Journal of Experimental Psychology: General
2007, Vol. 136, No. 4, 577–592

0096-3445/07/$12.00 DOI: 10.1037/0096-3445.136.4.577

# Discovery Misattribution: When Solving Is Confused With Remembering

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This study explored the *discovery misattribution hypothesis*, which posits that the experience of solving an insight problem can be confused with recognition. In Experiment 1, solutions to successfully solved anagrams were more likely to be judged as old on a recognition test than were solutions to unsolved anagrams regardless of whether they had been studied. Experiment 2 demonstrated that anagram solving can increase the proportion of "old" judgments relative to words presented outright. Experiment 3 revealed that under certain conditions, solving anagrams influences the proportion of "old" judgments to unrelated items immediately following the solved item. In Experiment 4, the effect of solving was reduced by the introduction of a delay between solving the anagrams and the recognition judgments. Finally, Experiments 5 and 6 demonstrated that anagram solving leads to an illusion of recollection.

*Keywords:* recognition, memory misattribution, recollection, insight problem

There is something very similar about the experience of recollection and that of discovery. In both cases, a thought comes to mind with a compelling sense of truth. In the case of recollection, the truth value of a remembered thought results from its association to the past, whereas in the case of discovery, veracity stems from the compelling manner in which a generated idea solves a problem. The subjective parallels between recollection and discovery raise the possibility that the two experiences could be confused with one another. Several studies have investigated instances in which remembering is mistaken for discovery, leading to cryptomnesia, or unconscious plagiarism (e.g., Brown & Halliday, 1991; Marsh, Landau, & Hicks, 1997). However, far less attention has been given to the possibility that discovering a solution may lead to false recollection. In this article, we present data supporting the hypothesis that the experience of successfully solving a problem can be confused with the experience of recollection, thus leading to a "discovery misattribution."

Considerable research has documented the ways in which misattribution processes contribute to false memories (e.g., Jacoby, Kelley, & Dywan, 1989; Johnson, Hashtroudi, & Lindsay, 1993). One source of evidence for misattribution processes in memory comes from situations in which perceptual fluency is confused with item familiarity. For example, Jacoby and Whitehouse (1989) found that increasing the perceptual fluency of items on a recognition test by preceding them with subliminally presented primes increased the proportion of "old" judgments to test items. In contrast, Whittlesea, Jacoby, and Girard (1990) found that decreasing the perceptual fluency of items on a recognition test by degrading their perceptual clarity reduced the proportion of "old" judgments to test items. In the above cases, the perceptual fluency of the recognition items influenced the experience of familiarity, which led to memory misattributions. Of note, these studies demonstrate that nonmemorial phenomenological states may influence memory judgments when those states resemble an experience associated with remembering.

In the case of discovery misattributions, the question arises as to whether there are phenomenological states associated with problem solving that may be confused with the experience of recollection. One likely candidate is the well-documented sense of "aha" that is associated with discovering the solution to insight problems (e.g., Bowden, Jung-Beeman, Fleck, & Kounios, 2005). The "aha" experience represents an emotional state (Gick & Lockhart, 1995) associated with the surprise of suddenly discovering the solution to an insight problem such as solving an anagram (Metcalfe, 1986). Indeed, Jung-Beeman et al. (2004) found that solving problems that elicit the "aha" experience is associated with activation of the amygdala, a brain region previously shown to be involved in emotional arousal (e.g., Phelps, 2004). We hypothesize that the emotional arousal elicited by successfully solving insight problems may be used to inform subsequent memory judgments (e.g., Schachter & Singer, 1962).

Although no study has specifically examined whether the "aha" experience associated with solving problems might be confused with recollection, a number of studies have demonstrated that the related experience of surprise influences recognition judgments. For example, Whittlesea and Williams (1998) demonstrated that on a recognition test including natural words, pseudohomophones of the words (e.g., *Frog* spelled *Phrawg*), and nonwords, the pseudohomophones were more likely to be classified as old than both natural words and nonwords. However, reading times for the natural words were faster than for the pseudohomophones, indi-

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The authors contributed equally to this research. Portions of this research were presented at the Annual Meeting of the Psychonomic Society, Dallas, Texas, November 1998, and the Third International Conference on Memory, Valencia, Spain, July 2001. This research was supported by a Mellon Fellowship to Sonya Dougal.

We are indebted to Marcia Johnson, whose comments motivated the design and analysis of Experiment 1, and Martin Conway, who suggested the use of a delay manipulation in Experiment 4.

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cating that the natural words were more perceptually fluent. The finding that the pseudohomophones were more likely to be judged as old despite the greater perceptual fluency of the natural words indicates that a different type of misattribution process was operating in their experiment. Whittlesea and Williams suggested that the tendency to call the pseudohomophones old may have resulted from a misattribution of the surprise that participants experienced when an unfamiliar letter string suddenly sounded like a real word (see also Whittlesea & Williams, 2000).

In more recent work, Whittlesea (2002) provides further support for the notion that a discrepancy between the expected and perceived processing fluency can influence memory judgments. In one experiment, participants studied words and were given a recognition test in which the recognition items (e.g., *boat*) were presented after either a high-constraint context (e.g., "the stormy seas tossed the boat") or a low-constraint context (e.g., "she saved her money and bought a boat"). When a 250-ms delay was introduced between the presentation of the sentence context and the recognition probe (e.g., "the stormy seas tossed the . . . boat"), the high-constraint sentence contexts increased the proportion of "old" judgments for both targets and distractors. Whittlesea argued that the high-constraint contexts caused individuals to misattribute the surprise associated with the sudden resolution of an expectation to recognizing the probe item. Specifically, he claimed that "the false-remembering effect occurs in this paradigm when people pass from a state of indefinite expectation and suspense to a state of specific understanding and resolution that they perceive as surprising" (p. 329).

As Whittlesea further observed, this type of transition from indefinite expectation to sudden resolution is very similar to "aha" experiences in problem solving.

> Suddenly, all of the pieces are reinterpreted and reimagined; a reintegration occurs, in which all of the pieces suddenly make an organic whole (the perception of integrality). One's response is an exclamatory, "I remember now!" That is probably also the basis of nonremembering, "Eureka!" experiences—sudden insights that make sense of formerly disparate elements. (Whittlesea, 2002, p. 343)

Although Whittlesea speculated about potential parallels between the subjective experience of remembering and "aha" experiences, no studies to date have demonstrated that discovering the solution to a problem can influence subsequent recognition judgments.

The closest empirical test of the discovery misattribution hypothesis comes from studies examining the revelation effect. The term *revelation effect* refers to the increased likelihood of judging an item as old on a recognition test if it has been revealed in partial or obscured form just prior to the recognition judgment (Watkins & Peynircioglu, 1990). Typically in studies investigating this effect, participants are given an algorithm for deciphering the revealed item so that solution success is assured. However, Peynircioglu and Tekcan (1993, Experiments 1 and 2) presented some items as anagrams on the recognition test but required subjects to solve them without an algorithm prior to making recognition judgments on the solutions. They found that the items presented as anagrams were more likely to be judged as old than items presented outright, but critically, they did not report the proportion of "old" judgments as a function of whether the anagram was correctly solved. Thus, their data do not indicate how anagram solving influenced recognition performance.

Westerman and Greene (1998, Experiment 1) also examined whether solution success had any impact on recognition judgments but concluded that there was "little support . . . for the hypothesis that successful completion of the revelation task causes the revelation effect" (p. 379). However, this conclusion was based on a variation of the revelation effect that may have shrouded the impact of solving per se. In Westerman and Greene's studies, the word fragment for Item A was gradually presented prior to a recognition judgment on Item B. Notably, though, Verde and Rotello (2004) demonstrated that the nature of the memory process leading to the revelation of one item influencing the recognition of a subsequent unrelated item (e.g., Westerman & Greene's paradigm) is different from that associated with the standard revelation paradigm. Thus, the fact that discovering the solution to one item does not affect the identification of a different item does not preclude the possibility that successfully solving an anagram might induce a temporary "aha" state that could lead to misattribution of memory for that specific item.

Finally, in a paradigm similar to that of revelation, Lindsay and Kelley (1996) cued participants with easy or hard word fragments that participants were falsely led to believe always corresponded with previously studied words. They found that the easy fragment cues were more likely to elicit a clear memory than hard fragment cues, and concluded on the basis of this finding that the ease with which an item came to mind led to misattributions of familiarity. However, in an unpublished analysis they also found that the effect of item difficulty was attenuated for responses that occurred within the 10-s period prior to presentation of the solution, and that difficult items were less likely to be retrieved during this period than easy items. These factors led Lindsay and Kelley to acknowledge that "the effects of cue difficulty on familiarity may have been mediated primarily by the fact that easy fragments more often enabled participants to bring completion to mind within the deadline" (1996). Thus, what may have been critical in their study was whether a solution was discovered at all, as would be expected according to a discovery misattribution account.

In the following series of experiments we sought to determine whether discovering the solution to an anagram test item increases the likelihood of it being judged as old and, if so, to evaluate the utility of the discovery misattribution hypothesis in accounting for the effect of solving. In Experiment 1, we examined the effect of discovering anagram solutions on recognition judgments by presenting anagram test items of sufficient difficulty to ensure that some would not be solved. Analysis of the recognition judgments conditionalized on whether the anagram was correctly solved prior to presentation of the solution demonstrated that the proportion of "old" judgments to old and new test items was significantly higher when the item was solved than when it was unsolved. In Experiment 2, we determined whether the effects observed in Experiment 1 were driven by successful or unsuccessful anagram solving by adding a baseline condition in which words were presented outright. In Experiments 3 and 4, we evaluated alternative accounts of the effect of discovery on recognition judgments. Finally, in Experiments 5 and 6, we sought evidence that discovery misattribution invokes a subjective state similar to the experience of explicit recollection.

## Experiment 1

The goal of Experiment 1 was to determine whether successfully discovering the identity of a test item influences the subsequent recognition judgment to that item. Participants studied a list of five-letter words and received a recognition test in which the test items were presented as either easy (last two letters reversed) or hard (all five letters rearranged) anagrams. After participants attempted to solve each anagram, they were given its solution and made a recognition judgment. An effect of solving would be observed if old and new test items corresponding to correctly solved anagrams were more likely to be called old than those corresponding to unsolved anagrams.

