RESEARCH REPORT

Sleep Can Eliminate List-Method Directed Forgetting

Magdalena Abel and Karl-Heinz T. Bäuml
Regensburg University

Recent work suggests a link between sleep and memory consolidation, indicating that sleep in compar-
ison to wakefulness stabilizes memories. However, relatively little is known about how sleep affects
forgetting. Here we examined whether sleep influences directed forgetting, the finding that people can
intentionally forget obsolete memories when cued to do so. We applied the list-method directed
forgetting task and assessed memory performance after 3 delay intervals. Directed forgetting was present
after a short 20-min delay and after a 12-hr delay filled with diurnal wakefulness; in contrast, the
forgetting was absent after a 12-hr delay that included regular nocturnal sleep. Successful directed
forgetting after a delay thus can depend on whether sleep or wakefulness follows upon encoding: When
wakefulness follows upon encoding, the forgetting can be successful; when sleep follows upon encoding,
no forgetting may arise. Connections of the results to recent studies on the interplay between forgetting
and sleep are discussed.

Keywords: forgetting, directed forgetting, sleep, delay

Recent work suggests a link between sleep and memory con-
solidation. Sleep in comparison to wakefulness has been suggested
to stabilize memories, leaving them less prone to time-dependent
forgetting and interference (Ellenbogen, Hulbert, Stickgold, Dinges,
& Thompson-Schill, 2006; Talamini, Nieuwenhuis, Takashima, &
Jensen, 2008). Such stabilization has been attributed to the reac-
tivation of memory traces during sleep, which may consolidate
memories and shelter them from forgetting (for a review, see
Diekelmann & Born, 2010). Effects of sleep-associated memory
consolidation have been reported for a number of memory tasks,
including tasks that induce forgetting (e.g., Drosopoulos, Schulze,
Fischer, & Born, 2007). However, whether sleep influences di-
rected forgetting—the finding that people can intentionally forget
obsolete memories, when cued to do so—has hardly been inves-
tigated to date.

In the literature on directed forgetting, two tasks have been
employed: the list-method task and the item-method task. In the
item-method directed forgetting task (IMDF), participants study a
list of items and the exposure of each single item is followed
closely by a cue either to remember it for a later test or to forget

it (Woodward & Bjork, 1971). Typically, recall of to-be-forgotten
items is found to be lower than recall of to-be-remembered items
on the final test. In contrast, in the list-method directed forgetting
task (LMDF), participants study two item lists and, after study of
the first list, receive a cue either to forget or to continue remem-
bering the list as a whole (Bjork, 1970). After subsequent study of
the second list, participants are asked to recall the first-list items,
irrespective of original cuing. Compared with remember-cued
participants, forget-cued participants typically show impaired re-
call of the precue items (for reviews on IMDF and LMDF, see
MacLeod, 1998, or Bäuml, 2008).[1]

Although, at first glance, IMDF and LMDF may appear to
reflect very similar forms of forgetting, over the years a number of
experimental dissociations between the two tasks have emerged
and, as a result, the two forms of directed forgetting have been
attributed to different mechanisms (e.g., Bäuml, 2008; MacLeod,
1998). Indeed, IMDF is typically explained by differential re-
hearsal, assuming that to-be-remembered and to-be-forgotten
items differ in the degree to which the single items are rehearsed
and strengthened in response to the respective cue (Bjork, 1972).
In contrast, LMDF has repeatedly been related to some form of
contextual forgetting. It has been argued (a) that the forget cue
causes the original (first-)list context to become inhibited by a
retrieval inhibition process (e.g., Geiselman, Bjork, & Fishman,
1983) or (b) that the forget cue may induce a change in partici-

---

[1] Typically, the forget cue also improves recall of the postcue items (e.g.,
Bjork, 1989). Because this study focused on the forgetting of precue items,
and participants at test were therefore asked to recall these items first, we
ignore the second effect of the forget cue in this paper. Indeed, preceding
recall of precue items often affects subsequent recall of the postcue items
(Golding & Gottlob, 2005; Pastötter, Kliegl, & Bäuml, 2012), which would
have made the conclusive interpretation of the effect of sleep on postcue
item recall impossible.

pants' internal context, which then impairs later recall of the original list due to a mismatch between the context at encoding and the context at retrieval (Sahakyan & Kelley, 2002). Although the two accounts differ in detail, attributing LMDF to an inhibitory or noninhibitory mechanism, they both emphasize impaired context access as the source of the forgetting.

