Sleep Deprivation and False Memories of Event Details

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Abstract

Many studies have investigated various factors that affect susceptibility to false memories. However, very few studies have investigated the role of sleep deprivation in the formation of false memories, despite overwhelming evidence that deprivation impairs cognitive function. Here, we investigated the relationship between self-reported sleep duration and false memories and the effect of 24-hours of total sleep deprivation on susceptibility to false memories. We found that under certain conditions, sleep deprivation can increase the risk of developing false memories. Specifically, sleep deprivation increased false memory in a misinformation task when participants were sleep-deprived during event encoding, but did not have a significant effect when encoding of the event occurred prior to deprivation. These experiments are the first to investigate the effect of sleep deprivation on false memories for event details and are particularly important because sleep deprivation is increasingly prevalent in society and false memories can have dire consequences.

Keywords: false memory, sleep deprivation, sleep, misinformation, suggestibility, crashing memories

Sleep Deprivation and False Memories of Event Details

Memories are not “recorded” in the brain. Rather, they are reconstructed using information from multiple sources, and they can change following exposure to misleading post-event information or other suggestive influences (for reviews, see Frenda, Nichols, & Loftus, 2011; Lindsay, 2008). Moreover, people sometimes recall entire events and experiences that never happened, and these false memories can be vivid, emotional, and held with great confidence (e.g., McNally, et al., 2004; see also Loftus & Ketcham, 2004). Though memory errors are sometimes trivial and unimportant, other times they may have serious consequences. For example, mistakes in memory are particularly worrisome in the context of the criminal justice system, where eyewitness misidentifications are thought to be the leading cause of wrongful convictions in the United States (e.g., Garrett, 2011). Many studies have investigated situations that are likely to lead to the formation of false memories. However, one unexplored question is whether sleep deprivation affects the likelihood that people will experience false memories of event details. Accordingly, the present studies investigated the effect of sleep deprivation on susceptibility to false memories using tasks designed to elicit false memories for event details.

False Memories

Early studies showed that suggestive questioning can influence memory reports (e.g., Loftus & Palmer, 1974), and since that time, myriad studies have shown that false memories can arise in a number of ways. One common method for studying false memories in the laboratory is the misinformation procedure, in which participants encode a stimulus (usually videos or photographs), are later exposed to misleading information about the material that they encoded, and are given a memory test for the original materials (e.g., Zhu, et al., 2010). Participants frequently incorporate the misleading information into their memories for the original materials. A strength of this approach is that the procedure includes three discrete stages (event encoding, misinformation, and retrieval/test) that theoretically correspond to stages of a process that unfolds in real-world contexts (e.g., a person witnesses a crime or other event, they are later exposed to suggestive or misleading information, and finally, they are asked to repeat their memory as testimony).

Relatedly, a handful of studies have shown that people can also be led to remember witnessing events that they did not actually observe. Specifically, people sometimes falsely remember that they viewed video footage of high-profile news events, when in fact no such footage exists (e.g., Princess Diana's fatal car collision, Ost, Vrij, Costall, & Bull, 2002; see also Ost, Granhag, Udell, & Hielmsäter, 2008; Crombag, Wagenaar, & van Koppen, 1996). Often, participants not only report that they viewed the nonexistent video footage, but also will report specific details they could not have seen. These findings are in line with research demonstrating that imagined events are sometimes confused with actual memories (e.g., Hyman, Husband, & Billings, 1995; Garry, Manning, Loftus & Sherman, 1996). A strength of this approach is the use of actual news events as the stimulus; memories of these events were encoded outside the laboratory and are rich with emotion and real-world significance.

Finally, a common method for creating false memories in the laboratory is the Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). In the DRM task, participants learn lists of words (e.g., *bed, rest, awake, tired*) that are semantically associated with a non-presented word—the "critical lure" (e.g., *sleep*). Later, participants are given a memory test and often report remembering the critical lures, even though they were not actually presented. False memories in the DRM task have been described as associative, or gistbased errors (see Schacter, Guerin, & St. Jacques, 2011). Although the DRM paradigm is widely used as a measure of false memory susceptibility, its relevance to false memories of *events* in more naturalistic contexts has been debated (e.g., Pezdek & Lam, 2007; Wade, et al., 2007) and remains unclear.

