The Influence of Midday Naps and Relaxation-Hypnosis on Declarative and Procedural Memory Performance

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The sleep enhancing effect on memory (sleep-memory-effect) is well documented for night-time sleep as well as for midday naps. Several reasons may account for this effect. One may be a diminished interference during sleep which may support an undisturbed memory consolidation. To test this hypothesis, memory performance was compared after a midday nap, after relaxation-hypnosis, inducing also a state of low interference, and after wakefulness. Subjects had to perform a declarative memory task (word-list learning) and a procedural memory task (mirror-tracing). Results indicate that declarative memory was better following the midday naps or relaxation-hypnosis compared to wakefulness, respectively. No differences were observed between both low interference conditions (sleeping, hypnosis). Procedural memory was not affected by the kind of treatment. The results support the interference-hypothesis for declarative memory, indicating, that a state of reduced interfering mental activity may account for the sleep-memory-effect. **(Sleep and Hypnosis 2011;13(1-2):7-14)**

Key words: Sleep, memory, sleep-memory-effect, hypnosis, declarative memory, procedural memory

INTRODUCTION

There are a number of different theories why humans are sleeping ranging from energy conservation to brain detoxification (1). For the last 15 years a growing number of studies examined memory consolidation as one possible function of human sleep. Memory consolidation is a process of reactivation and incorporation of afore labile memory traces into a more permanent form embedded in long–term–memory (2).

Early findings (3) already showed a diminished forgetting rate for nonsense syllables after intervals of sleep compared to intervals of wakefulness. The authors concluded "that forgetting is not so much a matter of the decay of old impressions and associations as it is a matter of interference, inhibition, or obliteration of the old by the new." (Jenkins & Dallenbach, 1924, p. 612). By now there is near consensus that sleep improves human memory performance when compared to periods of wakefulness. Many studies have shown this quite robust effect called the sleep–memory–effect (4). The vast majority of these experiments compared a whole night of sleep with an equivalent interval

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of wakefulness using different memory tasks. The sleep–memory–effect was demonstrated for declarative memory tasks (5) as well as for procedural memory tasks (6,7).

Because studies using a night–sleep–paradigm are confounded by factors such as a difference in alertness level, circadian factors or the level of cortisol, in the last years there is a growing interest in daytime–napping–studies. During daytime naps the alertness–level shows a significantly lower variation. In addition, researchers can take advantage of the post–lunch–dip – a time frame of heightened sleep propensity in the early afternoon (8). Daytime napping is quite common and monophasic sleep patterns, which most western adults adopt, seem to be a concession to sociocultural demands and the working life. Bi– and polyphasic sleep patterns can be found in early infancy and after retirement, as well in countries with a warm climate (e.g. Siesta in Spain; 8).

Studies using a daytime–napping–paradigm with comparatively short sleep duration were able to show a beneficial effect of sleep for different memory–tasks. For example, Backhaus and Junghanns (9) found an improvement in procedural motor memory (a mirror–tracing task), but not in declarative memory performance (paired association and face association learning) following a daytime nap. In contrast to this study, Tucker et al. (10) showed greater improvement of the nap–group compared to the waking–group in a declarative paired association task, but not in procedural mirror tracing. Lahl et al. (11) found a superior memory performance for a declarative memory task, namely a 30–item wordlist, after napping when compared to waking activity. In a second experiment they could show, that even an ultra short nap of only six minutes duration is sufficient to boost declarative memory performance beyond waking control levels.

There are different explanations for the sleep–memory–effect (12). One of the possible explanations is that sleep protects the organism against the encoding of new interfering material (3,13) This so–called interference–hypothesis states that sleep serves as a shield to protect already encoded material or memory that is under consolidation from retroactive interference (4). On the other hand, subjects who are awake during a retention interval are engaged in relatively high amounts of interference encountering all kinds of new experiences which may result in a weak or impaired consolidation of a specific memory trace (14).

To test the interference–hypothesis, Gottselig et al. (15) examined the performance in an auditory tone perception task and compared three conditions with different levels of interference: a nap–group, a restful waking– and a busy waking– group. While the napping–group had to stay in bed for 2 hours trying to sleep, the restful waking–group was instructed to lie in bed and relax without falling asleep. The busy waking–group had to watch an educational film for the same time period. While the nap– and the restful waking–group showed a significant improvement from the pre–treatment session to the post–treatment session, no improvement was found for the busy waking–group. Although the nap–group was slightly superior compared to the restful waking–group, this difference did not reach statistical significance. 15. interpreted their results based on the interference–hypothesis stating, that the reduction of sensory input was crucial for the advantage of both, sleep– and restful waking–group, over the busy waking–group.