Two recent studies on the role of sleep in IMDF showed that sleep can modulate IMDF. Rauchs et al. (2011) applied the IMDF task and compared memory performance after regular sleep to performance after sleep deprivation. Better recall of to-be-remembered than to-be-forgotten items was found after sleep, whereas the forgetting was reduced after sleep deprivation due to elevated recall levels for to-be-forgotten items. Saletin, Goldstein, and Walker (2011) also applied the IMDF task and found that, in comparison to time spent awake, a daytime nap enhanced the forgetting by selectively improving memory for to-be-remembered items. IMDF thus seems to be enhanced by sleep.

Whether sleep affects LMDF as well has not been investigated to date. However, a recent study on the role of relevancy of memory content for sleep effects suggests that the results on IMDF may generalize to LMDF. Applying paired-associate learning, Wilhelm et al. (2011) manipulated participants' expectancy of a memory test. After initial encoding and an immediate test, participants were told that, after a delay, either they would be tested on the same material again or they would participate in a different task. Benefits of sleep compared to wakefulness were found only if participants believed that the studied material was still relevant for the upcoming test. Because suggested relevancy or irrelevancy of precue items is also at the core of the LMDF task, one might expect sleep-associated memory consolidation to be present mainly after the remember cue. If so, sleep in comparison to wakefulness would amplify the forgetting of precue items, thereby replicating the effects of sleep on IMDF (Rauchs et al., 2011; Saletin et al., 2011).

A different view on the role of sleep on LMDF arises from the results of a recent study on the role of sleep for context effects. Using a context-change paradigm, Cairney, Durrant, Musgrove, and Lewis (2011) asked participants to study two item lists in two separate rooms. The participants were then tested on both lists in one of the two rooms, after either a 12-hr wake delay or a 12-hr sleep delay. A mismatch between study and test context reduced memory performance after wakefulness but did not affect performance after sleep, suggesting that sleep may counteract effects of impaired context access. Because LMDF (but not IMDF) may also reflect a case of impaired context access (e.g., Geiselman et al., 1983; Sahakyan & Kelley, 2002), sleep may be expected to reduce or even eliminate the forgetting, thereby contrasting with the prior findings on IMDF.

In this study, we report the results of an experiment designed to investigate whether sleep reduces or amplifies LMDF. We applied the LMDF task and assessed memory performance for the precue items after a 12-hr delay interval that was filled either with sleep or with wakefulness. An additional, third delay condition employing a short 20-min delay was implemented to examine time-of-day effects (e.g., Abel & Bäuml, 2012; Payne, Stickgold, Swanberg, & Kensinger, 2008; Scullin & McDaniel, 2010). The results will provide first evidence on the interplay between sleep and LMDF. In addition, the results will indicate whether sleep has equivalent or different effects on the two directed forgetting tasks.

Method

Participants

Originally, 210 students participated in the experiment. Prior to analysis, the data of participants reporting sleep disorders, alcohol intake between sessions, or having taken a nap although instructed to stay awake were removed from the sample. The data of 192 healthy students remained ($M = 22.5$ years; range $= 18–30$ years; 76 men). Participants were equally distributed across conditions. Conditions did not differ with regard to participants' age, IQ (estimated via speed of cognitive processing; Oswald & Roth, 1987), and ratings on the Epworth Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973), $ps > .10$.

Material

Item material comprised two lists, each containing 16 concrete nouns (Van Overschelde, Rawson, & Dunlosky, 2004) and serving equally often as List 1 and List 2. Items were unrelated and, within lists, had unique initial letters. For each list, eight items were randomly selected and defined as target items. Recent research on LMDF indicates that the forgetting of precue items declines as more and more list items are recalled at test, so that the forgetting effect is typically present for the tested-first half of a 16-item list but is absent for the second (Bäuml & Samenieh, 2010, 2012b). To get relatively pure measures of the effect of the forget cue, we therefore followed recent work and restricted analysis of participants' recall to the eight target items (Bäuml & Samenieh, 2012a, 2012b).

Design

The experiment had a 2×3 design with the between-participants factors of cue (remember, forget) and condition (12-hr wake, 12-hr sleep, short delay). For half of the participants, List 1 was followed by a cue to remember the items; for the other half, it was followed by a cue to forget the items. In two of the delay conditions, memory performance was tested after 12 hours (12-hr delay conditions): In the 12-hr wake condition, participants studied both lists at 9 a.m. and returned for the test after 12 hours of wakefulness; in the 12-hr sleep condition, participants studied the lists at 9 p.m. and returned for the test after 12 hours including regular sleep (see Figure 1a). Effects of sleep versus wake were assessed by comparing memory performance across the two 12-hr delay conditions. Because testing in these conditions took place at different times of day, a short-delay condition was implemented to separately analyze potential circadian effects on memory performance. Half of the participants in this condition completed the whole experiment at 9 a.m. (a.m. condition), and the other half completed the whole experiment at 9 p.m. (p.m. condition).

