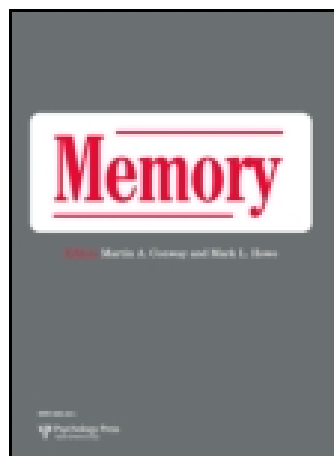


This article was downloaded by: [University of Regensburg]

On: 21 April 2015, At: 04:04

Publisher: Routledge

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Memory

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/pmem20>

Sleep can reduce proactive interference

Magdalena Abel^a & Karl-Heinz T. Bäuml^a

^a Department of Experimental Psychology, Regensburg University, Germany

Published online: 05 Apr 2013.



[Click for updates](#)

To cite this article: Magdalena Abel & Karl-Heinz T. Bäuml (2014) Sleep can reduce proactive interference, *Memory*, 22:4, 332-339, DOI: [10.1080/09658211.2013.785570](https://doi.org/10.1080/09658211.2013.785570)

To link to this article: <http://dx.doi.org/10.1080/09658211.2013.785570>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

Sleep can reduce proactive interference

Magdalena Abel and Karl-Heinz T. Bäuml

Department of Experimental Psychology, Regensburg University, Germany

Sleep has repeatedly been connected to processes of memory consolidation. While extensive research indeed documents beneficial effects of sleep on memory, little is yet known about the role of sleep for interference effects in episodic memory. Although two prior studies reported sleep to reduce retroactive interference, no sleep effect has previously been found for proactive interference. Here we applied a study format differing from that employed by the prior studies to induce a high degree of proactive interference, and asked participants to encode a single list or two interfering lists of paired associates via pure study cycles. Testing occurred after 12 hours of diurnal wakefulness or nocturnal sleep. Consistent with the prior work, we found sleep in comparison to wake did not affect memory for the single list, but reduced retroactive interference. In addition we found sleep reduced proactive interference, and reduced retroactive and proactive interference to the same extent. The finding is consistent with the view that arising benefits of sleep are caused by the reactivation of memory contents during sleep, which has been suggested to strengthen and stabilise memories. Such stabilisation may make memories less susceptible to competition from interfering memories at test and thus reduce interference effects.

Keywords: Proactive interference; Retroactive interference; Sleep; Delay; Forgetting.

A vast amount of research links sleep to processes of memory consolidation. Sleep, in comparison to wakefulness, has been shown to stabilise memories and to leave them less prone to forgetting over time (for a review, see Conte & Ficca, 2013). The beneficial effects of sleep are generally attributed to the reactivation of memory contents; hippocampal networks involved in encoding are assumed to be reactivated during slow-wave sleep, stabilising the contents by initiating their transfer to neocortex for long-term storage (e.g., Diekelmann & Born, 2010). Although knowledge about the interplay of sleep and memory accumulates rapidly, relatively little is known about the role of sleep in interference effects in episodic memory. Two previous studies examined the issue, indicating that sleep may counteract retroactive interference but not proactive interference.

Experimentally, interference effects have often been examined by employing paired-associate learning. With this method, participants initially study a first list of word pairs (e.g., door-cherry, or A-B) and, after a short distractor task, study a second list of pairs (e.g., door-lion, or A-C). On the final test the pairs' shared first items are presented as retrieval cues (e.g., door-?, or A-?), and participants are asked to recall the pairs' second items, regardless of whether they were studied in the context of the first or the second list (i.e., cherry, lion; or B, C). Typically, the additional encoding of the other list impairs memory for each of the two lists, when compared to a control condition, in which participants study a single list only (e.g., Barnes & Underwood, 1959; Underwood, 1957). Retroactive interference refers to reduced memory for the first list because of subsequent list-2 encoding, whereas proactive interference refers to

Address correspondence to: Karl-Heinz T. Bäuml, Department of Experimental Psychology, Regensburg University, 93040 Regensburg, Germany. E-mail: karl-heinz.bauml@ur.de

The project was conducted as part of Magdalena Abel's doctoral dissertation.

reduced memory for the second list due to prior list-1 encoding (for a review, see Crowder, 1976). Interference effects have mostly been attributed to a retrieval-based mechanism, according to which memories linked to the same retrieval cue compete for recall when the common cue is presented, thereby making recall of the single memories less likely than in a no-interference condition in which no such competition arises (for reviews, see Crowder, 1976; Wixted, 2004).

