TESTING: POTENTIAL TO OVERWRITE ORIGINAL MEMORY?

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By

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CHAPTER I

INTRODUCTION

A new memory must undergo an initial consolidation process in order to become a stable memory trace (Dudai, Y, 2004; McGaugh, 2000). If the consolidated memory is later reactivated, the memory must be re-stabilized in a reconsolidation process. Importantly, according to the reconsolidation hypothesis, following reactivation a memory may be made temporarily labile under certain circumstances. It is possible to impair or facilitate the original memory during this period if the reconsolidation process has not completed (e.g. Nader, 2000; Rodriguez, Horne, & Padilla, 1999; see Agren, 2014 for recent review).

Despite a growing body of evidence for reconsolidation based amnesia in non-human animals (e.g. Monfils, Cowansage, Klann, & LeDoux, 2009), there is considerably less evidence in humans. This is in part due to the unsuitability of many pharmacological consolidation blocking drugs for human use (for exceptions see Kindt, Soeter, & Vervliet, 2009; Soeter & Kindt, 2010; 2012). Despite this difficulty, there is evidence of reconsolidation in humans in fear conditioning (Schiller, Monfils, Raio, Johnson, Ledoux, Phelps, 2009; Agren et al., 2012), appetitive memory (Xue et al., 2012), and procedural memory (Walker, Brakefield, Hobson, & Stickgold, 2003). The evidence for reconsolidation based overwriting of declarative memories in humans has provided weaker results. While there has been some evidence consistent with reconsolidation
(Forcato, Argibay, Pedreira, & Maldonado, 2009; Forcato et al., 2007; Forcato, Rodriguez, Pedreira, & Maldonado, 2010; Hupbach, Gomez, Hardt, & Nadel, 2007; Hupbach, Gomez, Nadel, 2009, 2011; Hupbach, Hardt, Gomez, & Nadel, 2008), these findings are open to alternative explanations (e.g., the temporal context model, Sederberg et al., 2011).

The idea that new information can overwrite an existing memory has not been confined to research on reconsolidation. In a seminal study of eyewitness suggestibility, Loftus, Miller, and Burns (1978) documented an experimental finding that would come to be known as the misinformation effect. Participants were shown a slide sequence depicting a car running a stop sign leading to an accident. During later post-event questioning, participants in the misled condition received misinformation about the traffic sign (i.e., the stop sign was incorrectly described as a yield sign), whereas participants in a control condition received no misinformation. In the final phase of the experiment, all participants received a test of their memory for the events depicted in the slide sequence where they were given a forced choice between a stop sign (the sign they had witnessed) and a yield sign (the post-event misinformation). The finding of interest was that 75% of control participants (who had not been misled), correctly chose the stop sign, but only 41% of the misled participants did so. Hence, the majority of misled participants incorrectly chose the suggested item (yield sign) over the stop sign they had actually seen. This misinformation effect – the finding that misled participants report the misinformation on tests of memory for the witnessed event – is a highly robust and reliable finding that has been replicated in countless studies across a wide range of
experimental materials, participant populations and methods for introducing the misleading suggestion (e.g. Ackil & Zaragoza, 1998; Ceci & Bruck, 1993; Higham, 1998; Karpel, Hoyer, & Toglia, 2001; Loftus, 1993; Loftus & Hoffman, 1989; Sutherland & Hayne, 2001; see Loftus, 2005; Zaragoza, Belli, & Payment, 2006 for reviews).

The original theoretical account of the misinformation effect proposed by Loftus (Loftus 1979; Loftus & Loftus, 1980; Loftus et al., 1978) fits well with the notion that memories can be overwritten during a reconsolidation process. Specifically, Loftus proposed a “destructive updating” process whereby misinformation replaced memory for the original event, effectively erasing, or overwriting, the original memory. This claim that misinformation erases (or overwrites) memory for the original event sparked debate with others who argued that post-event misinformation rendered the original memory less accessible (e.g., Bekerian & Bowers, 1983; Christiaansen & Ochalek, 1983), but did not erase it from memory.

Arguing against a destructive updating process (as well as other forms of memory impairment caused by misinformation) was an article by McCloskey and Zaragoza (1985). The central argument advanced by McCloskey and Zaragoza (1985) was that misinformation effects cannot be taken as evidence of impaired memory for the witnessed event (hereafter referred to as “memory impairment”), because there are a number of other reasons, unrelated to memory impairment, why misled participants can be expected to perform more poorly than controls on these tests. An important observation made by McCloskey and Zaragoza was that, even in the absence of suggestive influences, participants’ memory for the originally witnessed events was far
from perfect. For example, in the Loftus et al. (1978) study described above, control performance was well below ceiling (75% correct on a 2-alternative forced choice), presumably because some participants failed to encode the critical details or had forgotten them by the time of the test. For participants who have no memory of the original critical item, the misinformation serves to fill a gap in memory, as there is no contradictory memory to overwrite. McCloskey and Zaragoza further reasoned that misled participants who do not remember the original item (stop sign) are likely to embrace the suggested item (yield sign) as the truth, because they have no reason to distrust it (i.e., it was presented by the experimenter who is an authoritative source, and they have no memory of their own to contradict it). Hence, participants who do not remember the witnessed detail (stop sign) should overwhelmingly choose the more recently presented misinformation (yield sign) on tests of memory for the witnessed event, because the misinformation is all they remember and they believe it to be true. In contrast, control participants will have no reason to select the incorrect, misleading alternative (yield sign) on the test. Control participants were never exposed to the misinformation, and for them, the misleading item (yield sign) is new. Instead, control participants who fail to remember the originally-witnessed item will be forced to guess on the test, and can be expected to choose the correct answer (stop sign) by chance 50% of the time. Hence, when the subset of participants who fail to remember the originally-witnessed critical detail are faced with a choice between the originally witnessed and misleading details (e.g., stop sign vs. yield sign), those in the misled condition will be systematically biased toward choosing the incorrect, misleading item (0% correct), and
those in the control condition will guess correctly 50% of the time, thus resulting in poorer overall performance in the misled group.

