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Brief Wakeful Resting Boosts New Memories Over the Long Term

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Abstract

A brief wakeful rest after new verbal learning enhances memory for several minutes. In the research reported here, we explored the possibility of extending this rest-induced memory enhancement over much longer periods. Participants were presented with two stories; one story was followed by a 10-min period of wakeful resting, and the other was followed by a 10-min period during which participants played a spot-the-difference game. In Experiment 1, wakeful resting led to significant enhancement of memory after a 15- to 30-min period and also after 7 days. In Experiment 2, this striking enhancement of memory 7 days after learning was demonstrated even when no retrievals were imposed in the interim. The degree to which people can remember prose after 7 days is significantly affected by the cognitive activity that they engage in shortly after new learning takes place. We propose that wakeful resting after new learning allows new memory traces to be consolidated better and hence to be retained for much longer.

Keywords

long-term memory, memory enhancement, memory consolidation, wakeful resting, episodic memory, cognitive neuroscience

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A brief wakeful rest following new learning can boost memory for the learned material over short delays. For example, both young and elderly adults forget fewer newly learned words over a 10-min delay if the learning period is followed immediately by wakeful resting than if it is followed by a new task (Cowan, Beschin, & Della Sala, 2004; Dewar, Cowan, & Della Sala, 2007; Dewar, Garcia, Cowan, & Della Sala, 2009).

According to one emerging view, wakeful resting might enhance memory (i.e., decrease forgetting) by allowing for superior *memory consolidation* (Dewar, Cowan, & Della Sala, 2010; Dewar et al., 2009; Tambini, Ketz, & Davachi, 2010; Wixted, 2004). Memory consolidation is the process that strengthens new memory traces so that they can be retrieved at a later point in time. Research on rats has shown that sequential neural activation associated with recent behavior (i.e., walking along a track) is actually replayed during states of wakefulness following encoding, particularly during periods of wakeful resting (Carr, Jadhav, & Frank, 2011; Foster & Wilson, 2006). Evidence for such replay in humans has come from recent functional MRI studies showing sustained encoding-related neural activity during postlearning wakefulness—activity that occurred automatically, without intentional rehearsal (Peigneux et al., 2006; Tambini et al., 2010). It is important to note that the degree of this neural activity is positively associated with the degree of memory retention after short delays (< 80 min), which indicates that this activity is related to memory consolidation. Wakeful resting might provide a favorable condition for such automatic replay by protecting it from interfering incoming information (Dewar et al., 2007, 2010; Mednick, Cai, Shuman, Anagnostaras, & Wixted, 2011), thereby boosting the strength of the ensuing memory representation—at least over the short term.

A short-term memory boost could be useful in some everyday situations, but a memory boost would be much more valuable if it were to last for longer—for instance, so that one can relay a detailed phone message to a family member who has been away for several days. In the study reported here, we explored for the first time whether a brief wakeful rest following learning can boost new memories over the long term.

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To this end, we conducted two experiments with normally aging elderly adults, who constitute a growing proportion of the population. In each experiment, the learning of a short story was followed immediately by either a 10-min unrelated spot-the-difference task or a 10-min wakeful rest. In Experiment 1, story retention was assessed after a 15- to 30-min delay and after a 7-day delay; in Experiment 2, story retention was assessed after a 7-day delay only.

Experiment 1

Method

Fourteen normally aging elderly adults (11 female, 3 male; mean age = 72.57 years, age range = 61–81 years) who had normal scores on an extensive neuropsychological battery participated in this experiment.

Experiment 1 included two testing sessions, Session 1 and Session 2, which were separated by 7 days. We applied a repeated measures design with within-subjects factors of delay condition (wakeful resting vs. spot the difference) and recall time (15 to 30 min vs. 7 days).

Session 1. As illustrated in Figure 1, Session 1 included two story-learning phases, which occurred one after the other. Each story-learning phase consisted of (a) an aural presentation of one of two short stories (Wechsler, 1997), with instructions to remember as many details of the story as possible for subsequent immediate recall; (b) immediate recall of that story; (c) a 10-min delay, which participants spent either wakefully resting or playing the spot-the-difference game; and (d) a 5-min spot-the-difference game (distractor task).

During the *wakeful-resting* delay, participants were asked to rest quietly with their eyes closed in the darkened testing room for 10 min while the experimenter left “to prepare the next test.” During the *spot-the-difference* delay, participants viewed pairs of pictures presented sequentially on a computer screen for 30 s each and tried to locate and point to two subtle differences between the pictures in each pair. Participants were instructed not to talk during the task. We employed this task because it required attention but was nonverbal and because its elements did not resemble those of the stories, which minimized effects of retrieval competition (Dewar et al., 2007).

