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Dream pictures, neuroholography and the laws of physics

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According to the laws of physics, electrical signals generate visible pictures if electrical signals are converted to electromagnetic waves (EMW) of the visible range (light photons of wavelengths between 350–700 nm). During dreams our eyes are closed, so the brain is isolated from visible EMWs of the surroundings, yet we can see visible dream pictures. It follows from the foregoing that electrical signals of the brain processes can generate visible pictures of dreams if and only if electrical signals are converted to weak, EMWs of the visible range (biophotons) in the brain. Nobody can explain origin of visible dream pictures if only the laws of physics are being taken into consideration! The homeotherm state and REM phases of sleep are developed simultaneously in evolution. In homeotherm creatures there appear well-regulated body and brain temperatures, restricted neurogenesis, and well-structured neuronal systems, which bear a relationship to the holograph-like operating mechanism of the brain. Exact temperature regulation is important for many holographic systems, because holographic pictures can be deformed if temperature fluctuations are too large. A structured neuron system is also needed to develop explicit memory, because it can guarantee a strong synchronization of different electric and biophoton signals. If dream pictures are generated by biophotons in the brain these processes also have to work during wakefulness. Dream pictures make a connection possible between the explicit and implicit memory systems in the brain. Dynamical series of pictures can carry unambiguous meaning which can be a base of development of words in different languages. The human memory can operate through dynamical pictures, and we link these pictures to each other in the learning process. Neurotransmitters, which play role in neuromolecular processes, also play a role in thermoregulation and in sleep/wake cycles. So, neurotransmitters and synapses are hardly units of information storage. It is proved by in vivo imaging that spontaneous ultra weak biophoton emission from a rat's brain correlated with cerebral energy metabolism (thermoregulation), EEG activity and oxidative stress.

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Sleep selectively benefits the consolidation of weak memory traces in a declarative memory task

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Introduction: The topic of sleep and memory consolidation has witnessed a remarkable revival of interest in the past few years. Here we report a series of experiments aimed to unravel the psychological conditions under which sleep supports consolidation of declarative memory. We hypothesized that weak associations are more likely to benefit from sleep than well learned associations. We employed two manipulations to investigate this idea, first by weakening previously learned associations by inducing interference and second by manipulating the degree of initial learning.

Methods: Subjects had to learn either two interfering (A–B, A–C) lists of unrelated word-pair associates to a criterion of 90% correct, or two non-interfering (A–B, C–D) lists of unrelated word-pair associates, to either a criterion of 90% or 60% correct. Memory performance was tested in four groups that slept after learning and in eight wake-control conditions (each 10 subjects of which 5 were male).

Results: For the interfering lists the data showed a release from the retroactive interference (i.e. interference from newer information on something learned before) that is induced by this type of learning, after sleep ($P > 0.45$ for memory performance on the two lists). In all the wake control conditions memory performance was better for the second list than for the first one ($P < 0.05$). For non-interfering lists memory performance was comparable for both lists in all groups ($P > 0.80$). Here, enhanced memory performance for both lists was found after sleep compared to the wake control conditions but only when the lists were learned to a criterion of 60% ($P < 0.05$ for all relevant comparisons).

Conclusions: Together the data support the view that declarative memory undergoes active consolidation during sleep. This effect though is related to the type of material learned (interference manipulation) and the degree to which the material is learned (criterion of 60% versus 90%), but in general we conclude that weaker memory traces benefit more than strong ones.

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Sleep 'renders' information

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Introduction: The topic of sleep and memory consolidation has witnessed a remarkable revival of interest in the past few years. Previous research has shown that the spatial component of memory (known to involve the hippocampus) is further processed and strengthened during sleep. The aim of this study was to investigate if the temporal component of memory, which is thought to rely on the same neuronal structures as spatial memory, is also consolidated during sleep.

Methods: Subjects learned a list of triplets (three single unrelated words that were presented one after another in the middle of a computer screen). Memory was tested in a sleep group and a wake control group (each 14 subjects of which 7 male). Half of the triplets were tested in a forward manner (order of presentation) whereas in the other half the backward association was tested.

Results: We found that sleep selectively enhanced the forward associations for the triplets while it worsened the backward ones as compared to wakefulness. In the wake group no difference in memory strength was found for the forward and backward associations [$F(1.26) = 5.72$, $P < 0.05$].

