented (a false memory). Specifically, unlike a true memory that was consciously encoded from its physical presentation at study, a false memory is generated at encoding (see Dewhurst, Bould, Knott, & Thorley, 2009) not from its physical presentation but rather from the internal spread of activation in associative memory that occurs automatically outside of conscious awareness. Thus, priming occurred with information that was not physically presented but was generated internally and automatically without conscious awareness. Moreover, this is distinct from priming that can occur in other forms of associative memory testing. For example, priming in word association tests, like true memories, involves the generation of the prime in an intentional, consciously effortful manner as when a cue is presented (e.g., cat) and the person is asked to generate related words (e.g., dog).

Therefore, we argue that the current findings are both important and unique in at least three senses. First, they extend the domain of false memory priming to higher cognitive (problem solving) processes. Second, they show that priming of problem solutions can and does occur even when the prime is generated automatically in the absence of conscious awareness and the presence of a physical stimulus (i.e., a false memory). Third, they have uncovered a hitherto unreported precondition for the effectiveness of false memories as primes (at least for problem solving tasks), namely, that false memories must become sufficiently activated that they become part of the output sequence on memory tests.

However, before we can safely conclude that these are priming effects that rely on false memory activation, we must somehow determine that the observed effects are not simply due to activation of the critical lure during preceding memory test. That is, we need to also establish that priming effects occur in the absence of a prior test of recall.[1] Remember that the importance of the current result lies in the fact that it is not just having seen a list of related items prior to the problem solving task that increases the rate and speed with which these problems are solved, but rather, that these effects only occur when the critical lure, which is also the solution to the CRAT, is falsely remembered on the recall test. Because problem solving is only enhanced under these conditions, the recall test is effectively confounded with changes in the probability of solving a particular problem and the speed with which it is solved using the current paradigm. In order to demonstrate that these effects are due to priming from the activation of the critical lure (e.g., during list encoding) and not simply activation during the recall tasks itself, we need to find a way to dissociate these effects. We resolve this problem in our second experiment.

Experiment 2

In order to resolve the problems associated with this confound, there are at least three additional issues that need to be addressed. First, it should be pointed out that there is a growing consensus that false memories are generated during the encoding phase of the DRM task and not during retrieval (see Dewhurst et al., 2009). What this means is that the likelihood that the critical lure itself was generated during recall is very low. Thus, although just the act of recalling an item during a memory test may enhance its activation at that time, a confound that still needs to be addressed, we would argue that the main priming effect came from the generation of the critical lure during encoding.

Second, because Experiment 1 demonstrated that it is not simply the presentation of a list prior to problem solving that is important, but rather that we require additional evidence that the false memory was in fact generated, means that we need some sort of memory measure by which to conditionalize problem solving success. Switching from an intervening recall test to a recognition test will not do and may actually worsen the problem. This is because such tests involve physically presenting the critical lure as part of the recognition test, amounting to having presented the solution to the CRAT prior to presenting the problem itself. If the likelihood of the CRAT solution is then increased, we do not know whether this advantage is due to the critical lure being generated during encoding, the critical lure having just been presented on a recognition test, or both. For this reason, we opted to use a recall test in Experiment 1.

Third, instead of interposing the memory test between list presentation and the administration of the problem solving task, we could have opted to have the list presentation followed by problem solving followed by the memory test (recall or recognition). The problem here is that performance on the memory test (i.e., false recall or recognition of the critical lures in question) is now confounded with two prior tasks, list learning and problem solving. Thus, any increase in the likelihood of participants' producing the critical lure on this later memory test could be due to generation of the critical lure during list encoding, generation of the critical lure as the solution to the CRAT during problem solving, or both. For this reason, we opted to administer the recall test after list encoding but prior to problem solving in Experiment 1.

In a sense, then, the methodology used in Experiment 1 is the least confounded one available given the options just outlined. However, the fact remains that falsely recalling the critical lure on the memory test does potentially increase its activation level and may contribute to the findings we obtained in the first experiment. In order to avoid this inevitable confound, we conducted an experiment without the intervening memory test. That is, participants were presented DRM lists and then solved problems without administering an intervening memory test. Although this procedure does not allow us to discriminate problems that were solved given false recollection of the critical lure versus when the critical lure had not been generated, it does remove the memory test confound. Given prior evidence that participants are likely to generate a sufficient number of false memories during encoding, despite the absence of a memory test that measures false memory production in this experiment, we predicted that the primed CRATs should be solved at a higher rate and more quickly on average than those CRATs that were not primed. Thus, although the current experiment removes the possibility that priming was an artifact of a preceding memory test, it does not permit the same analytical precision as the first experiment. That is, it does not allow us to separate primed problems in which the false memory was recalled from primed problems where the false memory was not recalled, a critical feature of the first experiment that produced an important qualifying condition to priming effects using false memories.

