Adapted Primary Literature for Teaching

Sleep Loss

Original research report:

Diekelmann, S. et al. (2008). Sleep loss produces false memories. PLOS One. 3 (10): e3512. doi: 10.1371/journal.pone.0003512

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Abstract

The authors point out that people commonly claim to remember things that actually never happened ("false memory"). They refer to sleep studies that indicate events are consolidated into memory during sleep and that sleep loss interferes with this process. Here, they tested whether or not sleep loss could contribute to false memories. They tested two possibilities for sleep loss effects: 1) that memories were poorly consolidated after learning without the sleep, or 2) that retrieval of memory was impaired. Subjects learned lists of words of similar meaning (such as "dark, night, coal" etc.) without the strongest associated "theme" word, such as "black" in this case. They compared memory performance between subjects who were sleep deprived or not at retrieval testing 9, 33, or 44 hours after learning. Results showed that false memories were more common at retrieval after sleep deprivation. Sleep deprivation at retrieval, but not sleep following learning increased false memories of theme words. The effect could be abolished by administration of caffeine just prior to retrieval. Since caffeine inhibits adenosine in the brain, and adenosine is a neurotransmitter, the false memory is attributed to impaired function of this neurotransmitter system.

Introduction

The authors begin by pointing out that new memory formation occurs by incorporation with what the brain already remembers. Thus, the new memory may be corrupted (become false). False memories are typically powerful because they have strongly associated meanings. They assumed that false memories are developed through the same brain processes as "true" memories. Namely, that includes a period of initial learning, followed by "off-line" processing that consolidates temporary memory to longer form, and retrieval.

The authors cite research reports showing that sleep helps to consolidate memories, and thus they hypothesized that sleep could similarly influence the formation of false memories. They also cited three papers that showed new memories were re-distributed in brain during consolidation and integrated with existing memories. They speculated that false memories could arise during this restructuring process because the memories could be re-shaped from the mixing with older memories. Since sleep promotes the redistribution/consolidation process, it could promote creation of lasting false memories.

They posed an alternative hypothesis that false memories could be created during retrieval, corrupted by new situations present at retrieval. If so, they thought that loss of sleep would promote false memories because a sleepy brain does not think or perform "executive functions" well.

Methods

The researchers conducted four experiments, applying the DRM false memory procedure, which uses word lists that reliably produce false memories. Subjects learned lists of related words (such as "dark, night, coal" etc.). But the strongest associated "theme" word, such as "black" in this case, was not presented during learning.

At retrieval testing 9, 33, or 44 hours later, list words were presented again along with the "theme" word and unrelated distractor words. Subjects were asked to whether they recognized each theme or distractor word as having been seen during during the learning session.

Subjects were divided into two equivalent groups who either slept or stayed awake immediately after learning. Some subjects were sleep deprived at the time of retrieval testing, but others were not.

Design of the four experiments is summarized in Fig. 1.

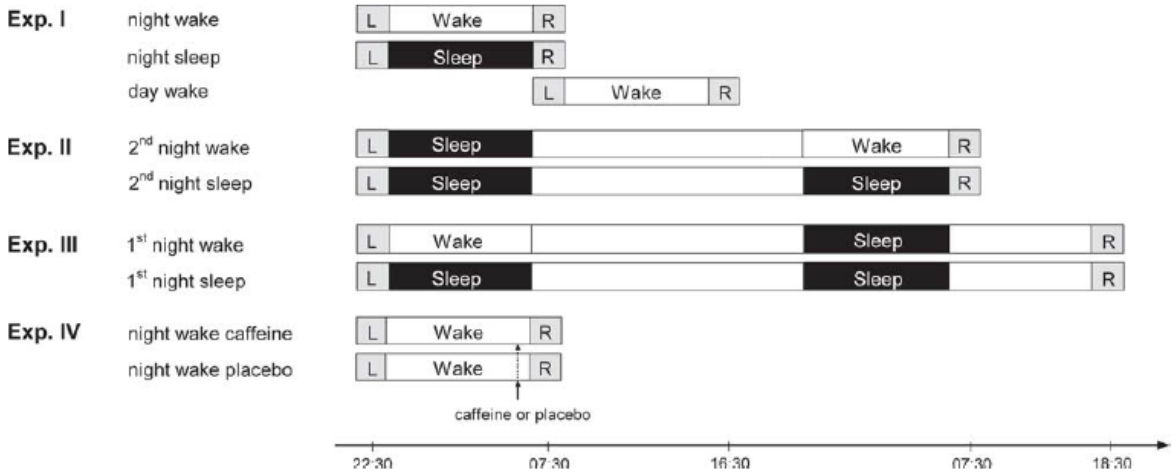

Figure 1. Experimental design. Subjects either slept or stayed awake in the consolidation phase following learning, and either were or were not sleep deprived at retrieval. Black fields refer to sleep periods; blank fields represent times of wakefulness. Times of learning (L) and retrieval (R) are indicated for Experiments I to IV.