A surprise delayed-recall test for both stories occurred after the second story-learning phase, 30 min after the presentation of Story 1. Participants were instructed to begin the test by recalling as many details as possible from the story that had been presented first; they were subsequently asked to do the same for the story that had been presented second. We tested participants’ retention of the two stories at the same time rather than separately after each delay to ensure that the recall test would come as a surprise in both delay conditions and thus to minimize the occurrence of intentional story rehearsal during the delays. Participants were not informed about any further story-recall tests. After the delayed-recall test, participants underwent a structured postexperiment interview, which included questions about what they had done during the wakeful-resting delay and whether they had attempted to rehearse story material during the delay periods.

The order of the two delay conditions and the order of presentation of the two stories were counterbalanced across participants. The 5-min distractor tasks ensured that the second story-learning phase and the delayed-recall test were preceded by the same task irrespective of the order of delay conditions.

Session 2. In Session 2, participants were again asked to recall both stories in as much detail as possible, beginning with the

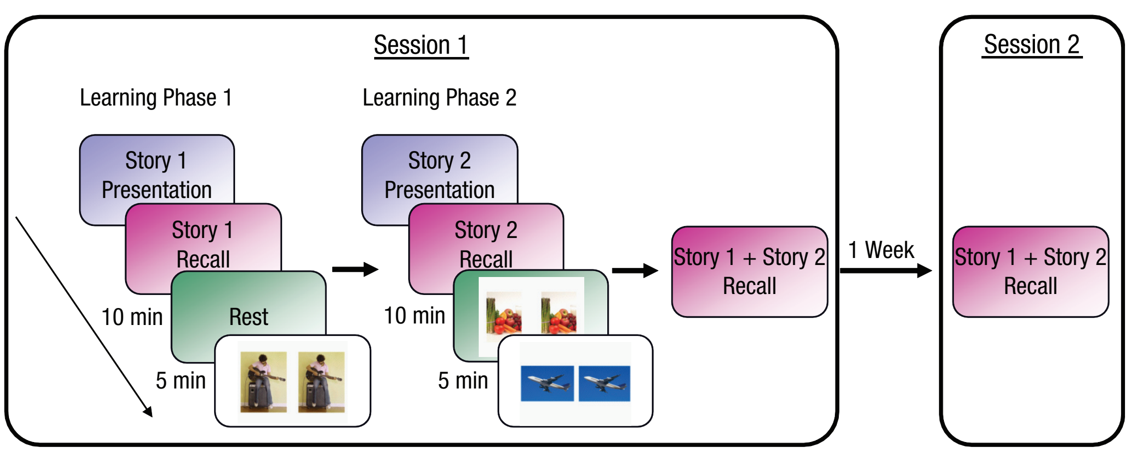

Fig. 1. Experimental procedure. The experiment consisted of two sessions separated by 7 days. In Session 1, there were two story-learning phases. The critical manipulation occurred during a 10-min delay in each phase. During the delay, participants engaged in either wakeful resting or a spot-the-difference game in which they saw pairs of pictures and attempted to point to the differences in each pair. The order of delay conditions was counterbalanced across participants; the figure shows the wakeful-resting delay occurring first. A surprise delayed-recall test followed Learning Phase 2 (15 to 30 min after story presentation) in Experiment 1 but not in Experiment 2. Another surprise delayed-recall test took place in Session 2.

story that had been presented first in Session 1. Participants subsequently underwent a second structured postexperiment interview, which included questions about whether they had expected a recall test in Session 2 and whether they had thought about the story material during the intervening 7-day period.

Scoring. Our measure of participants' performance for each story recall was the number of story units correctly recalled (out of 25 total units). To examine how much of the immediately recalled material was retained over the short delay and the long delay in each condition (wakeful resting, spot the difference), we computed for each participant a percentage-retention score for the 15- to 30-min recall and the 7-day recall in each condition. We calculated the retention scores by dividing the number of story units recalled correctly after a given delay by the number of story units recalled correctly at immediate recall in Session 1 and multiplying the quotient by 100. Retention scores were capped at 100%.