In addition to the above, McCloskey and Zaragoza (1985) offered several other reasons why misled participants can be expected to perform more poorly on these tests, even in the absence of memory impairment. For example, McCloskey and Zaragoza note that because the misinformation is presented by the experimenter as truth, even participants who do remember the original critical detail (stop sign) may sometimes choose to select the misleading alternative (yield sign) on the test, either because they feel pressure to go along with the experimenter, or because the misinformation leads them to doubt their own memory (e.g., “I thought it was a stop sign, but I guess it must have been a yield sign.”). Consistent with this proposal, studies have shown that when a warning is used alerting participants that they may have been misled, the misinformation effect is attenuated (see Blank & Launay, 2014 for recent meta-analysis). In summary, according to McCloskey and Zaragoza (1985), there are a variety of reasons why misled participants should be expected to choose/report the misinformation on tests of memory for the witnessed event, all of which are completely unrelated to impaired memory for the originally-witnessed event. Hence, the finding that misled participants perform more poorly than controls, cannot be taken as evidence that memory for the originally-witnessed details has been impaired by the misinformation.

To assess whether post-event misinformation impairs the original memory, McCloskey and Zaragoza (1985) developed a Modified Test procedure, where the misleading suggestion was not an option. In their experiments, participants who had
witnessed an office theft where a maintenance man was holding a tool (e.g., a hammer), were later exposed to misinformation (e.g., that he was holding a screwdriver). Unlike the traditional measure of eyewitness suggestibility developed by Loftus et al. (1978), participants were not given a choice between the originally-seen detail and the misinformation (e.g., hammer vs. screwdriver). Rather, on the final test of memory, participants in the Modified Test condition were given a choice between the originally-seen item and a novel item (e.g., hammer vs. wrench). If misinformation impairs memory for the hammer, misled participants should perform more poorly on the Modified Test. In six experiments conducted with the Modified Test procedure they found no evidence of memory impairment, insofar as misled participants were as accurate as controls (grand mean was 72% versus 75% for the misled and control conditions, respectively). In the same experiments, McCloskey and Zaragoza (1985) showed that when a second group of participants was given the standard test (a choice between the original and suggested items, e.g., hammer vs. screwdriver) they obtained robust misinformation effects (grand mean was 37% versus 72% accuracy for misled and control conditions, respectively). Collectively, the results showed that when misled participants are given the opportunity to select the misleading alternative on the final test, the majority of them do so. However, when the misleading alternative is not an option on the test, misled participants revealed that they could remember the originally witnessed event as well as control participants who were not misled.

Following the publication of McCloskey and Zaragoza (1985), the overwriting hypothesis fell out of favor, in part because of the inherent difficulty of proving that
information has been erased from memory permanently. Even if one were to show impaired memory for the originally-witnessed items using the Modified Test (and some studies have, e.g., Schreiber & Sergent, 1998), it is difficult to rule out the possibility that the misinformation has merely impaired retrieval of the original memory, rather than erasing it from memory altogether.

Now, several decades later, a recent paper by Chan and LaPaglia (2013) claims to provide new evidence that misleading post-event suggestions can cause reconsolidation-based overwriting of originally witnessed memories. Guided by research and theories of reconsolidation, Chan and LaPaglia (2013) reasoned that overwriting of originally-witnessed memories is likely to be dependent on whether or not the original memory is reactivated prior to exposure to the misinformation. To this end, they conducted experiments using the standard, 3-phase, misinformation paradigm (participants witnessed an event, listened to a narrative account of the event containing contradictory misinformation, and received a final test of their memory for the witnessed event), but introduced one, key, innovation: half the participants were given an additional cued recall test of the witnessed critical details prior to exposure to the misinformation, and the other half were not. The purpose of the cued recall test was to induce participants to reactivate the original memory prior to being misled, thereby rendering it susceptible to alteration by the misinformation during reconsolidation. Participants who were not given the cued recall test completed a filler task, and hence were treated identically to participants in the typical misinformation experiment.
To assess whether the original memory for the critical items had been impaired by the misinformation, Chan and LaPaglia (2013) used a misinformation-free true/false recognition test (Belli, 1989; Tversky & Tuchin, 1989). This test is in some ways similar to McCloskey and Zaragoza’s Modified Test, in that the misinformation was never presented to participants at the time of test. However, whereas the Modified recognition test is a 2-alternative forced choice, the test employed by Chan and LaPaglia (2013) had participants evaluate each test item separately (true or false). For some critical items, participants received the originally witnessed version, and for others they received a novel version. To illustrate, in Chan and LaPaglia (2013), participants saw an episode of the television show “24” that depicted a terrorist using a hypodermic syringe on a flight attendant. Participants in the misled condition were later misinformed that the terrorist had instead used a stun gun. At the time of test, participants were either presented with the witnessed version (“the terrorist used a hypodermic syringe on the flight attendant” – True or False) or a novel false detail (e.g., “the terrorist used a chloroform rag on the flight attendant” – True or False). The measure of memory for the critical details was hits minus false alarms (i.e., accurate “true” responses to witnessed details minus incorrect “true” responses to novel details). As in prior studies, the measure of memory impairment was poorer memory performance in the misled condition relative to the not-misinformed control condition.

Chan and LaPaglia (2013) predicted that on the final test of memory for the witnessed event, memory impairment would be observed in the reactivation conditions only, and their results supported this prediction. That is, for participants that did not have
their memory reactivated prior to receiving the post-event narrative, there was no evidence of memory impairment caused by misinformation, as misled performance was as accurate as control performance (thus replicating McCloskey and Zaragoza (1985). However, for participants that had their memory reactivated via a cued recall test, performance was significantly worse in the misled condition relative to the control condition (the same result was obtained when the analysis was restricted to those cases where participants correctly retrieved the witnessed detail on the initial test). Importantly, this impairment effect was shown to occur only when the misinformation followed reactivation during the reconsolidation window (i.e. when the narrative followed shortly after the cued recall test); there was no impairment effect when there was a 48 hour delay between the initial test and the misinformation. This evidence was put forth as the first data to demonstrate “that human memory can be selectively rewritten during reconsolidation” (Chan & Lapaglia, 2013).