Procedure

Study phase. Participants were initially asked to memorize as many to-be-presented items as possible. List 1 items were then presented in random order, centrally on the computer screen and at a rate of 4 s each. Two study cycles were conducted to prevent floor effects after the 12-hr delay. After study of the list, participants in the remember condition were asked to keep that list in
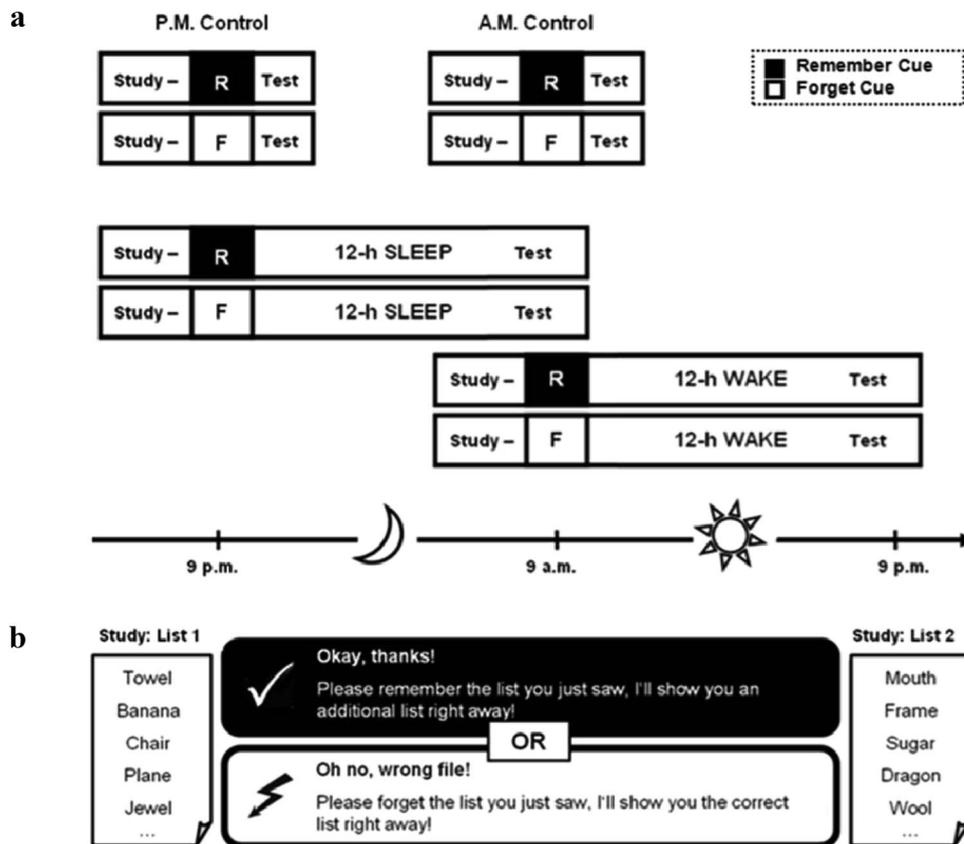
Figure 1. (a) Illustration of conditions in the main experiment: Across all conditions, participants received either a remember cue or a forget cue after List 1 study. In the short-delay conditions, participants completed the whole experiment either at 9 p.m. (p.m. condition) or at 9 a.m. (a.m. condition) and were tested after a short delay. In the 12-hr delay conditions, memory was tested after a 12-hr delay. Participants started the experiment at 9 p.m. and were tested after nocturnal sleep (12-hr sleep condition), or they started the experiment at 9 a.m. and were tested after diurnal wakefulness (12-hr wake condition). (b) General procedure in the study phase: After study of the first item list, half of the participants received a remember cue, indicating that the just studied list would be tested later. The other half of the participants received a forget cue; they were told that they had been presented with the wrong list and were asked to try to forget it, because it would not be tested later. Then, all participants studied the second item list. R = remember; F = forget.

mind and to additionally study a second list. In the forget condition, a software crash was simulated and participants were told that the wrong file had inadvertently been opened; they were asked to forget the irrelevant preceding items and to focus on the items coming up next instead. List 2 was then presented in the same way as List 1 (e.g., Barnier et al., 2007; see Figure 1b). After engaging in several distractor tasks (e.g., the connect-the-numbers test; Oswald & Roth, 1987) for approximately 20 minutes, participants either took the final memory test (short-delay condition) or left the laboratory and completed the experiment after a delay of 12 hours (12-hr delay conditions).