Sleep Deprivation

Thus far, knowledge about the effects of sleep deprivation on susceptibility to false memories has relied primarily on studies using the DRM task. Sleep deprivation impairs performance across a wide range of cognitive tasks—it slows reaction times (Koslowsky & Babkoff, 1992), decreases working memory capacity (Chee & Choo, 2004), interferes with normal learning (Drummond & Brown, 2001), and impairs executive function (Nilsson et al., 2005; see Harrison & Horne, 2000, and Thomas et al., 2000 for reviews). These findings have led researchers to predict that sleep deprivation might also increase false memory. However, studies investigating the relationship between sleep deprivation and false memory have shown mixed results. In one study, participants who studied DRM lists and then endured a single night of sleep deprivation prior to testing showed higher rates of false recognition compared to rested participants (Diekelmann et al., 2008). However, in a later study, participants encoded DRM lists in the evening and were tested following a night of either sleep or sleep deprivation and there were no differences in false recall between the groups (Diekelmann, Born, & Wagner, 2010). Finally, participants in one study (Darsaud, et al., 2010) learned DRM lists at night and then either slept or endured a night of sleep deprivation. They were tested after a period of recovery sleep and again, no differences in false recall emerged between the groups.

Thus, although there is tentative evidence suggesting that sleep deprivation may contribute to the formation of false memories, the existing evidence is both sparse and inconsistent. Another concern is that the majority of the research on this topic has been conducted using the DRM task. This places limits on our knowledge about sleep deprivation and false memory, particularly since there are multiple routes to false memories, each characterized by unique processes (see, e.g., Schacter et al., 2011). There is virtually no research investigating whether sleep deprivation causes an increased susceptibility to false memories for richer, real-world stimuli[1]. The average amount of nightly sleep is decreasing in the population (Schoenborn & Adams, 2010) and false memories can have catastrophic consequences in certain contexts. Thus, this gap in the literature needs to be addressed.

In the present research, we capitalized on the multiple methods for creating false memories in the laboratory. In Experiment 1, we tested whether self-reported sleep duration on the night prior to an experiment was associated with false memories of witnessing nonexistent video footage of a news event, and false memories in a misinformation task. In Experiment 2, we manipulated sleep deprivation to examine its effects on the formation of false memories at various stages of a misinformation task.

Experiment 1

Method

Participants

We drew the current dataset from a large, multi-session study in which undergraduates at the University of California, Irvine completed a battery of personality measures, memory tests,

[1] One exception is a unique study (Blagrove, 1996), which found that sleep-deprived participants were more likely than rested participants to yield to leading questions about a story they had read. In that study, however, the sleep-deprived participants were tested at a different circadian time than the rested participants, which introduced a serious confound, thereby limiting the conclusions that can be drawn. Furthermore, it is unclear whether the findings indicate that sleep deprivation caused memory distortion per se, or whether it merely increased participants' tendency to acquiesce to the leading questions.

and cognitive tasks for course credit. Only procedures relevant to the current study will be described here; these procedures all took place on the same day, during the same testing session.

One hundred ninety-three participants (M_{age} = 20.3, *SD* = 3.5, 76% female) recorded their sleep for seven days prior to the testing session and completed two tasks designed to elicit false memories.

Materials

Sleep Diaries. Participants completed a brief sleep diary every morning for one week prior to the day of their testing session. Each day, they reported the time they got in bed at night, the length of time it took them to fall asleep, the time they awoke, and the time they got out of bed the next morning, and whether they awoke during the night or napped during the preceding day. Research staff reminded participants each morning via email to complete their sleep diaries for the night that had just passed.

News event. Participants completed a questionnaire in which they were asked whether they had seen video footage of the plane crash in Shanksville, Pennsylvania on September 11th, 2001. Although images of the aftermath were widely available, the crash was not captured on video. Participants read a passage, which described the event and claimed that video footage of the crash had been widely seen on the news and the Internet. The critical segment of the questionnaire asked participants whether they had seen "video footage of the plane crashing, taken by one of the witnesses on the ground," and participants responded by selecting "yes" or "no."

Prior to debriefing, research staff, blind to the study's hypotheses, conducted short semi-structured interviews with participants to probe their memory reports for the footage. Critically, interviewers repeated the suggestion that a video of the crash had been widely seen, and then asked participants to indicate verbally whether or not they had seen the footage. The primary purpose of this interview was to ensure that the participants understood the question that was being asked. Each interview was audio recorded (see Supplemental Online materials for interview and coding procedures).

Misinformation task.

Event encoding. We assembled two sets of photographs from materials originally developed by Okado and Stark (2005). One set of photographs depicted a man breaking into a parked car and the other depicted a woman encountering various people on a city street, including a thief who steals her wallet. Each set contained 50 photographs that were presented in a fixed order for 3500ms per slide. Participants received an instruction stating that they would be shown a series of images and that they would be asked questions about them at a later time.