Results

Experiment 1, comparing false memory rates in three groups at 9 hours between learning and retrieval. Two groups learned in the evening and were tested in the morning, with one group getting a normal sleep and the other required to stay awake all night. The third group learned in the morning and were tested that same night with no intervening sleep. Statistically significant false rate difference among the three groups. Students in the sleep-deprived group falsely recognized 88% of the theme words on average. The other two groups averaged 77% and 75%false theme-recognition rate, with no significant difference between those who had an intervening sleep and those who learned and were tested during the daytime without sleep. "Hit rate" (number of correctly recognized words) did not differ among the groups. See Fig. 2.

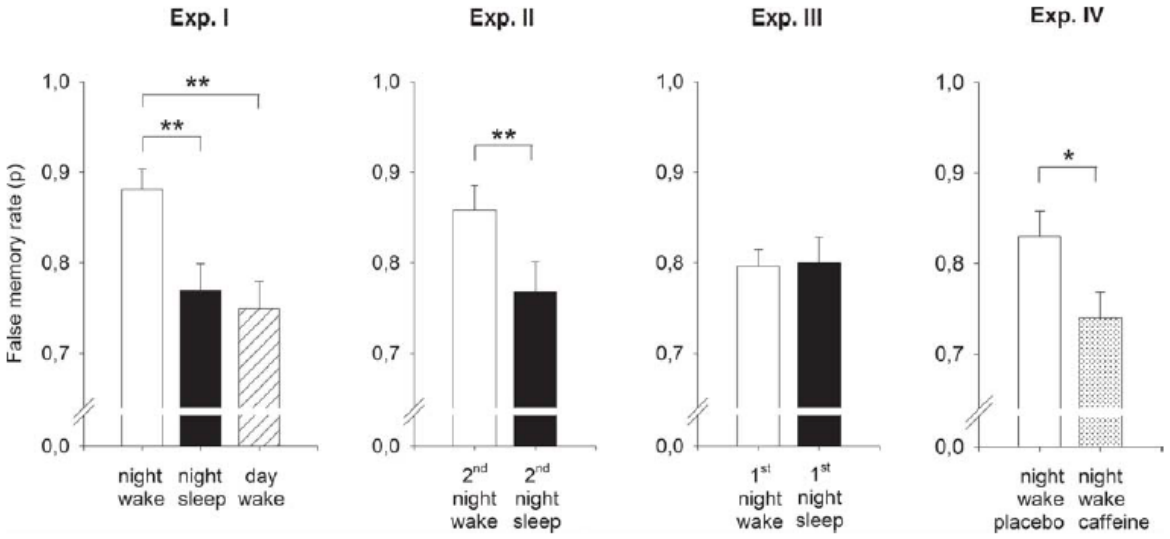

Figure 2. Proportion of false memories in the recognition test. Under sleep deprivation at retrieval false memory rate was significantly enhanced in Experiment I (higher false memory rate in the sleep deprived "night wake" group compared to both non-deprived groups), while sleep after learning compared to wakefulness did not increase false memories (no difference between the "night sleep" and "day wake" group). Experiments II and III further strengthen these findings in showing that sleep deprivation at retrieval also enhanced false memory rate when "sleep vs. wakefulness after learning" was held constant and subjects only were or were not sleep deprived at retrieval ("2nd night wake" vs. "2nd night sleep" in Experiment II), and that sleep after learning neither enhanced false memories when retrieval was tested after a recovery night and controlling for circadian phase ("1st night wake" vs. "1st night sleep" in Experiment III). The administration of caffeine one hour before retrieval testing in Experiment IV abolished the sleep deprivation-induced enhancement in false memories. False memory rate refers to the mean proportion of the judgment "old" to 18 theme words that were not presented during learning (mean±SEM). * P<0.05, ** P<0.01.
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They also tested the possibility that the groups might have differed in willingness to accept items independently of any learning. No difference in response bias was seen.

Experiment II. Only sleep deprived and non-deprived groups were tested for false memory at retrieval. Two groups learned in the evening and both slept normally the first night. But on the second night, one group stayed awake to be sleep-deprived at the time of testing. Both groups were tested the morning after the second night.

The sleep-deprived group showed more false memory than the not-deprived group, similar in magnitude to the error rate seen in Experiment I. Correction for propensity bias still showed a difference.

Experiment III. No subjects sleep-deprived at retrieval, but one group had a period of sleep deprivation right after learning. Both groups learned in the evening, but one group was kept awake that night. Both groups slept normally on the second night and were tested the next afternoon.

False memory rates were essentially the same in both groups.

Experiment IV. Because the first three experiments showed it was sleep deprivation at the time of retrieval that was promoting false memory, this experiment explored possible biochemical reasons for the effect. The authors cited papers showing that sleepiness is promoted by the accumulation of the neurotransmitter adenosine in the brain. Caffeine is known to block adenosine receptors in brain and thus tends to counteract sleepiness.

