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Published version:
DOI: 10.1016/j.jbtep.2018.02.002

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Accepted Manuscript

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PII: S0005-7916(17)30163-5

DOI: 10.1016/j.jbtep.2018.02.002

Reference: BTEP 1373

To appear in: *Journal of Behavior Therapy and Experimental Psychiatry*

Received Date: 21 July 2017

Revised Date: 12 January 2018

Accepted Date: 12 February 2018

The effects of one night of partial sleep deprivation on executive functions in individuals reporting chronic insomnia and good sleepers

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Abstract:

Background and objectives: The aim of the present study was to investigate the effects of a partial sleep deprivation night on executive functions in participants reporting chronic insomnia and good sleepers using a Task Switching paradigm.

Methods: Sixteen participants reporting symptoms of chronic insomnia and sixteen good sleepers were tested after a night of habitual sleep and after a night of partial sleep deprivation (5 hours of sleep allowed). The Switch Cost (SC) and the Backward Inhibition (BI) were computed as measures of switching attention and response inhibition, respectively.

Results: We observed a marginally significant interaction Night × Group on SC ($F_{(1,29)}$=4.06, p=0.053, η^2=0.123. Fisher's least significant difference (LSD) post-hoc revealed a smaller SC after the sleep deprived night relative to the habitual night for the good sleepers (p=0.027;M=192.23±201.81 vs M=98.99±141.16). Differently, participants with insomnia did not show any change after the two nights.

Limitations: Several limitations must be acknowledged including the use of a convenient sample of university students and the use of a single task of cognitive performance.

Conclusions: We found that SC was smaller in the good sleepers after a night of partial sleep deprivation compared to a habitual night, indicating a better switching performance. The insomnia group showed no differences in performance after the two experimental nights. Several factors may account for these results, including increased levels of arousal and cognitive effort during task execution.

Keywords: sleep, insomnia, cognition, executive functions, inhibition, flexibility

1. Introduction

Executive functions (EFs) are commonly described as a set of cognitive processes involved in the control of basic psychological processes such as attention, memory, and emotion [1]. Experimental studies showed that total sleep deprivation markedly impairs EFs (e.g., [2]). With respect to chronic insomnia disorder, which is characterized by alternation in the quantity and/or quality of sleep [3], previous research showed inconsistent results, with some authors finding impaired EFs performance (e.g. [4], [5]) and some authors not (e.g., [6], [7]). The aim of this study was to examine the effects of a partial sleep deprivation night on EFs in individuals reporting chronic insomnia (CI) and good sleepers (GS).

2. Material and methods

2.1. Participants

Thirty-two participants (23.91±2.05 years; 56.3% females) were recruited from student community of the Department of Psychology of Sapienza University of Rome. Sixteen participants (24.31±1.89 years; 9 females) reporting symptoms of chronic insomnia and sixteen good sleepers (23.50±2.19 years; 9 females) were recruited. Inclusion criteria for the CI group were the presence of symptoms of insomnia as reported in the DSM-5 [8]. Inclusion criteria for the 16 GS were the absence of any sleep complaints. Participants voluntary agreed to participate in the study and provided informed consent. They received 20 Euro for their participation.

2.2. Self-report measures

Sleep Disorders Questionnaire (SDQ)

The SDQ [9] was used to select participants for the present study. The SDQ is a valid, sensitive and specific brief self-report questionnaire used to assess the presence of insomnia according the DSM 5 [8].

Insomnia Severity Index (ISI)

The ISI [10] was used to assess the severity of insomnia during the preceding two weeks. A score ≥7 is considered the cut-off for the presence of clinically significant insomnia.

Beck Depression Inventory (BDI-II)

The BDI-II [11], a 21-item self-report questionnaire, was used to assess the presence and severity of depressive symptoms based on DMS-IV criteria [12].