Test phase. Before testing started, participants in the forget condition were informed about the purpose of the previously simulated software crash and were asked to try to remember List 1, irrespective of the prior instruction to forget it. Then, the eight target items of the first list were tested. Items' unique initial letters were presented as retrieval cues, in random order and for 10 s each. Participants were asked to recall List 1 items that fit the initial-

letter cues. The remaining List 1 and the List 2 items were tested as well, but the results are not reported (see also Bäuml & Samenieh, 2010, 2012b).

Finally, participants' compliance with instructions was controlled: All participants included in the wake-delay condition reported no napping during the day, whereas all participants included in the sleep-delay condition reported regular sleep during the night (mean sleep duration = 7.6 hr; range 5–10 hr); none of the participants reported alcohol intake between sessions, and none of the participants cued to forget the first list reported having suspected they would be tested on it.

Results

Short-Delay Condition

A 2 × 2 analysis of variance (ANOVA) with the factors of cue (forget, remember) and time of day (a.m., p.m.) revealed a signif-

icant main effect of cue, $F(1, 60) = 10.05$, $MSE = 408.37$, $p = .002$, $\eta^2 = .14$, reflecting directed forgetting of the outdated precue items (i.e., lower recall after the forget cue than after the remember cue; 31.6% vs. 47.7%). No other effects emerged, $Fs(1, 60) < 1.0$, indicating that memory performance was not affected by circadian effects, irrespective of which cue had been provided (for details, see Table 1).

12-Hr Delay Conditions

Figure 2a shows target recall after the 12-hr delay. A 2 × 2 ANOVA with the factors of condition (12-hr wake, 12-hr sleep) and cue (forget, remember) revealed significant main effects of condition, $F(1, 124) = 23.37$, $MSE = 242.61$, $p < .001$, $\eta^2 = .17$, and of cue, $F(1, 124) = 6.89$, $MSE = 242.61$, $p = .010$, $\eta^2 = .05$. The main effect of cue reflects directed forgetting of the precue items (38.3% vs. 45.5%). The main effect of condition reflects better overall recall in the sleep group than in the wake group (48.8% vs. 35.0%), a pattern that was present in both the forget condition (48.0% vs. 28.5%), $t(62) = 5.23$, $p < .001$, $d = 1.10$, and the remember condition (49.6% vs. 41.4%), $t(62) = 2.03$, $p = .047$, $d = 0.50$. Most important, the ANOVA revealed a significant interaction of condition and cue, $F(1, 124) = 4.23$, $MSE = 242.61$, $p = .042$, $\eta^2 = .03$, indicating that target recall was differently affected by cue depending on whether the participants slept or stayed awake during the delay interval. Consistently, in comparison to the remember cue, the forget cue impaired target recall when participants stayed awake (28.5% vs. 41.4%), $t(62) = 3.29$, $p = .002$, $d = 0.77$, but did not affect recall when participants slept during the retention interval (48.0% vs. 49.6%), $t(62) < 1$. Compared to the performance rates observed after the short delay, sleep even enhanced memory performance above this baseline in the forget condition, $t(62) = 3.60$, $p = .001$, $d = 0.82$, but not in the remember condition ($p > .65$).[2]

Interim Discussion

The results provide first evidence for a critical role of sleep in LMDF. Whereas participants in the 12-hr wake condition showed reliable directed forgetting, participants in the 12-hr sleep condition did not and remembered the target items equally well regardless of whether a remember or a forget cue had originally been provided. Successful LMDF after a delay thus may depend on whether sleep or wakefulness follows upon encoding; when wakefulness follows upon encoding, the forgetting can be successful; when sleep follows upon encoding, no such forgetting may arise. The finding is not attributable to circadian effects, because time of

Table 1
Mean Target Recall in the Short-Delay Condition of the Main Experiment as a Function of Time of Day (a.m., p.m.) and the Items' Memory Status (to Be Remembered, to Be Forgotten)

Memory status	Short-delay condition		
	a.m	p.m	Combined
To be remembered	47.7 (4.5)	47.7 (5.6)	47.7 (3.5)
To be forgotten	32.0 (5.4)	31.3 (4.7)	31.6 (3.5)

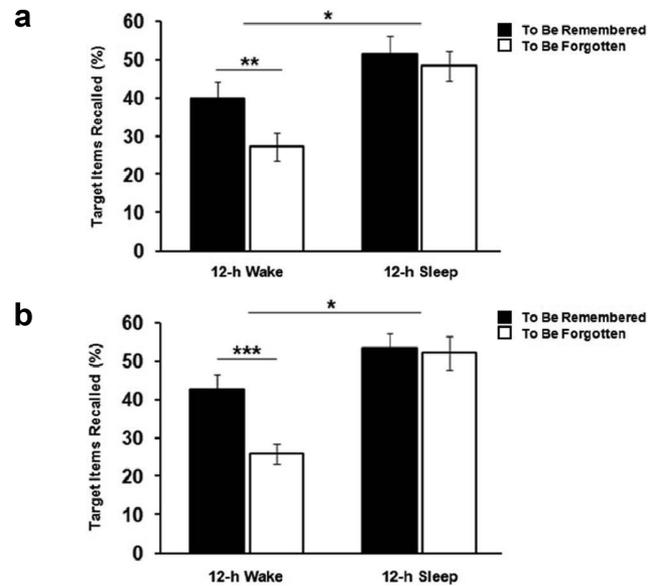*Note.* Standard errors are displayed in parentheses.