So, they compared two groups that learned in the evening, were kept awake all night, to be tested in the morning. One group was given 200 mg of caffeine one hour before retrieval testing, while the other group got a placebo. The treatment was randomized and double-blind.

The caffeine-treated group had fewer false memories 0.47% versus 55% for the placebo group, and this difference still existed after correction for response bias.

Subject Confidence Ratings. In all experiments, subjects rated how well they thought they performed in terms of "remember/know/guess." Ratings were consistently higher for theme words and list words, compared to the distractors. The proportion for "remember" judgments was significantly higher for theme words and list words than for distractors. There were no differences across the four experimental groups.

Subject Sleepiness Ratings. As expected, sleep deprived groups rated themselves more sleepy and less motivated and attentive than the subjects in the groups that were not sleep-deprived. In Experiment IV, the caffeine group participated rated themselves less sleepy and more motivated and attentive than did the placebo group.

Sleep Data. Quality of sleep was estimated by EEG in Experiments 1 and III and by questionnaires in Experiments II and III. In Exp. I, EEGS indicated total sleep time on average of 411 min. Of the total Stage I constituted 4.4%, Stage 2 was 55.8%, slow-wave sleep was 18.5%, and rapid-eye movement sleep was 20.8%). In Exp. II, subjects slept at home the first night after learning and both groups reported they went to bed and awakened at about the same times. In Exp. III, the night-sleep group was in the lab on the first night, and EEGs indicated their sleep quality was not different from the group in Exp. I. On the second night, both groups slept at home and those sleep deprived on the first night reported going to bed earlier than the group that had not been sleep-deprived the previous night. Total amount of sleep on that second night did not differ between groups.

Salivary Cortisol. Authors cited literature showing that the stress hormone, cortisol, had big effects on false memory and false recognition. They compared such data, collapsed across before, during, and after retrieval conditions. Statistical significant differences were found**:** mean of 23.66 +/- 2.88 nmol/L in the night-sleep group, 11.12 +/2.06 in the night-awake group, and 5.45 +/- 0.77 in the day awake group. The cite other research suggesting that these data are consisting with what is known about normal diurnal variation in cortisol release. Individual cortisol levels did not differ in the false memory rate, hit rate, or false alarm rate. Thus, the sleep-deprivation effect does not seem accounted for by stress or stress hormone.

Discussion

Authors claim that Exp. I and III show that being sleep deprived at time of retrieval promotes false memory. Moreover, it was sleep deprivation at retrieval rather than sleep deprivation after learning that causes more memory error. Exp. IV showed that this effect could be counteracted by caffeine given one hour prior to retrieval testing.

Authors concede that the sleep-deprivation effect could result from less motivation or reduced compliance. They discount that possibility because hit rate and false-alarm rate were not affected by sleep loss. Also, sleep-deprived subjects did not rate themselves as less confident or more prone to guessing. Correction for response bias showed that could not for the sleep-deprivation increase in false memory.

Authors cite literature that indicates impaired function of the prefrontal cortex by sleep deprivation. They cite work based on electrical recordings suggesting that subjects who were good at discriminating items that had been studied versus those not-studied differed in the evoked activity in the right prefrontal cortex from the response in poor performers. From this, these present authors

concluded that good performers monitor their thinking better and that sleep deprivation might impair this monitoring ability, leading to false memory. That is, the deprivation would impair the ability to discriminate previously encountered words from new words.

They point out that one might expect sleep deprivation to increase false alarms on distractor words, but this was not observed. They explain this by saying that discriminating presented list words from highly associated theme words should be much more difficult than discriminating old list words from non-associated distractors and thus more sensitive to the effects of sleep loss.

As for the caffeine study (Exp. IV), the authors conclude that adenosine is at least one factor involved the sleep-loss effect. They cite papers showing that caffeine, which blocks adenosine, increases cortical and hippocampal electrical activity and increases acetylcholine release in the prefrontal cortex.

Authors cite other reports showing that the prefrontal cortex is not the only brain area affected by sleep loss, and that these other areas could also participate in the creation of false memory. For example, sleep loss impairs attentiveness and lower arousal increases false memory. However, other research shows that lowering arousal reduces false memory, but excess arousal, from psychological stress or strong emotional arousal also increases false memory.

Authors concede that implicating adenosine may not be the whole story. They point out it would be important to test other drugs that promote attentiveness through other mechanisms that do not involve adenosine.

Authors also discuss the discrepancy that allowing sleep right after learning did not seem to change the level of false memory or hit rate. They point out that this present study was limited to recognition memory, and other studies have shown that recognition memory does not benefit much from improved consolidation during sleep.

Finally, authors point out that there are other factors besides sleep loss that can affect false memory. These include whether or not the gist of the memory is sufficient or whether highly specific details are remembered (their example was eye-witness testimony). Also, suggestive interview procedures at time of retrieval can be a major factor (a review is cited).