### Method

*Participants.* Twenty-two undergraduate students (age 18–21; 14 female, 8 male) enrolled in an introductory psychology class at New York University participated in exchange for partial fulfillment of a course requirement. Data from 2 participants were discarded because of chance-level recognition performance.

*Design.* The experimental design was a 2 × 2 × 2 factorial with three within-subject factors: recognition item (target, distractor), anagram difficulty (easy, hard), and anagram solution success (solved, unsolved). Half of the items of each type were presented as easy anagrams, and the other half were presented as hard anagrams. Anagrams were considered unsolved if no solution or an incorrect solution was given.

*Stimuli.* Stimuli were selected from a pool of 120 low-frequency ($M$ = 30/million; Francis & Kučera, 1982) five-letter anagrams taken from Tresselt and Mayzner (1966) and Gilhooly and Johnson (1978) with the constraint that they have only one solution. Hard anagrams with an approximately 50% solution success rate were selected, and easy anagrams were constructed by reversing the order of the last two letters of the words. For each participant, 60 of these words were randomly selected to be targets and the remaining 60 items served as distractors. On the recognition test, half of each item type (target, distractor) were presented as easy anagrams, and the other half were presented as hard anagrams. Recognition test order was randomized for each participant, and assignment of words to conditions was counterbalanced to control for potential item selection effects (e.g., Watkins & Gibson, 1988).

*Procedure.* The experimental procedure consisted of two parts: a study phase and the recognition test phase. During the study phase, participants were instructed to memorize 60 words that were presented in the center of a computer screen one at a time, for 3 s each, with no interstimulus interval.

Participants received the recognition test immediately after the study phase. Each recognition trial consisted of presentation of an anagram that participants were instructed to solve, followed by a recognition judgment on the anagram's solution. The anagrams remained on the screen until participants either discovered the solution and entered it with the computer keyboard or typed an *x* to indicate that they were unable to solve the anagram. Next, regardless of whether the anagram had been solved, the correct solution was presented on the computer screen and participants made an old–new recognition judgment on the anagram solution. To respond "old," participants pressed the *Z* key; to respond "new," participants pressed the slash key. No recognition accuracy feedback was provided, and participants were given unlimited time for anagram solving.

### Results

In the experiments reported here, we submitted the dependent measures to an analysis of variance (ANOVA) with all of the independent variables as factors, unless otherwise indicated. The criterion for significance was an alpha level less than .05. We report probability values only for marginally significant effects and planned comparisons. Partial eta squared is reported as an estimate of effect size for ANOVAs, and Cohen's $d$ is reported as an estimate of effect size for $t$ tests.

*Anagram solution accuracy.* The probability of solving an easy anagram was higher ($M$ = .88, $SE$ = .02) than the probability of solving a hard anagram ($M$ = .62, $SE$ = .04), $F(1, 19) = 62.02$, $\eta_p^2 = .77$. Anagrams corresponding with studied items were also more likely to be solved ($M$ = .78, $SE$ = .02) than anagrams corresponding with nonstudied items ($M$ = .72, $SE$ = .03), $F(1, 19) = 15.20$, $\eta_p^2 = .44$. There was no interaction between anagram difficulty and old–new status ($F < 1$).

*Proportion of "old" judgments.* The proportion of "old" judgments to recognition items is shown in Figure 1 as a function of old–new status, anagram difficulty, and solution success. As expected, the proportion of "old" judgments was higher for old ($M$ = .66, $SE$ = .04) than for new recognition items ($M$ = .32, $SE$ = .04), $F(1, 19) = 36.31$, $\eta_p^2 = .66$. Critically, there was a main effect of anagram solving; the probability of calling a recognition item "old" was higher if its corresponding anagram was solved ($M$ = .56, $SE$ = .02) than if it was unsolved ($M$ = .42, $SE$ = .04), $F(1, 19) = 13.72$, $\eta_p^2 = .42$. Planned comparisons indicated that the effect of solving was observed for studied items corresponding with easy, $t(19) = 2.30$, $p < .05$, $d = 0.50$, and hard anagrams, $t(19) = 5.38$, $p < .01$, $d = 1.19$, and for new items corresponding with hard anagrams, $t(19) = 2.98$, $p < .01$, $d = 0.68$. There were no other main effects or interactions (all $ps > .10$).

*Signal detection analysis.* We computed the standard signal detection measures of $d'$ and $c$ (see Macmillan & Creelman, 2005, for a description) to determine the effect of solving on recognition accuracy and response bias. There were no reliable effects on recognition accuracy as measured by $d'$ (all $Fs < 1.10$). However,

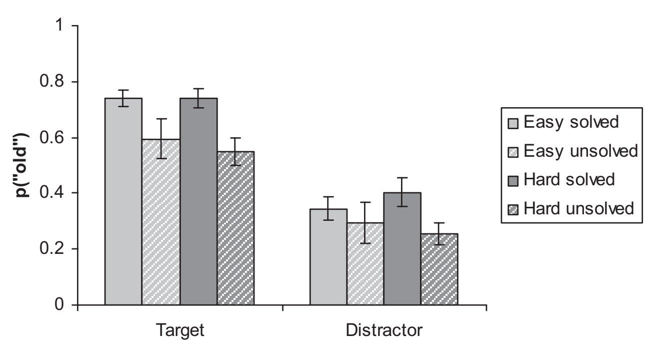


*Figure 1.* The proportion of "old" responses as a function of old–new status, anagram difficulty, and anagram solution success for Experiment 1. Error bars indicate plus or minus one standard error of the mean.

anagram solving resulted in a more liberal response bias for the subsequent recognition judgments, $F(1, 19) = 11.19$, $\eta_p^2 = .37$; $c$ was lower for solved anagrams ($M = -0.16$, $SE = 0.08$) than for unsolved anagrams ($M = 0.29$, $SE = 0.15$). There were no other main effects or interactions (all $ps > .10$).

### Discussion

The results of Experiment 1 revealed an effect of anagram solving on subsequent recognition judgments to the same item. Old and new test items presented initially as anagrams were more likely to be called old when participants successfully discovered the solution compared with when the anagram was not successfully solved and the solution was provided. Thus, the influence of anagram solving on "old" judgments indicates that anagram solving creates the illusion of prior experience, in that new items were also more likely to be judged as old.

Of note, the signal detection analysis revealed that the effect of anagram solving resulted in a more liberal response bias, not a change in memory accuracy. This finding distinguishes the effect of anagram solving on subsequent recognition from the revelation effect, where initial presentation of recognition items in degraded form reduces memory sensitivity (Hicks & Marsh, 1998; Verde & Rotello, 2003, 2004). Furthermore, this finding is consistent with recent evidence that emotionally arousing stimuli consistently result in a more lenient response bias on recognition tests (Dougal & Rotello, in press) and, more generally, with the hypothesis that the subjective experience of discovery associated with successfully solving an anagram can be misattributed to recognizing the anagram solution on the recognition test regardless of old–new status.

Another potential explanation for the present results is that they are due to a misattribution of the ease of perceptual fluency. For example, Whittlesea et al. (1990) observed that degrading the perceptual clarity of recognition test items reduced the likelihood of those items being judged as old. If items that are solved tend to be more fluently processed than those that are unsolved, then the enhanced fluency associated with solved items could influence the recognition judgments. However, if fluency underlies the effect of solving, then easy solved items should have been more likely to be called old than hard solved items, as the ease of solving the anagram by reversing the last two letters would have resulted in a greater sense of fluency than solving a difficult anagram. Indeed, Lindsay and Kelley (1996) used this argument to explain why words cued with easily completed word fragments were perceived as more familiar than words cued with fragments that were more difficult to complete. However, we found no difference in the proportion of "old" judgments to easy and hard solved items. Thus, a simple perceptual fluency account is not sufficient to explain the present findings because this account would predict that the most fluent items, the easy anagrams, would be most likely to be recognized.

## Experiment 2

The results of Experiment 1 demonstrated that successfully solving an anagram can influence subsequent recognition judgments to the same item. However, because a no-anagram control condition was not included, it remains unknown whether this effect was driven by the success of solving an anagram or by the failure of not solving an anagram. The direction of the solving effect is important in evaluating the discovery misattribution hypothesis. If successfully solving an anagram produces an "aha" experience that is confused with remembering, then solved items should be more likely to be called old than words initially presented outright. In Experiment 2, we added a no-anagram baseline condition to determine whether the effects observed in Experiment 1 were due to an increase in the proportion of "old" judgments resulting from solving or a decrease in the proportion of "old" judgments resulting from a failure to solve.

### Method

*Participants.* Thirty-two undergraduate psychology students (age 18–25; approximately 50% male) from the University of Pittsburgh participated in exchange for partial fulfillment of a course requirement.

*Design and stimuli.* The experimental design was a 2 × 2 × 2 × 2 mixed factorial with three within-subject factors: recognition item (target, distractor), anagram difficulty (easy, hard), and anagram solution success (solved, unsolved). There was one between-subjects factor: whether no-anagram trials (words presented outright) were included on the recognition test (anagram trials only, no-anagram trials). For the no-anagram trials condition, one third of the recognition items were presented in word form, one third were presented as easy anagrams, and one third were presented as hard anagrams. In the anagram trials only condition, half of the items were presented as easy anagrams and the other half were presented as hard anagrams. Half of the items of each type were studied, and the others were distractors on the recognition test. Stimuli were identical to those in Experiment 1. Assignment of anagrams to conditions was completely randomized.

*Procedure.* The experimental procedure was similar to Experiment 1 with two changes. For those participants in the no-anagram trials condition, one third of the test trials consisted of initial presentation of a word outright. For each of these trials, participants were instructed to make an old–new recognition decision. Trials in the anagram trials only condition were identical to the test trials in Experiment 1 except that they consisted of only two thirds of the test trials. The time allowed for anagram solving was unlimited.

### Results

*Anagram solution accuracy.* The probability of solving an easy anagram was higher ($M = .83$, $SE = .02$) than the probability of solving a hard anagram ($M = .56$, $SE = .03$), $F(1, 30) = 148.88$, $\eta_p^2 = .83$. Anagrams corresponding with studied items were more likely to be solved ($M = .72$, $SE = .03$) than anagrams corresponding with nonstudied items ($M = .66$, $SE = .03$), $F(1, 30) = 7.94$, $\eta_p^2 = .21$. The proportion of correctly solved anagrams tended to be higher in the condition that included no-anagram trials ($M = .74$, $SE = .03$) than in the condition in which all items were presented as anagrams ($M = .65$, $SE = .03$), $F(1, 30) = 3.89$, $p = .06$, $\eta_p^2 = .12$. This finding was unanticipated but may have occurred because participants in the condition that included no-anagram trials had intermittent breaks between anagram solution attempts.

