Research Article

Recalling a Witnessed Event Increases Eyewitness Suggestibility

The Reversed Testing Effect

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ABSTRACT—*People's later memory of an event can be altered by exposure to misinformation about that event. The typical misinformation paradigm, however, does not include a recall test prior to the introduction of misinformation, contrary to what real-life eyewitnesses encounter when they report to a 911 operator or crime-scene officer. Because retrieval is a powerful memory enhancer (the testing effect), recalling a witnessed event prior to receiving misinformation about it should reduce eyewitness suggestibility. We show, however, that immediate cued recall actually exacerbates the later misinformation effect for both younger and older adults. The reversed testing effect we observed was based on two mechanisms: First, immediate cued recall enhanced learning of the misinformation; second, the initially recalled details became particularly susceptible to interference from later misinformation, a finding suggesting that even human episodic memory may undergo a reconsolidation process. These results show that real-life eyewitness memory may be even more susceptible to misinformation than is currently envisioned.*

Since Bartlett's (1932) pioneering work, researchers have repeatedly demonstrated the malleability of human memory (e.g., Jacoby, Woloshyn, & Kelley, 1989; Roediger & McDermott, 1995). Loftus's (1979) misinformation paradigm, in particular, has translated traditional verbal-learning research findings (e.g., Keppel & Underwood, 1962) into an ecologically relevant setting, showing that eyewitnesses' memories are malleable and can be influenced by exposure to misinformation. Loftus's paradigm (e.g., Lindsay, Allen, Chan, & Dahl, 2004; Loftus, Miller, & Burns, 1978) includes three phases: First, subjects witness an event (e.g., by watching a video). Second, they are exposed to a narrative description of the witnessed event that contains misinformation. Third, subjects are tested on their memory for the event. The typical finding is that subjects who have been exposed to misinformation in this way are less likely to recall the correct details than are those who have received no misinformation. However, this three-phase procedure misses a potentially important component in real-life situations—the occurrence of a recall test prior to the introduction of misinformation (for exceptions, see Lane, Mather, Villa, & Morita, 2001; Saunders & MacLeod, 2002[1]). In real-life situations, an eyewitness usually recalls the witnessed event at the crime scene, most likely prior to encountering any misinformation. How might taking such immediate "tests" affect eyewitnesses' suggestibility?

Research suggests that taking an immediate test may reduce a person's susceptibility to misinformation. According to the traditional verbal-learning literature (Erdelyi & Becker, 1974) and the more recent testing-effect literature (Chan, McDermott, & Roediger, 2006), immediate recall should enhance retention of the witnessed event, thereby rendering an eyewitness less susceptible to misinformation. In the present study, we conducted three experiments to test this hypothesis. In Experiment 1a, we compared the

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[1]In both of these studies, subjects performed retrieval practice on the witnessed event before they encountered misinformation. However, unlike in the current study, Lane et al. used free recall instead of cued recall for the initial test. In Saunders and MacLeod's experiments, all subjects took an initial free-recall test before the misinformation was introduced (i.e., a no-test group was not included).

final recall performance of young adults who had completed an immediate cued-recall test with the performance of young adults who had not taken such a test. In Experiment 1b, we attempted to replicate Experiment 1a and extend its findings to older adults, who are more prone to erroneous recollection (Chan & McDermott, 2007a; Thomas & Sommers, 2005). In Experiment 2, we attempted to uncover the mechanisms underlying the findings of the preceding two experiments.

EXPERIMENT 1A

Method

Participants

Thirty-six undergraduate students (20 females and 16 males; $n = 18$ in each testing condition) from Washington University in St. Louis participated in this experiment for credit toward a course requirement.

Materials and Procedure

Subjects first viewed approximately 40 min of an episode of the television program "24" (the witnessed event).[2] No subjects had seen this video before. Subjects in the test condition then took an immediate cued-recall test on 24 details about the video. For example, they were asked, "What did the terrorist use to knock out the flight attendant?" (The correct answer, which was not provided to subjects, was "a hypodermic syringe.") Subjects were told to type in each answer they knew within 25 s of the question's onset. Accuracy was encouraged, and participants were not required to produce an answer. No corrective feedback was provided. Subjects in the no-test condition played Tetris (a computerized falling-rock puzzle game) for the same amount of time that the recall test took (12 min). Subjects in both the test and the no-test conditions then completed a brief demographic questionnaire and two distractor tasks, a synonym and antonym vocabulary test (Salthouse, 1993) and a computerized operation span (OSPAN) task (Kane & Engle, 2003). This distractor phase lasted approximately 25 min. All tests and questionnaires were computerized.