Misinformation narrative. Approximately 40 minutes after participants viewed the photographs, they read two text narratives that told the story of the photographs they had seen earlier. Importantly, the narratives for each set of photographs contained three statements that directly contradicted the events shown in the photographs. Therefore, each participant read six pieces of misinformation embedded among the true information—three for each photo set. We created two versions of the misinformation narrative, each containing 6 pieces of misinformation. Participants received one of the two possible versions. Therefore, each participant received misinformation corresponding to one of two possible sets of questions on the memory test. Participants were instructed to remain focused on the narratives for their entire duration. We did not warn participants that there would be differences between the photographs and the narratives.

Test. Approximately 20 minutes after participants read the misinformation narratives, we tested their memory for the photographs using a three-alternative forced-choice test. Each question pertained to a specific detail depicted in one of the photographs (Figure 1), and participants were asked to select an answer choice on the basis of their memory for the original photographs. "Critical questions" pertained to information that was presented inaccurately in the narratives, and had three answer choices: one was correct (i.e., consistent with the original photograph), one was misinformation-consistent (i.e., consistent with the narrative inaccuracy), and one was a novel foil (i.e., present in neither the photographs, nor the narratives). After participants completed the entire series of questions, they then completed a source test. In the source test, participants viewed each question again and elaborated on their earlier responses by selecting one of the following response choices: "in the pictures only," "in the narratives only," "in both and they were the same," "in both and they were different," or "I guessed." Critically, the source test allowed us to assess whether or not the participants remembered seeing misinformation in the original images (Figure 1).

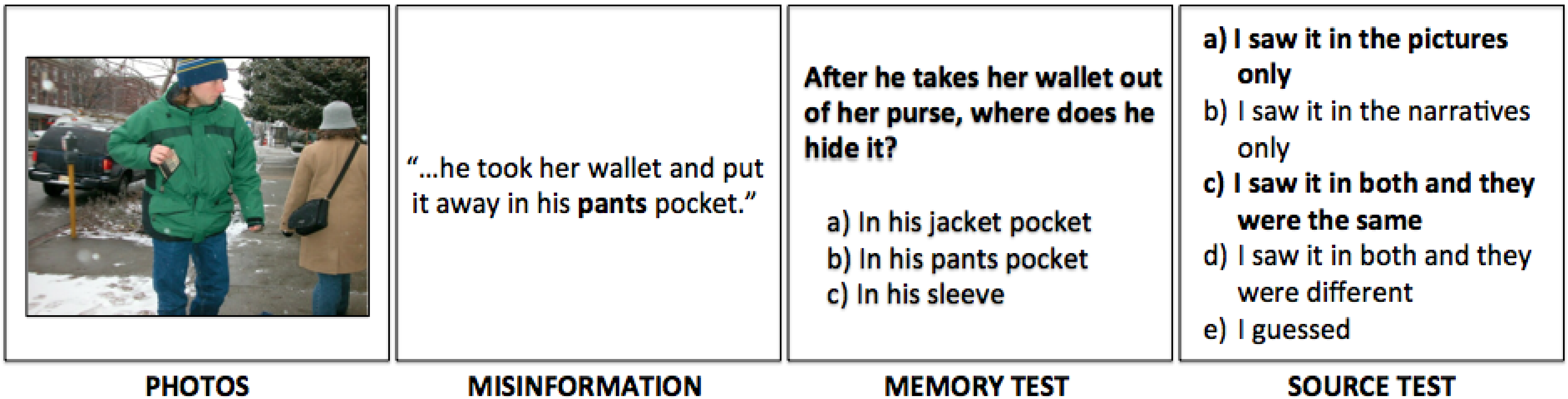

Figure 1. Example of misinformation procedure used in Experiments 1 and 2. Bolded response pattern indicates false memory.

Procedure

Participants arrived to the lab for a preliminary study session and were greeted by research staff. They read an information sheet describing the study procedures, and consented to participation. They first provided demographic information and then they answered a battery of questionnaires (these measures were used to address questions unrelated to the current study). Importantly, participants were given detailed instructions about how to complete their daily sleep diary, which they were instructed to fill out each morning for one week.

Exactly one week later, participants returned to the lab for the study session, which involved the false memory tasks. During the study session, participants first saw the two sets of photographs (i.e., the event encoding phase of the misinformation procedure). Next, they completed the news event questionnaire about their memories for the United 93 plane crash video footage. Immediately following this, participants completed another questionnaire battery assessing various attitudes and personality, unrelated to the present research questions. Then, participants viewed the misinformation narratives, followed by another series of personality questionnaires. Following this, participants completed the testing phase of the misinformation procedure. Finally, they completed the in-person interview with research staff, to confirm their responses in the news event questionnaire. Participants were thoroughly debriefed, and thanked for their participation prior to leaving the laboratory.