*Proportion of "old" judgments.* The proportion of "old" judgments to recognition items is shown in Figure 2 as a function of

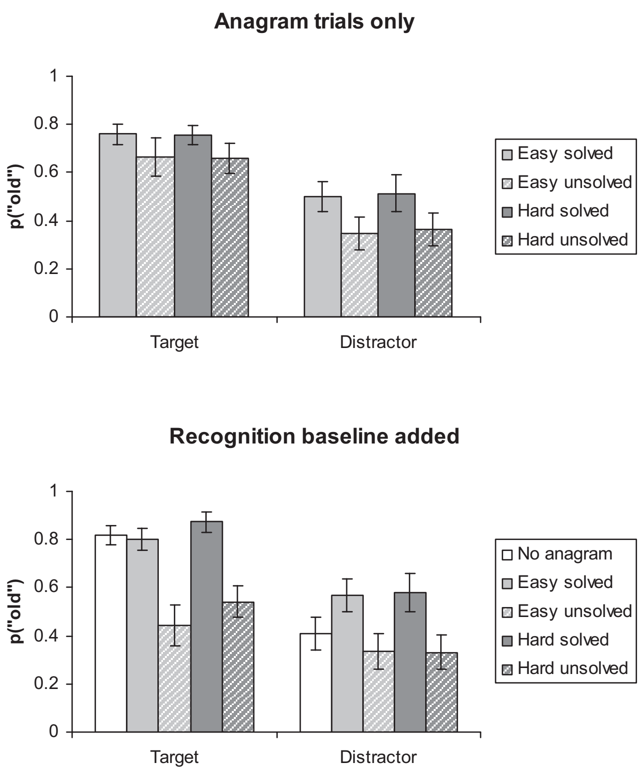


*Figure 2.* Proportion of "old" responses as a function of old–new status, anagram difficulty, and anagram solution success for Experiment 2. Error bars indicate plus or minus one standard error of the mean.

old–new status, anagram difficulty, and solution success for the no-anagram and the anagram trials only conditions. The proportion of "old" judgments to words presented outright is also shown for the no-anagram trials condition. As expected, the proportion of "old" judgments was higher for old ($M$ = .69, $SE$ = .03) than for new recognition items ($M$ = .43, $SE$ = .04), $F(1, 30) = 50.53$, $\eta_p^2 = .63$. Again, there was a main effect of anagram solving, $F(1, 30) = 37.51$, $\eta_p^2 = .56$; the probability of calling a recognition item "old" was higher if its corresponding anagram was solved ($M$ = .65, $SE$ = .03) than if it was unsolved ($M$ = .47, $SE$ = .04). Furthermore, there was an interaction between old–new status, anagram solving, and whether the no-anagram trials were included on the recognition test, $F(1, 30) = 3.59$, $\eta_p^2 = .18$, such that the effect of solving was greater in magnitude for the studied items in the condition including no-anagram test trials than in the condition with anagram trials only. Contrasts revealed that the solving effect was observed for old and new test items in both conditions—anagram trials only condition: old solved versus old unsolved, $t(15) = 2.79$, $p < .05$, $d = 0.71$; new solved versus new unsolved, $t(15) = 3.63$, $p < .01$, $d = 0.88$; no-anagram trials condition: old solved versus old unsolved, $t(15) = 5.74$, $p < .01$, $d = 1.42$; new solved versus new unsolved, $t(15) = 2.83$, $p < .05$, $d = 0.68$. There was also a trend for the effect of solving to be larger in magnitude when no-anagram trials were included on the recognition test compared with the anagram trials only condition, $F(1, 30) = 3.59$, $p < .07$, $\eta_p^2 = .11$. There were no other main effects or interactions (all $p$s $> .10$).

Next, we performed planned comparisons on the proportion of "old" judgments to anagram trials and words presented outright in the no-anagram trials condition to determine whether anagram solving increased or decreased recognition judgments compared with baseline. The proportion of "old" judgments to both easy and hard solved distractors was higher than for no-anagram trials: easy solved versus no-anagram, $t(15) = 3.66$, $p < .01$, $d = 0.89$; hard solved versus no-anagram, $t(15) = 3.01$, $p < .01$, $d = 0.75$. However, for the targets, the proportion of "old" judgments to no-anagram trials was higher than for both easy and hard unsolved anagrams: no-anagram versus easy unsolved, $t(15) = 3.22$, $p < .01$, $d = 0.82$; no-anagram versus hard unsolved, $t(15) = 5.14$, $p < .01$, $d = 1.25$. Thus, anagram solving both increased and decreased the proportion of "old" judgments compared with baseline. No other comparisons approached significance (all $p$s $> .10$).

*Signal detection analysis.* There was an interaction between anagram solving and whether no-anagram trials were included on the recognition test on memory accuracy, $F(1, 30) = 6.09$, $\eta_p^2 = .17$. In the anagram trials only condition, $d'$ was higher for unsolved than for solved items, $t(15) = -2.19$, $p < .05$, $d = 0.56$. In contrast, in the no-anagram trials condition, $d'$ did not differ between the solved and unsolved items ($p > .20$). This interaction was due to a somewhat greater effect of anagram solving on the distractors in the anagram trials only condition.

As in Experiment 1, anagram solving modulated response bias, $F(1, 30) = 32.31$, $\eta_p^2 = .52$; $c$ was lower for solved ($M = -0.56$, $SE = 0.12$) than for unsolved ($M = 0.15$, $SE = 0.14$) anagrams, therefore resulting in more liberal response bias. Also, the effect of solving on response bias interacted with whether the no-anagram trials were present on the recognition test, $F(1, 30) = 4.58$, $\eta_p^2 = .13$, such that the magnitude of the solving effect on $c$ was greater in the condition including the no-anagram trials than in the anagram trials only condition: no-anagram trials condition, solved versus unsolved, $t(15) = -5.23$, $p < .01$, $d = 1.29$; anagram trials only condition, solved versus unsolved, $t(15) = -2.99$, $p < .01$, $d = 0.75$.

Finally, we compared response bias for the words presented outright with the anagram trials in the no-anagram trials condition. Planned comparisons indicated that $c$ was lower for both the easy solved and the hard solved anagrams than for the no-anagram trials: easy solved versus no-anagram, $t(15) = 2.89$, $p < .05$, $d = 0.72$; hard solved versus no-anagram, $t(15) = 3.27$, $p < .01$, $d = 0.82$. In contrast, $c$ was higher for the hard unsolved anagrams than for the no-anagram trials, $t(15) = 2.37$, $p < .05$, $d = 0.59$. Thus, response bias was more liberal for anagrams that had been solved compared with the words presented outright. In contrast, it was more conservative for hard unsolved anagrams than for the no-anagram trials. There were no other main effects or interactions (all $p$s $> .10$).

### Discussion

In Experiment 2, we also observed that anagram solving influenced recognition judgments to both old and new items, although the effect of solving was greater for distractors in the anagram trials only condition. Experiment 2 further revealed that the effects of solving were driven both by the success of solving items and by the failure of not solving them. The proportion of "old" judgments to solved distractors was higher than the proportion of "old" judgments to words presented outright, and the proportion of "old" judgments to unsolved targets was lower than the proportion of "old" judgments to words presented outright. Furthermore, the signal detection analysis revealed that the solving effect was driven by changes in response bias, which replicates the findings of Experiment 1 and further distinguishes between the effect of solving and the revelation effect.

The finding that solving increased the proportion of "old" judgments to distractors relative to the items presented outright is consistent with the discovery misattribution hypothesis. According to this view, the experience of discovering the solution to an anagram was confused with recognizing the test item. That this effect of solving was observed for items that were never studied suggests that discovery misattribution may represent a potent source of memory illusions (Roediger, 1996). Indeed, the finding in both experiments that anagram solving results in a more lenient response bias is consistent with this conclusion.

Anagram solving also decreased the proportion of "old" judgments to targets relative to the items presented outright, which suggests the additional contribution of an identification heuristic to the effect of solving (e.g., Higham & Vokey, 2000). According to this view, participants may reason that failing to solve an anagram means that the word was not studied. Although this strategy could have caused a bias to call unsolved items new in this experiment (and, as will be argued subsequently, is likely to represent a component of the effects of discovery), the difference between "old" judgments to unsolved items and baseline items was not replicated in subsequent experiments. Thus, we must be cautious in drawing strong conclusions about this particular aspect of Experiment 2.

## Experiment 3

The results of Experiment 2 indicated that the effect of solving increases the proportion of "old" judgments to unstudied items compared with a baseline condition in which items are presented outright. This finding is similar to the revelation effect, in which items initially presented in degraded form are more likely to be judged as old than items presented outright. However, many studies of the revelation effect have observed that the effect holds even for recognition judgments to a different item (e.g., Westerman & Greene, 1998). Thus, the goal of Experiment 3 was to further investigate the relationship between the effect of solving and the revelation effect by determining whether solving effects are also observed for recognition judgments to a different item. If discovering the solution to an anagram produces a temporary state of "aha" that could be confused with recognition, then the "aha" associated with solving one item could be erroneously transferred to subsequent recognition judgments on a different item. The idea that effects of solving could transfer to recognition of a different item is consistent with observations that "aha" experiences produce mild emotional reactions (e.g., Gick & Lockhart, 1995) and that misattributions of emotional states can be broadly generalized (Clore, 1992).

If discovery can influence the proportion of "old" judgments to words unrelated to the discovered item, then the question arises as to why Westerman and Greene (1998) did not observe a solving effect when they used this paradigm. One possibility is that discovery misattribution may not extend to recognition judgments on a different item. Alternatively, an association between the experience of discovery and recognition may have to be established for solving effects to emerge on a different recognition item. In Westerman and Greene's study, participants never had the experience of solving and identifying the same item. If such associations are critical for solving one item to influence recognition judgments to a different item, then the absence of this could explain their failure to find effects of solving.

In Experiment 3 we compared Westerman and Greene's procedure, in which the recognition item is always different from the anagram solution, with a condition in which both unrelated and related anagram trials were present.

