

LEARNING-RELATED NEURAL CHANGES ARE ACCESSIBLE
DURING REM SLEEP

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Perceptual learning is thought to be the result of neural changes that take place over a period of several hours or days, allowing information to be stored in long-term memory. Evidence suggests that contents of long-term memory may improve attentive and pre-attentive sensory processing. Therefore, it is plausible to hypothesize that learning-induced neural changes that develop during wakefulness could improve automatic information processing during human REM sleep. The MMN, an objective measure of the automatic change detection in auditory cortex, was used to evaluate long-term learning effects on pre-attentive processing during wakefulness and REM sleep. When subjects learned to discriminate two complex auditory patterns in wakefulness, an increase in the MMN amplitude was obtained in wake and REM states. The automatic detection of the infrequent auditory pattern was improved in both brain states presumably by reactivating information from long-term memory. These findings suggest that long-term learning-related neural changes are accessible during REM sleep as well.

NAPPING: A NATURAL WAY TO SPEED UP CONSOLIDATION OF VISUAL PERCEPTUAL LEARNING

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Within-day over-exposure to a perceptual learning task, the texture discrimination task (TDT), leads to impaired performance. Previous research has shown that learning-related neural changes that underlie the consolidation process of perceptual learning partially occur during nocturnal sleep. We hypothesized that detrimental effects on performance from within day, consecutive testing may be reversed by a daytime nap. All subjects were tested on the TDT in four sessions separated by 2-hour intervals. The experimental group took a nap of either 60 min. or 30 min. between the 2nd and 3rd session. We found that 60 min. naps reversed the detrimental effects on performance observed in the control group, whereas the benefit of half hour naps was more ephemeral. Further, in the hour nap condition, improvement was correlated with the amount of slow wave sleep (SWS; $r=.68$, $p=.05$). These results, however, do not distinguish between whether the nap induced stimulus-specific neural changes or if experimental subjects were just generally more rested.

Improvement in the TDT has been shown to be retinotopically specific, in which case the learning-related neural changes and the performance decrement should also be retinotopic. We also tested this hypothesis. Retinal specificity was evaluated by switching the target stimulus to the opposite lower quadrant for the last of four within-day testing sessions. The no-switch group evidenced the aforementioned decline in performance across sessions, whereas the switch group's performance returned to baseline during the 4th session. Therefore, the performance decline caused by over-exposure to the TDT seems to be specific to neural changes in early visual cortex and not due to generalized tiredness. These results suggest that benefits of daytime naps may stem from a speeding-up of learning-related, local neural changes in early sensory cortex during the SWS periods.