Whereas Chan and LaPaglia (2013) focused on the consequences of reactivation-before-misinformation on memory for the originally witnessed details, other work by Chan and others has shown that the very same cued recall manipulation also has powerful effects on later memory for the misinformation. Specifically, numerous studies have shown that participants who are given a cued recall test of the witnessed event prior to being misled later show greatly increased reporting of the misinformation on a final cued recall test, relative to those who were not tested (e.g. Chan & Langley, 2011; Chan & LaPaglia, 2011; Chan, Thomas, & Bulevich, 2009; Gordon & Thomas, 2014), a finding known as “retrieval enhanced suggestibility” (RES). Note that RES can only be observed
on tests that permit participants to report the misleading suggestion and hence will not be observed on misinformation-free tests, such as those discussed above (e.g., Chan and LaPaglia, 2013; McCloskey and Zaragoza, 1985). It is interesting to note that RES is most likely to be observed when misinformation follows reactivation closely in time, and is attenuated when there is a long delay between reactivation and misinformation exposure (Chan & LaPaglia, 2011). Hence, there are close parallels between situations that Chan and LaPaglia (2013) found gave rise to memory impairment effects following reactivation, and those that have been found to predict RES.

The goal of the present study was to assess if I could replicate Chan and LaPaglia’s (2013) finding that reactivating a memory renders it susceptible to impairment using a different set of materials and using the Modified Test. Although the findings of Chan and LaPaglia (2013) are consistent with reactivation-dependent overwriting, there are alternative explanations for their results. In particular, for many of the same reasons discussed above, misled participants may perform more poorly than controls on a misinformation-free true/false test even if their memory for the witnessed details has not been overwritten. For example, to the extent that participants believe the misinformation is true, they may reject their true memories as false on this test, even though they can still remember them.

In the present study, the Modified Test was used to assess potential reactivation-dependent overwriting, because performance on the Modified Test should not be influenced by belief in the misinformation. If, as Chan and LaPaglia (2013) claim, reactivating a memory makes it susceptible to being overwritten by post-event
misinformation, one should be able to replicate their findings using the Modified Test. Like Chan and LaPaglia (2013) the present study uses a reactivation-relearning paradigm. Participants were shown a slide sequence depicting an office theft (McCloskey & Zaragoza, 1985) which served as the eyewitness event. Half of the participants were then tested on details from the slide sequence with a cued recall test, serving to reactivate their memory for the event. All participants then read a narrative containing misinformation (e.g. a hammer was described as a screwdriver) for two of the critical details (Misled condition) and described the two remaining critical details (Control condition) in a generic way (e.g. a hammer was described as a tool). To assess potential memory impairment caused by exposure to misinformation, in Experiments 1a and 1b, participants were given a Modified Test, which gave them a forced choice between the originally-witnessed item and a novel item (e.g., hammer vs. wrench).

Rather than using the materials from Chan & LaPaglia (2013), for the experiments reported here, I chose to use McCloskey and Zaragoza’s (1985) materials because they allow for complete counterbalancing of the critical items (i.e., having three versions of each critical item allows each version to serve equally often as the original item, the misleading item, and the novel item across the experiment), which eliminates potential item effects on the Modified Test. Because I am using a new set of materials it was important to establish that I could replicate the RES effect with the current materials (i.e., demonstrate that testing a memory prior to misinformation exposure increases misinformation reporting on a final test). In this way, I could establish that the reactivation manipulation used here produces the same effects that Chan and others have
obtained in studies documenting RES. Hence in Experiment 1a participants received two tests of memory for the witnessed event: a cued recall test (for assessing RES) followed by a Modified Recognition Test (for assessing memory impairment). In Experiment 1b the cued recall test was eliminated in order to have a cleaner measure of memory impairment using just the Modified Recognition Test.
CHAPTER II

EXPERIMENT 1a

Method

Participants
A total of 236 (145 female, 74 male, 17 gender not reported) undergraduates completed the experiment in partial fulfillment of an introductory psychology course requirement. Sample size was based on an a-priori power analysis (G*Power 3; Faul, Erdfelder, Lang, & Buchner, 2007) to detect an effect size \( d = .37 \) (based on an estimated between groups effect size of experiment 4 in Chan and LaPaglia, 2013), at \( \alpha = .05 \), \( 1-\beta = .80 \) which indicated a necessary sample of 228 participants. The experimental design was a 2 (Initial Test: Initial Test, No Test) x 2 (Item Type: Misled, Control) mixed design. Initial Test was manipulated between-subjects and Item Type was manipulated within-subjects. One participant was removed from analyses for failing to answer a critical item on the Modified Test. Groups of participants were randomly assigned to either the Initial Test group \( (N = 117) \) or the No Test Group \( (N = 118) \).\(^1\) Participant mean age was 19.55 years (SD = 2.65).

Materials and procedure

\(^1\) Note that complete counterbalancing is not achieved when using data from all participants due to testing participants in groups. For the purposes of power all participants are included. The significance of all analyses reported do not differ when restricting data to achieve complete counterbalancing (total \( N = 216 \)).
Participants were tested in groups of up to seven. As a cover for the true purpose of the experiment, participants were informed that the experiment involved their intuitions about memory for different presentation formats and were instructed to pay close attention to the slides as well as the written narrative.

**Phase 1: Eyewitness Event**

Participants first viewed a series of 79 slides (displayed at 4 seconds/slide) depicting an office theft (McCloskey & Zaragoza, 1985). The slide sequence contained four critical items (a coffee jar, magazine, soda can, and a tool). Across participants, 3 versions of each critical item were used with each participant viewing one version of each critical item (e.g. 1/3 of participants saw a maintenance man holding a hammer, 1/3 holding a screwdriver, and 1/3 holding a wrench). The three versions of each of the four critical items were as follows: coffee jar (Folgers, Nescafe, Maxwell House), magazine (Glamour, Vogue, Mademoiselle), soda can (Coke, Sunkist, 7Up), and tool (hammer, wrench, screwdriver).

**Phase 2: Memory Reactivation Manipulation**

Immediately following the slide sequence, participants in the Initial Test condition were administered a 17-question cued recall test on the slide sequence, with one question about each of the four critical items (see Appendix A), and the remaining 13 questions serving as fillers. The questions about the critical items served as the reactivation manipulation. Participants were instructed to be as accurate as possible and were told not to guess. They were permitted to leave questions blank. The cued recall test
lasted approximately 5 minutes. Participants in the No Test condition, were not given the cued recall test, and instead worked on a word search puzzle for 5 minutes.