The first study to look into the interplay of sleep and interference effects was conducted by Ekstrand (1967). Across several study–test cycles, participants encoded either a single list of paired associates or two interfering lists (A-B, A-C). Memory was tested after a retention interval of several hours, filled with either sleep or wakefulness. Ekstrand reported beneficial effects of sleep on memory for both the single list and the two interfering lists; yet a more pronounced benefit of sleep was found for the first list (A-B) than for the second list (A-C), which led Ekstrand to conclude that sleep counteracts retroactive, but not proactive, interference. Drosopoulos, Schulze, Fischer, and Born (2007, Experiment 1) re-examined the issue. Again, participants encoded either a single list of paired associates or two interfering lists (A-B, A-C) via repeated study–test cycles. Sleep in comparison to wake was found to benefit retention of the first list (A-B), while no such benefit was observed for the second list (A-C) and the single list. Thus, consistent with Ekstrand (1967), retroactive interference was present after wake, but not after sleep, whereas no sleep effects emerged for proactive interference and single-list performance.

On the basis of their finding that sleep was selectively beneficial for the first list (A-B), and because rather high recall levels had been observed for the other two lists (i.e., for the second list, A-C, after the short delay, and for the non-interfering single list after the wake delay), Drosopoulos et al. (2007) hypothesised that sleep might be especially beneficial for memories initially recalled at a lower level. They addressed the issue in their second experiment, in which they asked participants to encode two non-interfering lists of paired associates (i.e., A-B, C-D) to a learning criterion of either 90% or 60% correct. Indeed, a benefit of sleep compared to wake was only evident for the weak (60%) but not for the strong (90%) encoding condition, indicating that initial recall level might play the critical role for sleep-related recovery from interference.

These results, together with those by Ekstrand (1967), are consistent with the view that sleep effects are driven by memories' initial recall level: only if memories' initial recall level is low, as was the case for retroactive interference in the two previous studies, is sleep beneficial; if the recall level is high, as was the case for proactive interference and the single-list conditions in the two previous studies, no or only a reduced beneficial effect of sleep arises (Drosopoulos et al., 2007). In the present study we revisited the issue, examining the role of sleep for retroactive and proactive interference under conditions in which both interference effects arise, and in which proactive interference is expected to create an even lower initial recall level than retroactive interference. Following the above proposal, under such conditions, sleep should be beneficial for both forms of interference and might even be more beneficial for proactive than retroactive interference.

To create a higher degree of proactive than retroactive interference, we employed a study format differing from that applied in the prior studies by Drosopoulos et al. (2007) and Ekstrand (1967). This decision was based on results reported by Tulving and Watkins (1974) who conducted several experiments in which participants encoded two interfering lists of paired associates (A-B, A-C), either via repeated study–test cycles to a specific learning criterion, or via pure study cycles. When study–test cycles were employed during encoding, recall of the first (A-B) list was inferior to recall of the second (A-C) list on the final test; yet when encoding was based on pure study trials without any initial testing the pattern reversed and recall of the first (A-B) list was superior to recall of the second (A-C) list (for related results, see Pastötter, Schickler, Niedernhuber, & Bäuml, 2011; Szpunar, McDermott, & Roediger, 2008). Both Drosopoulos et al. (2007) and Ekstrand (1967) examined sleep's influence on interference effects employing study–test cycles during encoding and, consistent with Tulving and Watkins (1974), found recall of the first (A-B) list to be inferior to recall of the second (A-C) list. In the present study we employed pure study cycles during encoding to create inferior recall of the second (A-C) list compared to recall of the first (A-B) list, i.e., to create a higher degree of proactive interference than retroactive interference.