Results

In order to assess whether restricted sleep was associated with false memory, we dichotomized the participants into two groups based their self-reported sleep duration on the night prior to the study. We operationally defined restricted sleep as obtaining five or fewer hours of sleep[2]. Participants reported an average of 6.8 hours of sleep (*SD* = 2.0), and 28 participants (15%) reported five or fewer hours of sleep that night. We coded these participants as having restricted sleep. The remaining 165 (85%) participants were used as our reference group. The two groups did not meaningfully differ on any demographic variables (e.g., age, gender, race/ethnicity).

News Event

We first compared the questionnaire responses to the question about video footage of the plane crash in the restricted sleep group and the reference group. Participants in the restricted sleep group were significantly more likely to report that they had seen the video (54%) than participants in the reference group (33%), $\chi^2(1, N = 193) = 4.2$, $p = .04$, $\varphi_c = .15$. However, the groups did not differ in the follow-up interview: 21% of the restricted sleep group and 20% of the reference group persisted in their claim that they had seen the video, when questioned in the interview $\chi^2(1, N = 193) = .03$, $p = .86$. In other words, restricted sleep was associated with initial false reports in the questionnaire, but not with false reports in the follow-up interview.

Misinformation Task

We first analyzed *correct memory* scores by calculating the rate of accurate responses to non-critical questions (i.e., questions that had no misinformation given between the photograph and test). There were no significant differences in correct memory rates between the restricted sleep group (87% correct, *SD* = 19%), and the reference group (89% correct, *SD* = 15%), $t(191) = .7$, $p = .5$. Correct memory rates were rather high in this experiment and the null result in correct memory may be due to ceiling effects on performance.

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[2] Previous studies have shown that sleep restricted to 4-6 hours for several nights can cause impaired cognitive functioning (cf. Dinges, et al., 1997; Van Dongen, Maislin, Mullington, & Dinges, 2003; Axelsson, et al., 2008). Although some studies have shown that 6 hours of sleep over several nights can cause cognitive deficits (e.g., Van Dongen, et al., 2003), we chose a more conservative measure of sleep restriction because we were investigating the effects of only a single night of restricted sleep.

Next, we examined *misinformation-consistent response rates*—i.e., the participants' tendency to incorporate information from the narratives into their responses to critical questions on the memory test. The sleep-restricted group incorporated the misinformation into their responses 33% of the time (*SD* = 26%), whereas the more rested group did so only 26% of the time (*SD* = 24%). This difference narrowly missed significance, $t(191) = 1.9$, $p = .06$, Cohen's $d = .27$ (Figure 2).

Finally, we compared *false memory rates* between the two groups. Here, we calculated the proportion of critical questions for which participants a) gave the misinformation-consistent answer choice on the memory test *and* b) reported that they specifically remembered seeing the misinformation *in the photographs* (i.e., by indicating in the source test that they saw the information "in the pictures only," or "in both [the pictures and the narratives] and they were the same"). The sleep-restricted group attributed misinformation-consistent responses to the photographs 18% of the time (*SD* = 20%), while the more rested group did so 13% of the time (*SD* = 17%). This difference was not statistically significant, $t(191) = 1.35$, $p = .18$.