### Method

*Participants.* The participants were 64 undergraduate psychology students from the same pool as described in Experiment 2.

*Design and stimuli.* The experimental design was a $2 \times 2 \times 2$ mixed factorial with two within-subject factors: recognition item (target, distractor) and anagram solution success (solved, unsolved). There was one between-subject factor: whether the anagram and recognition items always involved different items (unrelated condition) or included trials in which the anagram solution and the recognition decision corresponded to the same item (related-and-unrelated condition). In addition, no-anagram trials were included as a quasi-factorial variable.

For those participants in the unrelated anagram condition, half of the words on the recognition test were presented outright, and the other half were preceded by an anagram corresponding with a word that had not been studied and that was different from the recognition item (e.g., Westerman & Greene, 1998). For those participants in the related-and-unrelated condition, the test list differed in that one third of the words were presented outright, one third were preceded by an unrelated anagram of a word that had not been studied, and one third were the anagram form of the item. Half of the recognition items of each type were targets, and the other half were distractors. Only the hard form of each anagram was used, in order to increase the number of observations per cell. We wanted to maximize the power to detect an effect of solving on unrelated anagrams because Westerman and Greene (1998) found a trend for it in their data. Stimuli were identical to those in Experiment 1 with the exception that only the hard form of each anagram was used. Assignment of anagrams to conditions was completely randomized.

*Procedure.* The experimental procedure was similar to the no-anagram trials condition in Experiment 2 with one change. Participants were given 13 s to solve each anagram. If participants had not typed in an anagram solution by this time, they were informed that the time was up, and the item was scored as an unsolved anagram. After entering the anagram solution or being informed that time was up, participants were always provided with the correct anagram solution.

### Results

*Anagram solution accuracy.* We analyzed anagram solution accuracy separately for the related and unrelated anagram trials, because the solutions to the unrelated anagrams were never studied items. Unrelated anagrams were more likely to be solved in the condition with only unrelated anagram trials ($M$ = .72, $SE$ = .02) than in the condition that included both related and unrelated anagram trials ($M$ = .63, $SE$ = .03), $F(1, 62) = 5.77$, $\eta_p^2 = .09$. This effect was likely due to fatigue given that the condition including both related and unrelated anagram trials consisted of more anagram trials than the condition with unrelated anagrams only. In the condition including both related and unrelated anagram trials, related anagrams corresponding with studied items were more likely to be solved ($M$ = .62, $SE$ = .03) than those corresponding with new items ($M$ = .57, $SE$ = .04), $F(1, 30) = 4.59$, $\eta_p^2 = .14$. There were no other main effects or interactions (all $p$s > .10).

*Proportion of "old" judgments.* The proportion of "old" judgments to items preceded by an unrelated anagram is shown in Figure 3 as a function of old–new status, anagram solution success, and whether the related anagram trials were also included on the recognition test. As expected, the proportion of "old" judgments was higher for old ($M$ = .75, $SE$ = .02) than for new recognition items preceded by an unrelated anagram ($M$ = .48, $SE$ = .03), $F(1, 62) = 115.11$, $\eta_p^2 = .64$. Of interest, the proportion of "old" judgments to items preceded by an unrelated anagram was higher overall for solved ($M$ = .65, $SE$ = .02) than for unsolved anagrams ($M$ = .58, $SE$ = .03), $F(1, 62) = 8.72$, $\eta_p^2 = .12$. However, there was an interaction between anagram solution success and whether the related anagram trials were included on the recognition test, $F(1, 62) = 4.87$, $\eta_p^2 = .07$. When related anagram trials were included on the recognition test, anagram solving increased the proportion of "old" judgments to items preceded by an unrelated anagram: solved versus unsolved, $t(31) = 3.66$, $p < .01$, $d = 0.64$; but there was no difference between solved and unsolved anagram trials in the unrelated trials only condition ($t < 1$). There were no other main effects or interactions (all $p$s > .10).

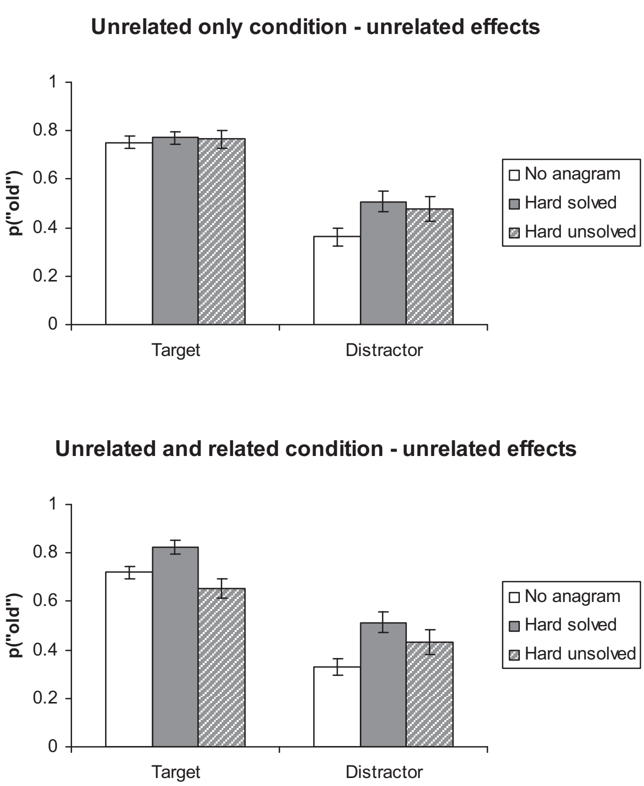


*Figure 3.* Proportion of "old" responses as a function of old–new status and anagram solution success for the unrelated anagram trials of Experiment 3. Error bars indicate plus or minus one standard error of the mean.

Planned comparisons were performed to compare the proportion of "old" judgments to the unrelated anagram trials with the words presented outright, to assess the directionality of the solving effect. For the unrelated trials only condition, the proportion of "old" judgments to distractors preceded by an unrelated anagram was higher for both the solved and the unsolved anagrams than for the words presented outright: solved versus no-anagram, $t(31) = 5.60$, $p < .01$, $d = 0.95$; unsolved versus no-anagram, $t(31) = 3.12$, $p < .01$, $d = 0.52$. This replicates Westerman and Greene's (1998) failure to observe an effect of solving on unrelated anagram trials and is comparable to their observation of a revelation effect on unrelated anagram trials. For the unrelated-and-related trials condition, the proportion of "old" judgments to targets and distractors preceded by an unrelated anagram was higher for the solved anagrams than for the words presented outright: solved targets versus no-anagram, $t(31) = 3.45$, $p < .01$, $d = 0.63$; solved distractors versus no-anagram, $t(31) = 3.94$, $p < .01$, $d = 0.68$. There were no differences in recognition judgments to words presented outright and unsolved anagram trials ($p > .10$).

*Signal detection analysis.* There were no reliable effects on $d'$ for recognition judgments to items preceded by an unrelated anagram (all $F$s < 1). However, there was a main effect of anagram solving on response bias, $F(1, 62) = 5.31$, $\eta_p^2 = .08$; $c$ was lower for items preceded by solved anagrams ($M$ = −0.50, $SE$ = 0.08) than for those preceded by unsolved anagrams ($M$ = −0.29, $SE$ = 0.11). There was also an interaction between anagram solving and whether related anagram trials were included on the recognition test, $F(1, 62) = 8.82$, $\eta_p^2 = .12$. Contrasts indicated that there was an effect of solving on $c$ for items preceded by an unrelated anagram when the related anagram trials were also included on the recognition test: solved versus unsolved, $t(31) = 4.06$, $p < .01$, $d = 0.72$; but not when the recognition test consisted of only unrelated anagram trials ($p > .10$).

Finally, we analyzed the related anagram trials in the condition including both trial types. The proportion of "old" judgments to recognition items for the related anagram trials is shown in Figure 4 as a function of old–new status and anagram solving. As expected, the proportion of "old" judgments was higher for old ($M$ = .74, $SE$ = .03) than for new recognition items ($M$ = .44, $SE$ = .03), $F(1, 31) = 111.98$, $\eta_p^2 = .79$. Also, the proportion of "old" judgments was higher for solved ($M$ = .64, $SE$ = .03) than for unsolved anagrams ($M$ = .55, $SE$ = .03), $F(1, 31) = 12.43$, $\eta_p^2 = .29$. Although the interaction between anagram solving and old–new status did not reach significance ($p > .10$), planned comparisons indicated that the effect of solving was reliable for distractors: solved versus unsolved, $t(31) = 1.98$, $p < .05$, $d = 0.40$; but not for targets ($p > .10$). There were no effects on recognition accuracy for the related anagram trials (all $F$s < 1). However, response bias was modulated by solving, $F(1, 30) = 12.67$, $\eta_p^2 = .30$; $c$ was lower for solved ($M$ = −0.47, $SE$ = 0.11) than for unsolved anagrams ($M$ = −0.14, $SE$ = 0.11), replicating the results of Experiments 1 and 2. There were no other main effects or interactions (all $p$s > .10).

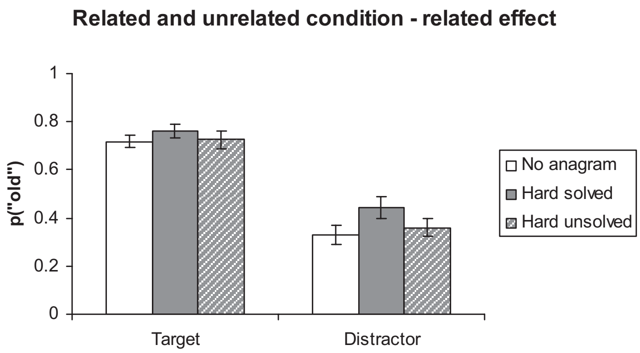


*Figure 4.* Proportion of "old" responses as a function of old–new status and anagram solution success for the related anagram trials of Experiment 3. Error bars indicate plus or minus one standard error of the mean.

### Discussion

In Experiment 3 we again observed that successfully solving an anagram can increase the proportion of "old" judgments to the identified item; however, unlike the previous results, here the solving effect was observed only for new items on the recognition test. Of note, though, Experiment 3 further demonstrated that successfully solving an anagram increased the proportion of "old" judgments to subsequently presented studied items, even when the anagram and the recognition item corresponded to different words. However, the effect of solving on unrelated anagram trials was observed only when trials were presented for which the anagram solution and recognition item were the same. We observed no effect of solving when the anagram trials were always unrelated, like Westerman and Greene (1998).