We report the results of an experiment designed to examine how sleep affects retroactive and proactive interference. Participants encoded two interfering lists or a non-interfering single list of paired associates via pure study cycles, and were

tested on the pairs after retention intervals filled with sleep or wake. In line with previous studies, and to avoid floor effects, a relatively high degree of learning was induced by presenting all lists on three successive study cycles. At test, the pairs' first items (A-terms) were presented as retrieval cues and participants were asked to recall the pairs' second items (B- and C-terms). Following Tulving and Watkins (1974) we expected higher recall for the first than the second interfering list, and thus a higher degree of proactive than retroactive interference. Following the proposal that memories' initial recall level predicts the amount of sleep's beneficial effect on memory performance (Drosopoulos et al., 2007), we expected sleep-related benefits for both interfering lists, with possibly higher benefits for the second than the first interfering list, i.e., more sleep-related reduction in proactive than retroactive interference.

METHOD

Participants

The data of 12 participants were eliminated from the sample prior to data analysis, because they reported alcohol intake or napping during the day. The final sample consisted of 144 participants (30 male), equally distributed across the six experimental conditions (mean age = 23.3 years, range = 18–30 years). All participants were healthy, fluent in German, and reported regular sleep–wake cycles (i.e., no shift work or other recurrent disturbances). They were randomly and evenly assigned to one of the experimental conditions; no differences concerning scores on the Epworth Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) or rough estimates of intelligence (Oswald & Roth, 1987) were evident between conditions (all $ps > .40$).

Materials

Materials comprised 45 unrelated neutral words, consisting of one- and two-syllable exemplars drawn from different semantic categories (Van Overschelde, Rawson, & Dunlosky, 2004). A total of 15 items were randomly chosen as retrieval cues. The remaining 30 items were transferred into lists of 15 items, and lists of paired associates were created by pairing the cue lists with the item lists and by sequentially pairing the randomised cues

and items across lists. The same material was used in interference and no-interference conditions.

Design

The experiment had a 2×2 design with the between-participants factors of Delay (12-h wake, 12-h sleep) and Interference (no interference, interference). Participants in the 12-h wake condition started the experiment at 9 am, participants in the 12-h sleep condition at 9 pm (Abel & Bäuml, 2012, *in press*; Ellenbogen, Hulbert, Stickgold, Dinges, & Thompson-Schill, 2006; Payne, Stickgold, Swanberg, & Kensinger, 2008; Scullin & McDaniel, 2010). Initially, participants studied either a single list (no-interference condition) or two interfering lists of paired associates (interference condition). Recall performance for the material was tested after a delay of 12 hours that included either diurnal wake (12-h wake condition) or nocturnal sleep (12-h sleep condition).

Because sessions took place at different times of day in the 12-h delay conditions, an additional short-delay control condition examined both circadian and interference effects at baseline. In this control condition half of the participants studied paired associates at 9 am (am condition), the other half at 9 pm (pm condition); all participants were tested on the pairs after a short delay of 10 minutes. To reduce sample size, interference was manipulated within participants; sequence of conditions was balanced across participants (see Figure 1a for an illustration of all conditions).¹

¹In literature on interference effects a distinction is frequently made between single-list conditions controlling for either retroactive or proactive interference (e.g., Anderson & Neely, 1996). This distinction pertains to the exact point of time at which single-list encoding takes place. It is reasoned that retroactive interference is adequately assessed when single-list encoding takes place at the same point of time as encoding of the first list in interference conditions, whereas proactive interference is adequately assessed when single-list encoding takes place at the same point of time as encoding of the second list in interference conditions. We also differentiated between the two single-list encoding conditions, and half of the participants in all no-interference conditions encoded the list as control for retroactive interference, while the other half encoded it as control for proactive interference. However, because comparisons between the two single-list encoding conditions never revealed significant differences in recall level in any of the delay conditions, all $ts(47) < 1.30$, all $ps > .200$, we pooled the data for the two single-list encoding conditions and report the results without further mentioning the distinction.

