The Time Course of Sleep Inertia in a Semantic Priming Paradigm

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The time course of 'sleep inertia' was studied with a semantic priming paradigm. With this automatic spreading activation task it was found that longer reaction times on target words after an awakening from sleep, as compared to those obtained after a period of wakefulness, appeared only during the first 2.5 minutes. Thus, sleep inertia could be observed but dissipated in a fast way. Moreover, no differences in sleep inertia could be found after forced awakenings from deep slow wave sleep compared to light slow wave sleep as well as to REM sleep. Characteristics of sleep inertia are discussed in terms of task difficulty in relation to awakenings from a particular sleep-wake state. It is suggested that the semantic priming task is an automatic and easy one, which is expressed in a relatively short period of sleep inertia. **(Sleep and Hypnosis 2003;5(2):78-82)**

Key words: *sleep inertia, time course, semantic priming*

INTRODUCTION

Shortly after awakening from sleep there is a lowered ability to perform tasks as compared to full wakefulness, although the subject seems clearly awake. The decrease in task performance implies that the cognitive capabilities of the brain are still not directly optimal immediately after awakening. This phenomenon is called, 'sleep inertia' (1). Several factors are involved in sleep inertia such as the type of task and prior sleep deprivation (2). Also the sleep stage prior awakening seems to play a role in the performance decrement: a forced awakening from deep slow wave sleep produces a more severe sleep inertia than awakenings from light slow wave sleep as well as from REM sleep (3). Nevertheless, there are still controversies about the involvement on sleep inertia of the sleep stage prior to awakening on sleep inertia (4).

Stickgold et al (5) studied reaction times on stimuli in a semantic priming paradigm just after arousing from sleep. The retrieval of information from semantic memory is fast and automatic. Responses to a target word (e.g. dog) preceded by a strongly related, prime, word (e.g. cat) are generally faster and more accurate than responses to weakly related primes (e.g. child-youth). With this paradigm Stickgold and colleagues (5) could also show the phenomenon of sleep inertia. This in the sense that reaction times were not only dependent from the degree of word relatedness, but also from the specific sleep or wake state from which the subject was aroused. This was fully

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confirmed in a paper by us (6).

A crucial issue is the time course of sleep inertia considering that in this period the essential cognitive abilities necessary in daily life are not optimal. Jewett et al (7) have noted a wide range in the duration of sleep inertia, which can last from one minute to some hours. The primary purpose of this study was to determine the time course of sleep inertia, by using the automatic spreading activation task underlying the semantic priming task as used by Stickgold et al (5). The priming task was also used to collect information about the capacity of the brain after arousing from different sleep stages.

METHODS

Data were obtained from 19 psychology students (3 men and 16 women) in the age of 18 till 25 years. Subjects stayed for one night in the sleep laboratory of the University of Amsterdam and received course credits for their participation. All subjects were requested to refrain from caffeine and alcohol after 5 pm of the day preceding the test night. During this preceding day napping was also forbidden. The subjects had no sleep disturbances and did not use hypnotics or other medicines. All subjects were native speakers of Dutch.

To register EEG and EOG silver chloride electrodes were placed on appropriate places and were linked with references on A1, according to the 10-20-electrode system. A ground electrode was placed on the forehead. The EEG signal was recorded with a sample frequency of 256 Hz and electrode impedance was less than 5 kOhms. The low pass filter was set at 70 Hz and the time constant was 0,16 Hz. The EOG was recorded in both the horizontal and vertical direction. Sleep stages were on line scored for 30 sec epochs according to the standard criteria of Rechtschaffen and Kales (8). Stimuli of the priming task were presented in the centre of a computer screen. A prime word appeared for 200 ms and just after this prime the target word appeared until a response was made. The stimulus material consists of 16 lists prime-target word pairs. Each list contains 12 strongly and 12 weakly related word pairs, 24 unrelated word pairs and 36 word-nonword word pairs. All word pairs were selected from lists which were also used in the previous experiment (6). Subjects were trained once in the semantic priming paradigm. They were instructed to read the first word (prime) and than to respond to the second word (target) as fast as possible. Pressing a button with the forefinger of the right hand was requested when the word was a genuine ‘word’ and pressing the left button was requested when the word was a ‘non-word’. The total test time was around 10 minutes and each session was arbitrarily divided into four bins of 2.5 minutes. Each bin comprised one list of prime-target word pairs.

The experimental night started at 10 pm with the preparation of the subjects for polysomnographic recordings. The subjects were exposed to one test-session before going to sleep and to three test-sessions during the night. The first session began at 11.15 pm (pre-sleep condition), before subjects started to sleep. Lights were turned off at 12 pm. In the slow wave sleep (SWS) condition subjects were awakened after 10 consecutive minutes in slow wave sleep by turning on the lights and calling the subject’s name. Within one minute after awakening the subject started with the experiment. Thereafter, the subjects were awakened after 3 am after the first minute of rapid eye movement sleep (REM-sleep condition) and again at 5 am after 5 minutes in sleep stage 2. The night finished at 7 am. Sleep-wake states were verified off-line and in case of a misfit the trial was excluded.