Hypnosis is a state with a considerable reduction of interference. The Society of Psychological Hypnosis (16) defines hypnosis as a procedure wherein changes in perception, sensation, emotion, thoughts or behavior are induced. Some researchers state that hypnosis in addition has effects on memory, but to date empiric data regarding the relationship between hypnosis and memory remains inconsistent.

Up to today there is still no consent whether sleep as a distinct physiological state facilitates memory consolidation per se, or whether sleep solely shields the brain from potentially interfering stimuli and thus enhances memory consolidation (17). In the latter case, the interference–hypothesis of sleep postulates an improved memory in other mental states of low interference, for example during hypnosis. The aim of the present study was to compare two different conditions with little interference, namely mid–day napping and relaxation–hypnosis, regarding their influence on declarative and procedural memory. It was predicted, that both of these conditions are superior with regard to memory recall when compared with a waking control group.

METHODS

Subjects

Fifty–one native German–speaking participants (42 female, 9 male) aged between 18–34 years were recruited for the study. They were nonsmokers which had neither a history of psychiatric nor neurological diseases, nor did they take any psychotropic drugs. They reported no sleeping problems for the last four weeks prior to the testing session. The subjects were randomly assigned to a waking–, napping– or relaxation–hypnosis–group. A total of four participants had to be excluded, due to the inability to fall asleep when assigned to the napping–group (n= 2), because of technical problems (n= 1) or for falling asleep in the relaxation–hypnosis–group (n= 1). The mean age of the remaining sample (n= 47) was 23.5 years (SD= 4.3). There was no significant age–difference between the participants of the three groups ($F_{2,44}$= 0.96, p= .39). 15 subjects remained in the waking–group, 17 in the napping– and 15 in the relaxation–hypnosis–group. The subjects gave written informed consent. They received a financial compensation.

Materials

To test declarative memory the subjects had to memorize a list of 30 unrelated auditory presented adjectives (wordlist generated with the software EquiWord 1.2; 18). The adjectives were presented four times in randomized order via PC with an interstimulus interval of 1000 ms. Prior to treatment (sleep, hypnosis, wakefulness) an immediate free recall was used to determine the baseline memory performance. The subjects were asked to name as many of the previously learned words as possible independent of order. Subjects were informed, that after the treatment a delayed free recall would be carried out.

For the assessment of procedural memory a mirror–tracing task was applied. The subjects had to move a photosensitive stylus along the black line of a given design, which they only could see in a mirror. First, a training session took place in which a square had to be traced; the actual test–outline thereafter was a star. The drawing time per outline, the number of errors and the error time (time spent off the black line) were detected. Equivalent to the test for declarative memory an immediate recall prior to and a delayed recall after the treatment were conducted.

Procedure

At the day of testing the subjects were not allowed to consume caffeine or alcohol. They were instructed to eat a light meal before testing, which took place between 13:30 and 15:30 p.m. Upon arriving at the sleep laboratory, EEG–, EOG– and EMG–electrodes were applied for standard electrophysiological sleep parameters. Afterwards all subjects learned the wordlist followed by the immediate free recall of the adjectives. Subsequently the mirror tracing training– and test–sessions took place. The group–assignment took place after the immediate recall of the mirror–tracing task.

After learning and recall the waking–group had to sit quietly for 10 minutes with their eyes open while EEG–recording was undertaken. This was done to enhance the comparability to the napping–group in which the subjects may rehearse under resting conditions before falling asleep. After the EEG–recording, the electrodes were removed and the subjects spent the remaining time playing simple nonverbal computer–games. The napping–group had to lie down after learning and recall, trying to fall asleep. During this time polysomnographic recording took place. After 50 minutes in bed the subjects were awakened and the electrodes were removed. The purpose of this was to let sleep inertia wear off during the 10 minutes needed for removal of the electrodes (19) and to make sure that the subjects were fully awake and alert at the time of delayed recall. In the relaxation–hypnosis–group subjects had to sit down in a comfortable position while listening to a relaxation–hypnosis–CD with closed eyes. During the whole time EEG was recorded. After approximately 35 minutes electrodes were removed and subjects played simple nonverbal PC–games for the remaining time of the retention–interval. Sixty minutes after the immediate recall the delayed free recall, as well as the mirror–tracing–task were performed. Additionally the group that underwent the relaxation–hypnosis completed a questionnaire about their relaxation experience.

