ORIGINAL ARTICLE

Effect of a Motor Learning Task on REM Sleep Parameters

Daniel Erlacher, Ph.D. and Michael Schredl, Ph.D.

Previous research has shown that learning of procedural tasks enhance REM sleep. An experiment in which eleven subjects either learned a motor task or engaged in a control task was carried out in a balanced within-design to investigate whether motor learning would affect sleep. An initial laboratory adaptation night and two experimental nights were consecutive. The results indicate that learning a motor task exerts no effect on REM sleep parameters and, therefore, the results do no support the hypothesis that learning a procedural skill is related to an increase in REM sleep parameters. One might speculate that the motor learning was not intense enough in comparison to other studies. In future studies, other motor tasks should be applied.
(Sleep and Hypnosis 2006;8(2):41-46)

Key words: Motor learning, procedural memory, REM sleep

INTRODUCTION

There is for long time evidence that sleep after learning enhances the performance in contrast to a similar period of time of wakefulness (1). In more recent studies, it was shown that procedural tasks, e.g., mirror tracing, sequential finger tapping, benefit from REM sleep (2).

There have been different paradigms to investigate the relationship between REM sleep and memory consolidation in humans: (1) manipulation of REM sleep after learning, e.g., REM sleep deprivation (3), (2) comparing time intervals with sleep to matched periods of wakefulness, e.g., late vs. early sleep (4), day sleep and night sleep (5), (3) correlating REM sleep parameters with improvements in task performance (e.g. [6]) and (4) measuring REM sleep after the learning task (e.g. [7]). Because of the methodological problems of REM sleep deprivation (disrupting the natural sleep pattern), comparison of sleep/wake intervals (circadian variations) and correlational studies (no experimental manipulation), some researchers (e.g. [8]) focus on the fourth approach studying the effect of learning on subsequent sleep. In his overview, Smith (9) reported that 14 of 16 recording studies that utilized tasks of a procedural nature reported enhancements in REM sleep, either in terms of increased amounts (minutes spent in REM sleep) or intensity (REM densities - number of eye movements per REM period).

Since the REM-augmenting effect is mainly

From Institute for Sport and Sportscience, University of Heidelberg (Dr. Erlacher) and Central Institute of Mental Health, Mannheim (Dr. Schredl), Germany

Address reprint requests to: Daniel Erlacher
Institute for Sport and Sportscience, University of Heidelberg, Im Neuenheimer Feld 700, 69120 Heidelberg, Germany,
phone: ++49-6221-544348, fax: ++49-6221-544387,
e-mail: daniel.erlacher@issw.uni-heidelberg.de.

Accepted February 21, 2006

found after procedural tasks, the experimental study of motor learning tasks in the sport domain should be very promising. Surprisingly only one of the studies reviewed by Smith (9) investigated the effect of learning a complex sport activity (trampolining) on REM sleep (10). In this study sixteen subjects were randomly assigned to an experimental and a control group. The participants of the experimental group participated in a basic training course in trampolining. All participants were novices to this task and practiced for a period of 13 weeks once a week for two hours. After each training session two subjects were recorded in the sleep laboratory between 0 a.m. and 8 a.m. After twelve weeks every participant was recorded three times. To ensure motor learning for the experimental group they had to accomplish different skill levels (e.g., tuck-, piked-, straddle-jump, and somersaults) and the progress of motor learning was quantified by an index of performance. Prior to the training session two baseline recordings were made for the participants of the experimental group and one baseline recording for the control group. The control group participated in the same procedure as the experimental group with the difference that they practiced a well-known anaerobic sport (dancing or soccer) without motor learning. The results showed a marked increase in REM sleep percent for the experimental group from the baseline condition (22.8 %, 22.6%) to the learning blocks (30.2%, 28.7%, and 27.4%). Further there was a significant difference in REM sleep percent between the experimental group and the control group (REM sleep percent for the control group was: 21.2 %, 24.2 %, and 20.9 %).

However, the results have to be interpreted with caution since the authors have not carry out an extra night prior to the baseline and experimental nights to allow adaptation to the sleep laboratory setting. Therefore the findings might be explained by the so-called first-night effect (reduced REM sleep percent, e.g., [11]) and because the baseline condition and the learning condition were not balanced for the within-subject comparison serial effects can not be excluded. Furthermore, the sleep recordings for the experimental group were not administered after the first learning session, for two subjects after the first session, for the next pair after the second session and so on. Despite the fact that a learning protocol was used to ensure motor learning, it is not clear whether motor learning was present to the same amount over the learning period of 13 weeks. I. e. one might assume that there was an adaptation to the trampolining task over the learning period of 13 weeks.