Participants then listened to an 8-min audio narrative that described the video. They were told that the narrative was a recap of the video (the experimenter did not warn subjects that some of the information in the narrative was untrue). Of the 24 details targeted by the immediate cued-recall test, 8 were presented correctly in the narrative (*consistent items*: e.g., "[the terrorist] knocks the flight attendant unconscious with a hypodermic syringe"), 8 were not mentioned in the narrative (*control items*: e.g., "[the terrorist] knocks the flight attendant unconscious"), and 8 were changed in the narrative (*misleading items*: e.g., "[the terrorist] knocks the flight attendant unconscious with a chloroform rag"). The misleading information always involved replacing a specific detail with a plausible alternative. Each critical detail appeared only once in the narrative, and whether the detail was consistent, control, or misleading was counterbalanced across subjects. Both focal and nonfocal details were modified. Pilot testing ensured that all items were able to elicit false recall at a reasonable rate ($M = 21\%$). The final cued-recall test was identical to the immediate test, and subjects were told to report the information presented in the video. Overall, the only difference between subjects in the two testing conditions was whether the subjects had taken the immediate test.

[2]Specifically, we used the first episode of the first season of "24" as the witnessed event. The audio narrative used to introduce misinformation later in the procedure was created by modifying the episode guide provided by Fox on www.fox.com/24.

Results and Discussion

Unless otherwise noted, all results reported were significant at an alpha level of .05; p_{rep} indicates the probability of replicating the direction of an effect.

During the immediate recall test, 63% of subjects' responses were accurate, and 3% matched the misinformation given later (i.e., base rate of false recall). The 24% of responses that matched neither the correct answer nor the misinformation were classified as "other." Subjects gave no answer or responded "I don't know" for 9% of the items.

More important for current purposes are the results from the final test. Surprisingly, not only did immediate testing fail to reduce the misinformation effect, but it greatly increased that effect. Figure 1 displays the mean probabilities of responding with accurate information and of responding with the misinformation as a function of testing condition and item type. The three-way interaction of testing condition (test vs. no-test), item type (consistent vs. control vs. misleading), and response type (correct answer vs. misinformation) was significant, $F(2, 33) = 4.51$, $p_{rep} > .93$. Subjects in the two testing conditions performed comparably on the consistent and control items, but not the misleading items. We did not conduct an analysis of variance (ANOVA) to examine the two-way interactions between testing condition and response type because the probabilities of responding correctly and of responding with misinformation were partially complementary (see Table 1 for the probabilities of "other" and "no answer" responses). A planned comparison of data from the misleading items, however, revealed that subjects who had taken the immediate test were much more likely ($\sim$20%; see Fig. 1) to recall the misinformation than were subjects who had not taken that test, $t(34) = 2.49$, $p_{rep} = .98$. Thus, suggestibility to misinformation showed a reversed testing effect.

For the control items, accurate recall was at 65% in the test condition and 62% in the no-test condition (see Fig. 1), $t < 1$, $p_{rep} = .62$. Why did these items fail to show a significant testing effect? The testing effect tends to increase with delay (Roediger & Karpicke, 2006), and it is possible that the delay in this experiment (25 min) was not long enough for the advantage of testing to be revealed, though the difference between conditions was in the expected direction.