Conclusions: The data provide further support for the view that sleep is involved in the consolidation of memory. We show that just like in spatial memory, temporal memory (which relies on the same neuronal structures as spatial memory such as the hippocampus) is also strengthened during sleep. Additionally this study is the first to provide evidence for the abolishment of 'unnecessary' memory traces during sleep as are the backward associations. Hence, we conclude that an additional role of sleep in the consolidation of memory is to 'render' the information and make it readily available in such a way that is most likely it will be needed at retrieval.

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Sleep-spindle activity after visuo-motor learning

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We have previously demonstrated that a newly acquired visuo-motor skill improves after one-night of sleep. Several reports have implied that sleep spindles are related to the consolidation process of procedural memory, which underlies the learning of motor skills. This relationship was investigated by qualitatively evaluating the activity of sleep spindles. Nine healthy student volunteers participated. A modified version of the mirror-tracing task was used. Standard polysomnogram recordings were made. Participants performed the task before retiring (learning session) and the next morning (test session). Improvement of motor performance was assessed by calculating the ratio of the tracing time and the number of errors in the learning and the test sessions. Participants were divided into three groups based on the level of improvement in motor performance ($n = 3$ each). The EEG was scored manually into sleep stages using the standard criteria. Number and density (number of spindles/number of NREM stage 2 epochs) of the fast spindle during the fourth cycle of NREM sleep stage 2 were calculated. These were compared between the upper third (high group) and the lower third (low group) groups. The statistical analysis was based on the *t*-test. Tracing time was shorter in the test session in comparison to the learning session by 37.9% in the high group and 8.9% in the low group. The number of errors was also reduced respectively in the two sessions by 26.1% in the high group and 14.7% in the low group. However there was no difference between the groups in the number of NREM stage 2 epochs, the number (high: 177.3 ± 15.41; low: 66.3 ± 13.22; $P = 0.005$) and density (high: 149.8 ± 21.20%; low: 50.1 ± 9.72%; $P = 0.013$) of fast spindles were significantly greater in the high group. Activity of sleep spindle was more enhanced in the high group who learned more skills after sleep. Thalamo-cortical network underlying the generation of sleep spindle is likely to have contributed not only to the process of maintaining and deepening of sleep but also to that of consolidating memory.

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ERP correlates of sleep-dependent memory consolidation in the probabilistic serial reaction time (SRT) task

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This ERP study investigated the sleep-dependent evolution of evoked activity after acquisition of a procedural skill.

Methods: Subjects performed a probabilistic SRT task, in which they had to press as fast and accurately as possible on the key corresponding to the location of a stimulus on the screen. Unknown to them, the sequential structure of the stimuli was based on a finite-state grammar. To assess learning, there was a 15% chance on each trial of replacing the grammatical (G) with a non-grammatical (NG), random stimulus. Eighteen blocks of 205 trials were administered on day 1, then 18 blocks on day 4, at the same time of day. During SRT practice, EEG was recorded on the scalp midline (Fz Cz Pz Oz) at 1000 Hz using Synamp Neuroscan. ERPs were epoched from 100 ms before to 800 ms after stimulus display for each stimulus type (G or NG). While the sleep deprivation (SD) group ($n = 9$) was kept awake during the posttraining night, the regular sleep (RS) group ($n = 11$) slept normally at home. The following two nights both groups did sleep at home.

Results: Gradually increasing differences between mean RTs elicited by G and NG stimuli were observed with practice, demonstrating successful learning of the sequential regularities. Overnight change in RTs and grammatical effects (G versus NG) were significant ($P < 0.001$), but the effect of posttraining sleep status (SD versus RS) or its interaction with other effects was not. ERP data were analyzed using a repeated measure ANOVA model within each group separately using 90 (10 ms time-bins. In RS subjects, the time course of ERPs elicited by G and NG items changed from day 1 to day 4 (Fz, Pz, $P < 0.05$; Cz, Oz, $P < 0.001$). However, in subjects deprived of sleep (SD), no such change was evident from day 1 to day 4 (all $P > 0.4$).