Figure 2. Mean percentage of predefined target items recalled as a function of condition (wake, sleep) and the items' memory status (to be remembered, to be forgotten). (a) Performance in the 12-hr delay conditions of the main experiment (12-hr wake, 12-hr sleep); (b) performance in the 12-hr delay conditions of the replication study (12-hr wake, 12-hr sleep). Error bars represent standard errors. $^* p \leq .05.$ $^{**} p \leq .01.$ $^{***} p \leq .001.$

day did not affect recall performance in the short-delay condition. These results are the first to demonstrate an attenuating effect of sleep on LMDF. To ensure that this novel finding was not spurious, we aimed to replicate the results of the two 12-hr delay conditions.

Replication Method

Again applying the LMDF task and assessing memory performance for the precue items, we replicated the 12-hr wake and the 12-hr sleep conditions with a new sample of healthy participants ($n = 112$; $M = 22.6$ years; range = 18–35 years; 23 men) and new item material, again comprising two lists of 16 concrete nouns each (Van Overschelde et al., 2004). Design and procedure were identical to those of the main experiment, with the exception that no short 20-min delay condition was included.

Replication Results

Figure 2b shows target recall after the 12-hr delay. A 2 × 2 ANOVA with the factors of condition (12-hr wake, 12-hr sleep) and cue (forget, remember) showed significant main effects of

---

[2] We also analyzed the occurrence of intrusion errors (i.e., cases in which participants recalled List 2 items when asked to recall List 1 items). The corresponding number of intrusion errors was generally low ($M = 0.56$, $SD = 0.95$), and there were no differences between sleep and wake or between forget and remember conditions ($ps > .17$). Similarly, number of extralist intrusions (i.e., cases in which participants falsely recalled unstudied items when asked to recall List 1 items) was generally low ($M = 1.45$, $SD = 1.83$), and there were also no differences between sleep and wake or forget and remember conditions ($ps > .25$).

condition, $F(1, 108) = 25.50$, $MSE = 376.93$, $p < .001$, $\eta^2 = .19$, and of cue, $F(1, 108) = 6.22$, $MSE = 376.93$, $p = .014$, $\eta^2 = .05$. The main effect of cue reflects directed forgetting of the precue items (39.1% vs. 48.2%). The main effect of condition reflects better overall recall in the sleep group than in the wake group (52.9% vs. 34.4%); this sleep-associated benefit was present in the forget condition (52.2% vs. 25.9%), $t(54) = 5.16$, $p < .001$, $d = 1.14$, and also in the remember condition (53.6% vs. 42.9%), $t(54) = 2.03$, $p = .047$, $d = 0.53$. Most important, a significant interaction of condition and cue again emerged, $F(1, 108) = 4.53$, $MSE = 376.93$, $p = .036$, $\eta^2 = .04$, which indicates that target recall was differently affected by cue depending on whether the participants slept or stayed awake during the delay interval. Consistently, in comparison to the remember cue, the forget cue impaired target recall when participants stayed awake (25.9% vs. 42.9%), $t(54) = 3.68$, $p = .001$, $d = 0.89$, but did not affect recall when participants slept during the delay (52.2% vs. 53.6%), $t(54) < 1$.

Discussion

Our goal in the present study was to examine whether sleep affects LMDF. Two findings stand out. First, the results of both data sets demonstrate that LMDF can be lasting. Participants in the 12-hr wake conditions recalled fewer precue items in response to a forget cue than in response to a remember cue, thus demonstrating successful LMDF. This finding critically extends prior work on LMDF that to date has studied LMDF with very short delay intervals of a few minutes only (see MacLeod, 1998). Second, the results from both data sets show that LMDF after a delay can be modulated by sleep. Whereas forgetting of precue items arose after a long wake delay, the forgetting was absent if participants slept during the delay interval. This finding indicates that sleep plays a critical role in LMDF and can reduce or even eliminate LMDF.