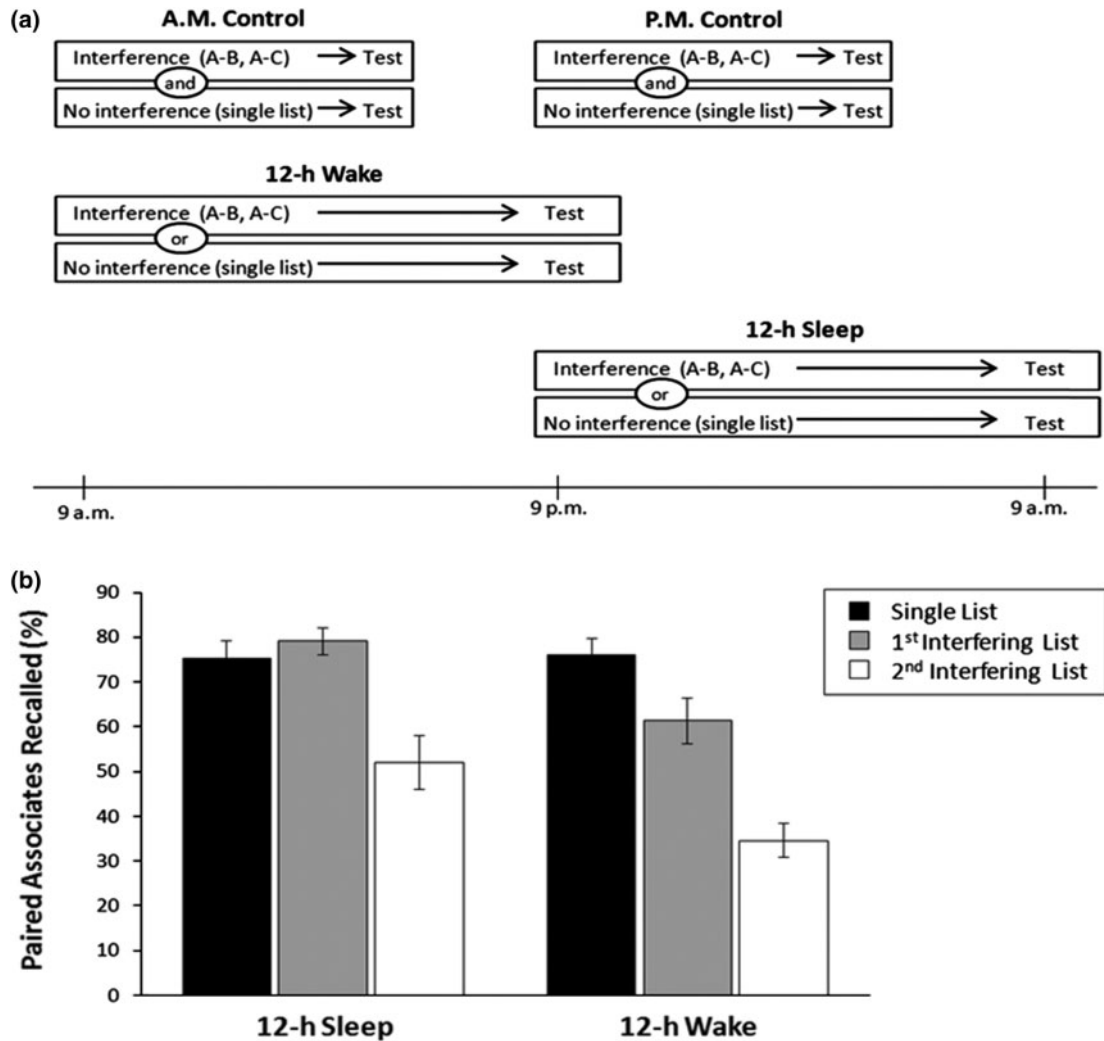


Figure 1. (a) Illustration of conditions: In the 12-h wake conditions participants studied paired associates at 9 am, and were tested on the material after a 12-h delay filled with daytime wakefulness. In the 12-h sleep conditions the experiment started at 9 pm and memory was tested after a 12-h delay filled with night-time sleep. In both 12-h delay conditions participants initially studied either two interfering lists of paired associates (A-B, A-C) or a non-interfering single list. In the short-delay control conditions at 9 am or 9 pm, participants successively encoded and recalled both the two interfering lists (A-B, A-C) and a single list; memory was in each case tested after only a short delay. (b) Mean recall performance as a function of delay (12-h sleep, 12-h wake) and list (single list, 1st interfering list, 2nd interfering list). Error bars represent standard errors.