Phase 3: Misleading Post-event Suggestion

All participants were then given a narrative to read describing the events of the slide sequence. For each participant, the narrative contained contradictory misinformation about two of the critical items they had witnessed (Misled condition). For example, in the Misled condition, participants that originally witnessed the maintenance man holding a hammer read a narrative describing the tool as either a screwdriver or a wrench. The remaining two critical items served in the Control condition and these were described in the narrative in a generic, or neutral, manner (e.g. hammer described as a “tool”). Across participants, the materials were counterbalanced, such that each of the four critical items served equally often in the Misled and Control conditions. In addition, in the Misled condition, each of the 3 versions of each critical item served equally often as the originally seen and contradictory misinformation. Reading of the narrative was self-paced. However, all participants were required to spend 10 minutes on the task in order to equate time. The instructions stated that the narrative described the event they had witnessed and did not inform participants that some details were inaccurate.

Following the narrative, and consistent with the cover task, all participants were given a question regarding their intuitions about their memory for visually presented and written material. As this is only a cover task, responses on this question are not reported here. Immediately following the question, all participants were given a word search puzzle filler task for 8 minutes.
Phase 4: Final Tests of Memory for the Witnessed Event

Final Cued Recall Test: To assess whether RES would be obtained with these materials, all participants were administered the same 17-question cued recall test that had been given earlier to participants in the Initial Test condition. Participants were instructed to answer the questions based on what they witnessed in the slide sequence. For purposes of assessing RES, the question of interest is whether participants in the Initial Test group were more likely than participants in the No Test group to report the misinformation when tested on their memory for the originally-witnessed items in the Misled condition.

Test of Memory Impairment: To assess potential memory impairment, all participants were then given a 17-question Modified Test (concerning the same 17 details as the cued recall test, see Appendix B). All test questions were in the form of sentences with a missing word and two-alternative forced choices. For example “The man put the calculator in the tool box under a _____. ” The two alternatives consisted of the originally witnessed item and a novel distractor. For items serving in the Misled condition, the novel distractor was dictated by the originally witnessed item and the item that served as misinformation in the narrative. For example, if the participant witnessed a hammer and was later misinformed that it was a screwdriver, the two alternatives at the time of test were hammer and wrench. The misinformation was never an option on the modified test. Across participants, each version of each critical item served equally often as the original, misinformation, and novel distractor. Additionally, the position of the correct answer (left/right) was counterbalanced across items and participants.
If exposure to misinformation leads to memory impairment, accuracy in the Misled condition should be lower than control performance on this test. Given McCloskey and Zaragoza’s (1985) findings, I anticipated that there would be no evidence of memory impairment in the No Test group. The question of primary interest was whether memory impairment would be observed in the Initial Test group, where the original memory had been reactivated before exposure to the misinformation.

Because the issue of primary concern in this study is participants’ memory for the critical items, in this and all other experiments reported in this paper, only performance on the critical items is reported.

**Experiment 1a Results**

*Initial Cued Recall Test*

Table 1 contains responses on the Initial Test for all experiments reported in this paper. Inspection of the table shows that recall of the original critical details is well below ceiling (as is typically the case in misinformation studies) and that participants very rarely spontaneously generate the misinformation as intrusions. As expected given that participants had not yet received the misleading narrative, there were no pre-existing differences in memory for the originally-witnessed details between Misled and Control items, and this was true for this experiment and all subsequent experiments, $t’s < 1$, $p’s > .10$. 

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Table 1

Mean probabilities of correct, spontaneous misinformation, other intrusions, and no response on the initial test as a function of Item Type in Experiments 1a, 1b, and 2. Note: Standard deviations are in parentheses.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Correct</th>
<th>Spontaneous</th>
<th>Other intrusions</th>
<th>No Answer</th>
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<tr>
<td><strong>Exp 1a</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control items</td>
<td>.44 (.36)</td>
<td>.01 (.06)</td>
<td>.06 (.16)</td>
<td>.50 (.37)</td>
</tr>
<tr>
<td>Misled items</td>
<td>.46 (.36)</td>
<td>.03 (.14)</td>
<td>.04 (.13)</td>
<td>.47 (.36)</td>
</tr>
<tr>
<td><strong>Exp 1b</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control items</td>
<td>.40 (.37)</td>
<td>.00 (.05)</td>
<td>.08 (.20)</td>
<td>.52 (.37)</td>
</tr>
<tr>
<td>Misled items</td>
<td>.40 (.36)</td>
<td>.03 (.13)</td>
<td>.06 (.17)</td>
<td>.50 (.36)</td>
</tr>
<tr>
<td><strong>Exp 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control items</td>
<td>.34 (.33)</td>
<td>.04 (.14)</td>
<td>.05 (.14)</td>
<td>.58 (.33)</td>
</tr>
<tr>
<td>Misled items</td>
<td>.35 (.32)</td>
<td>.00 (.00)</td>
<td>.08 (.19)</td>
<td>.57 (.32)</td>
</tr>
</tbody>
</table>

Final Cued Recall Test

Figure 1 shows the distribution of participants’ responses to questions about the critical items as a function of Initial Test (Initial Test vs. No Test), and whether the item was in the Control (left hand panel) or Misled (right hand panel) condition. As can be seen in the figure, participant responses on the final cued recall test fell into four categories: *correct, misinformation, other* (any incorrect response not matching the misinformation), *or no answer* (blank response or “I don’t know”). To assess whether provision of an initial test affected responses on the cued recall test, for each response category in each of the Misled and Control conditions, the proportion of responses in the Initial Test and No Test groups were compared using t-tests (to correct for multiple comparisons, the critical t was set at $p < .0125$).
Figure 1: Probability of response type as a function of Item Type (Control vs. Misled) and reactivation condition (Initial Test vs. No Test) on the Final Cued Recall test in Experiment 1a. Error bars represent within-subjects 95% confidence intervals.

As illustrated in the right hand panel of Figure 1, the results provided clear evidence of retrieval enhanced suggestibility (RES). For items in the Misled condition, participants in the Initial Test group were significantly more likely to report the misinformation when tested on their memory of the witnessed event than were participants in the No Test group, $t(233) = 4.06, p < .001, d = 0.53$. Provision of an initial test also led to fewer No Answer responses in the Misled condition $t(233) = 4.9 \ p < .001,$
\( d = 0.64 \). For all other response categories in the Control and Misled conditions, there were no differences between the Initial Test and No Test conditions (all \( p \)'s > .10).