DAYTIME SLEEPINESS, MOOD, AND PERFORMANCE FOLLOWING EXPERIMENTALLY-INDUCED SLEEP FRAGMENTATION

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Introduction. Experimental Sleep Fragmentation (SF) involves inducing arousals by administering intrusive auditory stimuli periodically throughout the night. It is intended to model the type of frequent and periodic disruption experienced in sleep disorders such as apnea and periodic limb movement. Previous research has shown that SF leads to daytime sleepiness, but evidence of performance impairment has been inconsistent (1). The purpose of this study was to investigate the *cumulative* effects of SF on daytime functioning. *Method.* Participants were six healthy adults (3 female, mean age=35.2) with no sleep complaints. Following a screening night, participants spent four consecutive 24-hour periods in the laboratory. The order of conditions was fixed as follows: baseline, SF1, SF2, recovery. On nights two and three, sleep was fragmented using methods similar to Philip et al (1). Stimuli were delivered via an earphone in the right ear for 10s beginning at 65 dB(A). If no EEG arousal resulted, the intensity was increased by 10 dB for each successive presentation to a maximum of 115 dB(A). During the day, participants performed a 35-minute computerized test battery at 2-hr intervals (09:00-19:00). The battery was fixed and included: Profile of Mood States (POMS), Stanford Sleepiness Scale (SSS), Alpha Attenuation Task, reaction time (10 min), an auditory odd-ball (ERP paradigm), serial addition/subtraction, and subjective perception of performance. The battery was practiced prior to the baseline night. *Results.* On pre- and post-sleep questionnaires, measures of sleepiness and fatigue (7-point scales), PANAS positive mood (2), and a visual analogue mood scale (energetic to sluggish) all revealed significant CONDITION effects ($p < .01$). For all of the variables, paired t-tests indicated that baseline differed from SF1, SF2, and recovery. SF1 did not differ from SF2. Polynomial analyses indicated a significant quadratic trend for all of these variables ($p < .01$). Analyses were also carried out on the average of daytime performance sessions for SSS, RT and math. Speed of performance on math or RT did not differ across experimental conditions. There was a significant CONDITION effect ($p = .02$) and a linear polynomial trend ($p = .03$) for the number of correct responses on the serial addition/subtraction task. Baseline, SF1, and SF2 were all significantly lower than recovery values. There was no difference between the 1st and 2nd SF conditions. *Discussion.* Following the 2nd night of SF, there was no change in subjective mood or sleepiness. Thus, there was neither habituation nor an additive effect on successive nights of SF, although it does appear that learning on the math task remains asymptotic during the sleep debt. Subjective measures of sleepiness and mood are somewhat at odds with performance measures on neurobehavioural tasks. We expect that subsequent analyses of electrophysiological measures of arousal and attention (EEG and ERPs) will support the subjective feelings of reduced well-being following this degree of partial sleep deprivation. *References.* (1) Philip P, et al. *Sleep* 1994;17:242-247. (2) Watson D, et al. *J Pers Soc Psych* 1988;54:1063-70.

AGE-RELATED CHANGES IN THE SLEEP QUALITY OF PRESCHOOL AND EARLY SCHOOL AGED CHILDREN

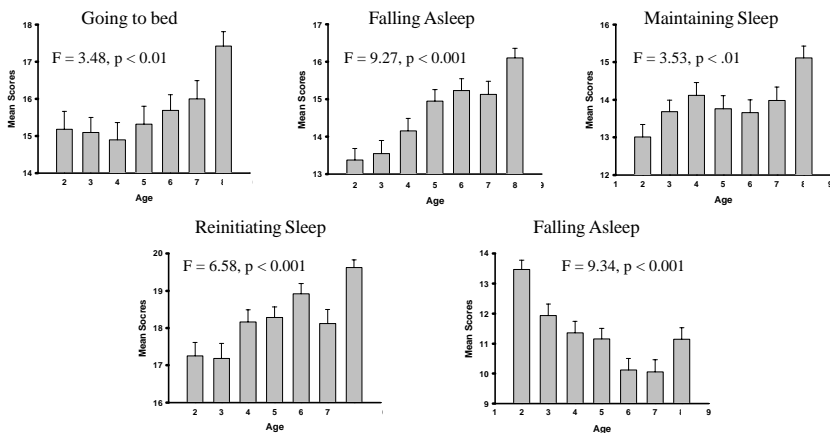
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Introduction: Despite growing awareness of the need for normative developmental data on children's sleep (Sadeh et al., 2000), such data are still lacking for preschool and early school-age children. The present study describes changes in the sleep of 2- to 8-year-old children along several developmentally meaningful dimensions using a new research instrument, the Children's Sleep-Wake Scale (CSWS).

Methods: Caretakers recruited from the local community were administered the CSWS via telephone. The CSWS is parent report instrument comprised of several subscales, including Going to Bed (7 items, $\alpha = 0.85$), Falling Asleep (6 items, $\alpha = 0.69$), Maintaining Sleep (6 items, $\alpha = 0.69$), Reinitiating Sleep (7 items, $\alpha = 0.71$), and Returning to Wakefulness (5 items, $\alpha = 0.85$). Higher scores reflect better sleep on the respective dimension. Data were collected on 485 children (236 male, 249 female), ages 2 to 8 years (mean = 4.9, SD = 2.0). Response rate was 88%.

Results: Mean scores on the CSWS subscales for each age group are shown in the following graphs.



Discussion: The results of this study suggest a general trend in the sleep-related changes across childhood. Children's success in going to bed and sleeping through the night increases with age, while their ability to awaken in the morning decreases as they get older.