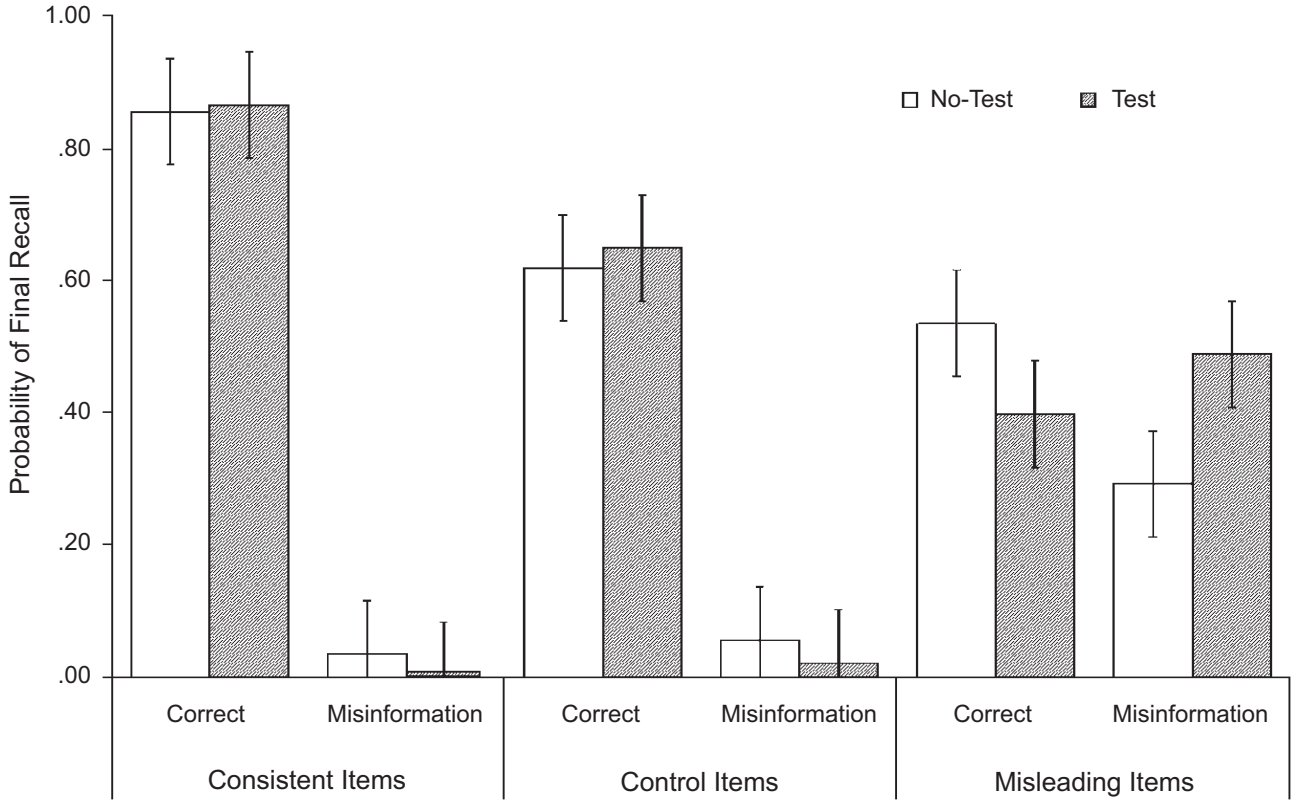

Fig. 1. Results from the final test in Experiment 1a: probability of responding with correct information and of responding with misinformation as a function of item type (consistent vs. control vs. misleading) and whether or not subjects had taken an immediate cued-recall test before exposure to the misinformation (test condition vs. no-test condition). Error bars indicate within-subjects 95% confidence intervals.

EXPERIMENT 1B

Experiment 1b was designed to extend the findings of Experiment 1a to a different subject group—older adults. Older adults are a relevant population for study because they are targets of crime and thus often serve as eyewitnesses. In addition, research suggests that they are particularly susceptible to the misinformation effect (Roediger & Geraci, 2007), but are also capable of suppressing false memories with appropriate training (McDermott & Chan, 2006; Thomas & Bulevich, 2006). Therefore, it was unclear whether older adults would show the same counterintuitive effect as the younger adults.

TABLE 1

Probabilities of "Other" and "No Answer" Responses as a Function of Testing Condition and Item Type

	Experiment 1a		Experiment 1b		Experiment 2	
Item type and response	Test condition	No-test condition	Test condition	No-test condition	Test condition	No-test condition
Consistent items						
Other	.11 (.10)	.11 (.07)	.19 (.19)	.23 (.19)	.18 (.13)	.16 (.11)
No answer	.02 (.05)	.00 (.00)	.08 (.12)	.13 (.22)	.02 (.04)	.03 (.06)
Control items						
Other	.26 (.17)	.30 (.18)	.35 (.22)	.41 (.20)	.25 (.14)	.34 (.17)
No answer	.07 (.11)	.03 (.05)	.20 (.21)	.23 (.19)	.07 (.09)	.14 (.14)
Misleading items						
Other	.09 (.11)	.17 (.19)	.20 (.15)	.30 (.14)	.18 (.13)	.24 (.15)
No answer	.03 (.05)	.01 (.03)	.08 (.14)	.13 (.17)	.04 (.11)	.02 (.05)

Note. Standard deviations are given in parentheses.