**Modified Test**

As can be seen in the left hand side of Figure 2, there was no evidence that reactivation of the original memory rendered it susceptible to memory impairment. In both the Initial Test and No Test groups, performance in the Misled and Control conditions did not differ, thus providing no evidence of memory impairment in either group. Performance on the Modified Test was analyzed using a 2 (Initial Test: Initial Test, No Test) x 2 (Item Type: Misled, Control) mixed ANOVA. There was no main effect of Initial Test \( F(1,231) = .91, p > .10 \), no main effect of Item Type \( F(1,231) = 2.61, p > .10 \), and no interaction between Initial Test and Item Type \( F(1,231) = 2.09, p > .10 \).

![Figure 2](image.png)

*Figure 2:* Proportion correct recognition in experiment 1a and 1b on the Modified Test.

Error bars represent within-subjects 95% confidence intervals.
Experiment 1a Discussion

A significant RES effect was demonstrated using the current set of counterbalanced materials, thus showing that the initial test manipulation employed here had consequences for memory. Despite having demonstrated RES with these materials, there was no evidence that reactivating the original memory through an initial test rendered it to susceptible to memory impairment when the Modified Test was used. However, the Modified Test immediately followed the final Cued Recall test and, as a result, it is possible that performance on the Modified Test was influenced by the final Cued Recall Test. Accordingly, experiment 1b was conducted to assess potential memory impairment on the Modified Test when there is no intervening Final Cued Recall Test.
CHAPTER III

EXPERIMENT 1b

Method

Participants

A total of 229 (143 female, 74 male, 12 gender not reported) undergraduates completed the experiment in partial fulfillment of an introductory psychology course requirement. Sample size was based on the same power analysis as experiment 1a. The experimental design was a 2 (Initial Test: Initial Test, No Test) x 2 (Item Type: Misled, Control) mixed design. Initial Test was manipulated between-subjects and Item Type was manipulated within-subjects. Groups of participants were randomly assigned to either the Initial Test group (N = 118) or the No Test Group (N = 111). Participant mean age was 19.42 years (SD = 1.71).

Materials and procedure

All materials and procedures in Experiment 1b were identical to Experiment 1a except for the length of the final filler task and omission of the Final Cued Recall test. After reading the narrative, participants were given the filler word search puzzle for 13 minutes (equal to the total length of time spent on the filler task and Final Cued Recall

Note that complete counterbalancing is not achieved when using data from all participants due to testing participants in groups. For the purposes of power all participants are included. The significance of all analyses reported do not differ when restricting data to achieve complete counterbalancing (total N = 192).
Test used in experiment 1a). They were then given the Modified Test which served as the primary dependent measure of interest.

Experiment 1b Results

*Modified Test*

As illustrated on the right side of Figure 2, the results replicated those of Experiment 1a: there was no evidence that reactivating a memory rendered it more susceptible to memory impairment, and there was no evidence of memory impairment in either test group. Performance on the Modified Test was analyzed using a 2 (Initial Test: Initial Test, No Test) x 2 (Item Type: Misled, Control) mixed ANOVA. Neither main effects nor the interaction were reliable (Initial Test: $F(1,226) = 1.64, p > .10$; Item Type: $F(1,226) = 2.46, p > .10$, Interaction: $F(1,226) = .01, p > .10$). In sum, there was no evidence that exposure to misinformation impaired memory for the originally-witnessed items.

*Conditional Analysis*

I next examined the data for only those cases where an item was correctly reported on the Initial Test. Recall that the reconsolidation hypothesis posits that existing memories can be overwritten by new information. Chan and LaPaglia (2013) further argued that it was the act of reactivating the original memory during the initial test that rendered it susceptible to overwriting by the contradictory misinformation. As such, it might be argued that one can only expect to see evidence of overwriting in those cases where participants are able to correctly reactivate the original memory prior to being
misled. For this reason, I examined Modified Test performance in the Initial Test group for the subset of cases in which a correct response was provided on the Initial Test. For purposes of power, data from experiment 1a and 1b were combined. If reactivating a memory renders it susceptible to overwriting, then for cases recalled correctly in the Initial Test condition, Misled performance should be poorer than Control performance on the Modified Test. However, the results provided no evidence that retrieving the original memory rendered it susceptible to impairment, as final test performance was at ceiling in both the Misled ($M = .99$) and Control ($M = .99$) conditions, $t < 1$, $p > .10$.

Experiment 1b Discussion

The results of Experiment 1b replicate the finding in Experiment 1a that reactivating the original memory prior to being misled did not render the memory susceptible to impairment. Rather, there was no evidence of memory impairment in either of the test conditions, as in every case performance in the Misled and Control conditions did not differ. These results stand in contrast to the findings of Chan and LaPaglia (2013) who demonstrated in several experiments that testing participants (and hence reactivating the original memory) prior to misleading them resulted in impaired memory performance on the final test. One reason for the disparity between the current findings and those reported by Chan and LaPaglia (2013) may be the differences in the type of final test: The current studies employed the Modified Recognition test and Chan and LaPaglia (2013) used a misinformation–free True/False recognition test. As discussed earlier, there are reasons to expect poorer Misled performance on the True/False test that are unrelated to impaired memory for the originally witnessed event. To determine whether the
discrepancy between these findings is due to the type of final test, in Experiment 2, a misinformation-free True/False recognition test was used to assess if Chan and LaPaglia’s (2013) findings could be replicated with the current materials.
CHAPTER IV

EXPERIMENT 2

Participants

A total of 243 (130 female, 92 male, 21 gender not reported) undergraduates completed the experiment in partial fulfillment of an introductory psychology course requirement. Sample size was based on the same power analysis as experiment 1a. The experimental design was a 2 (Initial Test: Initial Test, No Initial test) x 2 (Item Type: Control, Misled) mixed design. Initial Test was manipulated between-subjects and Item Type was manipulated within-subjects. Three participants were removed from analyses due to experimenter error (N = 1) and failing to answer a critical item question on the True/False test (N = 2). The remaining groups of participants were randomly assigned to the Initial Test group and the No Test group (N’s = 120). Participant mean age was 19.29 (SD = 1.25).