The present results on the role of sleep in LMDF contrast with the results of two recent studies on the role of sleep in IMDF. Whereas these recent studies reported greater IMDF after sleep (Rauchs et al., 2011; Saletin et al., 2011), we found LMDF to be eliminated after sleep. It has been suggested that IMDF is mediated by differential rehearsal (Bjork, 1972), whereas LMDF reflects impaired context access (Geiselman et al., 1983; Sahakyan & Kelley, 2002). The different role of sleep in the two directed forgetting tasks thus may point to a crucial role of contextual information for the elimination of LMDF after sleep, suggesting that sleep may counteract impaired context access. Consistently, recent work on the role of sleep for context-dependent memory found sleep, in comparison to wakefulness, to reduce the influence of environmental context cues at test (Cairney et al., 2011).

The present result of an elimination of LMDF after sleep mimics the recent finding of an elimination of LMDF by means of selective memory retrieval (Bäuml & Samenieh, 2010). In this prior work employing the LMDF task, participants studied two item lists and after study of the second list were asked to recall four predefined target items from the first list. Testing differed in whether participants were asked to retrieve the target items first or after guided cued recall of four, eight, or 12 of the list's remaining (nontarget) items. The results showed that, as more and more of the nontarget items were previously retrieved, target recall decreased linearly in the remember condition but increased linearly in the forget condition. The finding is consistent with the view that

guided cued recall of some of a list's to-be-forgotten items can reactivate the items' original encoding context and thus improve recall of the remaining list items (Bäuml & Samenieh, 2012b). Because sleep-associated memory consolidation is generally attributed to the reactivation of memory traces during sleep (e.g., Diekelmann & Born, 2010), the present finding may suggest that sleep reactivates at least some of the to-be-forgotten items. This reactivation may revive the remaining obsolete memories, in a manner similar to how guided cued recall of some of the to-be-forgotten items does in wake. The present results are silent on the adequacy of this view, but future work may address the issue in more detail.

The present finding that, in LMDF, mainly irrelevant (to-be-forgotten) memory content benefits from sleep contrasts with recent work indicating that sleep consolidates mainly relevant (to-be-remembered) memory content. In this prior work, participants studied and retrieved material before they were informed about whether it would be of relevance for the next day (Wilhelm et al., 2011); participants were not explicitly instructed to forget the irrelevant material. No further material (i.e., no second list) was encoded after the irrelevance information was provided, a procedure that typically does not create forgetting of outdated memories (Gelfand & Bjork, 1985; Pastötter & Bäuml, 2007, 2010). Consistently, forgetting of the precue items was present after wakefulness in the present study but was absent in the previous study (Wilhelm et al., 2011). The difference in results between studies thus may indicate that memory consolidation of outdated memories depends on whether the memories were successfully forgotten before.

In LMDF experiments, list items are typically presented once, whereas in the present study, the items of both lists were presented twice to prevent possible floor effects. One might like to argue that the multiple study cycles prior to presentation of the forget cue left a weak trace of relevance for those memories and that the similar recall levels in the two cue conditions after sleep were due to sleep strengthening these somewhat weakened items (e.g., Drosopoulos et al., 2007; Scullin & McDaniel, 2010). At least two arguments speak against such a view, however. First, multiple study cycles have been found to increase the lists' recall levels but to not affect the magnitude of the LMDF effect (Sahakyan, Delaney, & Waldum, 2008). Consistently, LMDF was observed after both the short delay and the 12-hr wake delay conditions of the present study. Second, although the assumption that number of study cycles may be related to perceived relevance may appear intuitive at first glance, the results from prior work suggest otherwise. Wilhelm et al. (2011) trained participants to a 60% learning criterion across multiple study cycles (resulting in higher recall levels than we observed in the present study), but the studied items could still be perceived as irrelevant. These findings challenge the view that presenting list items twice triggered processes related to future relevance in the present study.

There is a long-standing debate in the literature on memory and sleep about how sleep benefits memories. The classic view is that sleep merely provides a passive protection from interference. Following this view, memory is better after sleep than after wake because new and potentially interfering learning takes place during wakefulness but hardly occurs during sleep (e.g., Jenkins & Dallenbach, 1924; Wixted, 2004). In contrast, more recent proposals suggest that sleep actively contributes to memory consolidation,

through neurobiological processes occurring during specific sleep stages (for a discussion, see Ellenbogen, Payne, & Stickgold, 2006). Our data are more consistent with the proposal of an active than a passive role of sleep, because a higher benefit of sleep was observed in the forget than in the remember condition, and because sleep even enhanced performance in the forget condition above short-delay baseline. If sleep merely protected memories from incidental interference arising during wakefulness, its associated benefit should have affected memories in the two cue conditions similarly and should not have enhanced performance in the forget condition above baseline. The present results thus are consistent with the view that memory contents are reactivated during sleep (e.g., Diekelmann & Born, 2010), although the results do not exclude the action of other sleep-related processes (e.g., Axmacher, Draguhn, Elger, & Fell, 2009; Mednick, Cai, Shuman, Anagnostaras, & Wixted, 2011; Tononi & Cirelli, 2006).