Procedure

Study phase. In the interference condition participants studied two lists. Before presentation of the first list, participants were asked to memorise paired associates on three study cycles. Item pairs were then presented in random order and at a rate of 4 seconds each centrally on the computer screen. When all pairs had been presented once, the second study cycle began and pairs were presented again in random order. With the third corresponding study cycle, encoding of the first list was completed. A short distractor

phase of about 10 minutes followed, before participants encoded the second list. Participants were asked to memorise the word pairs in addition to the ones they had already studied. The study procedure for the second list was identical to that for the first list. After study of the second list, another distractor phase of about 10 minutes followed. Subsequently participants from the short-delay control condition took the final memory test assessing recall for both lists of paired associates; participants from the 12-h delay conditions left the laboratory and returned after 12 hours to take the same test. In the

no-interference condition, participants studied a single list of paired associates on three consecutive study cycles. The general study procedure was similar to the interference condition, but participants engaged in an additional distractor task of equal length while participants in the interference conditions studied the additional list. Distractors comprised cognitive tests, like the connect-the-numbers test (Oswald & Roth, 1987), as well as unrelated decision tasks.

Test phase. In the interference condition testing took place in the form of a *modified modified free recall* test (e.g., Barnes & Underwood, 1959; Drosopoulos et al., 2007; Ekstrand, 1967): Participants saw the retrieval cue centrally on the computer screen and were asked to write down both items they had previously studied in relation to the respective cue. In addition, participants were asked to indicate which of the items had been studied first and which second. After 15 seconds the next cue appeared on the screen. In the no-interference condition testing took place in the same way. However, because only one item had been studied in relation to each cue, presentation time of cues was reduced to 10 seconds.

Before dismissing participants we checked for compliance with instructions: All participants included in the 12-h wake condition reported not to have taken naps during the day, while all participants included in the 12-h sleep condition reported to have slept regularly during the night (mean sleep duration: 7.5 hours; range 5–10 hours). None of these participants reported alcohol intake between sessions.

RESULTS

Short-delay control condition

Mean recall levels after the short delay are displayed in Table 1. A 3×2 ANOVA with the factors of Interference (single list, 1st interfering list, 2nd interfering list) and Time of day (am, pm) revealed a significant main effect of Interference, $F(2, 92) = 30.23$, $MSE = 187.52$, $p < .001$, $\eta^2 = .40$, indicating that, after the short delay, memory performance was affected by the encoding of the additional list. Indeed, recall was reduced for both the first (A-B) and the second (A-C) interfering list compared to the single list, reflecting retroactive and proactive interference (retroactive interference: $t(47) = 5.45$, $p < .001$,

TABLE 1

Mean recall in the short-delay condition as a function of time of day (am, pm) and list (single list, 1st interfering list, 2nd interfering list)

	Short-delay condition		
	AM	PM	Combined
Single list	90.6 (4.1)	94.2 (1.6)	92.4 (2.2)
1st interfering list	84.2 (4.4)	87.2 (2.7)	85.7 (2.5)
2nd interfering list	69.4 (6.9)	72.8 (5.4)	71.1 (4.3)

Standard errors are displayed in parentheses.

$d = 0.79$; proactive interference: $t(47) = 6.40$, $p < .001$, $d = 0.93$). Additionally, recall of the second interfering (A-C) list was inferior to recall of the first interfering (A-B) list, $t(47) = 4.52$, $p < .001$, $d = 0.65$, which demonstrates higher proactive than retroactive interference. The ANOVA revealed no other significant effects, $F_s < 1.0$, indicating that memory performance was not affected by Time of day.

12-h delay conditions

Figure 1b shows recall performance after the 12-h delay. Regarding retroactive interference, a 2×2 ANOVA with the factors of Delay (12-h wake, 12-h sleep) and Interference (single list, 1st interfering list) revealed a significant main effect of Delay, $F(1, 92) = 4.50$, $MSE = 383.26$, $p = .037$, $\eta^2 = 0.05$, reflecting overall better memory after sleep compared to wake (77.2% vs 68.7%), but no main effect of Interference, $F(1, 92) = 1.84$, $MSE = 383.26$, $p = .18$. However, a significant interaction of the two factors emerged, $F(1, 92) = 5.42$, $MSE = 383.26$, $p = .022$, $\eta^2 = 0.06$, indicating that memory in the two conditions was differently affected by wake and sleep. Indeed, while sleep in comparison to wake did not benefit single-list performance (75.3% vs 76.1%), $t(46) < 1.0$, it improved recall of the first interfering (A-B) list (79.2% vs 61.4%), $t(46) = 3.04$, $p = .004$, $d = 0.81$. Thus retroactive interference was present after wake, $t(46) = 2.36$, $p = .023$, $d = 0.65$, but was absent after sleep, $t(46) < 1.0$.