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LIGHT EXPOSURE OF CHICK EMBRYO AS A DETERMINANT OF MONOCULAR SLEEP

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Birds, like some aquatic mammals, exhibit a unique behavioral and electrophysiological state called “unihemispheric sleep”, in which one cerebral hemisphere is awake and the other is sleeping. Slow-wave sleep in one hemisphere is associated with closure of the contralateral eye, whilst the eye contralateral to the awake hemisphere is open. Closure of both eyes, in contrast, is associated with bihemispheric slow-wave sleep or with REM sleep. During the last three days of incubation chick's embryo is turned in the egg so that, the right eye lies adjacent to the egg shell and is stimulated by light penetrating the shell and membranes. We measured the number and the duration of episodes of binocular and monocular sleep in chicks hatched from eggs maintained in the dark before hatching and in chicks exposed to light during the last three days before hatching. In the first two day of life light-incubated chicks slept prevalently with their left eye open, whereas dark-incubated chicks prevalently with their right eye open. The difference tended progressively to disappear until, on day five, both light- and dark-incubated chicks preferentially slept with their left eye open. These result suggest the role of enviromental factors in modulating complex phenomena as unihemispheric sleep.

EFFECTS OF THE HYPNOTIC DIAZEPAM ON MEMORY IN THE VISUAL AND AUDITORY MODALITY

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Central topic of research is to clarify the relation between level of vigilance and learning and memory processes. In the present study, the classic hypnotic diazepam (valium), which is known to have amnesic effects, was used to decrease vigilance. Memory was tested after diazepam intake (10 mg orally). Two main effects of diazepam on memory were investigated: anterograde amnesia (impaired recall of what is learned under drug influence) and retrograde facilitation (enhancement of recall of what is learned just before drug intake). It was questioned whether both memory effects are present in the visual and the auditory modality and in both complex and simple tasks. The experiment was performed in a double-blind, placebo-controlled way. All 20 subjects were exposed to memory tests: an auditory 15 words test (simple auditory task), a short story recall test (complex auditory task), a visual 15 words test (simple visual task) and the Complex Figure of Rey (complex visual task). Anterograde amnesia was found for both modalities, for simple and complex tasks. Retrograde facilitation was found in both modalities, but only for simple tasks, although the effects were in the same direction for the complex tasks. In all, the data demonstrate that anterograde amnesia is not modality-specific and present in both simple and complex tasks. Retrograde facilitation is not modality-specific either, being present in both the visual and auditory modality for simple tasks.

It was demonstrated that the decrease of vigilance level after diazepam leads to

- 1) An impaired recall of new material, and
- 2) An improved recall of already learned material

Perhaps less resources are available for the consolidation of new material in a diazepam-induced lowered state of vigilance. On the other hand, the process of ongoing consolidation of already learned material faces less interference, as there is less new material consolidated during this decreased level of vigilance. This lack of 'competition' in consolidation between new and already learned material, is expressed in a better recall of this already learned material: retrograde facilitation.

INCREASED SLEEP SPINDLE ACTIVITY FOLLOWING SIMPLE MOTOR PROCEDURAL LEARNING IN HUMANS

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A number of recent studies have suggested that Stage 2 sleep is involved in the consolidation of simple motor procedural memory (1, 2). Other studies have found that the number of spindles are positively correlated with procedural learning (3), and intelligence (IQ) (4).

Method: Eight female undergraduate students spent three consecutive nights in the sleep lab (acclimatization, baseline and test). The experimental group was exposed to two hours of simple motor procedural tasks, while the controls were not. The experimental group was retested on the tasks one week later.

Results: It was found that the number of sleep spindles increased 42% after learning ($F = 8.22, p < .03$). When split according to high and low Performance IQ a planned orthogonal comparison revealed only the high Performance IQ group had a significant increase in the number of spindles ($t = 5.58, p < .01$). These results were supported by Sigma analysis of Stage 2 sleep in high Performance IQ participants.

It was also found that the baseline spindle density and Sigma were related to Performance IQ but not Verbal or Full Scale IQ.

Discussion: The results demonstrate that after exposure to simple motor procedural learning, the number of sleep spindles increases. The results suggest that the function of spindles is to consolidate simple motor procedural memories.

