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Research Article

Effects of sleep deprivation on sustained attention in young adults

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AT A GLANCE

This study revealed that sleep deprived young adults have their sustained attention capability decreased. Further, demonstrated that at the beginning of the task, subjects were able to maintain or even improve performance, nevertheless, subjects failed to maintain such performance after the fifth minute, showing a dramatic decrease in sustained attentional capability.

ABBREVIATIONS

CR Correct responses
TPT Tolouse-Piéron

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BACKGROUND: Sleep deprivation is common nowadays and considering that attention is important to our daily activities, it is important to compare the effects of sleep deprivation on sustained attention.
AIM: This study investigated the effects of sleep deprivation on sustained attention in young adults.
METHOD: Sixteen adults were evaluated both after a normal and after one night of sleep deprivation. Sustained attention was assessed through the Tolouse-Piéron Test (TPT), measuring the number of correct responses (CR), omissions, and attention coefficient, at first, fifth and tenth minutes of the test.
RESULTS: Results revealed a reduction in the number of CR in the fifth compared to the first minute but only in the post-test session. The number of omissions increased in the fifth compared to the first minute in the post sleep deprivation. Attention coefficient decreased in the fifth and tenth compared to the first minute.
CONCLUSION: Sleep deprivation deteriorates sustained attention, especially when adults are required to maintain attention for long periods.

KEYWORDS: Sleepiness | Attention | Toulouse-Piéron Test

INTRODUCTION

Sleep restriction and even deprivation have become a common occurrence nowadays. Several changes in our daily routines such as long work journeys and social and family activities have led many to sleep less and usually in inappropriate conditions. Such dramatic change in sleep habits have influenced many to investigate the behavioral and functional effects of sleep restriction and deprivation on several activities, such as cognitive tasks (e.g.[1]), memory and decision making[2] and postural control[3].

Among the many functions impaired by sleep deprivation, attention has been widely investigated. In general, it has been demonstrated that sustained[4] and selective attention[1] are affected by sleep deprivation, leading to worsening of performance in adults. However, the effects of sleep deprivation are not so consistent regarding the use of a dual-task in

sleep-deprived adults. While decline in a primary task performance was observed (e.g.[5]), in other experimental conditions the addition of a secondary task even attenuated the negative sleep deprivation effects on the performance of the primary task (e.g.[6]). Despite this controversy, there is consensus that sleep deprivation and restriction impact the use of attention and such effects are quite dramatic to many of our activities.

Several methods and tools can be used to examine attention performance. From the wide variety of methods, some implies the use of sophisticated and expensive equipment such as the electrooculography[7] and the eye tracking systems[8]. On the other hand, there are several similarly effective tests widely used to infer attentional capabilities that demand less technological resources. For example, simple reaction time test performed on a personal organizer has been used to infer sustained attention performance[9]. Through the use of such simpler and less demanding protocols, it has recently been demonstrated that vigilance performance is deteriorated by sleep deprivation[10]. Negative effects of sleep restriction on sustained attention and mood were also shown using an one-line system designed and programmed to delivery stimuli over the Internet[11].

Another important test to measure attention resources is the Tolouse-Piéron Test (TPT), also referred as Tolouse-Pieron Scale (1986)[12], and validated according to the Brazilian's conditions [13]. The TPT has been commonly used by psychologists to evaluate concentration range and to detect attention anomalies[14], attention-deficit and hyperactivity disorder[12], relationship between memory and attention deficits and emotional disorders[15], sleep quality and attention[16].

Evidence suggests that sleep deprivation affects performance especially when the task has a relatively long duration[17]. Since the TPT involves a ten-minute-period, it seems suitable to investigate the impact of sleep deprivation on attentional function. An important unresolved question is whether sleep deprivation affects performance in an attentional task throughout the entire time of the test or if changes in performance are observed only after the subject has been executing the task for a relatively long period. Therefore, the purpose of this study was to investigate the effects of one night of sleep deprivation on sustained attention in young adults in the first-, fifth- and tenth-minute periods.

METHODS

Participants

Sixteen healthy young adults (aging 23.6±6.0 years) participated as volunteers in this study. Participants were undergraduate students, had normal or corrected-to-normal vision, and reported no diagnosed sleep disturbances. Prior to participation, volunteers signed a written consent form according to the procedures approved by the Institutional Ethics Committee.