Results

Mean memory performance at the three recall times in the two delay conditions is presented in Figure 2a, which depicts the raw number of story units recalled, and in Figure 3, which depicts the percentage-retention scores. As shown in Figure 3, participants retained significantly more story material after the short delay (15–30 min) if the learning of the story had been immediately followed by wakeful resting than if it had been immediately followed by the spot-the-difference game, $F(1, 13) = 26.219$, $p < .001$, $\eta_p^2 = .669$. Retention dropped significantly in both delay conditions over the 7-day delay, $F(1, 13) = 26.776$, $p < .001$, $\eta_p^2 = .673$. However, the superior performance in the wakeful-resting condition relative to the spot-the-difference condition was sustained, indicating long-term memory enhancement, $F(1, 13) = 14.377$, $p < .01$, $\eta_p^2 = .525$, and there was no significant Recall Time × Delay Condition interaction, $F(1, 13) = 0.006$, $p = .938$, $\eta_p^2 = 0$. The same pattern of results was obtained when the number of story units recalled (see Fig. 2a) was analyzed.

The results of Experiment 1 confirm that a short period of wakeful resting following learning enhances the retention of stories over short delays, and further show that this enhancement is maintained for at least 7 days. It is unclear, however, whether the delayed-recall test following the short delay might have modulated this long-term enhancement of memory by reinforcing the early effect of wakeful resting. Even one act of explicit retrieval of a recently learned story is sufficient to boost 7-day retention significantly (Roediger & Karpicke, 2006). If the long-term enhancement observed was independent of such retrieval, it should also be observed when no explicit retrieval follows the short delay. This hypothesis was our focus in Experiment 2.

Experiment 2

In Experiment 2, we compared how a 10-min wakeful-resting period after learning and a 10-min spot-the-difference period after learning affected story retention following a 7-day period.

Method

Nineteen new normally aging elderly adults (15 females, 4 males; mean age = 70.32 years, age range = 61–87 years) who had normal scores on an extensive neuropsychological battery participated in this experiment. The procedure of Experiment 2 was the same as that of Experiment 1 (see Fig. 1), except that no delayed-recall test occurred at the end of Session 1.

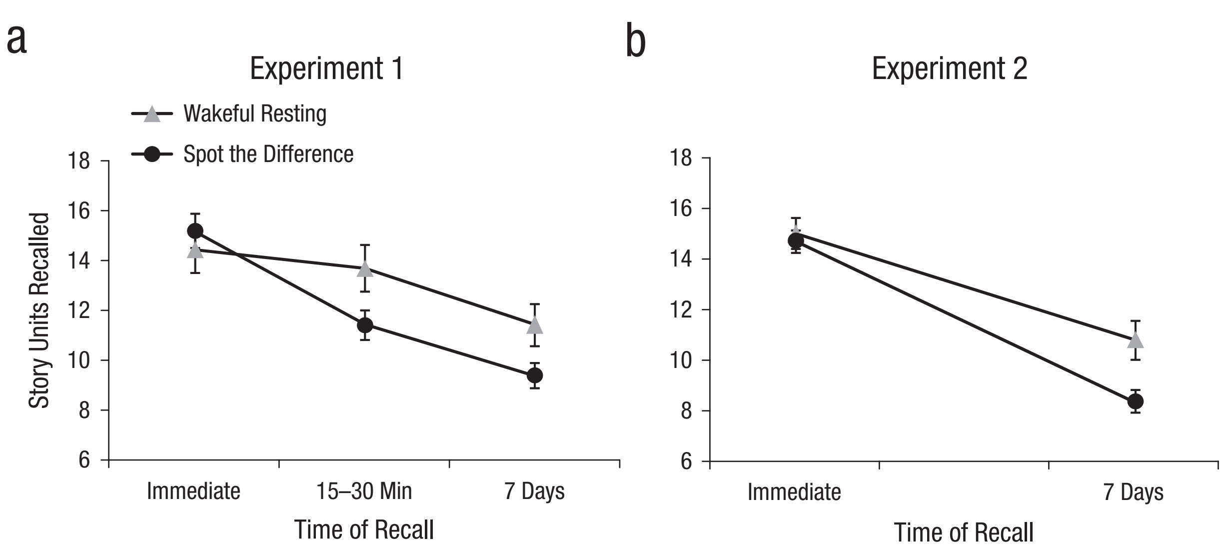

Fig. 2. Mean number of story units recalled (out of 25 total units) as a function of delay condition (wakeful resting vs. spot the difference) and time of recall. The graphs show results separately for (a) Experiment 1 and (b) Experiment 2. Recall tests occurred immediately after story presentation (Experiments 1 and 2), 15 to 30 min after story presentation (Experiment 1 only), and 7 days after story presentation (Experiments 1 and 2). Error bars represent standard errors of the mean.