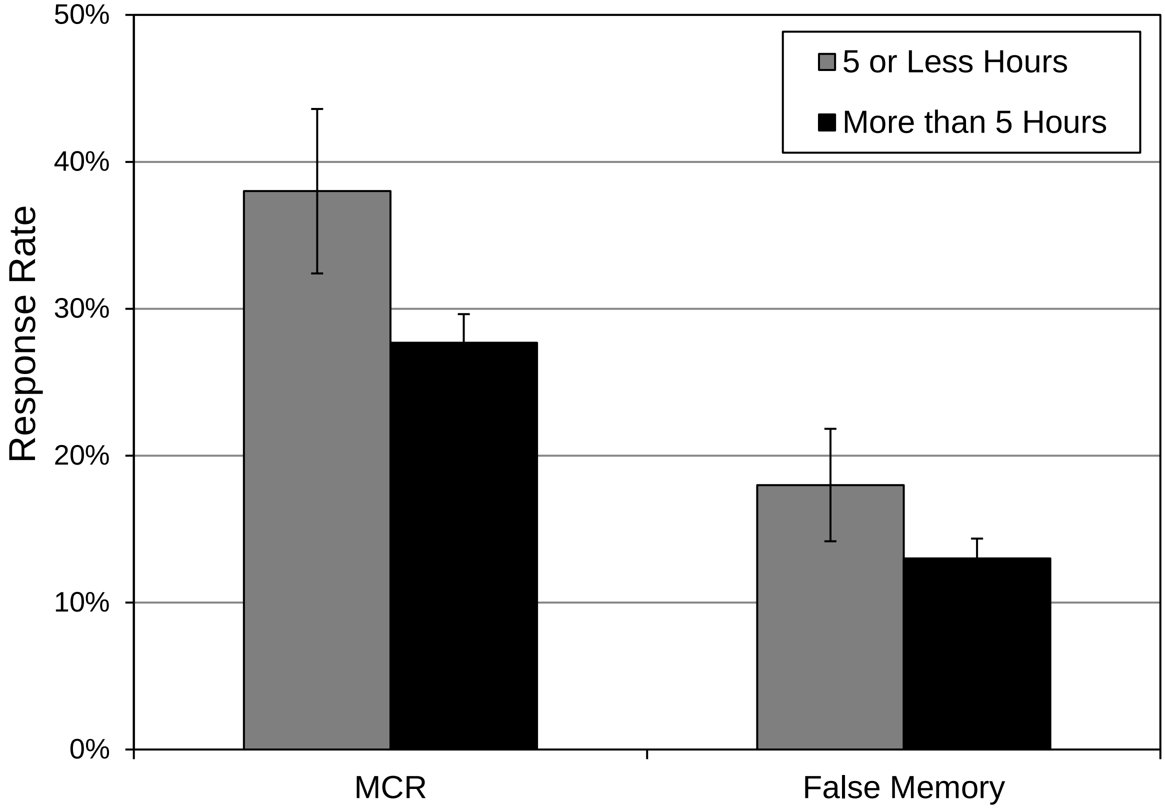

Figure 2. Mean misinformation-consistent response (MCR) and false memory rates in participants who slept 5 or fewer hours and those who slept more than 5 hours. Error bars represent standard errors of the mean.

Interim Discussion

These findings tentatively suggest that restricted sleep is related to memory suggestibility. However, several questions remain. First, because we did not experimentally manipulate sleep, we cannot conclude that sleep restriction caused the observed increase in false memory. Moreover, because all three stages of the misinformation procedure were completed following restricted sleep (or a state of relative restedness), we were unable to examine *when* restricted sleep may influence the formation of false memories. For example, restricted sleep may have impaired the initial encoding of memories (cf. Yoo et al., 2007), rendering those memories more vulnerable to distortion following exposure to misinformation. Alternately, restricted sleep could have affected processes occurring at the later stages in the misinformation procedure (i.e., at retrieval). With this in mind, we designed an experiment utilizing the same misinformation materials used in Experiment 1, to measure the effect of 24-hours of total sleep deprivation on susceptibility to false memories. Here, we also manipulated time of encoding: in one condition all three stages of the misinformation procedure were conducted after sleep deprivation, and in another, participants encoded the photographs in a rested state but completed the misinformation and test phases after a period of sleep deprivation.

Experiment 2

Method

Participants

We recruited 104 Michigan State University undergraduates for participation in the study[3]. Participants had a mean age of 19.2 (*SD* = 1.3; 54% female) and were native English speakers who were not taking any medications that affected sleep. We included only participants who

[3] One participant had difficulty sleeping in the laboratory and did not complete the experiment.

slept regularly (a minimum average of 6 hours per night) in the week preceding the experiment. We asked participants to refrain from consuming alcohol or caffeine for 24 hours prior to the experiment, and to refrain from napping on the day of the experiment. Participants who did not adhere to these guidelines were excused prior to the start of the experiment.

Design and Procedure

The experiment used a 2 x 2 between-subjects design. The independent variables were amount of sleep (8 hours or sleep-deprived) and time of encoding (morning or evening). Participants were blind to condition prior to arriving at the lab; we told them that they might be chosen to sleep or to remain awake throughout the night and to be prepared for either.

Participants arrived in the lab, at 22:30 and completed the Positive and Negative Affective Schedule (PANAS) to assess mood (Watson, Clark & Tellegen, 1988), the Stanford Sleepiness Scale (SSS) to assess sleepiness (Hoddes et al., 1973), and the Operation Span (OSPAN) task to assess working memory capacity (Turner & Engle, 1989). Immediately after the PANAS, SSS, and OSPAN tasks, participants in the morning-encoding condition were assigned to either the sleep or the deprivation condition and participants in the evening-encoding condition completed the event encoding phase and were then assigned to either sleep or to sleep deprivation (Figure 3).