Procedures

Sleep diaries were used to monitor participants' sleep schedules three days before the experiment and they were instructed to keep regular sleep during this period. Participants arrived at the laboratory in the morning, after a normal night of sleep for the first test session, which occurred between 8am and 11am. After this first test session, they were allowed to

go about their daily activities and then returned to the lab approximately at 8pm, where they remained awake during the entire night. A second test session was performed after this sleep deprivation night, also between 8am and 11am. During the sleep deprivation period in the laboratory, volunteers engaged in activities that did not involve physical demands, such as reading and playing cards, and were provided with food. Alcohol and caffeine were prohibited. Two experimenters accompanied participants throughout the sleep deprivation night in order to assure that all the study compliances were fulfilled.

Sustained attention was evaluated in both test sessions, before and after the sleep deprivation night, through the Tolouse-Piéron Test (TPT). In order to do so, participants were provided with a sheet of paper containing 1200 squares, displayed in 30 lines and 40 columns, with lines from these squares pointing to different directions. At the top of the sheet, there are three target squares. The task was to identify among all 1200 squares which ones are identical to ones of the three target squares, that is, the squares which have the line pointing to the same direction to one of the three target squares. The participant was asked to scan as much as possible all of the 1200 squares and mark with a pencil every match square as fast and accurate as possible. The total duration of the test was 10 minutes. The TPT test was applied by the two experiments, previously trained, and they followed all the test application requirements.

In order to track the progression of the subjects' performance throughout the 10-minute-period of the test, at every minute the experimenter gave a sign so participants would draw an "x" on the square that was being scanned at that exact moment. In this way, it was possible to screen the results from the entire test period (i.e., 10 minutes) as well for specific periods of the test (e.g., 1st – from the beginning to minute 1; 5th – from minute four to minute five; and 10th –from minute 9 to minute 10, as used in this study).

The responses were compared to a matrix in order to identify the correct responses, the errors and the omissions. Performance on the TPT was examined using three dependent variables: number of correct responses (CR), number of omissions and attention coefficient. The number of correct responses was the number of marks that correctly matched the target figures. The number of omissions corresponded to the number of correct figures presented in the sheet of paper but not marked by the subject. Finally, the attention coefficient was calculated according to the following:

$$AttentionCoefficient = \frac{(CR - Errors)}{(Errors + Omissions)} \quad (1)$$

where, Errors represent the number of figures marked by the subject which did not match any of the target figures. All three dependent variables were calculated for the periods corresponding to the first, fifth, and tenth minutes of the test.

Statistical Analysis

Three analyses of variance (ANOVAs) having as factors the test, pre- and post-sleep deprivation, and the minute within the test (1st, 5th, and 10th), both factors treated as repeated measures, were conducted on each of the dependent variables: number of CR, number of omissions and attention coefficient. When necessary, Tukey HSD post hoc tests

were conducted and the effect size (Cohen's d) were presented, when comparisons reached significance. The significance level was set at 0.05 and all analyses were performed using the SPSS software

RESULTS

Sleep diaries showed that participants maintained regular sleep three days before the experiment (average of 7.9±0.7 sleep-hour per night) and slept in average 8.1±0.6 hours in the night prior to the experiment. According to sleep diaries, participants had been awake for 3.1±1.1 hours in the first test session (pre-sleep deprivation) and for 27.0±1.1 hours in the second test session (post-sleep deprivation).

Figure 1 depicts the number of correct responses for the pre- and post-sleep deprivation tests and for the 1st, 5th, and 10th minutes. ANOVA revealed test, $F(1,15)=9.17$, $p<0.009$, and minute effect, $F(2,30)=3.42$, $p<0.05$, and test and minute interaction, $F(1,21)=5.10$, $p<0.03$. The number of CR was higher in the post- compared to the pre-sleep deprivation test ($d=1,36$). None of the comparisons among the number of CR in the 1st, 5th, and 10th minutes reached significance. Post hoc tests only showed a reduced number of CR in the 5th compared to 1st minute ($d=-1,27$) for the post-sleep deprivation test.