In the present study a within-subject design with adaptation night and balanced conditions was used to study the changes of sleep parameters after learning a novel complex sport activity in contrast to a control condition (sport activity without motor learning).

METHODS

Participants

Eleven sport students (8 women, 3 men) participated in the study. Their mean age was 27.1±5.8 years, ranging from 22 to 41 years of age. The participants had given written informed consent and were not paid for their participation.

Design

Overall, the subjects spent three consecutive nights in the sleep laboratory. Night 1 served as an adaptation night and included measures of nasal and oral airflow, chest and abdomen movements, blood oxygen saturation and anterior tibialis electromyogram in both legs. In a balanced design, the participants completed an ergometer training session or a snakeboard training session at 5 pm to 7 pm prior to

Night 2 and Night 3. After each laboratory night the participants completed the sleep questionnaire SF-A.

Ergometer and Motor Learning Sessions

Learning snakeboard riding was new to all participants. A Snakeboard is a modification of the skateboard. These variants have a central bar with two pivoting platforms attached at each end. Wheels are attached to the ends as they are in normal boards. The user puts one foot on each pivotant board and by moving them in and out, and when combined with a coordinated shift of one's body, one can move in a manner similar to that of a snake. The participants had to accomplish different skill levels (e.g., mount the board, drive a prefixed course) according to a standardized learning protocol. The duration of the session was two hours.

The two-hour ergometer aimed at a moderate exertion with control of heart rate (120 bpm). After these sessions the participants rated their perceived exertion on the Borg scale (12). This scale ranges from 6=very, very light to 19=very, very hard and 20=exhaustion.

Sleep

Sleep was recorded between 23.00 hrs and 7.00 hrs by means of the following standard procedures: EEG (C3-A2, C4-A1), electrooculogram (EOG), submental electromyogram (EMG) and electrocardiogram (ECG). Sleep records were scored under blind conditions by applying the commonly used criteria of Rechtschaffen and Kales (13). The following sleep parameters were computed:

Sleep continuity: Measures were taken of sleep period time (SPT; time between sleep onset and final morning awakening), sleep efficiency (ratio of time in bed minus time awake to time in bed), sleep latency (time span from „lights off“ to occurrence of first stage 2 or REM), and the number of awakenings of at least 0.5 minutes duration.

Sleep architecture: Stage 1, 2, slow-wave sleep (stage 3 and 4) and REM (expressed in percent of SPT) were measured.

REM sleep: REM latency is the time period between sleep onset and the first REM period of at least 3 minutes. In addition, a second measure was derived for REM latency by subtracting all epochs scored as "being awake“. REM density is the ratio of 3-second miniepochs with eye movements to all 3-second epochs of REM sleep. This was done for the entire night as well as for the first REM period. In addition, the length of the first REM period and the number of REM periods were included in our analyses.

Sleep questionnaire

The SF-A (14) comprises 22 items measuring composite scores such as sleep quality (9 items), feeling refreshed in the morning (7 items) of the night before. The composite scores (averages) ranged from 1 to 5 since most scales of the SF-A followed this five-point format ranged from 1=none to 5=very strong.

Statistical analysis

T-tests for dependent samples were carried out to analyze the differences between ergometer and motor learning nights. Since for REM sleep variables the direction of the effect was predicted, one-tailed tests were applied. All other sleep parameters were tested two-tailed. Statistical analyses were carried out with the SAS for Windows (Version 8.02) software package.

RESULTS

Two participants had mild to moderate indices of periodic limb movements during sleep ranging from 14.6 to 31.2 per hour without arousals and 2.0 to 3.5 per hour with

Table 1. Sleep parameters of adaptation, ergometer and motor learning nights (Means ± SD)