Materials and procedure

Materials in Experiment 2 were identical to Experiment 1b with the exception of the format of the final test. Following an 8 minute final filler task, all participants were given a misinformation free True/False Recognition Test. Participants were given 17 statements about the slide sequence (4 concerning the critical items) and were instructed to indicate whether the statement was true or false given what they had seen in the slide show
For the critical items, each participant received 2 true statements (1 Control Item, 1 Misled Item) and 2 false statements (1 Control Item, 1 Misled Item). For example, a true item for a participant that originally saw a hammer was “The man lifted a hammer from his tool box.” A false item if the participant was misinformed that the tool was a screwdriver would be “The man lifted a wrench from his tool box.” The misinformation was never used on this test. Critical items were counterbalanced such that each version was presented equally often as originally witnessed, misinformation, and (novel) false statement. As in Chan and LaPaglia (2013), the measure of memory performance on the True/False Recognition Test was hits minus false alarms, and this served as the primary dependent measure.

Experiment 2 Results

True/False Recognition Test

The results provided a partial replication of Chan and LaPaglia’s (2013) findings. When all of the data were considered, the Misled-Control performance difference in the Initial Test group was not reliable, thus failing to replicate Chan and LaPaglia (2013). However, when the analysis was restricted to the subgroup of cases where participants retrieved the original memory on the Initial Test, the Misled condition evidenced a substantial decrement in performance. Additionally, while the Initial Test had significant effects on both hit rate and false alarms, the effects of each largely offset each other overall. The statistical analyses supporting these claims are reported below.
The measure of hits minus false alarms as a function of Initial Test and Item Type is presented in Figure 3. These data were submitted to a 2 (Initial Test: Test, No Test) x 2 (Item Type: Misled, Control) mixed ANOVA. Although performance in the Misled conditions is numerically lower than in the Control conditions, the main effect of Item Type was not reliable ($F(1,238) = 1.24, p > .10$), nor was the main effect of Initial Test ($F(1,238) = 1.18, p > .10$). Importantly, the interaction between Initial Test and Item type that is predicted by the reactivation/overwriting hypothesis was also not reliable, $F(1, 238) = .14, p > .10$.

![Figure 3](image.png)

*Figure 3.* Mean hit rate minus false alarm rate as a function of Item Type and Initial Test in experiment 2. Error bars represent within subjects 95% confidence intervals.

Table 2 presents the data broken down by hits and false alarms. Inspection of the table reveals that the initial test did influence performance on Misled items, but affected
hits and false alarms in offsetting ways. For items in the Misled condition, the Initial Test group had fewer correct hits than the No Test group (although this difference was only marginally reliable, \( \chi^2 (1, N = 240) = 3.27, p = .07, \phi = .12 \), but also committed fewer incorrect false alarms than the No Test group (\( \chi^2 (1, N = 240) = 11.05, p < .01, \phi = .21 \)). In contrast, for items in the Control condition, there were no differences in hits or false alarms for the Initial Test and No Test groups (all \( p \)'s > .10). With regard to Misled versus Control performance differences, for both the Initial Test and No Test groups, there were fewer hits in the Misled condition than in the Control condition (McNemar’s \( \chi^2 (1, N = 120) = 21.06, p < .001, \phi = .42 \), and McNemar’s \( \chi^2 (1, N = 120) = 3.19, p = .098, \phi = .16 \), for the Initial Test and No Test groups, respectively). In contrast, whereas there were fewer false alarms in the Misled than Control conditions of the Initial Test group (McNemar’s \( \chi^2 (1, N = 120) = 16.95, p < .001, \phi = .38 \), for the No Test group, the Misled versus Control differences in false alarms failed to reach statistical significance (McNemar’s \( \chi^2 (1, N = 120) = 3.19, p = .098, \phi = .16 \), see Table 1.

Table 2

Mean hits and false alarms on the true/false recognition test in experiment 2. Note:

Standard deviations are in parentheses.

<table>
<thead>
<tr>
<th></th>
<th>Hits</th>
<th>False Alarms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Misled</td>
</tr>
<tr>
<td>No Test</td>
<td>.71 (.46)</td>
<td>.56 (.50)</td>
</tr>
<tr>
<td>Initial Test</td>
<td>.75 (.43)</td>
<td>.44 (.50)</td>
</tr>
</tbody>
</table>
Conditional Analysis

Because the reconsolidation hypothesis proposes that existing memories can be overwritten by new information, I next examined the data for only those cases where overwriting can occur, namely, those instances where participants have demonstrated memory for the critical item (i.e. recalled the witnessed item on the initial cued recall test). Because only the Initial Test group took this test, it is not possible to conduct a similar conditional analysis for the No Test group. Table 3 shows hits and false alarms on the final True/False test for the subset of cases where participants in the Initial Test group retrieved the original detail on the Initial Test. Note that this analysis is restricted to a subset of items, and consequently most participants did not have an observation in each of the four cells (hit and false alarm to both Misled and Control items). Hence, although collapsing across participants results in an overall hit minus false alarm estimate that was lower in the Misled condition (.73) than in the Control condition (.93) a statistical analysis was not conducted on the overall data. However, analyses conducted on the hits and false alarms separately support the conclusion that performance was significantly poorer in the Misled condition when compared to the Control condition. Although there were significantly fewer hits in the Misled condition than in the Control condition ($\chi^2 (1, N = 88) = 11.48, p < .001$) there were no Misled-Control differences in false alarms ($\chi^2 (1, N = 85) = .91, p > .10$) in all likelihood because false alarm rates were near floor. In sum, the results of the conditional analysis are consistent with those of Chan and LaPaglia (2013).