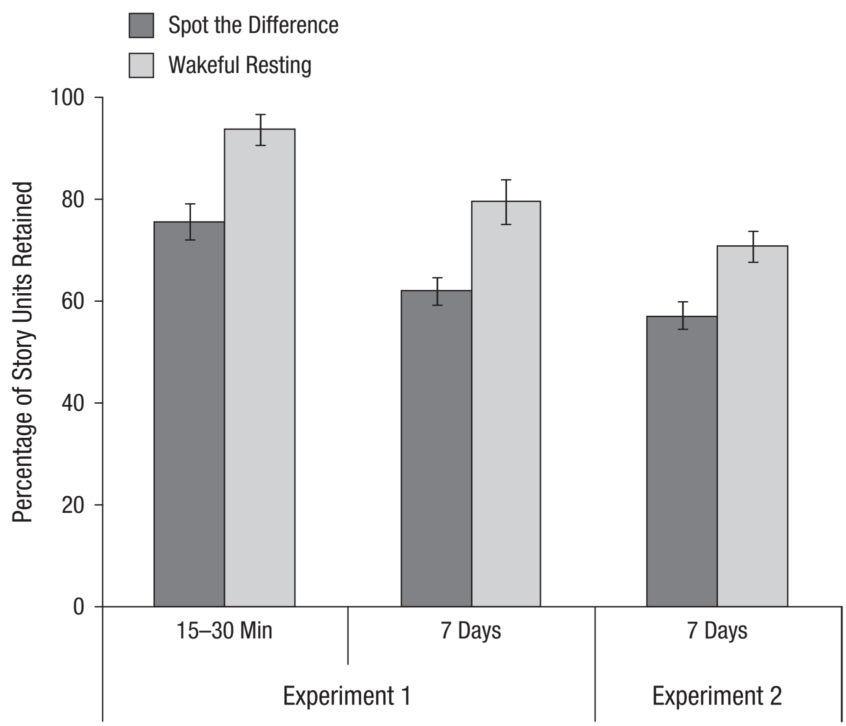

Fig. 3. Mean percentage-retention scores in Experiments 1 and 2 as a function of delay condition (spot the difference vs. wakeful resting) and time of recall. Percentage-retention scores were calculated by dividing the number of story units recalled correctly in the delayed-recall test by the number of story units recalled correctly at immediate recall in Session 1 and multiplying the quotient by 100. Delayed-recall tests occurred after 15 to 30 min and after 7 days in Experiment 1, and after 7 days only in Experiment 2. Error bars represent standard errors of the mean.

Results

As shown in Figure 3, participants retained significantly more story material after the 7-day delay when story learning had been immediately followed by wakeful resting than when it had been immediately followed by the spot-the-difference game, $F(1, 18) = 18.478$, $p < .001$, $\eta_p^2 = .507$. The same pattern of results was found when the number of story units recalled (see Fig. 2b) was analyzed. These data demonstrate that a 10-min period of wakeful resting enhances story memory for at least 7 days, even in the absence of a recall test following the short delay.

Experiment 1 and Experiment 2: Combined Results

Comparison of 7-day retention in the two experiments

Analysis of the 7-day percentage-retention data from Experiments 1 and 2 combined (see Fig. 3) revealed a significant effect of delay condition, $F(1, 32) = 33.052$, $p < .001$, $\eta_p^2 = .508$, and a marginal effect of experiment, such that overall retention was higher in Experiment 1 than in Experiment 2, $F(1, 31) = 3.478$, $p = .072$, $\eta_p^2 = .101$. However, there was no significant interaction between experiment and delay condition, $F(1, 31) = 0.551$, $p = .464$, $\eta_p^2 = .017$, a result indicating that delayed recall in Session 1 did not substantially modulate the memory enhancement observed after 7 days. The same pattern of results was found when the number of story units recalled (see Fig. 2) was analyzed.

Expected recall

Ten participants reported that they had expected a recall test in Session 2. Their 7-day percentage retention in both conditions was significantly higher than that of the 23 participants who did not expect the test, $F(1, 31) = 6.152$, $p < .05$, $\eta_p^2 = .166$. Critically, however, removing these 10 participants from analysis did not affect our results concerning the enhancement of 7-day retention via wakeful resting, $F(1, 22) = 25.706$, $p < .001$, $\eta_p^2 = .539$. Thus, recall expectancy does not appear to have mediated the sustained memory enhancement.