2.3. Task Switching

The Task Switching paradigm was used to assess the executive processes of switching attention and response inhibition [13]. The task required participants to apply one of thee different rules (A,B,C) in consecutive trials, presented in rapid succession according to random sequences of triplets of rules (A-A-A,A-B-A,C-B-A, Fig. 1 a). First, either a square, a rhombus, or a circle appeared on the screen. Thus, a digit from 1 to 9 appeared inside the geometric figure. According to the geometric figure, participants were asked to judge whether the number was odd or even, bigger or smaller than five, or central (3,4,6,7) or extreme (1,2,8,9). Number 5 was never shown. The numbers were black and centrally displayed on a grey background. Switching from one rule to another implies performance cost. Also, switching back to a recently executed task is harder than switching back to a less recently executed task. Thus, two performance indices were computed. The Switch Cost index (SC) reflects increased mean reaction times (RT) on the third trial of switching triplets (A-B-*A*,C-B-*A*), vs the third trial of repetition triplets (A-A-*A*). It is computed subtracting the RT of the switching trials from the RT of repetition trials. The Backward Inhibition index (BI) reflects slower RT on the third trial of alternating triplets (A-B-*A*) vs the third trial of non-alternating triplets sequences (C-B-*A*). This is due to residual inhibition suffered by the rule A in A-B-*A* vs C-B-*A* sequences [14]. BI is computed by subtracting the RT of the alternating trials from the RT of the non-alternating trials. We also assessed the number of correct responses to the task.

2.4. Sleep Assessment

Subjective sleep was measured using sleep diaries throughout the entire duration of the study. In addition, during the sleep deprivation night, participants were asked to wear the headband of a wireless system (Zeo, Inc., Newton, MA; [15]) at 10 pm to objectively control whether they were compliance to the sleep deprivation instructions.

2.5. Procedure

The study was in agreement with Helsinki Declaration and was approved by the Ethical Committee of the Department of Psychology at the Sapienza University of Rome. Upon recruitment, participants were invited to an initial lab session during which they signed an informed consent and received the instructions and the materials for the study. They were then asked to return to the laboratory after a night of habitual sleep and after a night of partial sleep deprivation (5 hours of sleep allowed). The order of the nights was counterbalanced among participants and between groups. When the deprivation night occurred first, a night of restoration was guaranteed before the habitual sleep since a restoration bias might occur after a night of poor sleep [16]. In the sleep deprivation night, participants were asked not to go to bed before 1 am and not to wake up after 6 am. After each night, participants were asked to come to the lab to complete the Task Switching. They were asked to abstain to consume caffeinated beverages and to smoke cigarettes before performing the task.

2.6 Data analyses

Total sleep time (TST) and sleep efficiency (SE) were calculated from the sleep diaries. Differences among demographic and self-report measures were compared using chi-square and t-tests for categorical and continuous data, respectively. Sleep manipulation check was performed using a 2x2 ANOVA Night (habitual vs deprivation) x Group (CI vs GS) on TST and SE, separately. To analyze the impact of sleep deprivation on EFs, we run the same 2 x 2 analysis on SC, BI and correct responses were conducted using BDI-II score as a covariate. This was done to control for the impact of depression on EFs [17]. Lastly, bivariate correlations were run to further explore the relationship between SC, BI and BDI-II.

3. Results

3.1 Sample characteristics

The two groups showed comparable age (t_{30}=-1.12, p=0.270). Also, as expected, CI and GS significantly differed on ISI (t_{30}= -9.29, p<0.001) and on BDI-II (t_{30}=4.89, p<0.001) scores.

3.2. Manipulation check

The ANOVA on TST revealed significant main effects of the Night ($F_{(1,30)}$=111.293, p<0.001, η²=0.788) and of the Group ($F_{(1,30)}$=7.748, p=0.009, η²=0.205). In the deprivation night, both groups slept less (273.50±31.33min) than in the habitual night (399.66±68.49min). Across the two nights, CI slept on average less than GS (318.37±9.25min vs354.78±9.25 min). The ANOVA on SE showed a main effect of the Group ($F_{(1,30)}$=11.745, p=0.002, η²=0.281), with CI showing lower SE in both nights as compared to the GS (91.67±0.87%vs 95.91±0.87%).