Variable	Adaptation Night	Ergometer Night	Learning Night	E vs. L t-test[1]
bedtime (min)	466.3 ± 13.2	478.0 ± 7.8	477.3 ± 6.3	-0.4 .6705
Sleep efficiency (%)	82.9 ± 8.6	90.1 ± 4.3	90.7 ± 4.2	0.3 .7604
Sleep latency (min)	28.8 ± 25.2	12.5 ± 11.6	12.5 ± 10.9	0.0 .9850
Number of awakenings	24.6 ± 11.7	25.3 ± 11.6	25.6 ± 9.0	0.2 .8269
Time awake (% SPT)	9.3 ± 3.3	7.0 ± 4.0	6.8 ± 3.9	-0.1 .9148
Stage NREM 1 (% SPT)	13.8 ± 7.1	10.9 ± 4.4	10.9 ± 5.6	0.0 1.000
Stage NREM 2 (% SPT)	54.3 ± 5.5	57.8 ± 4.7	56.9 ± 6.2	-0.4 .7160
Slow-wave sleep (% SPT)	8.0 ± 6.0	6.8 ± 6.4	7.9 ± 6.4	1.2 .2625

[1]probability values are two-tailed

Table 2. REM sleep parameters of adaptation, ergometer and motor learning nights (Means ± SD)

Variable	Adaptation Night	Ergometer Night	Learning Night	E vs. L t-test[1]
Stage REM (% SPT)	14.5 ± 3.3	17.5 ± 5.2	17.4 ± 5.6	-0.1 .5200
REM latency (min.)	121.0 ± 43.2	98.0 ± 25.8	102.0 ± 72.0	0.2 .4326
REM latency (3 min REM)	128.5 ± 40.6	106.9 ± 31.1	102.5 ± 71.8	-0.2 .5657
Duration (1. REM period)	17.5 ± 12.0	17.2 ± 15.0	11.8 ± 7.4	-1.6 .9282
REM density (1. REMP)	16.1 ± 10.9	12.0 ± 5.0	14.2 ± 5.9	1.2 .1251
REM density (total night)	18.7 ± 9.4	19.2 ± 8.0	18.3 ± 6.6	-0.5 .6911

[1]probability values are one-tailed

Table 3. Subjective sleep parameters of adaptation, ergometer and motor learning nights (Means ± SD)

Variable	Adaptation Night (N= 11)	Ergometer Night (N= 10)	Learning Night (N= 11)	E vs. L t-test[1]
Sleep quality	2.89 ± 0.72	3.85 ± 0.48	3.80 ± 0.69	-0.4 .7164
Feeling of being refreshed in the morning	3.03 ± 0.79	3.31 ± 0.65	3.43 ± 0.58	0.6 .5599

[1]probability values are two-tailed

arousal. The clinical cutoff is 5 limb movements per hour with arousal (15), so these participants were not excluded. The perceived exertion during the ergometer session (13.4±1.7) was comparable to the perceived exertion during the snakeboard session (13.1±2.7, t =0.3, p=.7710).

Table 1 shows the sleep parameters of the adaptation, ergomenter and motor learning nights. There were no effects of motor learning on sleep efficiency or sleep continuity. Regarding REM sleep parameters, the percentage of REM sleep was not altered after the motor learning task (see Table 2). The other REM sleep parameters such as REM latency, REM density, duration of first REM period did also not differ between the two nights. In addition, the subjective sleep quality and feeling of being refreshed in the morning were similar after both nights (see Table 3).

DISCUSSION

The findings of the present study indicate no effect on sleep parameters after learning a specific novel complex sport activity. Neither REM parameters nor other sleep parameters (SWS, Stage 2 etc.) and subjective sleep ratings showed any differences between the experimental and control condition.

Because of the findings of the present study one might speculate that the increase in REM sleep percent for the within-subject comparison in the study by Buchegger et al.

(10) might be explained by the first-night effect, which means that the baseline level (first lab nights for the participants) of REM sleep percent was seriously underestimated. Even though in the Buchegger study two baseline nights were conducted for the learning group; some authors suggest that the first-night effect may last more than one night (13). In the present study the first-night effect was controlled by one adaptation night prior to the control or learning condition. To ensure that the first-night effect is also controlled for the subsequent nights in the sleep laboratory the control and learning condition were applied in a balanced manner.