Method

Participants

Sixty healthy, community-dwelling older adults (39 females and 21 males; $n = 30$ in each testing condition) participated in exchange for $15. They were recruited from the older-adult subject pool maintained by the psychology department at Washington University. None of the participants had seen "24" before. The average age was 72.57 years ($SD = 8.56$) for the test group and 74.37 years ($SD = 7.79$) for the no-test group, $t < 1$. Average years of education was 15.33 ($SD = 3.46$) for the test group and 14.00 ($SD = 2.42$) for the no-test group, $t(58) = 1.73$, $p = .09$. Finally, the average vocabulary score was .72 ($SD = .27$) for the test group and .58 ($SD = .27$) for the no-test group, $t(58) = 1.94$, $p = .06$.[3]

Materials and Procedure

The materials and procedure were the same as in Experiment 1a with two exceptions. First, subjects completed the tests on paper instead of on a computer. Second, the older adults worked on logic and lateral-thinking problems (available on the Web at http://www.folj.com/lateral/) instead of the OSPAN task, because pilot testing revealed that the OSPAN task was too difficult for them.

Results and Discussion

Older adults recalled approximately 40% of the details correctly during the initial test and provided an answer that matched the misinformation 7% of the time. They did not answer 19% of the questions, and 34% of the time they provided an answer in the "other" category.

Figure 2 displays results of the final test and shows that older adults demonstrated the same surprising pattern as their younger counterparts. The three-way interaction of testing condition, item type, and response type was significant, $F(2, 57) = 7.86$, $p_{rep} = .99$. That is, like younger adults, older adults showed dramatically heightened (~20%) susceptibility to misinformation if they had taken the initial test, $t(58) = 3.87$, $p_{rep} = .99$. Interestingly, unlike younger adults, older adults exhibited a sizable testing effect on both the control items (~9%) and the consistent items (~10%), though neither comparison showed a statistically significant testing effect, possibly because of power issues (observed powers < .35), both ps > .10, but both p_{rep}s > .79. One possible reason that older adults demonstrated a greater (though nonsignificant) testing effect than younger adults is that older adults might forget information at a faster rate (Floden, Stuss, & Craik, 2000), and the testing effect is typically more robust after forgetting has set in. (See Table 1 for probabilities of "other" and "no answer" responses.)

In sum, although the older adults were much less likely than the younger adults to recall the correct details during the final test, they were as likely as the younger adults to recall the misinformation. Critically, both younger and older adults were more susceptible to the misinformation effect after having taken an initial recall test.

EXPERIMENT 2

Experiments 1a and 1b show that, contrary to the hypothesis suggested by the testing effect, initial testing can substantially enhance the misinformation effect. What processes could have led to such counterintuitive results? Two findings may prove helpful in further understanding this reversed testing effect in the misinformation paradigm. The first, coming from the verbal-learning literature, is the *insulation effect* (Tulving & Watkins, 1974). Specifically, if subjects need to learn two paired associates sequentially (e.g., A-B and then A-D), recall of the second is improved if subjects have taken a test on the first before they learn the second. That is, prior testing enhances learning of new information. Thus, perhaps Experiments 1a and 1b showed a reversed testing effect because the subjects in the test condition learned the misinformation better than the subjects in the no-test condition (see also Izawa, 1967).

Another finding that may prove helpful in explaining our results is that consolidated memories can return to a labile state after they have been reactivated (Nader, Schafe, & Le Doux, 2000; Walker, Brakefield, Hobson, & Stickgold, 2003). That is, when a consolidated memory is reactivated, it must undergo reconsolidation, during which it is particularly susceptible to interference (Nader et al., 2000; Walker et al., 2003). Thus, perhaps subjects in the test condition of Experiments 1a and 1b reactivated their memories of the witnessed event during the immediate test, thereby making those memories more susceptible to interference (by misinformation) than the memories of subjects in the no-test condition.[4]