3.3. Behavioral results

Neither the Group ($F_{(1,29)}$=0.93, p=0.34, η²=0.031) nor the Night main effect ($F_{(1,29)}$=0.005, p=0.94, η²=0.000) reach a statistical significance. However, we observed a marginally significant interaction Night × Group on SC ($F_{(1,29)}$=4.06, p=0.053, η²=0.123, Fig. 1 b). Fisher's least significant difference (LSD) post-hoc revealed a smaller SC after the sleep deprived night relative to the habitual night for the good sleepers (p=0.027; M=192.23±201.81 vs M=98.99±141.16). Differently, participants with insomnia did not show any change after the two nights. No significant Group ($F_{(1,29)}$=0.61, p=0.44, η²=0.021) or Night ($F_{(1,29)}$=0.001, p=0.97, η²=0.000) main effect or Night x Group interaction ($F_{(1,29)}$=2.39, p=1.33, η²=0.076) were found for BI. Similarly, there was no significant Group ($F_{(1,29)}$=0.107, p=0.74, η²=0.004) or Night ($F_{(1,29)}$=0.25, p=0.62, η²=0.009) or Night x Group ($F_{(1,29)}$=2.78, p=0.602, η²=0.009) effects for the number of correct responses.

Correlational analysis showed that SC and BI were associated with BDI-II after the night of sleep deprivation in GS (r=0.50, p=0.048 and r=-0.65, p=0.007, respectively) but not in CI. No significant associations were observed after the habitual night of sleep in both the groups.

Please insert Figure 1 here

4. Discussion

The aim of this study was to investigate the effects of experimentally induced partial sleep deprivation on executive functions [14] in CI and GS. Our results showed that after a night of partial sleep deprivation, GS exhibited smaller SC as compared to a habitual night of sleep, suggesting a better switching performance. Several factors may be hypothesized to explain this result. For instance, five hours of sleep may not be enough to determine EFs deficits. Additionally, participants may engage in this challenging task with increased cognitive efforts to compensate their deficits [18], which may also be facilitated by the increased arousal levels typical of sleep deprivation periods [19]. While GS tended to perform better after the sleep deprivation night as compared to the habitual night, CI did not show any difference between the two nights. The heightened level of cognitive arousal usually showed by CI [19] may have paradoxically facilitated their performance in this task. Moreover, it has been reported that CI tend to mobilize extra cognitive resources to compensate their deficits [18] which may result in a habitual efficient performance. Finally, results from correlational analyses confirmed the established association between poorer performance in EFs tasks and depression symptoms [17].

5. Conclusions

Our results show that after a single partial sleep deprivation night, GS exhibited a more efficient switching performance than after a night of habitual sleep. On the contrary, CI performance was comparable after the two nights. Increased levels of arousal, as well as compensatory effort during task execution have been hypothesized to account for these findings. Further studies are needed to better understand how insomnia perform in sleep deprivation conditions.

Declaration of interest

The authors have no conflict of interest to disclose.

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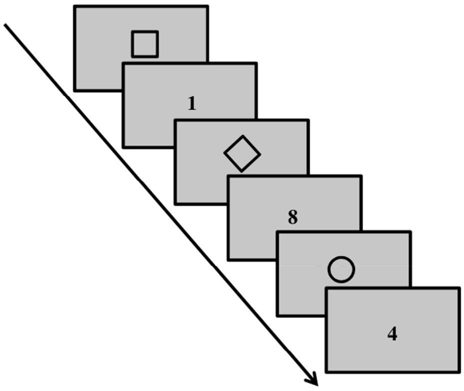
a) 

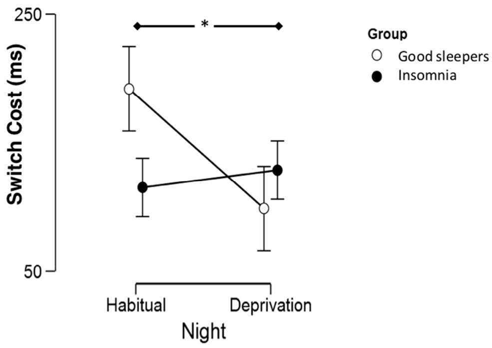
b) 

Fig. 1. a) Task Switching paradigm. Schematic representation of task stimuli. The task was composed of 162 trials presented on a 19" computer monitor placed frontally at a distance of about 70cm. **b)** Switch Cost as a function of the experimental nights for the two groups. *: p = 0.05.

Highlights

- The effects of partial sleep deprivation on task-switching is tested.
- Good sleepers exhibited better performance after sleep deprivation.
- Insomniacs' performance was not affected by sleep loss.