The present findings help to clarify the discrepancy between the consistent effects of solving in the present experiments and Westerman and Greene's (1998) failure to observe the effect. In their experiment, Westerman and Greene presented only anagrams and recognition items that corresponded with different words. Our data indicate that the additional presentation of trials in which the anagrams and recognition judgments correspond with the same item causes individuals to confuse the experience of solving with that of recognition. Once this tendency to conflate the two experiences is established, it then carries over to trials in which the anagram and recognition items correspond to different items. The results of Experiment 3 also indicate that the solving effect is not caused by increased familiarity to recognition items due to time spent attempting to solve the anagrams. If the effect of solving were a consequence of increased exposure to the target word, then the effect should not be observed when the identity of the anagram and recognition item are different.

The results of Experiment 3 also address the possibility that the effect of solving is due to an artifact related to the types of words that tend to be solved. For example, it is possible that solved items are more likely than unsolved items to possess some trait (e.g., high familiarity) that predisposes such words to also be recognized (Watkins & Gibson, 1988). However, such an account could not explain the results of Experiment 3, because the words that were solved were not the words on which old–new judgments were made.

## Experiment 4

The purpose of Experiment 4 was to determine whether the effect of solving could be diminished by a delay in time between anagram solving and the recognition judgments. The discovery misattribution hypothesis posits that the "aha" experience associated with solving an anagram informs the subsequent recognition judgment; thus, the magnitude of the solving effect should depend on the duration between solving the anagram and making the recognition decision. Specifically, if there is a delay between solving an anagram and making a recognition judgment, the subjective experience of discovery associated with solving the anagram should be reduced, which should also reduce the effect of solving. However, if a strategic process such as an identification heuristic (e.g., Higham & Vokey, 2000) is being used to make the recognition judgments, then delay should have no effect on solving as long as information regarding the solution success or failure is available on the recognition test. In this case it is not the affective experience that informs the recognition judgment but instead the knowledge that an item was or was not solved.

In Experiment 4 we also sought to determine the subjective experience associated with solving. Prior investigations of the revelation effect have suggested that revelation enhances the experience of familiarity. For example, LeCompte (1995) found that relative to baseline control, revelation increased the feeling of familiarity associated with revealed items but decreased the experience of recollection with such items (see also Cameron & Hockley, 2000; Westerman, 2000). In contrast, investigations of the misattribution of surprise have found that increases in "old" judgments are associated with a greater subjective experience of recollection (e.g., Whittlesea, 2002). In Experiment 4 participants indicated whether each recognition judgment was made on a "remember" or a "know" basis (Tulving, 1985). If the subjective experience of solving is the same as that of revelation, then there should be an increase in know but not remember judgments. However, if the experience is more like that associated with misattributions of surprise, then it should primarily affect remember judgments.

### Method

*Participants.* The participants were 34 undergraduate psychology students from the same pool as described in Experiment 2.

*Design and stimuli.* The experimental design was a 2 × 2 × 2 × 2 mixed factorial with three within-subject factors: item type (target, distractor), anagram difficulty (easy, hard), and anagram solution success (solved, unsolved). There was one between-subject factor: timing of the recognition judgments (delayed, immediate). In addition, no-anagram trials were combined in a quasi-factorial fashion with item type and timing of the recognition judgment. One third of the items of each type were presented outright as words, one third were presented as easy anagrams, and the remaining third were presented as hard anagrams. Stimuli were identical to those in Experiment 1.

*Procedure.* In the immediate test condition, the experimental procedure was identical to the no-anagram trials condition in Experiment 2. Participants received anagrams and words on the recognition test. If an anagram was presented, they attempted to solve it, were presented with the anagram solution, and made a recognition judgment on the anagram solution. Anagram solving was limited to 13 s. The order of presentation was random for each participant.

For those participants in the delay condition, the test phase consisted of separate anagram solution and recognition phases that were completed sequentially and separated in time by approximately 15 min. First, participants attempted to solve a list of anagrams presented by computer. If they knew the anagram solution, they entered it with the keyboard and took 1–2 s to write it down on a piece of paper. If time ran out, they indicated on the paper that time had run out for that trial. Next, they wrote down the correct anagram solution on the paper. In addition, they indicated by placing an *X* in the column next to the solution whether each anagram had been solved correctly. These anagram trials were intermixed with no-anagram trials; if a word was presented, participants were instructed to write it on the paper. During the recognition phase of the experiment, participants indicated which of the items they recognized from the studied list by circling the "old" items, thus allowing access to whether the anagram had been correctly solved previously. Finally, whenever participants made an "old" judgment, they were instructed to also indicate whether they "remembered" or "just knew" that the item had been studied.

The remember–know instructions were based on the descriptions of remembering and knowing provided by Rajaram (1993). Remembering was described as "the ability to become consciously aware again of some aspect or aspects of what happened or what was experienced at the time the word was presented (e.g., aspects of the physical appearance of the word, or of something that was happening in the room, or of what you were thinking or doing at the time)." In contrast, knowing was described as the feeling that "you recognize that the word was in the study list but you cannot consciously recollect anything about its actual occurrence or what happened or what was experienced at the time of its occurrence."

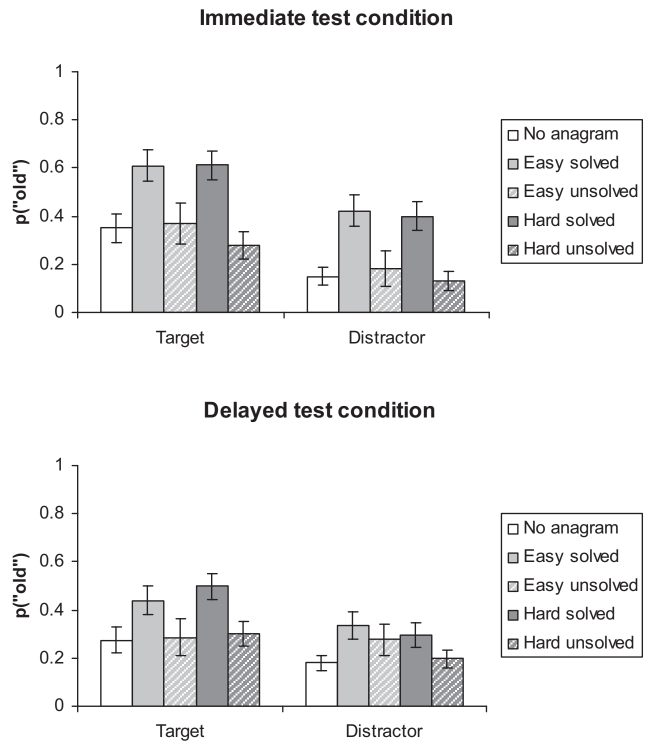


*Figure 5.* Proportion of "old" responses as a function of old–new status, anagram difficulty, and anagram solution success for Experiment 4. Error bars indicate plus or minus one standard error of the mean.

## Results

*Anagram solution accuracy.* The probability of solving an easy anagram was higher ($M$ = .87, $SE$ = .03) than the probability of solving a hard anagram ($M$ = .55, $SE$ = .03), $F(1, 32) = 148.23$, $\eta_p^2 = .82$. Anagrams corresponding with studied items were more likely to be solved ($M$ = .73, $SE$ = .03) than anagrams corresponding with nonstudied items ($M$ = .68, $SE$ = .03), $F(1, 32) = 17.99$, $\eta_p^2 = .36$. There was also a trend for an interaction between old–new status, anagram difficulty, and the delay condition, $F(1, 32) = 3.81$, $p = .06$, $\eta_p^2 = .11$. In the immediate recognition condition, solution rates were greater for the studied than for the new items if the anagram was easy but not if it was hard. In the delayed recognition condition, old–new status affected solving both easy and hard anagrams.

*Proportion of "old" judgments.* The proportion of "old" judgments to recognition items is shown in Figure 5 as a function of old–new status, anagram difficulty, and anagram solution success for both the delayed and the immediate test conditions. As expected, the proportion of "old" judgments was higher for old ($M$ = .40, $SE$ = .04) than for new recognition items ($M$ = .25, $SE$ = .03), $F(1, 32) = 41.85$, $\eta_p^2 = .57$. There was also a trend for an interaction between old–new status and whether there was a delay between anagram solving and the recognition judgments, $F(1, 32) = 3.16$, $p = .09$, $\eta_p^2 = .09$. The difference between old and new items tended to be greater in the immediate test condition than in the delay condition; thus, recognition accuracy was greater when the recognition judgments were made immediately following solution of each anagram.

Again, there was a main effect of anagram solving, $F(1, 32) = 34.68$, $\eta_p^2 = .52$; the proportion of "old" judgments was higher for solved anagrams ($M$ = .40, $SE$ = .04) than for unsolved anagrams ($M$ = .25, $SE$ = .03). There was also a trend for an interaction between anagram solving and old–new status; the effect of solving tended to be greater for targets than for distractors, $F(1, 32) = 3.17$, $p = .08$, $\eta_p^2 = .09$. Of note, there was an interaction between anagram solving and the immediate versus delayed test conditions, $F(1, 32) = 4.68$, $\eta_p^2 = .13$. Planned comparisons revealed that in the immediate test condition, the effect of solving was statistically reliable for easy targets, $t(16) = 2.44$, $p < .05$, $d = 0.59$; hard targets, $t(16) = 5.20$, $p < .01$, $d = 1.26$; easy distractors, $t(16) = 2.28$, $p < .05$, $d = 0.53$; and hard distractors, $t(16) = 4.07$, $p < .01$, $d = 0.95$. In the delayed test condition, the effect of solving was reliable only for the hard targets, $t(16) = 3.89$, $p < .01$, $d = 0.95$. There were no other main effects or interactions (all $p$s > .10).