Regarding proactive interference, an analogous 2×2 ANOVA with the factors of Delay (12-h wake, 12-h sleep) and Interference (single list, 2nd interfering list) revealed a significant main effect of Interference, $F(1, 92) = 51.59$, $MSE = 485.10$, $p < .001$, $\eta^2 = 0.36$, indicating the presence of proactive interference, and a

marginally significant main effect of Delay, $F(1, 92) = 3.38$, $MSE = 485.10$, $p = .07$, reflecting the tendency for better memory after sleep. Importantly, a significant interaction of the two factors emerged, $F(1, 92) = 4.09$, $MSE = 485.10$, $p = .046$, $\eta^2 = 0.04$, showing that memory for the two lists was differently affected by wake and sleep. While sleep in comparison to wake did not affect single-list performance (see above), it improved memory for the second interfering (A-C) list (52.1% vs 34.7%), $t(46) = 3.04$, $p = .004$, $d = 0.81$. Proactive interference was evident in both 12-h delay conditions (wake: $t(46) = 6.48$, $p < .001$, $d = 1.36$; sleep: $t(46) = 3.20$, $p = .003$, $d = 0.84$).²

A final 2×2 ANOVA with the factors of Delay (12-h wake, 12-h sleep) and Interference (1st interfering list, 2nd interfering list) showed that results on the influence of sleep on proactive interference were comparable to those on retroactive interference. Analysis revealed significant main effects of Delay, $F(1, 46) = 7.74$, $MSE = 812.18$, $p = .008$, $\eta^2 = 0.14$, and Interference, $F(1, 46) = 51.88$, $MSE = 300.49$, $p < .001$, $\eta^2 = 0.53$; the main effect of Delay reflects higher performance after sleep than wake (65.6% vs 48.1%); the main effect of Interference reflects higher recall for the first (A-B) than second (A-C) interfering list (70.3% vs 43.3%), i.e., a higher amount of proactive than retroactive interference. No interaction of the two factors arose, $F(1, 46) < 1.0$, indicating that the beneficial effect of sleep on proactive interference was equivalent in size to the effect on retroactive interference.

Confusion of list source and intrusion errors

The analyses above are based on correct recall rates. When participants in the interference conditions incorrectly indicated that a specific recalled item belonged to a different list context—e.g., that an item belonged to the first interfering (A-B) list although it had been presented on the second interfering (A-C) list—this was regarded as a case of list-source confusion.

² Retroactive and proactive interference after the 12-h delays were analysed by means of two separate 2×2 ANOVAs, because interference was manipulated between participants in these conditions. As participants studied either the single list or both interfering lists, no all-encompassing 2×3 ANOVA could be calculated.

A 2×4 ANOVA with the factors of List (1st interfering list, 2nd interfering list) and Condition (am control, pm control, 12-h wake, 12-h sleep) showed that there was a significant difference between lists (first interfering list: $M = 0.50$, $SD = 0.96$; second interfering list: $M = 0.24$, $SD = 0.86$), $F(1, 92) = 6.18$, $MSE = 3.26$, $p = .015$, $\eta^2 = 0.06$, but no difference between conditions, $F(3, 92) = 1.22$, $MSE = 1.13$, $p = .307$, $\eta^2 = 0.04$, and no interaction between the two factors, $F(3, 92) < 1.0$.³ Intrusion errors were analysed as well, and included all cases in which items were incorrectly recalled in connection to previously unassociated cues (i.e., incorrectly paired items from the same list, or falsely remembered unstudied items). Intrusion rates were low ($M = 0.53$, $SD = 0.64$), and did not vary across conditions, all $ps \geq .167$.

DISCUSSION

The results show retroactive interference after wake, but reduced and even eliminated retroactive interference after sleep. Two prior studies have already reported such a pattern when using study–test cycles during encoding (Drosopoulos et al., 2007; Ekstrand, 1967), and the present study generalises this pattern to a different study format with pure study in the absence of any retrieval cycles. More importantly, the present results show proactive interference after wake, but reduced proactive interference after sleep. To our knowledge this is the first demonstration of recovery from proactive interference after sleep in the literature. Drosopoulos et al. (2007) and Ekstrand (1967) had already addressed the issue but, by employing study–test cycles during encoding, likely created too low amounts of proactive interference to make any possible sleep benefits measurable.