Conclusions: Although SD and RS subjects similarly performed the SRT task, ERP differences between G and NG items at day 4 were attenuated in the RS but not SD condition, suggesting that posttraining sleep favors the successful integration of deviant stimuli at the cortical level.

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Hypoglycemia during sleep impairs consolidation of declarative memory in type 1 diabetic and healthy humans

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Objective: Early nocturnal sleep has been shown to enhance the consolidation of declarative memory. Patients with type 1 diabetes mellitus (T1DM) frequently experience hypoglycemic episodes during sleep. Here, we investigated whether a short-term hypoglycemia during early nocturnal sleep affects the consolidation of declarative memory.

Methods: We tested 16 T1DM patients and 16 healthy subjects. On one condition, a linear fall of plasma glucose to a nadir of 2.2 mmol L^{-1} was induced within 60 min by infusing insulin during early night-time sleep. On the control condition, euglycemia (> 3.86 mmol L^{-1}) was maintained, and spontaneous hypoglycemia was prevented by glucose infusion whenever necessary. In the following morning, subjects performed a declarative memory task in which word-pairs learned in the preceding evening had to be recalled. To assess whether mood and attention are adversely affected by short-term nocturnal hypoglycemia, we applied a symptom questionnaire, an adjective check list, the Stroop test, and recorded event related brain potentials during an auditory vigilance task.

Results: Following the euglycemic night, subjects recalled 1.5 ± 0.54 more words-pairs learned before sleep than following the hypoglycemic night ($P < 0.01$). They remembered +1.97 ± 0.57 more word-pairs than at an immediate recall test at acquisition the evening before sleep ($P = 0.002$), whereas no such gain occurred across the hypoglycemic night (+0.5 ± 0.6 words; $P = 0.407$; $P = 0.01$ for 'hypo x time' interaction). Hypoglycemia during sleep also decreased mood ($P < 0.05$), but did not affect measures of attention. Effects of hypoglycemia were well comparable between T1DM patients and healthy controls.

Conclusions: Our findings indicate a specific sensitivity of declarative memory consolidation during sleep to rather short episodes of mild hypoglycemia. This effect may disable memory processing in T1DM patients prone to nocturnal hypoglycemic episodes and underlines the

importance of considering sleep as a critical period in the treatment of these patients.

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Encoding difficulty promotes postlearning changes in spindle activity during napping

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Introduction: Learning-dependent increases in sleep spindle density have been reported during nocturnal sleep following a learning session. Here, we investigated changes in daytime sleep EEG activity after learning of unrelated wordpairs differing in their encoding difficulty.

Methods: At weekly intervals in counterbalanced order, 13 male subjects (21–28 years) spent 3 (24 h in the laboratory under constant routine conditions. Around midday, they carried out one of two wordpair learning tasks or a nonlearning control task. The two learning lists differed in the concreteness level of the words, resulting in an easier (e.g. ink-flag) and a more difficult (e.g. union-rate) encoding condition. After immediate cued recall, subjects were allowed to sleep for 4 h. Delayed cued recall was tested after awakening. Polysomnographical data were subjected to spectral analysis and a sleep spindle detecting algorithm.

Results: All subjects performed better in the easier than in the more difficult encoding condition (66 versus 48%; $P < 0.05$); performance remained stable between the immediate and delayed recall in both conditions ($P > 0.1$). In comparison to the control condition, sleep EEG activity in the low sigma range (11.5–13.25 Hz) was significantly increased after the difficult encoding, particularly at the left frontal site (F3, $P < 0.05$). The incidence of low frequency sleep spindles was significantly enhanced in the fronto-central areas (F3, F4, C4; $P < 0.05$). After the easier word list, no such changes were observed.

Discussion: Our results suggest that changes in daytime sleep EEG oscillations following wordpair learning depend upon the encoding difficulty of their associates. Frontal sleep spindles in the low sigma range are predominantly increased after learning which supports the hypothesis of a functional implication of fronto-central located spindles in memory processing.

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Sleep organization and memory prospective task

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Introduction: The sleep organization has been shown to influence the morning recall of a memory declarative task given before sleep (1). Investigations about the relationship between sleep and prospective memory are missing. This research aims to explore the role of sleep organization on the recall of a memory prospective task.