As in the previous experiments, we performed planned comparisons on the proportion of "old" judgments to words presented outright compared with solved and unsolved anagrams. In the immediate test condition, the proportion of "old" judgments was higher for the easy and hard solved anagrams than for the no-anagram trials: easy solved targets versus no-anagram targets, $t(17) = 2.57$, $p < .05$, $d = 0.60$; hard solved targets versus no-anagram targets, $t(17) = 2.83$, $p < .05$, $d = 0.70$; easy solved distractors versus no-anagram distractors, $t(17) = 3.58$, $p < .01$, $d = 0.88$; hard solved distractors versus no-anagram distractors, $t(17) = 3.74$, $p < .01$, $d = 0.91$. The same pattern was observed in the delayed test condition: easy solved targets versus no-anagram targets, $t(17) = 3.52$, $p < .01$, $d = 0.83$; hard solved targets versus no-anagram targets, $t(17) = 4.03$, $p < .01$, $d = 0.95$; easy solved distractors versus no-anagram distractors, $t(17) = 3.76$, $p < .05$, $d = 0.95$; hard solved distractors versus no-anagram distractors, $t(17) = 2.57$, $p < .01$, $d = 0.55$. We observed no differences between the unsolved anagrams and the no-anagram trials ($p$s $> .10$).

*Signal detection analysis.* There were no effects on recognition accuracy (all $F$s $< 1$). However, as in the previous experiments, $c$ was lower for solved anagrams ($M = 0.32$, $SE = 0.13$) than for unsolved anagrams ($M = 1.01$, $SE = 0.14$), $F(1, 32) = 41.49$, $\eta_p^2 = .57$, indicating that anagram solving resulted in a more liberal response bias. There was also a trend for the effect of solving on $c$ to be reduced by the delay, $F(1, 32) = 2.92$, $p = .09$, $\eta_p^2 = .08$. There were no other main effects or interactions (all $p$s $> .10$).

*Remember–know judgments.* We computed estimates of recollection and familiarity from the remember ($R$) and know ($K$) judgments to assess the impact of discovery on the subjective experience of remembering. According to the independence assumption (Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998), recollection is indexed as $R$(hits) – $R$(false alarms), and familiarity is indexed as independent $K$ (the probability that an item received a know response given that it did not receive a remember response, $K/[1 - R]$). As can be seen in Figure 6, recollection was higher for solved ($M = .19$, $SE = .03$) than for unsolved anagrams ($M = .04$, $SE = .03$), $F(1, 32) = 13.40$, $\eta_p^2 = .30$. In addition, recollection was higher for hard anagrams ($M = .15$, $SE = .03$) than for easy anagrams ($M = .07$, $SE = .03$), $F(1, 32) = 7.49$, $\eta_p^2 = .19$. There were no other main effects or interactions (all $p$s $> .10$).

Planned comparisons indicated that recollection was higher for hard solved anagrams than for no-anagram trials in the immediate test condition, $t(16) = 2.17$, $p < .05$, $d = 0.54$, consistent with the discovery misattribution hypothesis. In contrast, recollection was higher for the no-anagram trials than for the hard unsolved anagrams in the delay condition, $t(16) = 2.77$, $p < .05$, $d = 0.73$, which is consistent with the use of an identification heuristic. There were no significant effects on familiarity as indexed by independent $K$ (all $F$s $< 1$).

## Discussion

The results of Experiment 4 demonstrate that the effect of solving is diminished, but not completely attenuated, when there is a delay between anagram solving and the subsequent recognition judgments. The delay between solving and recognizing attenuated the effect of solving on new items, although the solving effect remained for the old items. Because the information regarding solution success was maintained in the delay condition, this suggests that the solving effect observed in this condition was due to strategic processing but not discovery misattribution. The finding that the effect of solving was of greater magnitude in the immediate test condition, though, indicates that an additional process was contributing to the effect given that the identification heuristic was equally useful in both conditions. We argue that the effect of solving in the immediate test condition was caused by the additional contribution of the experience of discovery.

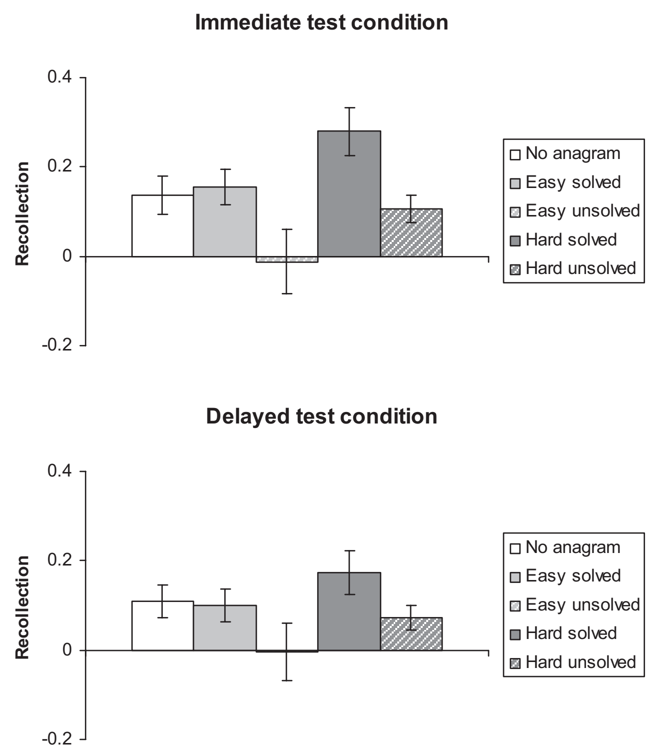


*Figure 6.* Recollection as a function of anagram difficulty and anagram solution success for Experiment 4. Error bars indicate plus or minus one standard error of the mean.

The finding that anagram solving increased the experience of recollection in the immediate condition is notable for several reasons. First, it contrasts with prior research on the revelation effect, which has found that revelation exclusively affects "just know" judgments and other measures of familiarity while having no effect on "remember" judgments or other measures of recollection (Cameron & Hockley, 2000; Niewiadomski & Hockley, 2001; Westerman, 2000). Second, it is consistent with Whittlesea's (2002) recent findings that the surprise associated with the sudden resolution of a constrained contextual stem can lead to illusions of remembering. In Experiment 5, we asked whether the effect of solving is observed for other judgments that depend on the phenomenology of recollection.

# Experiment 5

A number of studies have extended the study of memory to include individuals' recollections of prior recollective episodes (Arnold & Lindsay, 2002, 2005; Joslyn, Loftus, McNoughton, & Powers, 2001). Such investigations of "remembering remembering" were prompted in part by case studies of discovered memories of abuse in which individuals' beliefs that their memories had been long forgotten were found to stem in part from their forgetting of prior documented occasions in which they were known to have recalled the abuse (Schooler, 1997, 2001). Consistent with this finding, studies of memory for prior recollections have documented various manipulations by which individuals can be induced to forget their prior episodes of recollection.

Although "remembering remembering" paradigms have largely been used to explore the situations surrounding the forgetting of remembering, they also offer an alternative method for measuring the phenomenological experience associated with memory illusions. If individuals come to falsely remember having recently recalled an item, then this judgment would likely involve the subjective experience of recollection. Accordingly, if the effect of solving increases the belief of previously recalling an item, this would complement the results of Experiment 4 in demonstrating that the solving effect induces the subjective experience of recollection. In Experiment 5, we explored this possibility by requiring participants to first recall previously studied words and then participate in an anagram-solving phase in which they decided whether anagram solutions corresponded to items they had previously recalled.

## Method

*Participants.* The participants were 43 undergraduate psychology students from the same pool as described in Experiment 2.

*Design and stimuli.* The experimental design was a 2 × 2 factorial with two within-subject factors: old–new status (target, distractor) and anagram solution success (solved, unsolved). No-anagram trials were included as a quasi-factorial variable. Half of the items of each type were presented as hard anagrams on the memory test, and the other half were presented as words. Stimuli were identical to those in the previous experiments. Only the hard form of each anagram was used.

*Procedure.* During the study phase, 60 words were presented in the center of a computer screen, one at a time, for 3 s each. Participants were instructed to memorize each word.

Immediately after the study phase, participants were asked to recall as many words from the studied list as possible and write them down on a piece of paper. Next, the paper was taken away and participants were given instructions for the second part of the memory test. They were informed that some of the items would be presented in anagram form and that they were to try to solve these anagrams. If they knew the solution, they were to enter it with the keyboard. Otherwise, time ran out after 13 s. In both cases, the correct solution was presented. After each anagram presentation, participants were to indicate whether the anagram solution was one of the words that they had recalled previously. To respond "recalled," participants pressed the *Z* key; to respond "not recalled," participants pressed the slash key. No recall accuracy feedback was provided.

## Results

*Anagram solution accuracy.* Anagrams corresponding with studied items were more likely to be solved ($M$ = .61, $SE$ = .02) than anagrams corresponding with nonstudied items ($M$ = .55, $SE$ = .02), $F(1, 42) = 15.02$, $\eta_p^2 = .26$.

*Proportion of "recalled" judgments.* The proportion of "recalled" judgments to test items is shown in Figure 7 as a function of old–new status, recognition trial type, and anagram solution success. As can be seen, anagram solving increased the likelihood

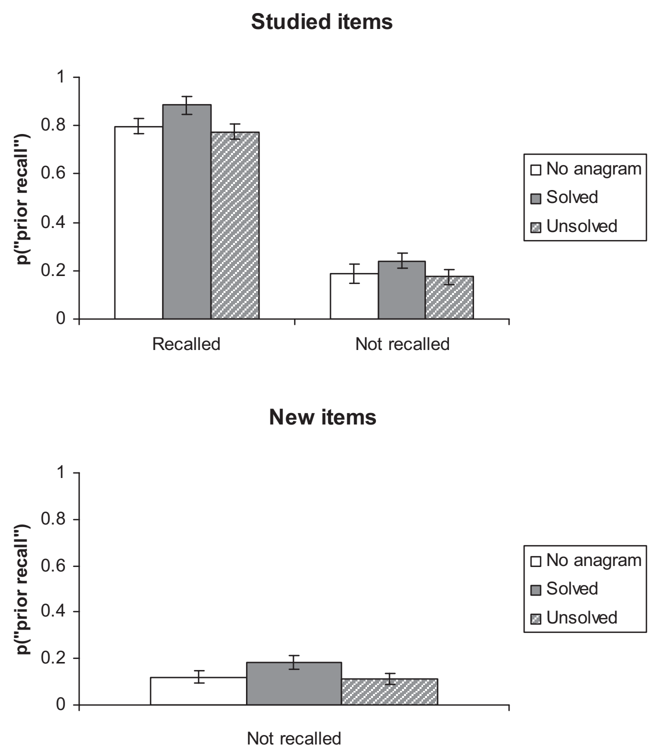


*Figure 7.* Proportion of "recalled" responses to targets and distractors as a function of actual recall success and anagram solution success for Experiment 5. Error bars indicate plus or minus one standard error of the mean.

of judging an item as previously recalled. The probability of judging a studied item as recalled was higher when its corresponding anagram had been solved ($M$ = .56, $SE$ = .03) than when it was unsolved ($M$ = .48, $SE$ = .02), $F(1, 42) = 9.92$, $\eta_p^2 = .19$. In addition, actual recall accuracy influenced the proportion of judgments of previous recall. The probability of judging a studied item as recalled was higher when it had actually been recalled ($M$ = .83, $SE$ = .03) than when it had not been recalled ($M$ = .21, $SE$ = .04), $F(1, 42) = 173.67$, $\eta_p^2 = .81$. It is interesting to note that solving also influenced the probability of judging a nonstudied item as recalled. The probability of judging a nonstudied item as recalled was higher when its corresponding anagram had been solved ($M$ = .18, $SE$ = .04) than when it was unsolved ($M$ = .11, $SE$ = .03), $F(1, 42) = 5.71$, $\eta_p^2 = .12$. Because there is no way a distractor item could have actually been recalled, a recall accuracy analysis on these items could not be performed.