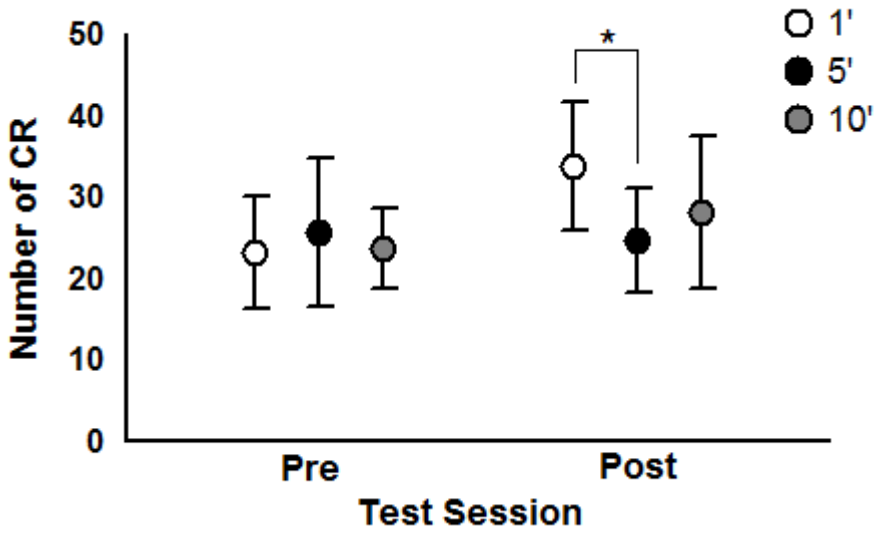

Figure 1. Average number of correct responses (CR) in the 1st, 5th and 10th minutes of the test during the pre- and post-sleep deprivation test sessions. Error bars represent standard deviation.

Figure 2 depicts the number of omission responses for the pre- and post-sleep deprivation tests and for the 1st, 5th, and 10th minutes. ANOVA revealed minute effect, $F(1,19)=6.04$,$p<0.02$, and test and minute interaction, $F(1,21)=3.80$, $p=0.05$, but no test effect, $F(1,15)=3.15$, $p>0.05$. Post hoc tests for the interaction showed that the number of omissions increased in the 5th compared to 1st minute ($d=1,04$), but only for the post-sleep deprivation test.

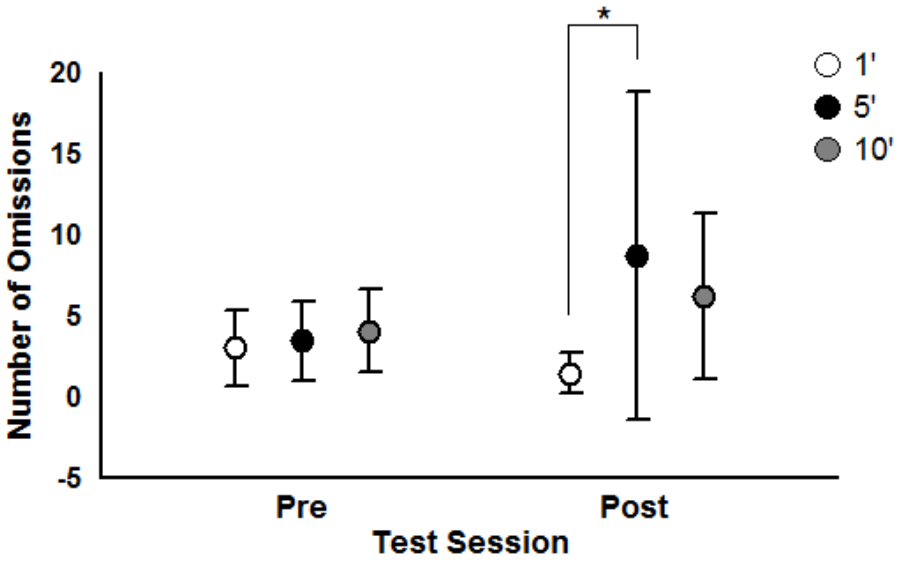

Figure 2. Average number of omissions in the 1st, 5th and 10th minutes of the test during the pre and post sleep deprivation test sessions. Error bars represent standard deviation.

Figure 3 depicts the attention coefficient for the pre- and post-sleep deprivation tests and for the 1st, 5th, and 10th minutes. ANOVA revealed minute, $F(2,30)=9.77$, $p<0.002$, but no test effect, $F(1,15)=1.23$, $p>0.05$, nor test and minute interaction, $F(2,30)=2.05$, $p>0.05$. Attention coefficient decreased in the 5th compared to the 1st minute ($d=-2,02$) and 10th minutes compared also to the 1st minute ($d=-2,3$).