RESULTS

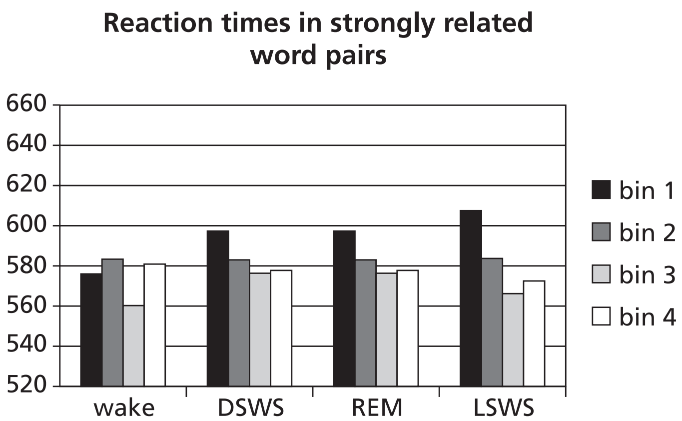
Subjects had to respond as quickly as possible on the target word of the priming task. The non-word targets were considered as a control condition and reactions to these nonwords were excluded from further analyses. Also all reaction times longer than 1000 ms and wrong responses were excluded from the data file. A test session of each sleep-wake state lasting about 10 minutes was divided into 4 bins of 2.5 minutes.

In Figure 1, the mean reaction times of the strongly and weakly related word pairs are shown. First of all it is clear that the paradigm worked adequate: in all four conditions reaction times were shortest for strongly related word pairs, slower for weakly related word pairs and slowest for unrelated word pairs. It is furthermore clear that the reaction times are slowest in the first bin of the four bins of the three sleep conditions. A repeated measure analyses of variance (ANOVA) of the reaction times of the strongly related word pairs, showed a significant main effect for the factor bin (df=3, F(8.03), p<.001) and for the reaction times of the weakly related word pairs also a significant main effect (df=3, F(3.89), p<.02). The sleep state x bin factor interaction showed no significant difference.

related word pairs reaction time in the deep slow wave sleep (DSWS) condition (t=1.86, p<.04) and light slow wave sleep (LSWS) condition (t=3.01, p<.009). In the rapid eye movement (REM) condition no significant differences could be found.

In the weakly related word pairs a trend was found between the first bin and fourth bin in the deep slow wave sleep (DSWS) condition (t=1.86, p<.08) and a significant difference is found in the REM sleep condition (t=2.86, p<.014) and in the light slow wave sleep (LSWS) condition (t=3.90, p<.002). A significant difference between bin 1 and bin 2 (t=6.31, p<.0001) and between bin 1 and bin 3 (t=3.46, p<.005) was also found for the weakly related word pairs.

The error data were also analysed. When a subject pushed the word button when a non-word response was required (and a non-word as a word was required), the response was scored as an error. The ANOVA showed no interaction error x wake-sleep state.



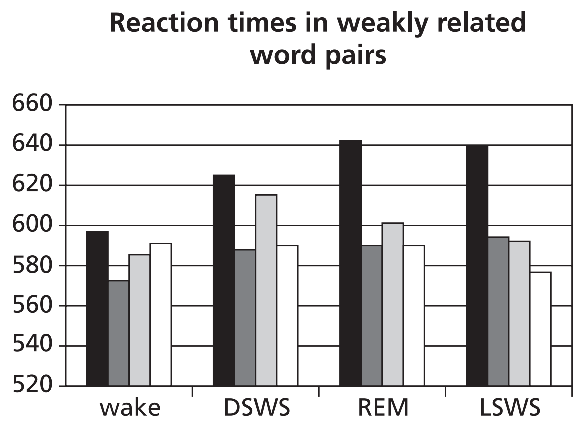


Figure 1. Reaction times in strongly and weakly related word pairs

There is no significant difference in reaction times between the different sleep states. A paired sample t-test was used to compare the reaction times between different bins. As expected, in the wake state no significant difference was found between the four different bins. There was a significant difference between the first bin and the fourth bin in the strongly

DISCUSSION

Sleep inertia plays a role in the decrement of performance in the priming task: reaction times are generally longer after awakening from sleep compared to those obtained during a period of wakefulness. The increase in reaction times is not only found after awakening from deep sleep but also from light slow sleep as well as from REM sleep, with no differences between these three states. A clear increase in reaction times is only seen in the first bin. The reaction times of the first bin of 2.5 minutes are significant longer than the reaction times of the fourth bin. This implies that only a shortly lasting impairment of performance is found. More or less the same picture emerged from both the strongly related as well as the weakly related words. Nevertheless, in comparing figures 1 and 2, one gets the impression that the differences between bin 1 and the other three bins are larger for the weakly related words. In the weakly related word pairs it is striking that bin 2, bin 3 and bin 4 are significantly different of bin 1. It is difficult to interpret this result, but it could mean that the recovery from sleep inertia in the weakly related word pairs is different compared to the strongly related word pairs. Perhaps, the task with the weakly related words is more difficult than those with the strongly related words. More examples of the influence of the task complexity can be found. Probably, the more intensive or demanding a task the longer is the period of sleep inertia (3,7). Previous studies of sleep inertia (2,9,10) also found the greatest impairment in performance within 3 minutes after abrupt nocturnal waking. These results were obtained in using automatic tasks as well in tasks requiring attention.

A number of researchers have found that the sleep stage prior to awakening could play a role in the performance of the task. A forced awakening from deep slow wave sleep produced more sleep inertia than such an awakening from REM sleep (2,3). Nevertheless, the exact role of the particular sleep stage on sleep inertia remains still unclear and contradictory (3). In the present experiment the reaction times found after deep slow wave sleep, light slow wave sleep as well as the REM sleep condition are not significant different from each other. This implies that qualitatively differences could not be found between awakening from slow wave sleep and REM sleep. Although these data support the findings of Balkin and Badia (11), the role of different sleep states in memory processes is still not completely clear. The putative relationship with the phase of the biological clock is another topic worth considering, though no hard evidence was found in the present experiment. Perhaps, for investigating this relationship a more complex and demanding task for which the sleep inertia period will be much longer is desired.

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