Planned comparisons were performed to compare the proportions of "recalled" judgments for anagram and no-anagram trials. For the studied items, the proportion of "recalled" judgments was higher for solved anagrams than for no-anagram trials for items that had actually been recalled, $t(42) = 2.26$, $p < .05$, $d = 0.36$, and items that were not recalled, $t(42) = 2.12$, $p < .05$, $d = 0.31$. For the distractors, the proportion of "recalled" judgments was higher for solved anagrams than for no-anagram trials, $t(42) = 2.17$, $p < .05$, $d = 0.33$. There were no other main effects or interactions (all $p$s > .10).

*Signal detection analysis.* Recall judgment accuracy and response bias could be computed only for the items that were not actually recalled (because distractors could not be recalled). We found no effects on recognition accuracy (all *F*s $< 1$). However, consistent with the results of the previous studies, successful anagram solving resulted in a more lenient response bias for the previous recall judgments; *c* was lower for solved ($M = 1.22$, $SE = 0.14$) than for unsolved anagrams ($M = 1.50$, $SE = 0.14$), $F(1, 42) = 5.65$, $\eta_p^2 = .12$. There were no other main effects or interactions (all *p*s $> .10$).

## Discussion

The results of Experiment 5 generalized the effects of solving to judgments of whether an item has been previously recalled. Items corresponding to successfully solved anagrams were more likely to be judged as recalled than items with unsolved anagrams or words that were presented outright. The finding that successful anagram solving increased the rate at which individuals remembered recently recalling words that had never been seen provides further evidence that anagram solving produces a phenomenological state similar to genuine recollection, thus supporting the conclusion of Experiment 4 that discovery misattribution results in the subjective experience of recollection. These findings are consistent with the notion that the experience of discovery can be confused with that of recollection.

It is particularly striking that successfully solving anagrams significantly increased (by more than 50%) the proportion of nonstudied items that individuals believed they had previously recalled. To our knowledge, this is the first time a manipulation has been found to enhance the illusion of having recalled items that were never actually presented. This finding speaks to the power of the illusory recollective experience associated with discovery and is consistent with the remember–know results of Experiment 4 as well as the findings of the previous studies showing that anagram solving increases the proportion of "old" judgments to new items.

# Experiment 6

Experiment 5 demonstrated that discovery not only increases the perception of having seen an item before but also enhances the belief that the item was actually recalled. This finding supports the hypothesis that the experience of solving an anagram is confused with that of recollection, thereby producing an illusion of actually recalling the item. It is important to note that this further differentiates the effect of solving from the revelation effect. A number of researchers have argued that revelation increases the experience of familiarity without affecting recollection (e.g., LeCompte, 1995; Westerman, 2000), and more recent evidence suggests that the revelation effect also can decrease memory sensitivity (Hicks & Marsh, 1998; Verde & Rotello, 2003, 2004). However, there is no evidence to suggest that revelation increases the experience of recollection.

If the effect of discovery is due to an enhanced experience of recollection whereas the revelation effect is due to a change in familiarity, then the judgment of previous recollection paradigm used in Experiment 5 should be differentially affected by the discovery experience that results from successfully solving an anagram compared with the gradual revelation of a test item via an algorithm. Specifically, anagram solving should lead to enhanced judgments of prior recall, but revelation should not. In Experiment 6, we explored this issue.

## Method

*Participants.* The participants were 76 undergraduate psychology students from the same pool as described in Experiment 2.

*Design and stimuli.* The experimental design was a 2 × 2 × 2 mixed factorial with two within-subject factors: item type (target, distractor) and test trial (anagram, no anagram). There was one between-subjects factor (whether an algorithm for solving the anagrams was given). Anagram solving (solved, unsolved) was a quasi-factorial variable. On the test of prior recall, half of the items of each type were presented as anagrams, and the other half were presented as words. The no-algorithm condition was identical to the anagram-solving manipulation in the previous experiments. For the group of participants who received an algorithm for solving the anagrams, anagram solution accuracy was near ceiling and a solving analysis was not performed. Instead, we compared recognition performance as a function of whether the words were presented outright or in anagram form (i.e., the typical revelation effect paradigm). Stimuli were identical to those in the previous experiments with the exception that only hard anagrams were presented. The anagrams in the algorithm and no-algorithm conditions were scrambled according to the same rule. Thus, the only difference between the conditions was whether the solution code was given.

*Procedure.* The procedure for the anagram-solving condition (no algorithm given) was identical to that used in Experiment 5. In contrast, participants in the revelation condition (algorithm given) were trained on how to use the algorithm prior to the test phase and were instructed to use it on the memory test when an item was presented in anagram form. The anagrams were scrambled according to a specific rule to assure correct completion (e.g., Westerman & Greene, 1996), which was presented on the computer screen directly underneath each anagram. The rule for solving the anagrams was always 51243. That is, the first letter of the anagram was in the fifth position of the solution, the second letter of the anagram was in the first position of the solution, and so forth. After each anagram presentation, all participants were to indicate whether the anagram solution was one of the words that they had recalled previously. To respond "recalled," participants pressed the *Z* key; to respond "not recalled," participants pressed the slash key. No recall accuracy feedback was provided.

## Results

*Anagram solution accuracy.* Anagrams corresponding with studied items were more likely to be solved ($M = .83$, $SE = .01$) than anagrams corresponding with nonstudied items ($M = .79$, $SE = .01$), $F(1, 74) = 10.24$, $\eta_p^2 = .12$. As expected, anagram solving interacted with whether the anagram-solving algorithm was given, $F(1, 74) = 6.42$, $\eta_p^2 = .08$. In the no-algorithm condition, anagrams corresponding with studied items were more likely to be solved ($M = .69$, $SE = .02$) than those corresponding with new items ($M = .63$, $SE = .02$), $t(37) = 3.14$, $p < .01$, $d = 0.50$. However, this difference was not observed in the algorithm condition, where anagram solution performance was at ceiling ($t < 1$). The probability of correctly solving an anagram was higher in the algorithm condition ($M$ = .96, $SE$ = .02) than in the no-algorithm condition ($M$ = .66, $SE$ = .02), $F(1, 74) = 151.93$, $\eta_p^2$ = .67. The few errors in the algorithm condition were due to misspelling and typographic errors. There were no other main effects or interactions (all $p$s > .10).

*Proportion of "recalled" judgments.* The proportion of "recalled" judgments is presented in Figure 8 as a function of old–new status and revelation in the algorithm condition or anagram solution success in the no-algorithm condition. As expected, the proportion of "recalled" judgments was higher for targets ($M$ = .23, $SE$ = .02) than for distractors ($M$ = .04, $SE$ = .01), $F(1, 74) = 329.28$, $\eta_p^2$ = .82. In addition, the effect of old–new status interacted with whether the anagram solution algorithm was given, $F(1, 74) = 6.26$, $\eta_p^2$ = .08. The magnitude of the old–new status effect was greater for the anagram-solving condition, $t(37) = 12.83$, $p < .01$, $d = 2.10$, than for the revelation condition, $t(37) = 13.18$, $p < .01$, $d = 2.00$.

Of note, the effect of solving on "recalled" judgments interacted with whether the anagram solution algorithm was given to participants, $F(1, 74) = 7.03$, $\eta_p^2$ = .09. For the no-algorithm condition, the proportion of "recalled" judgments was higher for items preceded by solved anagrams ($M$ = .17, $SE$ = .02) than for words presented outright ($M$ = .14, $SE$ = .01), $t(37) = 2.61$, $p < .01$, $d$ = 0.50. However, there was no difference in "recalled" judgments for items that were revealed with the algorithm compared with items presented outright ($p > .10$). For completeness, we also examined the effect of solving on the proportion of "recalled" judgments in the anagram-solving condition. The proportion of "recalled" judgments was higher for distractors that were solved ($M$ = .18, $SE$ = .02) than for those that were unsolved ($M$ = .11, $SE$ = .02), $F(1, 42) = 5.71$, $\eta_p^2$ = .12. There were no other main effects or interactions (all $p$s > .10).

*Signal detection analysis.* Memory sensitivity and response bias were computed for the items presented as anagrams and words on the judgment of prior recall test. Memory sensitivity was higher for the anagram-solving condition ($M$ = 1.31, $SE$ = .06) than for the revelation condition ($M$ = 1.11, $SE$ = .06), $F(1, 74) = 4.97$, $\eta_p^2$ = .06.

For response bias, we observed an interaction between revelation and whether the algorithm was given for solving the anagrams, $F(1, 74) = 3.99$, $\eta_p^2$ = .05. For the anagram-solving condition, $c$ tended to be lower for the anagram trials than for trials in which the word was presented outright, $t(37) = 1.82$, $p$ = .07, $d$ = 0.31. However, when the solution algorithm was given, $c$ did not differ ($p > .10$). There were no other main effects or interactions (all $p$s > .10).