Methods: Twelve subjects were assigned, before sleep, a memory prospective task that they should perform next morning at the awakening. Sleep was polygraphically recorded for each of three night conditions: continuous sleep (Co), sleep interrupted at the end of NREM-REM cycle (C+) and before the end of NREM-REM cycle (C−).

Results: The percentage of task recall was high in the three conditions (Co: 91.67%; C+: 75%; C−: 91.67%) without statistically significant differences (Cochran Q test = 1.6; d.f. 2; NS). The interval between awakening and task recall was 3.36 min. for Co, 2.28 for C+ and 2.27 for C−, without statistically significant differences (F = 0.35; d.f. 1,6; NS).

Conclusions: At variance with recall of verbal material, the organization of sleep is not deeply influencing the recall of a memory prospective task and the quickness to retrieve it. This has relevance for those who at the evening plan a new activity next morning, whatever their sleep quality.

Reference:

1. Ficca G. et al., Behav Brain Res., 2000, 112: 159–163.

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The role of sleep in motor memory consolidation assessed by fMRI

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The aim of this study was to characterize the cerebral correlates of overnight procedural memory consolidation, using a motor skill task (the finger tapping task). Subjects were trained to the task then divided in two groups whether they slept ($n = 16$) or were totally sleep-deprived ($n = 15$) on the following night. Both groups were tested on the task 3 days later, allowing two recovery nights for the sleep-deprived subjects. Functional MRI data were acquired during both training and testing sessions (3T Allegra MR scanner, Siemens) and analysed using SPM2 (http://www.fil.ion.ucl.ac.uk). Finger tapping performance (i.e. speed) on the learned sequence improved in both groups during training. A significant response to the practice of the learned sequence modulated by performance improvement was observed bilaterally in the ventral putamen. Subjects of the sleep group significantly improved their performance from the end of training to the beginning of the test session ($P = 0.02$). Response to the learned sequence was significantly larger in the left hippocampus during the test session as compared to the training session. In contrast, sleep-deprived subjects did not significantly improved their performance between the two sessions ($P = 0.48$). Response to the learned sequence was significantly larger in the right ventral putamen during the test session as compared to the training session. Our results confirm that posttraining sleep, but not sleep deprivation, leads to improved motor skill performance at delayed testing session. This sleep-dependent improvement was linked to an activation in the hippocampus whereas in sleep-deprived subjects the response to the sequence remained in the putamen. It suggests that posttraining sleep supports the reorganization of brain representations in sequential motor memory, especially involving novel representations in the hippocampus.

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Keywords: Memory, sleep, fMRI

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Sleep-dependent changes in brain activity subserving human navigation

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Hippocampus-dependent spatial memories are replayed and consolidated during sleep [1]. Using functional magnetic resonance imaging (fMRI) and a navigation task, we investigated how sleep deprivation

would interfere with this process. On day 1, 22 volunteers explored a virtual town for 35 min. They were scanned while performing 10 tests of place finding alternating with rest periods using a block-design fMRI paradigm. For each test, they were assigned a starting point and instructed to reach a target location. Distance travelled towards destination was used as an index of performance. During the first posttraining night, 12 subjects were allowed regular sleep (RS group) while the others were totally sleep deprived (TSD group). On day 4, after two recovery nights, a similar fMRI session was conducted. Behavioural performance did not differ between groups (RS versus TSD) and days (4 versus 1). On both days, navigation elicited BOLD response in a large brain network, including the hippocampus in which the level of activity positively correlated with performance. In both groups, neural responses during navigation on day 4 (versus 1) were larger in the caudate nuclei but smaller in the hippocampal regions. On day 4, brain activity in the caudate nuclei was larger in RS than TSD subjects and positively correlated with performance in the RS group but negatively so in the TSD group. Increased navigation-related activity in the striatum in RS subjects on day 4 may reflect the use of a different cognitive strategy of navigation. In line with this suggestion, practice on a navigation task led to a shift in cerebral activity from the hippocampus to the caudate nucleus, paralleled by a change from a spatial to a response cognitive strategy of navigation [2]. Sleep appears to favor this covert reorganization of brain activity while leaving overt behaviour unaffected.

Acknowledgement: Supported by FNRS, Fondation Fyssen, FMRE and PAI P5/04.