Although the main focus of the present study was on the role of sleep for LMDF, an interesting side result of the study is that LMDF does not vanish during a 12-hr wake interval. This finding is new and of potential interest for theoretical accounts of LMDF. As explained above, the retrieval inhibition account attributes the forgetting to inhibitory action, however, without being explicit on whether the inhibitory effect should persist or vanish as time passes. The context-change account of LMDF attributes the forgetting to a mismatch between the context during study and the context at test, supposedly induced by a change in participants' internal context in response to the forget cue. On the basis of this view, one might like to argue that, after a longer wake delay, the change in context in the remember condition should gradually approximate the change in context in the forget condition, so that the forgetting effect should be reduced, or even be eliminated, after longer delay. Future work may study the role of delay in LMDF in more detail and find such data useful to evaluate, complement, or modify theoretical accounts of LMDF.

References

Abel, M., & Bäuml, K.-H. T. (2012). Retrieval-induced forgetting, delay, and sleep. *Memory, 20,* 420–428. doi:10.1080/09658211.2012.671832

Axmacher, N., Draguhn, A., Elger, C. E., & Fell, J. (2009). Memory processes during sleep: Beyond the standard consolidation theory. *Cellular and Molecular Life Sciences, 66,* 2285–2297. doi:10.1007/s00018-009-0019-1

Barnier, A. J., Conway, M. A., Mayoh, L., Speyer, J., Avizmil, O., & Harris, C. B. (2007). Directed forgetting of recently recalled autobiographical memories. *Journal of Experimental Psychology: General, 136,* 301–322. doi:10.1037/0096-3445.136.2.301

Bäuml, K.-H. (2008). Inhibitory processes. In H. L. Roediger III (Ed.), *Learning and memory: A comprehensive reference: Vol.* 2. Cognitive psychology of memory (pp. 195–220). Oxford, England: Elsevier.

Bäuml, K.-H. T., & Samenieh, A. (2010). The two faces of memory retrieval. *Psychological Science, 21,* 793–795. doi:10.1177/0956797610370162

Bäuml, K.-H. T., & Samenieh, A. (2012a). Influences of part-list cuing on different forms of episodic forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38,* 366–375. doi:10.1037/a0025367

Bäuml, K.-H. T., & Samenieh, A. (2012b). Selective memory retrieval can impair and improve retrieval of other memories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38,* 488–494. doi:10.1037/a0025683

Bjork, R. A. (1970). Positive forgetting: The noninterference of items intentionally forgotten. *Journal of Verbal Learning and Verbal Behavior, 9,* 255–268. doi:10.1016/S0022-5371(70)80059-7

Bjork, R. A. (1972). Theoretical implications of directed forgetting. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory* (pp. 217–235). Washington, DC: Winston.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. Roediger, III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 309–330). Hillsdale, NJ: Erlbaum.

Cairney, S. A., Durrant, S. J., Musgrove, H., & Lewis, P. A. (2011). Sleep and environmental context: Interactive effects for memory. *Experimental Brain Research, 214,* 83–92. doi:10.1007/s00221-011-2808-7

Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature Reviews Neuroscience, 11,* 114–126. doi:10.1038/nrn2762

Drosopoulos, S., Schulze, C., Fischer, S., & Born, J. (2007). Sleep's function in the spontaneous recovery and consolidation of memories. *Journal of Experimental Psychology: General, 136,* 169–183. doi:10.1037/0096-3445.136.2.169

Ellenbogen, J. M., Hulbert, J. C., Stickgold, R., Dinges, D. F., & Thompson-Schill, S. L. (2006). Interfering with theories of sleep and memory: Sleep, declarative memory, and associative interference. *Current Biology, 16,* 1290–1294. doi:10.1016/j.cub.2006.05.024

Ellenbogen, J. M., Payne, J. D., & Stickgold, R. (2006). The role of sleep in declarative memory consolidation: Passive, permissive, active or none? *Current Opinion in Neurobiology, 16,* 716–722. doi:10.1016/j.conb.2006.10.006

Geiselman, R. E., Bjork, R. A., & Fishman, D. L. (1983). Disrupted retrieval in directed forgetting: A link with posthypnotic amnesia. *Journal of Experimental Psychology: General, 112,* 58–72. doi:10.1037/0096-3445.112.1.58

Gelfand, H., & Bjork, R. A. (1985, November). *On the locus of retrieval inhibition in directed forgetting.* Paper presented at the meeting of the Psychonomic Society, Boston, MA.