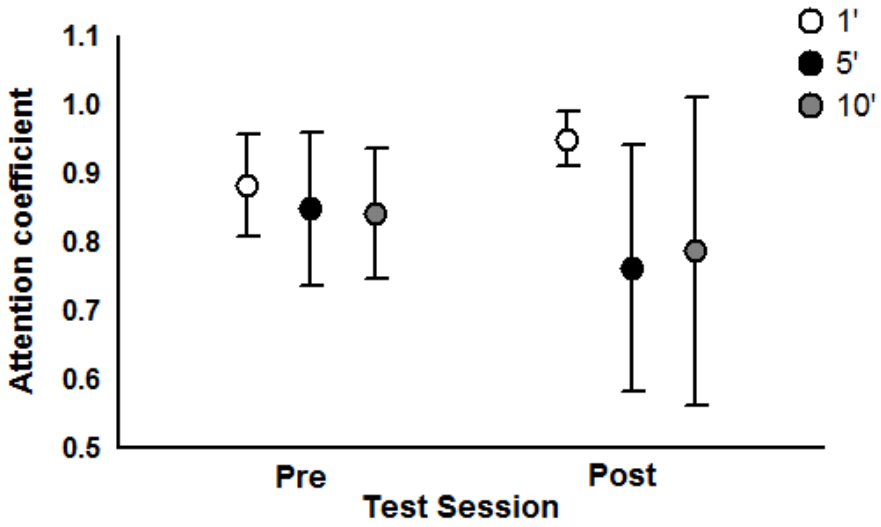

Figure 3. Average attention coefficient values in the 1st, 5th and 10th minutes of the test during the pre and post sleep deprivation test sessions. Error bars represent standard deviation

DISCUSSION

This study examined the effects of one night of sleep deprivation on sustained attention in young adults. Surprisingly, the results indicated that at the beginning of the attentional test young adults improved their performance after sleep deprivation. However, after the fifth minute of the test protocol, performance was considerably deteriorated. Taken together, these results suggest that sleep-deprived young adults seem to allocate more attention to perform a task, but soon such effort is not sustained to maintain initial performance for relatively long periods. Such difference in performance throughout the test is not observed prior to sleep deprivation.

After one night of sleep deprivation, at the beginning of the TPT, the number of correct responses increased. Such result is surprising since one could expect that after being sleep deprived, attention would be impaired, as previously observed [8,18] and even using the TPT [19]. However, performance of both correct and of omission responses was not sustained throughout the 10-minute-period of the test after sleep deprivation. The number of correct responses significantly decreased when measured at the fifth and the tenth minutes compared to the first minute. Similarly, number of omissions dramatically increased at the same fifth and tenth minutes compared to the first minute. A possible explanation for such results is that at the beginning of the test, young adults were able to use attentional resources and even improve their performance. Such suggestion seem to be in line with results showing no decrement in performance after sleep deprivation for certain tasks which is believed to depend on the nature of the cognitive task being performed[5]. For instance, in more complex tasks, such as logical reasoning (grammatical transformation), it was observed an increasing of cerebral responses for sleep-deprived adults, interpreted that sleep-deprived adults would be compensating for the deleterious effects of the lack of sleep in order to try to maintain performance[20].

In this way, a conscious cognitive effort employed by adults at the first minutes of the task would be a possible explanation of why performance was maintained or improved after sleep deprivation. The novelty of our results is that such effort was shown to fail after a relatively long period of sustained performance, which led to increased number of omissions and fewer correct responses. In this case, such performance detriment was observed after the fifth minute of the task.

Several studies have suggested that sustained attention after sleep deprivation is affected[21-23]. Our results clearly showed that despite the effort and even performance improvement at the beginning, after a period of time (at least after a five-minute period), young adults are not capable of sustaining the same level of attention when sleep-deprived. Moreover, the deterioration of performance was quite dramatic, as observed with the significant increase in omissions observed at the fifth- and tenth-minute periods. Although attention coefficient did not reach statistical significance (test and minute interaction), it was also observed a tendency of decrease in attention coefficient at the fifth and tenth minutes. Again, no changes were observed in any of the three variables (correct responses, number of omissions, and attention coefficient) prior to the sleep deprivation.

Sustained attention is important in many of our daily activities and, in many cases that one is not capable of maintaining attention for a period of time, the consequences might be undesirable. This becomes extremely important when considering that many tasks commonly performed by sleep-deprived individuals have high level of attentional requirements; examples include driving and patient care related tasks performed by doctors

on long work-shifts[24, 25]. With this regard, although the TPT shows limitations and still needs to be further used, our results indicated that the TPT could be considered as a simple but important measure of attentional functions of individuals under sleep deprivation. However, the need for the assessment to account for variations in performance throughout the 10-minute period of the test instead of using just standardized global variables must be emphasized, as our results demonstrate that sleep deprivation effects were observed only after the period of 5 minutes of task onset.

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