The relationship between spindles and IQ indicate that not only are spindles a product of new simple motor procedural learning, but they are also related to aptitude for learning and can serve as a biological marker for both. These results implicate thalamo-cortical loops in the consolidation of simple motor procedural memory from which spindles originate.

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INTRA-AMYGDALA SCOPOLAMINE INFUSIONS DURING A
PARADOXICAL SLEEP WINDOW IMPAIRS CONDITIONED CUE
PREFERENCE ACQUISITION

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Introduction: There is now substantial evidence that paradoxical sleep (PS) is involved with memory processing in animals (1,2) and humans (3). In rats, paradoxical sleep windows (PSWs) have been identified for several tasks. PS deprivation during these PSWs results in memory impairments (1,2). Recently, a PSW at 9 -12 hours after acquisition has been identified for the conditioned cue preference (CCP) task (4). In addition, it has been demonstrated that an intact lateral amygdala is required for CCP acquisition (5). In the present study, the acetylcholine antagonist, scopolamine, was used to suppress cholinergic activity in the lateral amygdalae. This was done to examine the involvement of the lateral amygdalae during a PSW for the CCP task.

Method: Cannulae were implanted bilaterally into the lateral amygdalae of Sprague Dawley rats (n=15). The rats were then trained on the CCP task for 8 consecutive days. Experimental rats were given bilateral intra-amygdala infusions of scopolamine either 9 hours (to be active during the PSW, n=4) or 12 hours (to be active after the PSW, n=4) after each training session. Control rats were given bilateral intra-amygdala infusions of saline either 9 hours (n=4) or 12 hours (n=3) after each training session. One day after the last training session the rats were tested on the CCP task. The number of light arm entries (correct responses) and dark arm entries (incorrect responses) were recorded. Time spent in the light arm, dark arm, and centre platform were also recorded.

Results: An ANOVA revealed that the scopolamine-infused animals made significantly fewer light arm entries than the saline-infused animals [$F(1,13) = 6.95, p < 0.02$]. An additional ANOVA revealed that the scopolamine-infused animals spent significantly less time in the light arm than the saline-infused animals [$F(1,13) = 13.10, p < 0.003$].

Discussion: The scopolamine-infused animals demonstrated significant impairments in CCP acquisition as compared to the control animals. Thus, suppressing cholinergic activity in the lateral amygdalae many hours after training appears to disrupt CCP acquisition. This suggests that the lateral amygdalae may be actively involved in processing memory for the CCP task several hours after training, presumably during a PSW.

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INTELLIGENCE AND STAGE 2 SLEEP SPINDLES

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Introduction: A number of studies have been done to examine the relationship between Stage 2 sleep and learning. One such study has reported that the number of sleep spindles was related to learning efficiency¹. Expanding on this idea, we predicted that the number of spindles and the mean amount of sigma power during Stage 2 would be related to the subjects' intelligence scores on the MAB-II IQ test.

Methods: Ten subjects (range: 18 - 29) were used in the study. Subjects were screened for abnormal sleep patterns and excessive drinking/drug use. Subjects' completed the MAB-II2 IQ test and spent the subsequent two nights (acclimatization and baseline) in the laboratory. The number of sleep spindles (12-16Hz) and the mean Sigma Power (12-14Hz) were assessed for each page of Stage 2 sleep on the baseline night. Epochs with large body movements or major artifacts were excluded. Spindle activity and sigma power were assessed for both the C3 and C4 derivations.

Results: The total number of spindles (C3+C4) for the night was highly correlated with Performance IQ ($r = .71, p = .022$), and with Full Scale IQ ($r = .76, p = .010$), but not with Verbal IQ ($r = .56, p = .094$). The mean sigma power of both C3 and C4 for the entire night was highly correlated with Performance IQ ($r = .76, p = .011$) and Full Scale IQ ($r = .77, p = .009$). When the night was divided into thirds, the mean sigma power in the last third of the night showed the strongest correlation with both Performance IQ and Full Scale IQ ($r = .87, p = .001$, and $r = .84, p = .002$ respectively). None of the correlations with Verbal IQ were significant.

Sigma power was found to be the most highly correlated with two of the sub-tests of the Performance IQ scale: Picture Completion and Object Assembly. Both tasks require perceptual and analytical skills for successful completion.