Delay activity and rehearsal

In the Session 1 interview, only 3 participants reported thinking about the stories during some of the wakeful-resting period. The other participants reported that they had rested and let their minds wander. Only 1 participant reported falling asleep. In the Session 2 interview, 12 participants reported thinking about the stories at least once during the 7-day interval between the two sessions; all of these participants reported thinking about both stories. There was no difference in 7-day percentage retention overall between these participants and participants who had not thought about the stories between sessions, $F(1, 31) = 0.002$, $p = .962$, $\eta_p^2 = 0$, nor was there an interaction between delay condition and the presence/absence of such thoughts, $F(1, 31) = 1.170$, $p = .288$, $\eta_p^2 = .036$. Moreover, participants in Experiment 2 did not receive a delayed-recall test in Session 1, and 14 of these participants did not think about the stories at any point between the immediate recall test and the 7-day recall test. Nevertheless, these 14 participants' 7-day percentage retention was significantly higher in the wakeful-resting condition than in the spot-the-difference condition, $F(1, 13) = 26.610$, $p < .001$, $\eta_p^2 = .672$.

Discussion

Our results demonstrate that story retention over a 7-day period can be boosted substantially by a brief wakeful rest following new learning. Wakeful resting allowed participants to retain story details for much longer than usual, as is evident from the finding that the 7-day retention of stories learned prior to wakeful resting was equivalent to the 15- to 30-min retention of stories learned prior to the spot-the-difference game (see Figs. 2 and 3). Our finding that the magnitude of the rest-induced memory enhancement was equivalent at the 7-day and 15-to 30-min recall tests indicates that the early enhancement of memory persisted, rather than being diluted over the 7-day delay. Although long-term memory can be enhanced by retrievals (Roediger & Karpicke, 2006) and by future relevance, such as the expectation of a later recall test (Rauchs et al., 2011; Wilhelm et al., 2011), these factors did not mediate the sustained memory enhancement we observed.

It is unlikely that this sustained memory enhancement could be accounted for by reduced retrieval competition at recall in the wakeful-resting condition relative to the spot-the-difference condition. Given that the spot-the-difference pictures were nonverbal and were unrelated to the stories, we assume that retrieval competition was equally low in the two delay conditions. Moreover, in both conditions, the 10-min delay was followed immediately by a 5-min spot-the-difference game, so any potential retrieval interference from the pictures should have occurred in both conditions. We note the possibility that the pictures could have interfered less with retrieval in the wakeful-resting condition than in the spot-the-difference condition because of higher temporal distinctiveness (Brown & Lewandowsky, 2010; Lewandowsky, Ecker, Farrell, & Brown, 2011): The wakeful-resting period could have temporally isolated the memory trace of the story from competing memory traces of pictures, rendering it more discriminable and easier to retrieve. However, it is a core assumption of this account that memory traces become less and less discriminable from one another as they recede into the past. Therefore, the memory traces of the story and the spot-the-difference pictures should have become almost equally indiscriminable in the two delay conditions over the long delay, which would have resulted in a much-diminished memory enhancement at the 7-day recall test. Temporal distinctiveness, at least as it is currently understood, cannot account well for the observed long-lived effect of wakeful resting.

We propose instead that the long-lived effect of wakeful resting was the result of superior memory consolidation that took place during the 10-min period. Given that only 3 participants thought about the stories during the wakeful-resting period, it is likely that this superior consolidation occurred automatically rather than via intentional story rehearsal (cf. Tambini et al., 2010).

As indicated in the introduction of this article, consolidation has been associated with replay of neural activations linked to recent experiences (Carr et al., 2011; Foster & Wilson, 2006; Peigneux et al., 2006; Tambini et al., 2010). Wakeful resting might provide conditions of minimal interference (Dewar et al., 2007, 2010), during which the various elements of an encoded story can be replayed more often than is possible during activity-filled (interference) periods, which are the norm in everyday life (Dewar et al., 2007, 2010). An increase in the number of these automatic replays via wakeful rest could allow all traces, including weakly encoded ones, to be strengthened to a higher degree than is possible during activity-filled periods. Assuming that the strength of memory traces is continuous rather than binary (i.e., present vs. absent), and that free-recall tests measure how many traces are above a set retrieval threshold at the time of testing (see, e.g., Kornell, Bjork, & Garcia, 2011), the superior strengthening of traces during wakeful resting could allow more traces to be above such a threshold, after both short and longer delays, even if some weakening occurs over longer delays.

Our data fit the view that new memories undergo a consolidation process that is initiated immediately after encoding (cf. Dewar et al., 2010; Dewar et al., 2009; Dudai, 2004; Peigneux et al., 2006; Tambini et al., 2010; Wixted, 2004), though we acknowledge that our data might not unambiguously support this single view of memory. To our knowledge, this is the first study to demonstrate that retention level after 7 days is affected significantly by the cognitive activity that one is engaged in shortly after new learning. In this age of information overload, there are few opportunities to sit back and rest. However, as demonstrated by our findings, postlearning resting can be highly beneficial if one wishes to retain new information over the long term.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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