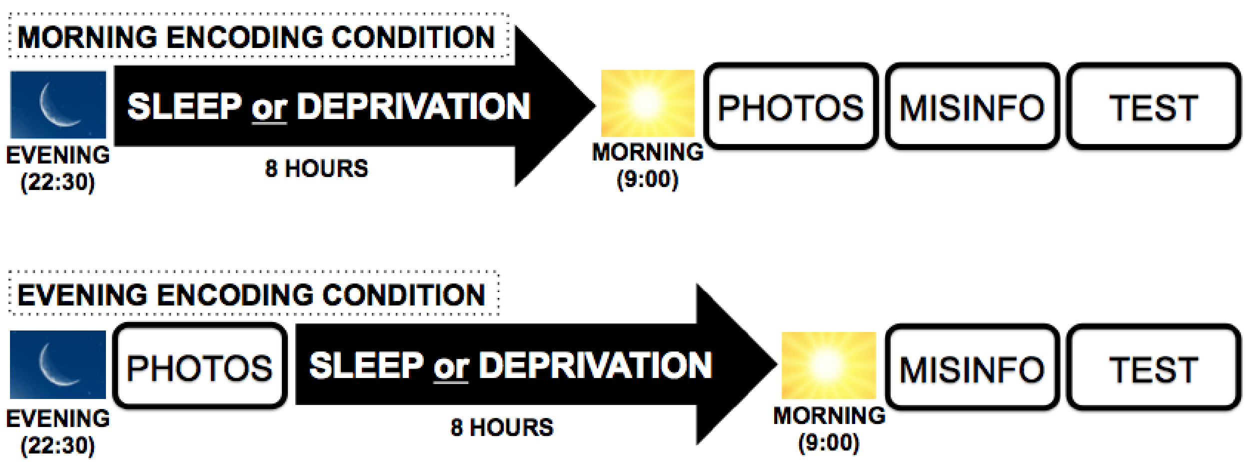

Figure 3. Experiment 2 design.

Participants assigned to the sleep condition were given from midnight until 08:00 the following morning to sleep, while those assigned to sleep deprivation were kept awake throughout the night. Neither group was allowed to consume caffeine. The participants in the deprivation group were permitted to watch movies, play games, or work on their computers, but were not permitted to nap or to engage in any physical exercise. They completed assessments of mood and sleepiness (using the PANAS and SSS) every two hours throughout the night. We also offered participants a small, carbohydrate-rich, snack every hour, to reduce the stress associated with SD. Two research assistants who napped earlier that day continuously monitored participants throughout the night.

To ensure that participants in the sleep conditions did sleep on the night of the study, they were set up for polysomnographic recordings. The following measures were taken: electroencephalography (EEG) recordings on the scalp (at F3, F4, C3, C4, O1, O2, with reference electrodes at M1 and M2), electrooculography (EOG) recordings on both eyes, electromyography (EMG) on the chin and legs, electrocardiography (EKG) to monitor heart rate, thoracic and abdomen belts to monitor respiratory effort, nasal cannule to monitor respiration, and pulse oximetry to monitor oxygen saturation. Data was collected using Embla N7000 recording systems (Embla ResMed, Denver, CO).

The following morning at 08:00, all participants were given breakfast and at 09:00, participants in the morning-encoding condition completed all three stages of the misinformation procedures, as described in Experiment 1. Participants in the evening-encoding condition completed the remaining two phases of the study, misinformation and test.

Results

Memory

We calculated *correct memory scores*, *misinformation-consistent response rates*, and *false memory rates*. For all analyses, we used 2 x 2 ANOVAs with sleep condition (sleep-deprived, rested) and time of encoding (morning, evening) as between-subjects factors. For correct memory, we found no main effect of encoding time, $F(1, 99) = 0.79$, $p = .38$. There was a trend for sleep-deprived participants to show lower correct memory than rested participants, but the main effect of deprivation did not reach significance, $F(1, 99) = 3.08$, $p = .08$. There was not a significant interaction between the factors, $F(1, 99) = 0.55$, $p = .46$.

For misinformation-consistent response rates, there were no main effects of either deprivation, $F(1, 99) = 0.15$, $p = .70$, or encoding time, $F(1, 99) = 1.70$, $p = .20$. However, there was a trend for an interaction between the factors, $F(1, 99) = 3.02$, $p = .09$. In the morning-encoding condition, misinformation-consistent responses were marginally higher after sleep deprivation than after sleep, but no differences emerged in the evening-encoding condition (see SOM for additional figures).

Next, we compared false memory rates. To compute this, we again assessed how often participants responded consistent with the misinformation in the memory test *and* attributed their memory for this information to the images. We found no main effect of deprivation, $F(1, 99) = 0.54$, $p = .46$ or encoding time, $F(1, 99) = 3.12$, $p = .08$. Consistent with the trend in misinformation-consistent responding, however, there was a significant interaction between the factors, $F(1, 99) = 4.52$, $p = .04$. Planned comparisons revealed that in the morning-encoding condition, the deprivation group showed significantly higher false memory than the sleep group, $t(51) = 2.01$, $p = .04$ (two-tailed), Cohen's $d = .56$. However, in the evening-encoding condition, there were no differences in false memory rates between the sleep-deprived and rested participants, $t(52)= 0.98$, $p = .33$ (Figure 4).