[3]To ensure that subject-selection artifacts did not contribute to the findings of Experiment 1b, we ran additional analyses. We equated vocabulary scores by selecting the 25 highest-scoring individuals in the no-test group ($M = .66$, $SD = .21$) and the 25 lowest-scoring individuals in the test group ($M = .66$, $SD = .27$), $t < 1$. Results for the misleading items still demonstrated a reversed testing effect on recall of misinformation (Ms = 32% and 50% for the no-test and test groups, respectively), $t(48) = 3.06$, and a regular, but nonsignificant, testing effect was found for accurate recall of the control items (Ms = 32% and 37%, $t < 1$) and the consistent items (Ms = 61% and 66%, $t < 1$). Similarly, we equated education level by comparing the 25 individuals with the most education in the no-test condition ($M = 14.56$, $SD = 2.14$) with the 25 individuals with the least education in the test condition ($M = 14.28$, $SD = 2.70$), $t < 1$. Again, we found a reversed testing effect on recall of misinformation (Ms = 32% and 51% for the no-test and test groups, respectively), $t(48) = 3.41$, and a regular, but nonsignificant, testing effect on accurate recall of the control items (Ms = 32% and 35%, $t < 1$) and the consistent items (Ms = 61% and 66%, $t < 1$). These results suggest that subject-selection artifacts did not contribute to the reversed testing effect on recall of misinformation.

[4]One assumption of this hypothesis is that memories of the video event had been consolidated to a greater extent in the no-test condition than in the test condition at the point when subjects encountered the interfering audio narrative—a delay of approximately 25 min. Although completion of memory consolidation is typically thought to takes hours to days (or years), recently researchers have suggested that consolidation can occur within minutes of encoding (Fulton, Kemenes, Andrew, & Benjamin, 2005).