Golding, J. M., & Gottlob, L. R. (2005). Recall order determines the magnitude of directed forgetting in the within-participants list method. *Memory & Cognition, 33,* 588–594. doi:10.3758/BF03195326

Hoddes, E., Zarcone, V., Smythe, H., Phillips, R., & Dement, W. C. (1973). Quantification of sleepiness: A new approach. *Psychophysiology, 10,* 431–436. doi:10.1111/j.1469-8986.1973.tb00801.x

Jenkins, J. G., & Dallenbach, K. M. (1924). Obliviscence during sleep and waking. *American Journal of Psychology, 35,* 605–612. doi:10.2307/1414040

MacLeod, C. M. (1998). Directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 1–57). Mahwah, NJ: Erlbaum.

Mednick, S. C., Cai, D. J., Shuman, T., Anagnostaras, S., & Wixted, J. T. (2011). An opportunistic theory of cellular and systems consolidation. *Trends in Neurosciences, 34,* 504–514. doi:10.1016/j.tins.2011.06.003

Oswald, W. D., & Roth, E. (1987). *Der Zahlenverbindungstest (ZVT) [Connect-the-Numbers Test].* Göttingen, Germany: Hogrefe.

Pastötter, B., & Bäuml, K.-H. (2007). The crucial role of postcue encoding in directed forgetting and context-dependent forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 977–982. doi:10.1037/0278-7393.33.5.977

Pastötter, B., & Bäuml, K.-H. (2010). Amount of postcue encoding predicts amount of directed forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36,* 54–65. doi:10.1037/a0017406

Pastötter, B., Kliegl, O., & Bäuml, K.-H. T. (2012). List-method directed forgetting: The forget cue improves both encoding and retrieval of postcue information. *Memory & Cognition, 40,* 861–873. doi:10.3758/s13421-012-0206-4

Payne, J. D., Stickgold, R., Swanberg, K., & Kensinger, E. A. (2008). Sleep preferentially enhances memory for emotional components of

scenes. *Psychological Science, 19,* 781–788. doi:10.1111/j.1467-9280 .2008.02157.x

Rauchs, G., Feyers, D., Landeau, B., Bastin, C., Luxen, A., Maquet, P., & Collette, F. (2011). Sleep contributes to the strengthening of some memories over others, depending on hippocampal activity at learning. *Journal of Neuroscience, 31,* 2563–2568. doi:10.1523/JNEUROSCI .3972-10.2011

Sahakyan, L., Delaney, P. F., & Waldum, E. R. (2008). Intentional forgetting is easier after two shots than one. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34,* 408–414. doi:10.1037/ 0278-7393.34.2.408

Sahakyan, L., & Kelley, C. M. (2002). A contextual change account of the directed forgetting effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 1064–1072. doi:10.1037/0278-7393 .28.6.1064

Saletin, J. M., Goldstein, A. N., & Walker, M. P. (2011). The role of sleep in directed forgetting and remembering of human memories. *Cerebral Cortex, 21,* 2534–2541. doi:10.1093/cercor/bhr034

Scullin, M. K., & McDaniel, M. A. (2010). Remembering to execute a goal: Sleep on it! *Psychological Science, 21,* 1028–1035. doi:10.1177/ 0956797610373373

Talamini, L. M., Nieuwenhuis, I. L., Takashima, A., & Jensen, O. (2008). Sleep directly following learning benefits consolidation of spatial asso-

ciative memory. *Learning & Memory, 15,* 233–237. doi:10.1101/lm .771608

Tononi, G., & Cirelli, C. (2006). Sleep function and synaptic homeostasis. *Sleep Medicine Reviews, 10,* 49–62. doi:10.1016/j.smrv.2005.05.002

Van Overschelde, J. P., Rawson, K. A., & Dunlosky, J. (2004). Category norms: An updated and expanded version of the Battig and Montague (1969) norms. *Journal of Memory and Language, 50,* 289–335. doi: 10.1016/j.jml.2003.10.003

Wilhelm, I., Diekelmann, S., Molzow, I., Ayoub, A., Mölle, M., & Born, J. (2011). Sleep selectively enhances memory expected to be of future relevance. *Journal of Neuroscience, 31,* 1563–1569. doi:10.1523/ JNEUROSCI.3575-10.2011

Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annual Review of Psychology, 55,* 235–269. doi:10.1146/annurev.psych .55.090902.141555

Woodward, A. E., Jr., & Bjork, R. A. (1971). Forgetting and remembering in free recall: Intentional and unintentional. *Journal of Experimental Psychology, 89,* 109–116. doi:10.1037/h0031188