Method

Participants

A new sample of 11 students, aged between 18 and 34 (*M* = 19.8 years, *SD* = 4.7 years), participated in the experiment. All participants provided written informed consent prior to the study and were fully debriefed about the purpose of the study upon completion.

Design, Materials, and Procedure

The same basic design, materials, and procedure were employed here as in Experiment 1. Again, a within-participant design was used where each participant was primed on half of the CRAT problems with a preceding DRM list whose critical lure was also the solution to one of the CRAT problems. No memory tests were administered so participants first studied a list that was presented verbally and were then given the distractor task (counting backwards by threes for 30 seconds). Once this had been repeated for each of the four lists, participants completed all eight CRAT problems in the same manner as before.

Results and Discussion

Because no memory test was administered, we cannot assess false memory rates. The mean CRAT solution rates (proportions) and the mean CRAT solution times (seconds) were calculated for each participant and analyzed separately in a series of analyses of variance (ANOVAs). Again because there was no memory test, the analyses focused solely on primed (list presented) versus unprimed (no list presented) CRAT solution rates and solution times.

Concerning solution rates, there was a main effect for solution type, $F(1, 10) = 6.88$, $p = .026$, ($^{2}_{p}$ = .407, where solution rates were higher for primed problems (*M* = .53, *SD* = .16) than for unprimed problems (*M* = .39, *SD* = .20)[2]. Concerning solution times, there was also a main effect for solution type, $F(1, 10) = 9.51$, $p = .012$, ($^{2}_{p}$ = .487, where solution times were faster for primed problems (*M* = 40.00, *SD* = 7.36) than for unprimed problems (*M* = 52.18, *SD* = 8.82).

Thus, even in the absence of an intervening recall test, participants performed better on CRATs that were primed by the presentation of a prior DRM list whose critical lure was also the solution to that problem performed better (i.e. solution rates and times were enhanced) than those that were unprimed. It would seem that the intervening recall test in Experiment 1 was not the primary source of the problem solving advantage observed in that experiment. Rather, these problem-solving advantages were more likely due to participants having generated the critical lure during list encoding and that it was this false memory generation that was the source of these priming effects.

General Discussion

Together, the results of these experiments clearly demonstrate for the first time that false memories can prime insight-based problem solving (Experiment 1) and that these priming effects are not simply due to the administration of a recall test prior to the problem-solving task (Experiment 2). Moreover, it was clear that when problem solutions were primed by the prior presentation of DRM lists whose critical lures were the solution to that problem, both the probability of, and speed with which, such problems were solved improved significantly. Importantly, it is not simply the priming of the problem solution given the presentation of a DRM list whose critical lure is the problem solution, but rather, the participant must also falsely remember that item as one having been presented in the list.

These results strongly suggest that false memories are capable of priming and facilitating problem solving. Specifically, DRM lists can prime and facilitate performance on problem-solving tasks both in terms of the rate at which problems are solved as well as the speed with which they are solved. However, this conclusion is restricted to cases in which the critical lure is falsely recalled (Experiment 1). Such facilitation is not found when the false critical lure has not been recalled. Indeed, priming with no recall of the critical lure resulted in problem-solving rates and times identical to conditions in which there was no priming.

These results are similar to findings showing critical lures can prime performance on related tests of implicit and explicit memory (e.g., McDermott, 1997; McKone & Murphy, 2000). The importance of the present research is that it extends the domain of false memory priming effects to more than changes in performance on related memory tasks. That is, false memories can prime performance on more complex problem solving tasks, in particular, insight problems. Moreover, the current research clearly demonstrates that these effects occur only when the critical lure is also falsely remembered on a memory test. That is, priming does not occur simply as a function of list presentation, but rather, is restricted to those instances in which false memories are also recollected. This theoretical constraint is important because it suggests that the ability of false memories to prime insight-based problem solving is limited to circumstances where false memories achieve activation levels that are sufficient enough to produce recall[3].

These results are not only interesting in and of themselves but also have a number of important implications. First, as argued earlier, these results add to the growing literature suggesting that false memories can exhibit effects similar to that of true memories. Second, the results add to an emerging consensus that false memories have beneficial effects in human cognition and emotion and not simply the negative consequences we are all familiar with in the forensic (e.g., eyewitness memory) literature. For example, McKay and Dennett (2009) have argued that ungrounded or false beliefs are adaptive, a conclusion that has implications for false (or ungrounded) memories. For example, the positivity bias in autobiographical memory, a tendency to accentuate the positive aspects of personal experiences when (inaccurately or falsely) remembering the past, has been linked to enhanced emotional regulation (Mather & Cartensen, 2005). That this positivity bias drives false recollection and not just selective remembering, has been amply shown in recent work by Fernandes, Ross, Wiegand, and Schryer (2008). Regulating emotion through falsely remembering a more positive past has been interpreted as being an extremely adaptive function of memory, or more accurately, of false remembering (also see Newman & Lindsay, 2009). This is because such recollections can directly benefit not only one's current self-image, but also influence one's future behaviors, motivations, and social relationships (see Wilson, Gunn, & Ross, 2009). That is, a more positive self-evaluation may serve a very healthy function inasmuch as it can lead to nurturing new and maintaining existing social relationships, maintaining and extending empathy, and securing intimacy in relationships with others (see Bluck, Alea, Habermas, & Rubin, 2005; Cuc, Koppel, & Hirst, 2007).