However, methodological issues can not explain alone the negative finding of the present study since the majority of the recording studies that utilized tasks of a procedural nature reported enhancements in REM sleep parameters (9) and even in the study by Buchegger et al. (10) the learning group has significant more REM sleep percent than the control group. One obvious difference in our study to other experiments applying the paradigm of measuring REM sleep after learning a task is the used learning task. The procedural tasks in other experiments reported by Smith (9) are: language learning, logic games, mirror tracing, tapping, serial reaction time, Tower of Hanoi, visual texture discrimination and trampolining. Only trampolining involves gross body movement and requires unfamiliar movements such as translation and rotation of the whole body in the three-dimensional space. In this study learning riding a snakeboard was used to invoke motor learning. The nature of the task is highly procedural since the participants had to learn complex coordinated movements of the whole body to accomplish the task with only minimal explicit instructions by the experimenter. The coordination requirements of snakeboarding are quite similar to trampolining but there are two differences: First, for snakeboarding no orientation skills in the three-dimensional space are necessary. Second, one might speculate that the motor learning task was not intense enough in comparison to trampolining. In further studies those factors should be considered and other motor tasks should be applied (e.g. with high orientation skills in space or higher intensity).

Whereas in the study by Buchegger et al (10) participants had a low background of sport in the present study sport students participated in the study. Even the participants had no previous experience with the learning task, learning progress varied markedly between the subjects. This might be explained by different backgrounds of the subjects regarding comparable sport activities (e.g. skateboarding, snowboarding). Unfortunately, this was not elicited in the present study. Nevertheless all participants needed the two hours training session to master the skill of riding a snakeboard, even if two participants had at the end of the training session some problems to accomplish a given parcours. One might speculate that because of high background of sport of our participants, the learning task evoked not the early phases of motor learning and thus – according to the theory of Smith (9)–no direct effects on REM sleep. In future studies, this factor should be controlled by using subjects with low learning experience.

To summarize, no changes in sleep parameters after learning a specific motor task (snakeboard riding) were found and, therefore, the results do no support the hypothesis that learning a procedural skill is related to an increase in REM sleep parameters. One might speculate that the motor learning was not intense enough (in comparison to trampolining) and that the background of comparables sport skills in the participants of the present study had a negative effect on the study's results. In future studies, other motor tasks should be applied to participants with no prior experience to this task.

REFERENCES

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

2. *Walker MP. A refined model of sleep and the time course of memory formation. Behav Brain Sci 2005;28:51-64.*

3. *Karni A, Tanne D, Rubinstein BS, Askenasy JJ, Sagi D. Dependence of REM sleep of overnight improvement of a perceptual skill. Science 1994;265:679-682.*

4. *Plihal W, Born J. Effects of early and late nocturnal sleep on declarative and procedural memory. J Cogn Neurosci 1997;9:534-547.*
5. *Fischer S, Hallschmid M, Elsner AL, Born J. Sleep forms memory for finger skills. PNAS 2002;99:11987-11991.*

6. *Stickgold R, Whidbee D, Schirmer B, Patel V, Hobson JA. Visual discrimination task improvement: A multi-step process occurring during sleep. J Cogn Neurosci 2001;12:246-254.*

7. *Mandai O, Guerrien A, Sockeel P, Dujardin K, Leconte P. REM sleep modifications following a morse code learning session in humans. Physiol Behav 1989;46:639-642.*

8. *Smith C. Sleep states and memory processes in humans: Procedural vs. declarative memory systems. Sleep Med Rev 2001;5 491-506.*

9. *Smith C. Different roles for REM and stage 2 sleep in motor learning: A proposed model. Psychol Belg 2004;44:79-102.*

10. *Buchegger J, Fritsch R, Meier-Koll A, Riehle H. Does trampolining and anaerobic physical fitness affect sleep? Percept Mot Skills 1991;73:243-252.*

11. *Agnew HW, Webb WB, Williams RL. The first night effect: An EEG study of sleep. Psychophysiology 1966;2:263-266.*

12. *Borg GA: Perceived exertion: a note on history and methods. Med Sci Sports 1973;5:90-93.*

13. *Rechtschaffen A, Kales A. A manual of standarized terminology, techniques and scoring system for sleep stages of human subjects. Washington: U. S. Public Health Service, 1968.*

14. *Görtelmeyer R: Schlaf-Fragebogen A und B (Sf-A, Sf-B). In: Scalarum CIP, ed. Internationale Skalen fur Psychiatrie, Vol 4. Weinheim: Beltz, 1986.*

15. *Allen RP, Picchietti D, Hening WA, Trenkwalder C, Walters AS, Montplaisi J. Restless legs syndrome: diagnostic criteria, special considerations, and epidemiology. A report from the restless legs syndrome diagnosis and epidemiology workshop at the National Institutes of Health. Sleep Med 2003;4:101-19.*