Hypnosis

To assure maximal standardization, the relaxation–hypnosis was presented by CD, using a record according to the hypnosis developed by Milton H. Erickson for the therapeutic setting (20). After an introduction–hypnosis there were no further suggestions until the trance was resolved. With this kind of hypnosis no specific goals are being pursued, it rather serves for general relaxation and activation of resources. The presentation lasted for about 35 minutes. To assess the subjective relaxation experience subjects had to fill in a questionnaire regarding their feeling prior, during and after the relaxation–hypnosis.

Polysomnographic-recording

Standard electrophysiological sleep parameters were recorded (EEG: C3, C4 referenced to mastoids; bipolar EOG and EMG) using a portable polysomnographic device (SleepScreen by Viasys Healthcare). Two independent judges blind to the experimental condition scored the sleep records in 30–second epochs according to the standardized criteria of Rechtschaffen and Kales (21). Relevant sleep parameters were sleep–onset latency (SOL), total sleep time (TST) and amount of time spend in sleep stages S1, S2, S3 or REM sleep.

Statistical analysis

Differences between the napping–, waking– and hypnosis–groups were analyzed by oneway analysis of variance (ANOVA) with the grouping factor Treatment (napping, hypnosis, waking). Post– hoc comparisons were made with independent samples t–Tests. The significance level was set at .05. For assessment of declarative memory performance (wordlist) the forgetting rate was calculated as an absolute recall measure (i.e. the number of words forgotten over the retention interval). For assessment of the procedural memory performance (mirror–tracing task) the error count (number of errors, i.e.: how often subjects were off the black line), speed (in ms) as well as error–time (total time spent off the black line during delayed recall) were calculated. Correlation analyses were performed between sleep–onset latency and memory performance and between total sleep time and performance at the Delayed Recall.

RESULTS

The sleep parameters of the napping–group are shown in Table 1. As can be seen the subjects needed on average 17 minutes to fall asleep and slept for 26 minutes. Sleep was dominated by the lighter sleep stages S1 and S2, none of the subjects reached the slow–wave sleep stage S3 or REM sleep.

Table 1. Sleep parameters of the napping-group

Sleep parameter (in minutes)	Mean	SD
TST	26.24	12.04
SOL	16.41	11.25
S1	11.59	6.39
S2	13.85	11.08

TST= total sleep time; SOL= sleep onset latency; S1= Time in stage 1 sleep; S2= Time in stage 2 sleep

Table 2. Declarative memory-performance of the three groups

	Waking (n = 15)		Napping (n = 17)		Hypnosis (n = 15)	
	Mean	SD	Mean	SD	Mean	SD
Number of words IR	16.93	6.09	15.94	5.52	14.27	4.68
Number of words DR	12.60	8.02	15.29	7.58	14.60	5.08
Forgetting rate*	-4.33	4.35	-0.65	3.35	0.33	3.31

IR = Immediate Recall; DR = Delayed Recall; *words recalled in DR minus words recalled in IR

Table 3. Procedural memory performance of the three groups

	Waking (n = 15)		Napping (n = 17)		Hypnosis (n = 15)	
	Mean	SD	Mean	SD	Mean	SD
Tracing speed (in ms) IR	15360.7	10446.94	15057.1	12327.57	16819.3	17190.96
Tracing speed (in ms) DR	5736.0	2185.68	6200.6	3374.47	5382.0	3311.86
Error count IR	65.21	15.08	71.16	10.17	61.15	21.23
Error count DR	63.24	12.98	65.66	14.51	55.04	19.86
Error-time (in ms)*	3707.83	1766.30	3858.37	1786.29	3126.23	2803.99

IR = Immediate Recall; DR = Delayed Recall; * total time spent off the black line during DR

The assessment of the subjective relaxation via questionnaire self–rating showed that the subjects of the relaxation–hypnosis–group felt considerably relaxed during and after the relaxation hypnosis. The EEG–recording showed a similar activation pattern as could be seen in the waking–group mainly consisting of alpha activity. No theta waves were recorded.