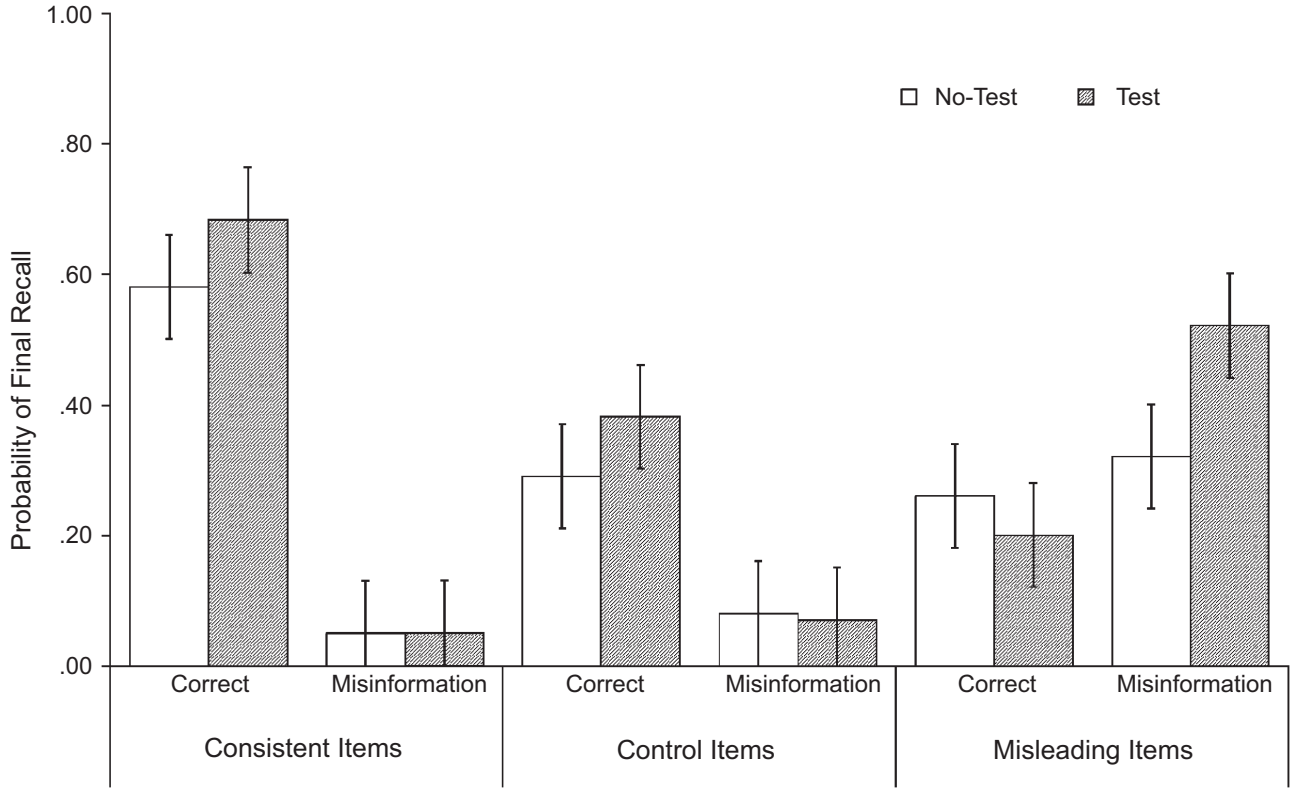

Fig. 2. Results from the final test in Experiment 1b: probability of responding with correct information and of responding with misinformation as a function of item type (consistent vs. control vs. misleading) and whether or not subjects had taken an immediate cued-recall test before exposure to the misinformation (test condition vs. no-test condition). Error bars indicate within-subjects 95% confidence intervals.

In Experiment 2, we tested these possibilities in a modified-modified free-recall (MMFR) design. Barnes and Underwood (1959) devised the MMFR procedure to minimize response competition when subjects needed to recall multiple targets associated with a single cue. In this procedure, subjects were told to recall everything that was associated with a cue regardless of the study order. That is, subjects who studied the paired associates A-B and A-D should have recalled both B and D when they encountered cue A.

Using the MMFR task allows one to observe how initial testing affects learning of subsequent misinformation. Specifically, according to the insulation effect, initial testing should enhance the recall probability of the misinformation, but should have little effect on the recall probability of the original (correct) details. In contrast, according to the reconsolidation account, initial testing should increase the original memory's susceptibility to interference, thereby reducing the probability of accurate recall, but should have little effect on recall of the misinformation.

Method

Participants

A total of 48 undergraduate students (28 females and 20 males; $n = 24$ in each testing condition) from Washington University participated. The witnessed event was the same episode of "24" used in the previous experiments. None of the participants had seen this particular episode within 1 month of the experiment, and 42 of them had never seen the first season of "24."

Procedure

All experimental protocols were the same as in Experiment 1a until the final test, at which point subjects were given the MMFR instructions. Subjects were told to recall everything they could remember for each question in the final test, regardless of the accuracy or source of the memory.

Results and Discussion

On the initial test, 63% of the responses were accurate, and 5% reported misinformation. Subjects gave no answer to 5% of the questions, and 27% of the responses were classified as "other." Figure 3 displays results of the final test (see also Table 1) and suggests that the reversed testing effect on recall of misinformation can be attributed to enhanced learning of the misinformation, which supports the insulation-effect account. We provide statistical support for this impression before turning to the reconsolidation account.

As in Experiments 1a and 1b, a 2 (testing condition) × 3 (item type) × 2 (response type) ANOVA showed a three-way inter-