Recently, Howe and Derbish (2010) have found that survival-related items and survival-related processing increased both true and false memory production. Given the evolutionary value of survival information, an increase in errors and false memories for this information may seem maladaptive. However, Howe and Derbish (2010) have suggested that the priming of strongly interconnected survival-related concepts in memory, whether actually present or simply activated by what has been presented, may be adaptive because it may guide attention to other survival relevant materials in the environment. For example, misremembering the presence of a predator at a watering hole when only signs of its existence were present (e.g., feces, paw prints) will make one more cautious upon return to that watering hole than an animal that correctly remembers there was no predator. Moreover, upon approaching the watering hole the animal with the false memory may make different decisions than the animal that remembers accurately, for example, by going to the watering hole at a different time, approaching it from a more secluded route, selecting a route where escape (e.g., into the trees) is easier, and so forth. Indeed, the ability to solve problems in a survival-related context is a crucial evolutionary trait (Leach & Ansell, 2008). An increase in false memories for survival information may not necessarily be maladaptive if they can prime and aid the solution of complex problems in a manner similar to true memories. As Howe and Derbish (2010) pointed out, that the byproduct of memory activation can be a false recollection may be a small price to pay if such false memories, like true memories, can aid the solution of more complex, survival-relevant problems.

The point is simply that false memories can contribute to changes in problem solving just as false beliefs can affect decision making (McKay & Dennett, 2009). These conclusions are consistent with the findings here. Indeed, we have shown that (1) priming can occur with information that has not been physically presented but that has been internally generated in an incidental and automatic manner outside of conscious awareness, (2) such priming effects can and do facilitate processing times and solution rates on tasks other than those related to implicit or explicit memory, namely, insight-based problems, and (3) these effects occur regardless of whether there is an intervening test trial but that when tests are present, priming only occurs when participants falsely believe (recall) that the critical lure was present on the list. This is a very clear demonstration that false memories, like ungrounded beliefs, can have a positive impact on cognition, one that contrasts with the more usual experimental, forensic, and clinical literatures that have focused primarily on the negative effects of false memories. The current research has taken us a step closer to realizing the positive aspects of false recollection and has clearly established that false memories can and do provide significant benefits when it comes to more complex cognitive processes, specifically insight-based problem solving.

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Footnotes

[1]We thank two anonymous reviewers for this suggestion.

[2]At first glance, it appears that the baseline problem-solving rates differed across these two experiments, with average rates being higher in the first experiment that involved testing memory than in the second experiment where there was no memory test. However, statistical analyses showed that such differences were not reliable for either the primed or unprimed problems. For primed problems, the mean solution rate for Experiment 2 was .53, a figure that compares favorably to the average solution rate of .55 found in Experiment 1 (this latter rate reflects the average solution rate for primed problems in Experiment 1 regardless of whether priming did or did not result in false recall). For unprimed problems, the mean solution rate for Experiment 2 was lower (.39) than that for Experiment 1 (.48), but this difference was not statistically significant ($t[51] = 1.874$, n.s.). Although such differences may be of interest should they recur in future research, we attribute these modest and statistically insignificant differences in the current study to sampling error.

[3]Is there any other way around the use of an intervening memory test that would given us the same information about false memory generation but without the added activation at test? One interesting suggestion is that instead of using a memory test we use variation in BAS as a proxy for the probability that a false memory would be generated during encoding (more likely with high BAS lists) and assess CRAT performance for high versus low BAS items (we thank another anonymous reviewer for this suggestion). When we calculated the correlations between BAS (which varied between .10 and .52 in our experiments) and subsequent problem solving success, none of the correlations were significant ($r = .35$ for solution rates and $r = -.42$ for solution times, two-tailed tests, N = 8). Although a larger sample and greater variation in BAS may produce significant relationships between BAS and problem solving, given the extent to which individual differences exist in false memory generation even with high BAS lists (e.g., Unsworth & Brewer, 2010), we are not confident that BAS provides as accurate a measure of false memory generation and activation as that obtained when using an intervening memory test.