There was no baseline difference between the three groups regarding declarative or procedural memory performance (Wordlist: $F_{2,44}$= 0.92, p= .41; Mirrortracing error count: $F_{2,44}$= 1.61, p= .21; Mirrortracing speed: $F_{2,44}$= 0.08, p= .93), suggesting that differences in delayed recall are not attributable to differences in initial learning. The mean number of words given at delayed recall (without intrusions) is displayed in Table 2. As can be seen, the napping–group performed better than the hypnosis–group (napping: M= 15.29, SD= 7.58 vs. hypnosis: M= 14.60, SD= 5.08), and these two conditions led to better recall than waking (wake: M= 12.60, SD= 8.02). The difference between delayed and immediate recall represents the forgetting rate. As shown in Table 2, relaxation–hypnosis led to a slight hypermnestic effect, whereas waking clearly led to forgetting (see relative memory performance).

There was a highly significant difference in the forgetting rate between the three groups ($F_{2,44}$= 6.83, p= .003). Post–hoc T–Tests revealed a significant difference between wake– and napping–group (forgetting rate: t= 2.70, p=.011) and between wake– and hypnosis–group likewise (forgetting rate: t= 3.34, p= .002). However, there was no significant difference between the napping– and the hypnosis–group (forgetting rate: t= –0.84, p= .41; see Fig. 1).

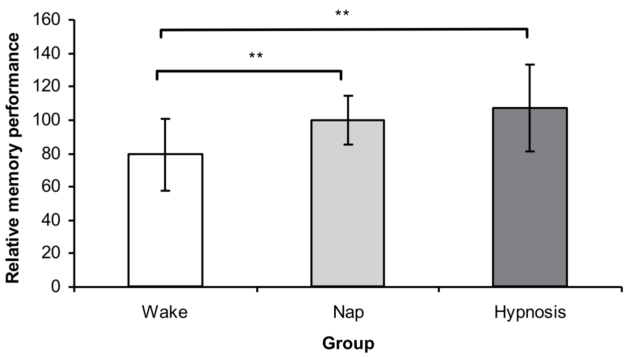

Figure 1. Relative declarative memory performance (in %) in the waking-, napping- and hypnosis-group. Error bars represent standard deviation. ** p<.01

In the mirror–tracing task the performance of the hypnosis–group was better than that of the waking–group, which in turn was better than that of the napping–group. However, this difference did not reach statistical significance (error count: $F_{2,44}$= 1.89, p= .16; speed: $F_{2,44}$= 0.27, p= .77; error–time: $F_{2,44}$= 0.50, p= .61). Measures of accuracy (error count), speed and the error–time are displayed in Table 3.

Bivariate correlation analyses revealed no significant correlation between sleep onset latency and declarative memory performance (forgetting rate: r= .34, p= .18) or between total sleep time and performance at the delayed recall (forgetting rate: r= .04, p= .88).

DISCUSSION

The purpose of the present study was to test the effect of interference on declarative and procedural memory consolidation. Therefore, two conditions with little interference (napping and relaxation–hypnosis) and one condition with more interference (wakefulness) were compared. It was expected, that napping as well as relaxation–hypnosis would lead to better memory consolidation, expressed by a better performance in the declarative and procedural task, than a comparable time spent awake.

In the declarative memory task, napping as well as hypnosis led to better recall than waking, whilst there was no significant difference between these two groups. As predicted by the interference–hypothesis both groups, in which sensory input was reduced, were superior compared to a waking–group, which may have had interference during memory consolidation from the mental activity during waking, e.g. from playing computer–games on a PC. Although we tried to reduce this potential interference in the waking–group, it is likely, that the ongoing mental stimulation and activity during wakefulness might have posed as an interference and thus impaired the consolidation of the previously learned material.

This result is in line with Gottselig et al. (15), who compared performance in an auditory learning task in subjects, who were assigned to a napping–, a restful waking– or a busy waking–group. While both, the sleep– and restful waking–groups showed significant improvements from baseline to post–treatment session, the busy waking group did not. In the experiment by Gottselig et al. (15) subjects slept on average 77 minutes and reached slow–wave sleep as well as REM sleep, while our subject had an average sleep–duration of 26 minutes and only reached the lighter sleeping stages S1 and S2. There are a number of studies showing the importance of slow–wave sleep (e.g. 22) or slow–wave sleep and REM–sleep (e.g. 23) for the post–sleep–improvement in a declarative memory task. Thus, one would expect comparable results in the present study for subjects of the napping–group and the relaxation–group, since both groups did not have slow–wave sleep or REM–sleep during the consolidation interval. Another reason for the similarity of memory performance in the napping and hypnosis conditions in this experiment could be, that hypnosis represents a distinct physiological state, that is comparable to light sleep in regards to different measures of brain arousal. However all of the subjects in the relaxation–hypnosis group were inexperienced regarding hypnosis, did not engage in any kind of relaxation technique (as for example meditation or autogenic training) and did not show any signs of deep trance during the relaxation–hypnosis (for example EEG theta waves). Rather their EEG was comparable to that of the waking–group showing mainly alpha activity. Taken together, this would not indicate that the subjects of the relaxation–hypnosis–group were in a special state comparable to that of the napping–group, but instead it was more likely comparable to that of the waking–group.