Drosopoulos et al. (2007) hypothesised that sleep effects might be driven by memories' initial recall level, such that sleep should be beneficial if memories' initial recall level was relatively low, whereas no beneficial effect of sleep should arise if the recall level was quite high. The present results are consistent with this view, demonstrating sleep benefits for the two interfering lists, which were reduced in recall level, but not for the non-interfering single list, which showed a high

³ A 2×2 ANOVA comparing the 12-h delay conditions only showed that there was no significant difference between conditions, and no significant interaction, all $F_s(1, 46) < 1.0$.

recall level. However, the results for the two interfering lists go beyond the prior view by indicating that sleep benefits do not decrease strictly with increases in initial recall level. Indeed, sleep-related recovery from retroactive interference was equivalent in amount to that observed for proactive interference, although initial recall level was considerably lower for proactive than retroactive interference (see [Figure 1b](#)). These results might suggest that, over a wide range of initial recall levels, beneficial effects of sleep are present and are well comparable in size, and that sleep effects are absent for very high recall levels only. However, further work is required to examine in more detail exactly how sleep effects depend on initial recall level, and whether there is a role for interference-specific sleep effects.

The currently prevailing account of sleep-related memory consolidation attributes the arising benefits of sleep to a reactivation of memory contents during slow-wave sleep that is assumed to strengthen and stabilise memories by initiating their transfer from hippocampus to neocortical sites of long-term storage (see [Diekelmann & Born, 2010](#)). This view fits well with the present results, indicating that sleep can reduce interference effects by actively stabilising single memories and thus making them less susceptible to competition from interfering memories at test. As a consequence, typical interference effects may emerge after wakefulness, but may be reduced or even eliminated after sleep (for a related result, see [Ellenbogen, Hulbert, et al., 2006](#)).

In contrast to this active account, the classic view on why sleep benefits memory claims that sleep passively protects memories from incidental interference (e.g., [Jenkins & Dallenbach, 1924](#); [Wixted, 2004](#); for a discussion see [Ellenbogen, Payne, & Stickgold, 2006](#)). Yet if this passive account were adequate, experimentally induced interference effects should remain intact after sleep. A reduction of experimentally induced interference effects might rather be expected to emerge after wake, because the incidental interference occurring only during wake should gradually reduce the difference between prior interference and no-interference conditions. The observed pattern of intact interference effects after wake but reduced interference effects after sleep thus contrasts with the predictions of the classic view, and challenges the proposal that sleep does nothing more than passively shield memories from incidental interference.

The present results indicate that sleep adds to the list of factors that can induce release from proactive interference. Prior work on release from proactive interference has reported a number of techniques to reduce this interference, like list-method directed forgetting, context change, and interpolated testing. These studies have shown that a cue to forget a previously studied non-target list can lead to a release from proactive interference (e.g., [Bjork, 1970, 1989](#)), an internal context change between the prior study of a non-target list and the subsequent study of a target list can reduce proactive interference (e.g., [Pastötter & Bäuml, 2007](#); [Sahakyan & Kelley, 2002](#)), and testing previously studied non-target lists before subsequent encoding of the target list can result in better memory for the target information (e.g., [Pastötter et al., 2011](#); [Szpunar et al., 2008](#); see also [Bäuml & Kliegl, 2013](#)). All of these techniques trigger release processes that operate prior to target list encoding, whereas sleep triggers release processes that operate subsequent to target list encoding.

In the interference literature of the past decades there has been a long ongoing debate about whether retroactive interference might recover over time (e.g., [Crowder, 1976](#)). While some researchers argued that recovery from retroactive interference was a reliable phenomenon (e.g., [Brown, 1976](#)), others questioned the proposal (e.g., [Keppel, 1968](#)). Consistent with the latter view, the present results do not provide evidence for recovery from retroactive interference across the wake delay. However, differentiating between delays filled with wake and delays filled with sleep, the results demonstrate that recovery from interference is certainly possible, although mainly if sleep, but not diurnal wakefulness, follows encoding of the lists. The finding that sleep reduces both retroactive and proactive interference may offer a new perspective in the ongoing debate on recovery from interference.