Conclusions: The data suggest that the number of spindles and sigma power from central derivations are both powerful predictors of how well an individual will perform on the Performance portion of an IQ test. This is especially true of perceptual and analytical skills. The reasons for these relationships are not yet clear.

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SLEEP EDUCATION AND CHANGES IN SLEEP AND SLEEPINESS IN COLLEGE STUDENTS

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A two-credit (100 min/week) "Sleep Management" course was offered by the first author in the spring semester in 1998 and 1999 at the National Chung-Cheng University, Taiwan. The aim of this course was not just to passively increase sleep knowledge but also to actively enhance sleep awareness and, thereby, practical impacts on the students' daily sleep and sleepiness might be found. The curricular activity of this course included lectures on basic sleep psychology, physiology, pharmacology, disorders and hygiene, dream, and circadian rhythm, group discussions on sleep old sayings and misunderstandings, and self evaluations on sleep. A web page was designed to provide on-line reviews of the course materials and an after-school discussion board. The students enrolled in this course were required to record 7-day sleep logs in March, April, and May as course assignment. The Epworth Sleepiness Scale (ESS), Morningness-Eveningness Questionnaire (MEQ), Pittsburgh Sleep Quality Index (PSQI), and Ullanlinna Narcolepsy Scale (UNS) were administered once in 1998 and three times in 1999. A total of 362 students were enrolled in the 1998 class and of 84 in the 1999 class. The control college student subjects were recruited from the friends of the course-enrolled students in 1998 and from respondents to ads placed on seven popular, university-based Bulletin Board System (BBS) in 1999. Results from statistical analyses showed several significant changes in sleep recorded in the sleep log across the three months of the semester. Both the course-enrolled and control students showed progressive decreases in the number of awakenings in night sleep and increases in sleep efficiency on weekdays across the semester. However, only the course-enrolled students showed significant progressively decreased sleep latency on weekdays, increased sleep efficiency and subjective sleep quality on both weekdays and weekend, and decreased ESS scores over the three months. These results suggested that sleep and sleepiness were improved along the progress of this course. Further studies are needed to verify the long-term impact of this kind of sleep course on sleep health.

SINGLE AND DUAL TASK PERFORMANCE UNDER CONSTANT ROUTINE CONDITIONS

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The purpose of this study was to investigate the endogenous circadian rhythmicity of cognitive performance on different levels of task complexity. In this research, a single task (mental arithmetic) and a dual task (unstable tracking combined with memory search) were utilized within a constant routine protocol. After a night of sleep registration, subjects participated in a 27 hour continuing experiment starting at 9 am (N=17, 8m, aa=22.4), or at 9 pm (N=14, 7m, aa=23.6), in order to balance for prior wakefulness. After two adaptation hours, tasks were presented every three hours. All subjects completed practice sessions on the day prior to the experiment. Regarding the dual task, the instruction was to handle a joystick with the dominant hand and to try to divide attention equally over the two subtasks. The mental arithmetic task contained multiplications ranked as 'easy' (single x single digit) and 'difficult' (single x double digit). Both tasks were approximately 3 minutes in duration. Time of day effects were analysed using repeated measures ANOVAs for measures of speed and accuracy.

Results exposed congruent circadian rhythmicity on tracking accuracy, and for response correctness on both tasks, for both groups, with a decrease during night hours and a trough at 8 am. Response latency displayed a similar pattern for the memory search task, but was absent for the mental arithmetic task. Also, response lapses showed this rhythmicity for both tasks. The mental arithmetic task revealed that computation difficulty resulted only in an overall decrease of accuracy as well as speed. Additional trade off analyses on the dual task provided insight in the strategy subjects used to perform concurrently on the two subtasks. Consistent time on task effects were found for each session. Time of day analysis showed no effect, suggesting that the division of attention was not affected by the circadian rhythm. Furthermore, TSD parameters were calculated for the memory task, which showed no compensatory strategy was used during the circadian trough.

In conclusion, measures of accuracy appear to be highly dependent on the circadian rhythm, as does response latency, when task complexity is advanced. Strategies used in dual task performance were not influenced by the circadian rhythm, whereas sleep deprivation (<40 hours) has little effect on overall performance.