The lack of significant differences among the three groups in the mirror–tracing task remains unclear. While some studies with midday naps found memory–improving effects on procedural tasks (9) others did not (10). There is evidence that procedural memory consolidation does mainly depend on REM–sleep (6,24). Since neither participants in the napping condition nor those in the relaxation–condition did show any signs of REM–sleep activity it is not surprising that measures of procedural memory were not affected in the present experiment.

A possible confounding factor, that could influence at least the declarative memory performance, is the amount of intended rehearsal. Subjects in every sleep–condition naturally need some time to fall asleep. This sleep onset latency could be used for deliberate rehearsal of the material learned afore, given, that the subjects know of the later recall. In contrast, subjects in a wake condition immediately start with whatever activity they shall engage in, therefore do not have the chance to rehearse. For this reason, in the present study it was decided to ask subjects of the waking–group to quietly sit for 10 minutes giving them the same opportunity to rehearse. The 10 minutes timeframe was chosen, because in a previous napping–experiment in our laboratory (11) subjects needed on average 11 minutes to reach S1. Because of this procedure it can be assumed that rehearsal–effects are not responsible for the observed superiority of the present napping–group over the waking–group. However, the subjects of the relaxation–hypnosis–group did not have time for potential rehearsal, because they started immediately with the presentation of the relaxation–instructions by CD.

A further factor that may contribute to memory consolidation and interference is the kind of activity or task, the subjects in the wake control group engage in during the retention interval. Different researchers used several approaches to occupy their wake controls: In some studies, the subjects are allowed to leave the laboratory during the retention interval, enabling them to do whatever they like (25), in others they stay in the room, reading their own or provided books or magazines (26), listening to music (17,27) or watching movies/ documentaries (5, 9). All these different activities are the source of more or less interference and can that way account for the observed advantage of the sleep–group over the wake–group. In the present work the subjects who were asked to stay awake were occupied with simple nonverbal computer–games like Tetris or Pacman. These were chosen to provide as little interference as possible while entertaining enough to prevent boredom during the 60 minute retention interval. For future research it would be interesting to compare a sleep–group with waking–conditions that differ regarding their amount of interference. For instance one could compare a conventional wake–group, that is engaged in some activities, with another wake–group, that is asked to stay awake while lying in bed in a darkened sound–proof room with eyes closed. The latter group would that way experience exactly the same conditions as a sleep–group, just without the actual occurrence of sleep. Of course it has to be ensured, that the subjects of this wake–group do not fall asleep, which can be achieved through online polysomnographic surveillance.

In sum, the present study could show beneficial effects of a midday–nap for declarative memory performance, but not for a procedural task. Moreover these positive effects were demonstrated for relaxation–hypnosis, a sleep–independent state of equally little interference as well. These findings support the interference–hypothesis of the sleep–memory–effect and do not support the role of sleep per se as the pivotal factor for improved memory consolidation. However, this interpretation should be regarded with caution and seems to hold only for declarative, but not for procedural memory, because it is still unclear, whether a longer sleep–duration containing slow wave or REM sleep would have boosted the memory performance of the napping–group beyond that of the relaxation–hypnosis–group. Furthermore, it remains to be tested whether the effect of the relaxation–hypnosis condition used in the present study could be replicated using another form of deep relaxation like meditation, autogenic training or progressive muscle relaxation.