### Discussion

The results of Experiment 6 provide additional evidence that the solving effect and the revelation effect involve distinct processes. As in Experiment 5, judgments of prior recall corresponding to trials in which the anagram was successfully solved were increased compared with both unsolved anagrams and words presented outright. In contrast, judgments of prior recall to anagrams revealed via the solution algorithm did not differ from the words presented outright. These findings further support the conclusion that the effect of solving is due to a misattribution of the experience of recollection, and that this mechanism is not involved in the superficially similar revelation paradigm. Given that the critical difference between these two paradigms involves whether participants are assured of reaching a solution, we can further infer that the illusion of prior recollection specifically stems from the phenomenal experience of solving, when the solution is not assured.

By discriminating between the effects of discovery and revelation, Experiment 6 further documented the utility of the judgment of previous recollection paradigm as a way of distinguishing the memorial processes underlying different memory paradigms. It is notable that the results of Experiment 6 converge with the remember–know findings of Experiment 4 in suggesting that discovering the solution to anagrams induces an experience of recollection. More research will be necessary to ascertain the precise degree to which judgments of prior recall correspond to the subjective experience of recollection; however, the correspondence between the conclusions derived from this measure and those from the remember–know procedure in Experiment 4 suggests that the judgment of previous recollection paradigm may provide a useful alternative method for assessing the phenomenal experience of recollection.

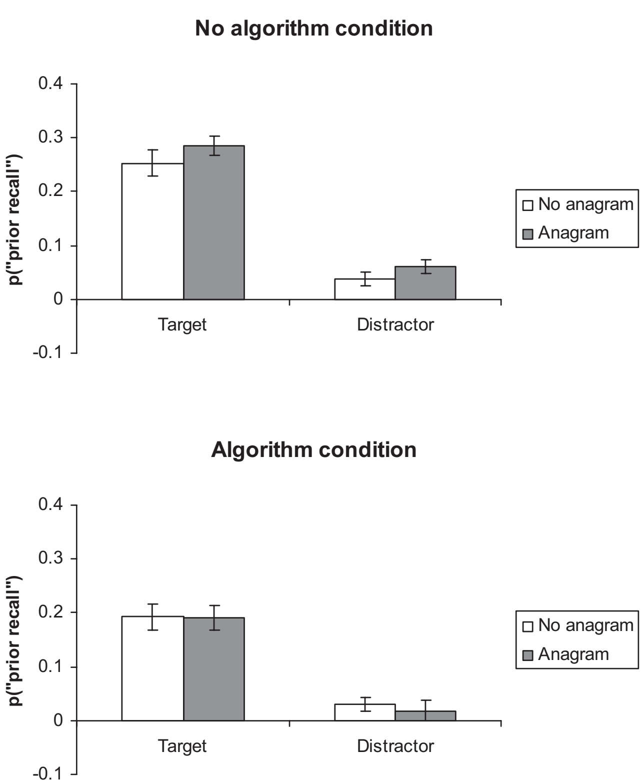


*Figure 8.* Proportion of "recalled" responses to studied items as a function of old–new status, revelation, and whether the anagram solution code was given for Experiment 6. Error bars indicate plus or minus one standard error of the mean.

## General Discussion

The results of six experiments suggest that the experience of successfully solving an anagram can be confused with recognition, even for items that were never studied. Indeed, we observed that anagram solving consistently increased the proportion of "old" judgments (Experiments 1–4) and "prior recall" judgments (Experiments 5–6) to new items and also consistently resulted in a more lenient response bias. Experiment 1 revealed that both old and new test items were more likely to be called old when they corresponded to successfully solved anagrams as compared with unsolved anagrams. In Experiment 2, we found that anagram solving increased the proportion of "old" judgments to distractors as compared with words presented outright. Experiment 3 indicated that under certain conditions, solving the anagram to one word increases recognition judgments to a different word. Experiment 4 showed that the effect of anagram solving increased the feeling of recollection and can be reduced by a delay. Experiment 5 demonstrated that the effect of solving generalizes to judgments of prior recollection. Finally, Experiment 6 further differentiated the effect of solving from the revelation effect by showing that anagram solving, but not revelation, induces the illusion of prior recall.

We also evaluated several alternative explanations of the effect of solving. According to an item selection account (Watkins & Gibson, 1988), the effect of solving is an artifact of an inherent difference between the items that are solved and those that are unsolved. The item selection view cannot account for the finding that anagram solving increases recognition judgments to unrelated items (Experiment 3) or that the effect of solving is reduced over time (Experiment 4). Moreover, the item selection account would predict symmetrical effects of anagram solving relative to baseline; the increased likelihood of judging solved items as old would be mirrored by the decreased likelihood of judging unsolved items as old. However, with one exception (Experiment 2), we did not observe that pattern of results.

A fluency account of the solving effect claims that solved anagrams are more likely to be recognized than unsolved anagrams because of the experience of fluency associated with solving an item (Lindsay & Kelley, 1996). This account predicts that easy anagrams (e.g., those that could be solved by reversing the last two letters) should be more likely to be called old than hard anagrams, because the solutions to easy anagrams should come to mind more readily than solutions to hard anagrams. However, we did not observe this pattern in our data, despite the fact that the easy anagrams were reliably more likely to be solved than the hard anagrams.

According to an item exposure account (Watkins & Peynircioglu, 1990), the effect of solving occurs because participants have more opportunity to process the solved items than the unsolved items, therefore increasing the familiarity of solved items. However, this account fails to explain the finding in Experiment 3 that solving an anagram can influence recognition judgments to a different item. It also does not explain why, in Experiment 6, anagram solving influenced performance on estimates of prior recall judgments in the solving condition (i.e., no algorithm given) but not the revelation condition (i.e., algorithm given), as both procedures allow opportunity for additional deeper processing.

An identification heuristic account claims that participants explicitly use their lay intuitions about implicit priming to inform their recognition decisions (e.g., Higham & Vokey, 2000). In this view, participants correctly reason that prior exposure to an item increases the likelihood that it will be deciphered, and therefore solved anagrams are more likely than unsolved anagrams to correspond with previously seen words. Of all of the alternatives we discuss here, the identification heuristic is the best contender to discovery misattribution. Indeed, as noted, this mechanism likely contributes to the effect of solving in the delayed condition of Experiment 4 and also accounts for the observation in Experiment 2 of an effect of failing to solve the anagram. However, the identification heuristic cannot explain the full pattern of findings. It cannot explain why an effect of solving was observed for unrelated anagram trials in Experiment 3, as presumably participants should not consider their ability to solve one item as having any bearing on whether they have previously seen a different item. It also fails to account for the reduction in the effect of solving as a function of delay in Experiment 4, given that information regarding solution success was preserved between the immediate and delayed conditions. Finally, it is not obvious why a simple heuristic of assuming that identified items must have been studied would lead to an increase of recollection (Higham & Vokey, 2004).

We argue that the present findings are generally consistent with the hypothesis that solving an anagram results in an affective state that may then inform subsequent recognition judgments. Accordingly, the increase in "old" judgments above baseline results from the unique affective state induced by anagram solving. The transfer of solution success from one item to another (in the condition including trials in which the anagram solution is the recognition item) results from the amorphous quality of the discovery experience. The reduction in the effect of solving with delay is due to the fact that the discovery experience is fleeting. And the effect of solving on remember judgments and judgments of prior recollection occurs because the experience of solving resembles that of genuine recollection.

Most prior discussions of memory misattribution processes have focused on either misattribution of the experience of familiarity (e.g., Jacoby & Kelley, 1987) or misattribution of source (e.g., Johnson et al., 1993). However, our results add to emerging evidence that misattribution processes can also apply to the experience of recollection (e.g., Higham & Vokey, 2004; Whittlesea, 2002). Such findings are consistent with our hypothesis that it is possible to induce a phenomenological state that can be misconstrued as recollection, even if such a state is not necessarily tied to access of specific contextual details. Indeed, recent findings indicate that the subjective experience of recollection is enhanced by emotional arousal even though remember judgments to emotional stimuli may not be made on the basis of a recollective process (Dougal & Rotello, in press). The present series of experiments adds to the literature on misattributions of recollection by demonstrating that the experience of discovery is a potential source of illusory states of recollection.

In assessing the novelty of the present contribution, it is important to compare our observed effects of solving with the revelation effect, which is empirically quite similar. The effects of discovery observed here do indeed share some important similarities with the revelation effect. Like revelation, solving effects require that an item initially be presented in an obscured manner and subsequently be deciphered. Also like the revelation effect, the solving effect can under some conditions carry over to unrelated items. However, effects of solving cannot be characterized as a form of revelation, because in this paradigm, both the solved and the unsolved items are "revealed" in the sense that their identities are initially obscured and later exposed. Because revelation is held constant for the solved and the unsolved items, it seems that revelation per se cannot be the source of the effect.

It could be argued that discovering the solution to an anagram is itself the basis of the revelation effect, as in most revelation studies revealed items are also deciphered by participants (with an algorithm that provides solution success). However, our data suggest that the effects of solving and revelation rely on different mechanisms. First, in contrast to the revelation effect, which carries over to unrelated items under a variety of conditions (Westerman & Greene, 1996, 1998), we found that discovery effects carried over only when participants had also experienced the anagram solution as the recognition item. Second, whereas revelation effects have been found to influence familiarity-based recognition judgments (e.g., LeCompte, 1995), we found that anagram solving affects the subjective experience of recollection. Third, in Experiment 6 we found empirical differences between the solving effect and the revelation effect, such that anagram solving without an algorithm increased estimates of prior recall, whereas revelation of anagram solutions via an algorithm did not. Finally, whereas recent data indicate that the revelation effect decreases memory sensitivity on recognition judgments to the revealed item (Verde & Rotello, 2003, 2004), the solving effect consistently resulted in a more liberal response bias without reducing memory sensitivity.

In conclusion, the present findings suggest that there may be a distinct phenomenological state associated with the "aha" experience of solving an anagram, one that can be distinguished both from the "duh" experience of having to be given the solution and from the "ho hum" experience of solving an anagram using a predetermined algorithm. The fact that only discovery experiences lead to misattributions of recollection suggests that individuals may rely on the distinct nature of the phenomenology of the discovery experience to make inferences about their state of knowledge (e.g., Clore, 1992). Given this view, future research might profitably explore other phenomenological states with which discovery experiences might be confused. Ultimately, understanding the situations under which discovery imbues the mundane with meaning may enable us to better determine when perceived discoveries are genuine and when they are merely the product of overgeneralization.

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Received April 11, 2005
Revision received January 8, 2007
Accepted January 15, 2007 ■