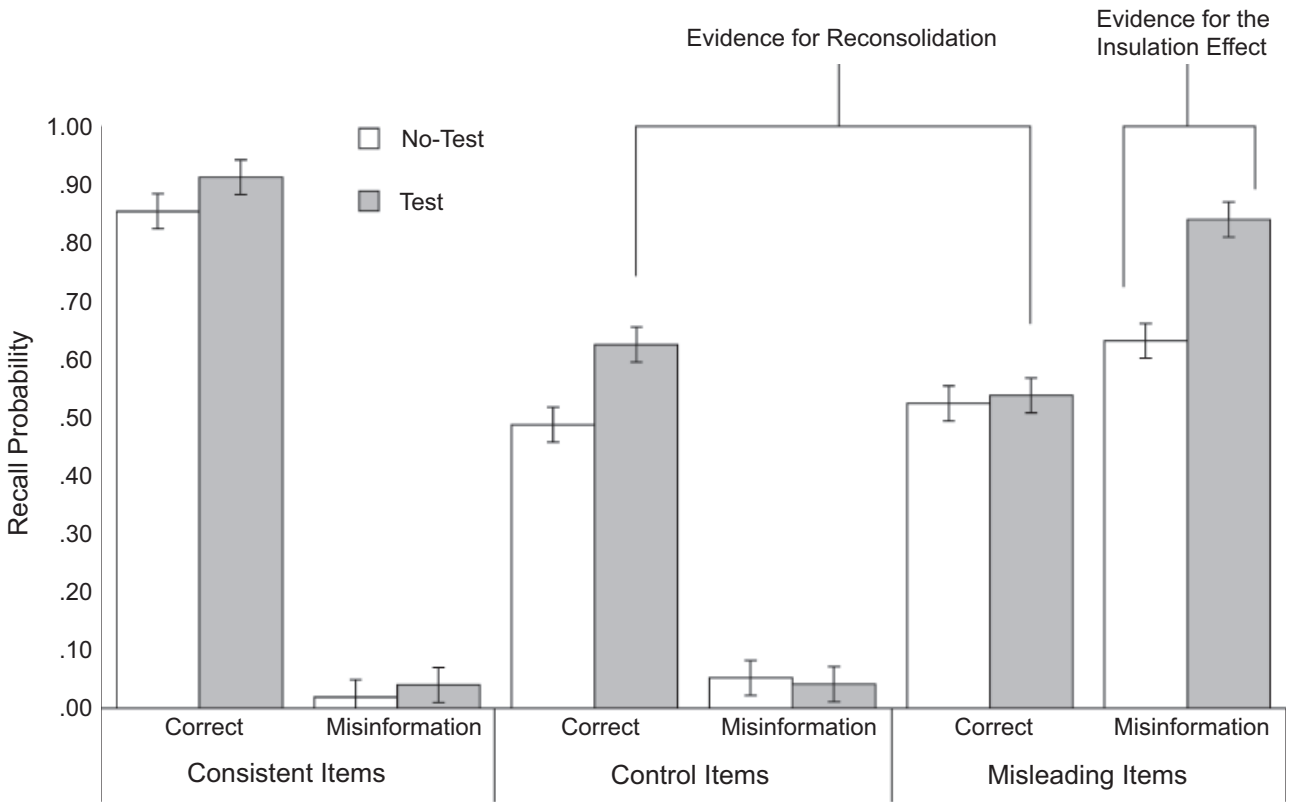

Fig. 3. Results from Experiment 2: probability of recalling correct information and of recalling misinformation as a function of item type (consistent vs. control vs. misleading) and whether or not subjects had taken an immediate cued-recall test before exposure to the misinformation (test condition vs. no-test condition). Brackets indicate the comparisons relevant to examining whether testing served to enhance learning of the misinformation (insulation effect) or to increase interference between the original and new information (reconsolidation). Error bars indicate within-subjects 95% confidence intervals.

action, $F(2, 45) = 9.12$, $p_{rep} = .99$. Of particular interest here is whether testing affected the recall probabilities for the misleading items, and it did. Specifically, there was a significant interaction between testing condition and response type, $F(1, 46) = 9.99$, $p_{rep} = .97$. A planned comparison showed that, as predicted by the insulation-effect account, subjects who had taken the initial test recalled considerably more misinformation from the misleading items than did subjects who had not taken the initial test (21% more), $t(46) = 5.03$, $p_{rep} = .99$. Moreover, the magnitude of this effect closely matched the magnitude of the reversed testing effect in Experiments 1a and 1b.

Results for the misleading items also showed that probabilities of correct recall did not differ between the test condition (54%) and the no-test condition (52%), $t < 1$, $p_{rep} = .30$ (see Fig. 3). On the surface, this null effect may seem to indicate that the reconsolidation account fails to explain the reversed testing effect we observed. However, this comparison is clouded by a confound between the benefits of testing and the negative impact of interference during the reconsolidation process. That is, this null effect might have occurred because a benefit from taking the initial test was masked by the negative impact of reconsolidation.

To examine whether our data support the reconsolidation account when this confound is not present, we examined whether the level of interference differed between the test and no-test conditions. The magnitude of interference was estimated by the within-subjects comparison between the accurate-recall probabilities of the control and misleading items. A 2 (item type: control vs. misleading) × 2 (testing condition: test vs. no-test) ANOVA on accurate recall revealed a significant interaction between item type and testing condition, $F(1, 46) = 5.47$, $p_{rep} = .92$. Specifically, no significant interference was found for subjects who did not reactivate their memories before encountering the misinformation (a −3% interference effect), $t(23) = 1.07$, $p_{rep} = .65$. However, substantial interference was observed (a 9% interference effect) for subjects in the test condition, $t(23) = 2.16$, $p_{rep} = .89$. This pattern is consistent with the reconsolidation account, which states that recently retrieved memories become particularly susceptible to interference.