Keywords: Sleep, memory, fMRI

Reference:

1. Peigneux et al. Neuron, 2004, 44, 535–45.2. Iaria et al. J Neurosci., 2003, 23, 5945–52.

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The role of sleep in the consolidation of emotional memories in humans: a fMRI study

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Emotional events are usually better remembered than neutral ones. This study used functional MRI to characterize the sleep-dependent cerebral correlates of the retrieval of emotional memories. Subjects participated to a learning session, during which they rated the emotional valence of 40 negative, 40 positive and 40 neutral pictures. Subjects were divided in two groups whether they slept (S, $n = 21$) or were sleep-deprived (TSD, $n = 18$) on the first posttraining night. A retrieval session was carried out after two recovery nights. The task consisted in making remember/know/new judgement about already presented and new pictures. During both sessions, fMRI data were acquired using a 3T Allegra MR scanner. Retrieval data were analysed using SPM2. Behavioural and brain imaging analyses investigated the main effects of emotion (negative versus neutral images), of memory (remember versus know) and of their interaction. Both groups (S versus TSD) were compared using 2-sample *t*-tests. There was a main effect of sleep on the number of correctly identified old items (hits; $P = 0.017$). There was also a main effect of image emotionality on memory retrieval ($P = 0.001$), but no interaction between the effects of sleep and of emotion ($P = 0.7$). Nonetheless, there was a significant effect of posttraining sleep on the patterns of brain responses observed during emotional memory retrieval : S subjects activated more the hippocampus and cortical areas (medial and lateral prefrontal, middle cingulate, superior temporal sulcus, intraparietal sulcus) whereas TSD subjects preferentially activated the amygdala and the parahippocampal gyrus. These results indicate that S and TSD subjects engaged different networks to retrieve emotional memories, suggesting that there is an offline processing of emotional memories during the first posttraining night.

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Effects of one night of postlearning sleep versus wakefulness on long-lasting memory for emotional pictures

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Sleep following learning, compared to wakefulness, is known to support memory consolidation of the learned material. Although most studies on sleep-associated memory formation have focused on acute effects (i.e. with memory testing taking place shortly after consolidation sleep), we have recently found that only 3 h of sleep, compared to wakefulness, lead to enhanced memory retention of previously acquired emotional text material even in a memory test performed after 4 years. Emotional learning material appears to be specifically useful for the investigation of long-term memory effects of sleep, because it can induce memory traces that are strong enough to be detectable even after very long time periods. In the present study we extend our previous findings to non-verbal memory by investigating long-lasting effects of a single night of postlearning sleep on the retention of standardized affective picture material (negative, neutral, and positive pictures from the International Affective Picture System, IAPS), in combination with the assessment of changes in emotional reactivity towards the pictures as assessed by subjective judgments of valence and arousal. Healthy subjects judged the pictures in the evening. Then, in the sleep condition, they slept for 8 h in the sleep laboratory, while in the wake control condition, they were kept awake overnight. In both conditions, subjects left the laboratory in the next morning to be engaged in their normal diurnal activities. Daytime sleep was not allowed (controlled by the 'Actiwatch' system) until subjects returned to the laboratory 2 days later for another judgment task. After 1 year, subjects were re-contacted to perform a surprise memory recognition task for the originally seen pictures, including again emotional evaluation of the stimuli. Preliminary results indicate that sleep only exerted a moderate long-term effect on picture retention depending on affective content, which was accompanied by specific changes in emotional evaluation of the pictures.

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Pilot study to investigate the relationship between REM sleep and cognitive procedural task learning

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Introduction: There is much interest in the possible role of sleep in memory consolidation. Sleep duration during military training is often curtailed, which may reduce the effectiveness of these courses. A pilot study was undertaken to investigate the effect on task learning of shortening nocturnal sleep, thereby reducing the proportion of REM to non-REM sleep.

Methods: Eight right-handed subjects undertook two learning episodes in a counter-balanced order: one before an 8 hour sleep period and one before a sleep period curtailed at 04:00 (after 5 h in bed). At

17:00 (6 h before bedtime) the EEG was recorded and power spectral density (PSD) calculated while subjects undertook a 'letter-learn' task, which involved memorising a unique key-press for each of 13 letters of the alphabet. Recall was tested at 21:00 (2 h before bedtime) and then again at 09:00 on the second morning after task learning. Data were analysed with respect to sleep period duration (5 and 8 h) and the order (first and second occasion) in which task learning was undertaken.