---

3 For the purposes of hit rate and false alarm analyses Control and Misled items were treated as between-subjects variables due to missing observations in many cells on a within-subjects level
Table 3

*Mean hit rate and false alarms on the true/false recognition test for items correctly recalled on the initial test in experiment 2. Note: Standard deviations are in parentheses.*

<table>
<thead>
<tr>
<th>Item Type</th>
<th>Hits</th>
<th>False Alarms</th>
<th>HR-FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control items</td>
<td>1.0 (.00)</td>
<td>.07 (.26)</td>
<td>.93 (.26)</td>
</tr>
<tr>
<td>Misled items</td>
<td>.76 (.43)</td>
<td>.03 (.16)</td>
<td>.73 (.46)</td>
</tr>
</tbody>
</table>

Experiment 2 Discussion

Taken together, the foregoing analyses suggest that the likelihood of observing impaired performance on the True/False recognition test following misinformation is dependent on the proportion of participants who remember the witnessed event. A consistent finding was that exposure to misinformation resulted in fewer hits, and this decrement in hits was more pronounced in the Initial Test condition. However, the decrement in hits was offset by fewer false alarms in the Misled conditions (and again initial testing reduced false alarms further). Presumably, both the reduced hits and reduced false alarms are attributable to the same cause, belief in the misinformation; a belief that is more likely to occur and potentially be believed more strongly following the Initial Test manipulation. However, in those cases where participants have robust memory for the witnessed event, the false alarm rate will be low, and there will be little opportunity for belief in the misinformation to lower the false alarm rate further. Without lower false

\[4\] Note that Chan and LaPaglia (2013) demonstrated higher overall memory on the Initial Test than that obtained here. Additionally, experiment 2 had the lowest Initial Test accuracy (see Table 1).
alarms to offset the decrease in hits, it is likely that performance will be poorer in the Misled condition relative to the Control condition.
CHAPTER V

GENERAL DISCUSSION

The present study tested the claim that reactivating a witnessed memory renders it susceptible to impairment using a new set of materials and a different memory test, the Modified Test (McCloskey & Zaragoza, 1985). If as suggested by Chan and LaPaglia (2013), reactivating a memory renders the memory labile and susceptible to overwriting by subsequent misinformation, then impairment should be seen using a Modified Test. In two experiments using the Modified Test (Experiments 1a and 1b), there was no evidence of reactivation-based memory impairment; performance in the Misled conditions did not differ from that of the not-misled Control conditions, and this was true regardless of whether or not the original memory had been reactivated by an initial test. This is especially surprising in Experiment 1a where participants were given a final cued recall test prior to the Modified Test. On the final cued recall test misinformation was reported at a high rate and thus many participants had committed to the misinformation (more so in the Initial Test group), a circumstance under which impairment on a subsequent Modified Test has been demonstrated (Schreiber & Sergent, 1998).

The results presented here also rule out the possibility that the initial test was ineffective at getting participants to reactivate their witnessed memories. Although the initial test manipulation employed here did not produce evidence of impaired original memories, it nevertheless had a number of other effects on memory performance. As
evidenced in Experiment 1a, when participants were given a cued recall test as the final
test, participants in the Initial Test condition incorrectly reported the misleading details at
significantly higher rates than those in the No Test condition, thus replicating the well-
established retrieval enhanced suggestibility (RES) effect. In addition, as evidenced in
Experiment 2, it is clear that the Initial Test manipulation affected performance on the
misinformation-free True/False recognition test, resulting in both fewer hits and fewer
false alarms than in the No Test condition. Collectively, this evidence shows that the
Initial Test manipulation was indeed effective. For this reason I conclude that the findings
with the Modified Test do not show evidence of overwriting by the post-event
misinformation, even when the original memory is reactivated.

The lack of reactivation-based impairment on the Modified Test stands in contrast
to the finding of reliable impairment effects when the misinformation-free True/False
recognition test is used (cf., Chan and LaPaglia, 2013). Why were Misled participants in
the Initial Test group able to correctly identify the witnessed item when given a forced
choice between the originally-seen item and a new item (i.e., the Modified Test) but
incorrectly rejected the originally-seen item as false when the originally-seen detail was
presented in isolation? There are several possibilities. One possibility is that exposure to
misinformation impairs retrieval of the originally-witnessed event, an effect that is
exacerbated when the original memory is reactivated prior to being misled. Participants
may be able to overcome this retrieval impairment when forced to choose between the
original and new item, but not when the original item is presented in isolation. By this
explanation, the difference in performance between the two measures reflects the fact that the Modified Test provides more retrieval support.

The other possibility, and the one I favor, is that the initial test increases both the belief in the misinformation as well as the likelihood of encoding the misinformation. If participants believe that the misinformation is true, they will assume that their memory for the witnessed event is mistaken, and reject it as false. By this account, participants can remember the original item but no longer believe it to be true. Recall that in these experiments the misinformation is presented by the experimenter as an accurate description of the events they witnessed, and participants are given no reason to distrust it. Why, then, might taking an initial test increase belief in the misinformation? When participants take the initial test of the witnessed event, they very rarely produce the misleading item as a response. Hence, when they later encounter the misinformation in the narrative (which differs from what they reported on the initial test) they are likely to interpret it as corrective feedback. Not only will this corrective feedback alter their beliefs about what they saw, but there is evidence that memory for the correction (in this case, the misinformation) will also be enhanced (Kornell, Hays, & Bjork, 2009). Even for participants who are confident in their original memories, the initial test may exacerbate the tendency for participants to embrace the misinformation as correct. For example, research has shown that high confidence errors are more likely to be corrected than errors held with low confidence (the “hypercorrection effect”, Butterfield & Metcalfe, 2001), and, relatedly, that feedback that is surprising is more likely to be remembered and reported on a later test (Fazio & Marsh, 2009). Participants in the No Test condition are
less likely to view the misleading narrative as corrective feedback, because they were never asked to report the critical detail. Moreover, there is evidence that participants who take an initial test process the misleading information differently than those who have not, with those who have taken the initial test allocating more attention to the relevant misleading details, as evidenced by longer reading times (Gordon & Thomas, 2014). By increasing attention to the misinformation, the initial test increases the likelihood the misleading details are encoded and the potential for belief.