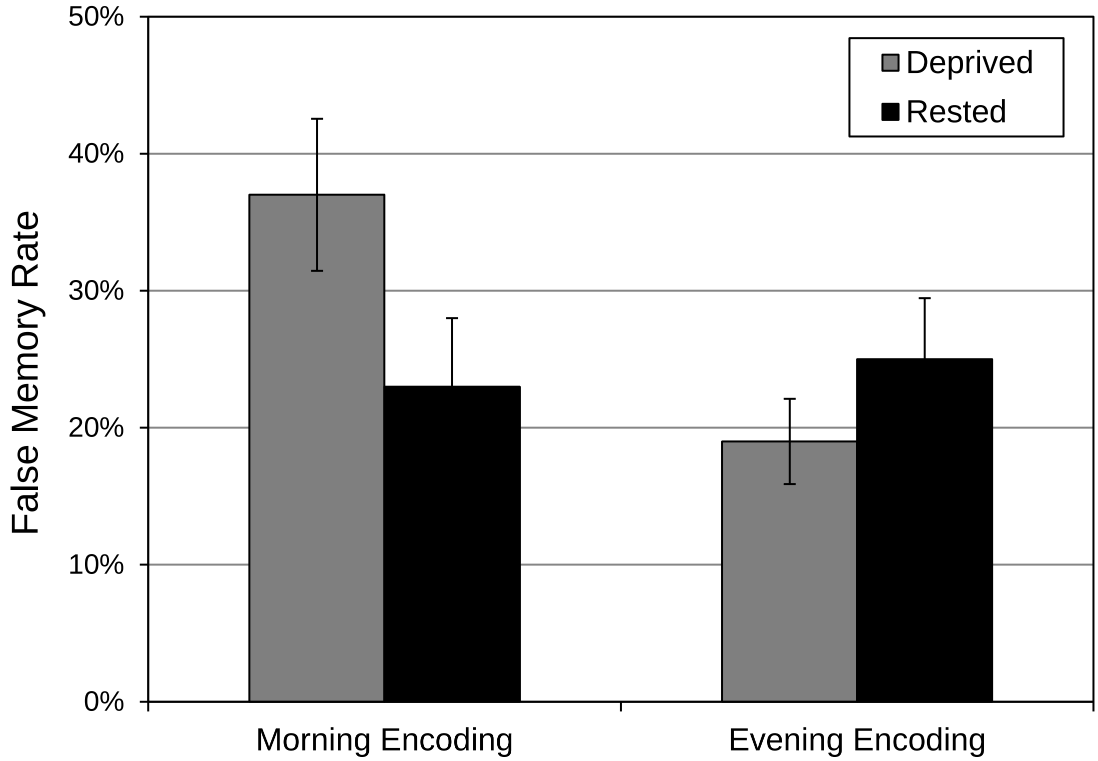

Figure 4. False memory rates in rested and sleep-deprived participants in two encoding conditions. Error bars represent standard errors of the mean.

Mood and Sleepiness

We also tested whether our experimental manipulations affected participants' sleepiness (as measured by the Stanford Sleepiness Scale), or their positive or negative affect (as measured by the PANAS). As expected, participants in the sleep deprivation condition reported significantly higher sleepiness in the morning than the evening, $t(43) = 9.24$, $p < .001$, but there was no relationship between morning sleepiness and susceptibility to either misinformation-consistent responding, $r(88) = .05$, $p = .62$), or false memory $r(88) = .02$, $p = .83$. Similarly, although sleep deprived participants showed a significant decrease in positive affect from evening to morning, $t(45) = 2.40$, $p = .02$, morning positive affect was not significantly associated with MCR, $r(91) = .03$, $p = .80$, or FM rates $r(91) = -.04$, $p = .74$.

Working Memory Capacity

Lastly, we tested whether working memory capacity (WMC, as measured by the OSPAN task) predicted susceptibility to misinformation-consistent responding or false memory. Specifically, we used two multiple regression analyses, one predicting misinformation consistent response and one predicting false memory rates. For each we entered sleep deprivation condition, encoding time, and WMC scores as predictors, followed by interaction terms. We found no main effects of WMC in either model (*p*s > .5). Also, none of the interaction terms achieved statistical significance in either model (all *p*s > .10), suggesting that the effects of either sleep deprivation or time of encoding did not depend on WMC.

Sleep

One participant in the sleep condition was not able to sleep well in the laboratory. This individual went home during the evening and did not complete the experiment. All other participants slept at least six hours on the night of the study. Mean duration of each sleep stage can be found in Figure 5.[4]

[4] Due to equipment failure or experimenter error, sleep data from four participants (n=1 in the morning encoding condition and n=3 in the evening encoding condition) could not be analyzed.