Results: Correct response time during task recall before bedtime was positively related to the duration of the first REM period during subsequent sleep ($P < 0.01$). Although sleep restriction had no effect on task learning, there were effects associated with the order in which subjects undertook task learning: (i) the duration of the first REM period was longer on the night after the first occasion of task learning compared with after the second ($P < 0.05$); (ii) there was a greater rate of change in response time from before sleep to after sleep on the first occasion of task learning compared with the second ($P < 0.05$); and (iii) PSD was reduced in beta 2 and gamma wave bands ($P < 0.05$) during the second episode of task learning.

Conclusions: These results suggest a link between cognitive procedural task learning and the duration of the first REM period.

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Paradoxical sleep amount modulates neuronal plasticity in adult rat hippocampus

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There is a growing evidence suggesting that paradoxical sleep (PS) regulates neuronal plasticity in the adult rat hippocampus, a structure well known for its key role in memory. Paradoxical sleep deprivation (PSD) impairs performance in many behavioural and learning tasks. Furthermore, recent studies showed severe alterations in neuronal plasticity underlying memory processing after PSD. However, the effect of a PS hypersomnia on synaptic plasticity is still unknown, and we address this question in the present work. Neuronal plasticity in the hippocampus was compared in three experimental conditions: control, PS deprivation (72 h of PSD), and PS rebound (PSR, PS hypersomnia during 150 mn after PSD) with a selective modulation of this vigilance state (respectively 11%, 2% and 31% of total time spent in PS). First, we performed the immunohistochemistry of the immediate early gene c-fos product, a marker of neuronal activation. Second, we investigated functional properties of the synaptic connections between Schaffer collaterals and CA1 pyramidal neurons *in vitro*. Our results showed a selective increase in the number of c-Fos positive neurons after PSR, specifically in the dentate gyrus and CA1 field. We further observed a strong modulation of long term potentiation (LTP) in PSD rats, characterised by an increase of the induction threshold. Interestingly, the alteration observed after PSD is completely restored in PSR rats, showing no difference in LTP compared to control. In addition, excitatory synaptic transmission exhibited a modulation in efficacy, decreasing after PSD and increasing after a PS rebound compared to control. Moreover, these changes in synaptic efficacy are correlated to the PS amount. This study strongly suggests that the PS strongly modulate the gating of excitatory neuronal transmission between different areas of the hippocampal formation. The molecular pathway involved in this modulation is currently under investigation.

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Time course of sleep inertia dissipation in semantic priming task

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Sleep Inertia (SI) is a period of drowsiness and impaired performance after the transition from sleep to wake. It could derives from a low arousal level, or from the interaction between an hypo-arousal and a low level of vigilance The time course of SI dissipation is the most controversial aspect. The aims of the present study were to assess the time course of SI dissipation with semantic priming task, never studied before, after a normal sleep night, as well as the possible effect of sleep stage of awakening on the time course of SI. Ten healthy young participants took part at the study (age 24.9 ± 3.14). All subjects spent seven non consecutive nights in sleep laboratory with standard polysomnographic control. Participants were tested in three conditions: morning awakening from REM sleep (REM), morning awakening from Stage 2 sleep (ST2), diurnal time (DT, as control); at regular time intervals (i.e. 10 min), for nine experimental trials which last on the whole 80 min. In each condition and in a different time window, participants accomplished a lexical decision task, in which a semantic priming was embedded. At the end of each trial a self evaluation of alertness was collected. The research was developed by a within-subjects design. TR and accuracy were analyzed. Semantic priming effect is present in all examined conditions and it does not modify during the time window analysed. It could be argued that the mechanism of spreading activation through the semantic network are not affected by SI. The interaction between condition (trial is significant ($F16, 144 = 2.09 - P < 0.05$): a general slowing effect after awakening from both sleep conditions is observed. The differences between sleep condition and diurnal control disappears after the fourth trial (30 min after awakening). The same pattern of results is obtained for the accuracy analysis. After a normal sleep night the effect of SI would slightly affect the performance in a semantic priming task until 30 min from the awakening. No sleep stage effect is observed.