In summary, the foregoing argument is that the initial test increases belief in the misinformation and encoding of the misinformation. This may lead participants to reject the original detail as untrue, even if they can remember it. This increased belief in the misinformation will not affect performance on the Modified Test, because participants are given a forced choice between the originally-witnessed item and a novel item. Given that participants can still remember the original item, when the witnessed item is pitted against a novel item, they will correctly choose the original item, even if the misinformation has led them to question its veracity. This hypothesis can also explain Chan and LaPaglia’s (2013) finding of no reactivation-based memory impairment when there was a 48 hour delay between the initial test and the misleading narrative. Although Chan and LaPaglia (2013) interpret this finding as evidence consistent with reconsolidation (in this case, there was no impairment because the misinformation occurs outside the reconsolidation window) an alternative possibility is that the test needs to be in reasonably close proximity to the narrative for participants to view the narrative as corrective feedback. It is also likely that the delay decreases attention to misleading
details in the narrative because memory for the critical details on the initial test is weaker; decreasing the likelihood the misinformation is encoded. One manipulation that could potentially reduce belief in the misinformation is warning participants that the narrative contained inaccurate information. In this regard, it is interesting to note that a warning has been shown to eliminate the RES effect (Thomas, Bulevich, & Chan, 2010). The latter finding is consistent with my contention that testing serves to increase belief in the misinformation.

Although the present results fail to provide evidence in support of the overwriting hypothesis, I note that the current findings cannot be brought to bear directly on the reconsolidation hypothesis. In studies of reconsolidation, a 3 day design is typically used in which the original detail is encoded on day 1. The memory is then given time to consolidate before being made labile through reactivation on day 2, during which time it may be facilitated or impaired. Finally, memory is tested on day 3 after reconsolidation has completed, at which point facilitation or impaired performance may be evidenced. Hence, a true test of the reconsolidation hypothesis requires conducting an experiment where the various phases are timed accordingly (Agren, 2013). In the present study, a one day design was used, which means that there was insufficient time for the original memory to consolidate, nor was reconsolidation complete before the final test. In Chan and Lapaglia (2013) they demonstrated reactivation based impairment using both a single day design as well as a 3-day reconsolidation design. As I have shown, impaired performance on the misinformation-free True/False recognition test may be due to factors other than overwriting of the original memory.
Although the present study did not find evidence of reactivation based overwriting, the present findings cannot rule out the possibility that there are other circumstances, yet to be identified, where destructive updating of memories can and does occur. Clearly, there are many situations where it is important, and sometimes imperative, to update information in memory, and people do (e.g., new phone numbers, the new year). Nevertheless, in the domain of declarative memories for experienced events, the claim that memory can be overwritten and erased from memory has yet to be demonstrated conclusively.
APPENDIX A

CUED RECALL TEST
APPENDIX A

CUED RECALL TEST

Note: Critical items are italicized

1. What color was the secretary’s purse?

2. What type of shoes was the man wearing?

3. What pattern was the man’s shirt?

4. What color was the coffeepot on the file cabinet?

5. *What brand was the coffee jar on the file cabinet?*

6. While fixing the chair the man smoked a cigarette. What brand of cigarettes did the man smoke?

7. What color was the magazine rack on the wall?

8. *The man put a cigarette in the ash tray. What was the name of the magazine next to the ash tray?*

9. What color was the sweater the man took out of the shopping bag?

10. What brand was the tennis racket in the shopping bag?

11. The man found an envelope with $20. What did the man use to open the envelope?

12. What brand of gum did the man take out of his pocket?

13. What color was the pocketknife the man used to try to pick the lock on the desk drawer?

14. *What brand of soda can was on the desk next to the key to the drawer?*

15. Where did the man leave the keys after taking the calculator?
16. The man removed a tool from his toolbox and placed the calculator under it. What tool did the man remove?

17. What did the man pick up off the ground just before leaving?
APPENDIX B

MODIFIED TEST
APPENDIX B

MODIFIED TEST

Note: Critical items are italicized. The answers to these questions were counterbalanced across conditions and items.

1. The secretary had a _________ purse.
   A. brown    B. black

2. The man wore _________ shoes
   A. dress    B. tennis

3. The man wore a _________ shirt
   A. plaid    B. striped

4. There was a _________ coffeepot on the file cabinet.
   A. gray     B. yellow

5. *There was a _________ jar next to the coffeepot on the file cabinet.*
   A. Nescafe  B. Folgers

6. The man smoked _________ cigarettes.
   A. Marlboro  B. Winston

7. There was a _________ magazine rack on the wall.
   A. red       B. yellow

8. *There was a _________ magazine by the ashtray the man used to put out his cigarette.*
   A. Glamour   B. Mademoiselle
9. The man took a__________ sweater out of the shopping bag.
   A. blue       B. yellow

10. There was a __________ tennis racket in the shopping bag.
    A. Spalding       B. Wilson

11. The man used a __________ to open the envelope with the $20.
    A. pocketknife    B. letter opener

12. The man took a pack of __________ gum from his pocket.
    A. Bubblicious   B. Bubble Yum

13. The man used a __________ pocketknife to pick the lock on the desk drawer.
    A. red           B. black

14. The key to the desk drawer was by a __________ can.
    A. Coke          B. Sunkist

15. The man left the keys __________.
    A. in the desk drawer B. on the desk

16. The man put the calculator in the tool box under a __________.
    A. Hammer       B. Screwdriver

17. The man picked up a__________ off the ground just before leaving.
    A. rag       B. key
APPENDIX C

TRUE/FALSE RECOGNITION TEST
APPENDIX C

TRUE/FALSE RECOGNITION TEST

Note: Critical items have been italicized. The underlined detail in these items is counterbalanced across participants.

1. The secretary carried a brown purse.
   True False

2. The man wore work boots.
   True False

3. The man wore a plaid shirt.
   True False

4. There was a gray coffeepot on the file cabinet.
   True False

5. A jar of Maxwell House coffee was on the file cabinet.
   True False

6. The man smoked Marlboro cigarettes.
   True False

7. There was a red magazine rack on the wall.
   True False

8. A copy of Glamour magazine was on the table.
   True False
9. The man took a blue sweater out of the shopping bag.
   True       False

10. A Spalding tennis racket was removed from the shopping bag.
    True       False

11. The man used a pocketknife to open the envelope with $20.
    True       False

12. A pack of Bubblicious gum was taken out of the man’s pocket.
    True       False

13. The man used a red pocketknife to pick the lock on the desk drawer.
    True       False

14. There was a can of 7up on a desk.
    True       False

15. The man left the keys in the desk drawer.
    True       False

16. The man lifted a hammer from his tool box.
    True       False

17. Just before leaving, the man picked up a rag off the floor.
    True       False
REFERENCES
REFERENCES