	Morning Encoding	Evening Encoding
Total Sleep Time	7.21 ± 0.46	7.11 ± 0.67
NREM 1	24.6 ± 13	28.8 ± 12
NREM 2	216.5 ± 31	189.1 ± 41
NREM 3	106.5 ± 26	131.7 ± 36
REM	85.5 ± 29	76.8 ± 32

Figure 5. Mean (± SD) duration (in minutes, except for Total Sleep Time) of each sleep stage and total sleep time for the sleep participants in the two encoding conditions.

General Discussion

We investigated the effect of reduced sleep and total sleep deprivation on susceptibility to false memories, using tasks that have not been previously used to investigate the effects of sleep deprivation on false memory. Experiment 1 provided initial evidence that restricted sleep is associated with increased false memory. Participants who reported five or fewer hours of sleep the night before the experiment were more likely to report that they witnessed a news event that they did not actually see, compared to more rested participants. There was also a trend for these participants to incorporate more misleading information into their memory for visual materials. In Experiment 2, the sleep-deprived group showed greater susceptibility to false memories relative to the rested group, but only when participants were sleep-deprived during all three stages of the misinformation procedure (encoding, misinformation, and test). When participants encoded the original event in a rested state, there were no discernable differences in false memory between participants who were rested and those who were sleep deprived during the other phases of the misinformation procedure.

This raises a question as to why sleep-deprived participants were more likely to fall sway to our suggestions in the morning encoding condition, but not in the evening encoding condition. One possibility is that sleep deprivation may increase false memories by influencing processes related to encoding. Sleep deprivation may have impaired encoding of the original event, thus making the memory more vulnerable to intrusions from misleading post-event information. This is supported by a trend for decreased correct memory, (in addition to the significantly increased false memory), in sleep-deprived participants in the morning encoding condition, and is consistent with previous research showing that sleep deprivation reduces the ability to encode new information (Yoo, et al., 2007). One complication, however, is that in the *evening encoding* condition, memory of the photographs could have been affected by sleep-dependent consolidation processes in participants who slept. In other words, sleep-deprived participants in the evening-encoding condition were different from the rested participants in two ways: they were in a state of deprived sleep *and* they did not have an opportunity to consolidate memory for the photographs. Thus, any comparison of rested and sleep-deprived participants in the *evening encoding* condition must be interpreted with caution. This limitation notwithstanding, it is important to note that we only observed differences in false memory rates for rested and sleep-deprived participants in the *morning-encoding* condition, wherein participants could not have consolidated memories of the photographs during sleep.

Our results also suggest that a full night of sleep deprivation may not be necessary to increase false memory. Instead, restricted sleep may also increase susceptibility to false memories, potentially by influencing retrieval processes. After a night of short duration sleep, participants showed a trend to be more likely to claim to have seen nonexistent video footage of a news event that occurred many years prior to the experiment. Previous research has suggested that false memories of witnessing news events (“crashing memories”) may emerge when imagined events are confused with actual memories at retrieval (see Ost, et al., 2002; also see Garry, Manning, Loftus & Sherman, 1996; Lindsay, 2008). In the present study, restricted sleep was associated with an increased likelihood of false memories of an event that had long since passed, suggesting that reduced sleep may impair the accuracy of source judgments at retrieval. However, the effect of sleep restriction was attenuated once participants were asked about their memory in a face-to-face interview. Therefore, the effect of sleep deprivation or sleep restriction on retrieval processes requires further investigation.

On the whole, sleep deprivation appears to increase the risk of false memories. However, sleep deprivation may affect the development of false memories differently based on the false memory procedure or method of testing. In a misinformation procedure, we found that sleep deprivation increased false memory but only when participants were sleep-deprived for all three stages of the procedure (including encoding). Further research might profitably explore emergent questions about the effects of sleep deprivation on post-encoding processes in the misinformation procedure. For false memories of witnessing news events, the present data suggest that sleep restriction may impair source accuracy at retrieval. Similarly, in the DRM paradigm, there is some evidence that sleep deprivation at retrieval may increase false memory in recognition testing (Diekelmann et al., 2008). However, sleep deprivation at retrieval did not affect false memory when a recall test was used (Diekelmann et al., 2010). A key insight emerging from the many approaches to studying false memories is that memory distortion phenomena are varied and not limited to just one process; rather, there are many ways that false memories can materialize. The present research, taken together with the previous literature on sleep deprivation and the DRM paradigm, points to the need for a diversity of methodological approaches in order to further advance our understanding of how sleep deprivation increases the risk of false memory.

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