Experiment 2 also showed a significant (13%) testing effect for the control items, $t(46) = 2.68$, $p_{rep} = .95$, such that initial testing enhanced later recall of correct information if no interfering misinformation was presented. This result shows that it is possible to obtain the reversed testing effect on recall of

misinformation even when a significant, regular testing effect is found for control items.

GENERAL DISCUSSION

Our results provide a first look into how immediate recall affects later eyewitness suggestibility. Contrary to the expectation that immediate recall would enhance retention of details of a witnessed event and thus reduce an eyewitness's susceptibility to misinformation, we found that immediate recall actually intensifies the misinformation effect (for both younger and older adults). This reversed testing effect on recall of misinformation might be based on two mechanisms. First, initial recall enhances the learning of later misinformation, and second, initial recall increases the recently recalled items' susceptibility to interference.

Testing Enhances Learning of Misinformation

The finding that retrieval enhances learning of subsequent misinformation joins other evidence in showing that testing has two primary effects on learning. First, testing directly enhances long-term retention of the tested material (Chan et al., 2006; Roediger & Karpicke, 2006). Second, testing enhances learning of new material that is presented after the initial test (Izawa, 1967; Tulving & Watkins, 1974). How can testing enhance subsequent learning of new, misleading information? There are two possibilities. First, testing may reduce the level of proactive interference that original learning exerts on new learning (Chan & McDermott, 2007b; Szpunar, McDermott, & Roediger, in press). One possible way for this to happen is that memory for the test episode may serve to differentiate the first encoding event (witnessed event) from the second encoding event (misinformation narrative). Second, testing may potentiate new learning by drawing attention to specific aspects of the witnessed event. When subjects encountered the misinformation narrative, the items that were presented during the initial test might have "popped out" and thus been better encoded. This would explain why Lane et al. (2001) did not find a reversed testing effect. That is, their immediate test was free recall, and subjects might not have recalled the critical details (i.e., the details that would eventually be presented as misinformation) during that test.

Recently Recalled Information Is Particularly Susceptible to Interference

The experiments we have reported demonstrate that recently recalled information may be particularly susceptible to interference. Although this pattern is consistent with the reconsolidation account, it does not completely rule out other potential explanations. In particular, it is possible that subjects in the test condition did not experience more interference (relative to subjects in the no-test condition) because of a reconsolidation process; rather, enhanced learning of the misinformation may have increased the level of response competition at retrieval during the final test. Because initial testing enhanced learning of the misinformation, it might also have increased the likelihood that recall of the misinformation would block retrieval of the original detail (Roediger, 1978), even though the MMFR procedure was supposed to minimize such blocking. Although this response-competition explanation seems plausible, there is one piece of evidence against it. Specifically, if response competition at retrieval was the basis for our pattern of results in the MMFR procedure, then it is difficult to see how subjects in the no-test condition showed no interference from the misinformation at all. That is, among these subjects, the probabilities of correct recall did not differ between the misleading items (recall of which would supposedly have been affected by interference from misinformation) and the control items (recall of which would supposedly not have been affected by such interference). This finding suggests that the MMFR procedure, to an extent, minimized the influence of response competition. Therefore, we might have indeed obtained evidence, although perhaps tentative evidence, for a reconsolidation process in human episodic memory (see also Hupbach, Gomez, Hardt, & Nadel, 2007).

Why are memories that are undergoing reconsolidation particularly susceptible to interference? From a cognitive perspective, recently reactivated memories may enhance binding of memories from the original encoding episode with memories from the new encoding episode because the recently recalled memories provide a clear context for such binding to occur (Lyle & Johnson, 2006). This hypothesis, though somewhat speculative, is supported by the evidence that the hippocampus plays an important role in both reconsolidation (Rossato et al., 2007) and binding (Mitchell, Johnson, Raye, & D'Esposito, 2000).

Conclusion

Regardless of the reasons underlying the reversed testing effect on recall of misinformation, our results indicate that even psychologists might have underestimated the malleability of eyewitness memory. When people have recently recalled information about a witnessed event and are then exposed to misinformation about that event, their susceptibility to such misinformation is increased substantially—and this effect occurs for both younger and older adults. These results confirm the notion that recall not only indicates what one knows, but also changes what one knows, and sometimes these changes can have far-reaching, and perhaps negative, consequences.

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