REFERENCES

1. *Rechtschaffen A. Current perspectives on the function of sleep. Perspect Biol Med 1998;41:359-390.*

2. *Peigneux P, Laureys S, Delbeuck X, Maquet P. Sleeping brain, learning brain. The role of sleep for memory systems. Neuroreport 2001;12:A111-A124.*

3. *Jenkins JG, Dallenbach KM. Obliviscence during sleep and waking. Am J Psychol 1924;35:605-612.*

4. *Rasch B, Born J. Reactivation and consolidation of memory during sleep. Curr Dir Psychol Sci 2008;17:188-192.*

5. *Gais S, Lucas B, Born J. Sleep after learning aids memory recall. Learn Mem 2006;13:259-262.*

6. *Plihal W, Born J. Effects of early and late nocturnal sleep on declarative and procedural memory. J Cogn Neurosci 1997;9:543-547.*

7. *Walker MP, Brakefield T, Morgan A, Hobson JA, Stickgold R. Practice with sleep makes perfect: sleep-dependent motor skill learning. Neuron 2002;35:205-211.*

8. *Broughton RJ. Chronobiological aspects and models of sleep and napping. In: Dinges DF, Broughton RJ, eds. Sleep and Alertness: Chronobiological, Behavioral, and Medical Aspects of Napping. New York: Raven Press, 1989;71-98.*

9. *Backhaus J, Junghanns K. Daytime naps improve procedural motor memory. Sleep Med Rev 2006;7:508-512.*

10. *Tucker MA, Hirota Y, Wamsley EJ, Lau H, Chaklader A, Fishbein W. A daytime nap containing solely non-REM sleep enhances declarative but not procedural memory. Neurobiol Learn Mem 2006;86:241-247.*

11. *Lahl O, Wispel C, Willigens B, Pietrowsky R. An ultra short episode of sleep is sufficient to promote declarative memory performance. J Sleep Res 2008;17:3-10.*

12. *Maquet P. The role of sleep in learning and memory. Science 2001;294:1048-1051.*

13. *Wixted JT. The psychology and neuroscience of forgetting. Annu Rev Psychol 2004;55:235-269.*

14. *Coenen AMI, van Luijtelaar ELJM. Effects of benzodiazepines, sleep and sleep deprivation on vigilance and memory. Acta Neurol Belg 1997;97:123-129.*

15. *Gottselig JM, Hofer-Tinguely G, Borbély AA, et al. Sleep and rest facilitate auditory learning. Neuroscience 2004;127:557-561.*

16. *Society of Psychological Hypnosis, Division 30, American Psychological Association (2005). The Division 30 Definition and Description of Hypnosis. Retrieved February 10, 2010 from http://www.apa.org/divisions/div30/define_hypnosis.html*

17. *Rieth CA, Cai DJ, McDevitt EA, Mednick SC. The role of sleep and practice in implicit and explicit motor learning. Behav Brain Res 2010;214:470-474.*

18. *Lahl O, Pietrowsky R. EQUIWORD: A software application for the automatic creation of truly equivalent word lists. Behav Res Methods 2006;38:146-152.*

19. *Hofer-Tinguely G, Achermann P, Landolt HP, et al. Sleep inertia: performance changes after sleep, rest and active waking. Cogn Brain Res 2005;22:323-331.*

20. *Bökmann M. Mit den Augen eines Tigers 2 – Tiefenentspannung nach Milton H. Erickson. [CD]. Heidelberg: Carl-Auer Verlag, 2002.*

21. *Rechtschaffen A, Kales A. A manual of Standardized Terminology, Techniques, and Scoring System for the Sleep Stages of Human Subjects. Washington: Public Health Service Publications, 1968.*

22. *Gais S, Born J. Low acetylcholine during slow-wave sleep is critical for declarative memory consolidation. Proc Natl Acad Sci USA 2004;101:2140-2144.*

23. *Mednick S, Nakayama K, Stickgold R. Sleep-dependent learning: a nap is as good as a night. Nat Neurosci 2003;6:697-698.*

24. *Plihal W, Pietrowsky R, Born J. Dexamethasone blocks sleep induced improvement of declarative memory. Psychoneuroendocrinology 1999;24:313-331.*

25. *Talamini LM, Nieuwenhuis ILC, Takashima A, Jensen O. Sleep directly following learning benefits consolidation of spatial associative memory. Learn Mem 2008;15:233-237.*

26. *Hockey GRJ, Davies S, Gray MM. Forgetting as a function of sleep at different times of day. Q J Exp Psychol 1972 ;24:386-393.*

27. *Gais S, Plihal W, Wagner U, Born J. Early sleep triggers memory for early visual discrimination skills. Nat Neurosci 2000;3:1335-1339.*