To conclude, this is the first study in the literature to show that sleep in comparison to wake not only counteracts retroactive interference but counteracts proactive interference as well. This sleep effect seems to be comparable in size for the two forms of interference. The finding is consistent with the currently prevailing account of sleep-related memory consolidation, according to which the arising benefits of sleep are caused by the reactivation of memory contents during sleep that is assumed to strengthen and stabilise memories. Such stabilisation may make memories

less susceptible to competition from interfering memories at test, and thus reduce both retroactive and proactive interference.

Manuscript received 10 January 2013
 Manuscript accepted 9 March 2013
 First published online 2 April 2013

REFERENCES

- Abel, M., & Bäuml, K.-H. T. (in press). Sleep can eliminate list-method directed forgetting. *Journal of Experimental Psychology: Learning, Memory, & Cognition*.
- Abel, M., & Bäuml, K.-H. T. (2012). Retrieval-induced forgetting, delay, and sleep. *Memory, 20*, 420–428.
- Anderson, M. C., & Neely, J. H. (1996). Interference and inhibition in memory retrieval. In E. L. Bjork & R. A. Bjork (Eds.), *Memory* (pp. 237–313). San Diego, CA: Academic Press.
- Bäuml, K.-H. T., & Kliegl, O. (2013). The critical role of retrieval processes in release from proactive interference. *Journal of Memory and Language, 68*, 39–53.
- Barnes, J. M., & Underwood, B. J. (1959). “Fate” of first-list associations in transfer theory. *Journal of Experimental Psychology, 58*, 97–105.
- Bjork, R. A. (1970). Positive forgetting: The non-interference of items intentionally forgotten. *Journal of Verbal Learning and Verbal Behavior, 9*, 255–268.
- Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 309–330). Hillsdale, NJ: Erlbaum.
- Brown, A. S. (1976). Spontaneous recovery in human learning. *Psychological Bulletin, 83*, 321–338.
- Conte, F., & Ficca, G. (2013). Caveats on psychological models of sleep and memory: A compass in an overgrown scenario. *Sleep Medicine Reviews, 17*, 105–121.
- Crowder, R. G. (1976). *Principles of learning and memory*. Hillsdale, NJ: Erlbaum.
- Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature Reviews Neuroscience, 11*, 114–126.
- 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.
- Ekstrand, B. R. (1967). Effect of sleep on memory. *Journal of Experimental Psychology, 75*, 64–72.
- 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.
- 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.
- Hoddes, E., Zarcone, V., Smythe, H., Phillips, R., & Dement, W. C. (1973). Quantification of sleepiness: A new approach. *Psychophysiology, 10*, 431–436.
- Jenkins, J. G., & Dallenbach, K. M. (1924). Obliviscence during sleep and waking. *The American Journal of Psychology, 25*, 605–612.
- Keppel, G. (1968). Retroactive and proactive inhibition. In T. R. Dixon & D. L. Horton (Eds.), *Verbal behavior and general behavior theory*. Englewood Cliffs, NJ: Prentice Hall.
- Oswald, W. D., & Roth, E. (1987). *Der Zahlenverbindungstest (ZVT) [Connect-the-numbers Test]*. Göttingen: 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.
- Pastötter, B., Schicker, S., Niedernhuber, J., & Bäuml, K.-H. T. (2011). Retrieval during learning facilitates subsequent memory encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37*, 287–297.
- 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.
- 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.
- Scullin, M. K., & McDaniel, M. A. (2010). Remembering to execute a goal: Sleep on it! *Psychological Science, 21*, 1028–1035.
- Szpunar, K. K., McDermodt, K. B., & Roediger, H. L. III (2008). Testing during study insulates against the buildup of proactive interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 1392–1399.
- Tulving, E., & Watkins, M. J. (1974). On negative transfer: Effects of testing one list on the recall of another. *Journal of Verbal Learning and Verbal Behavior, 13*, 181–193.
- Underwood, B. J. (1957). Interference and forgetting. *Psychological Review, 64*, 49–60.
- 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.
- Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annual Review of Psychology, 55*, 235–269.