Is Orienting of Attention Selectively Impaired After Sleep Loss? The Role of Disengagement

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Abstract

Research on the effects of sleep deprivation on covert orienting of attention have produced evidence indicating either a negative or a null impact of sleep loss. Moreover, it is still unclear whether, following sleep deprivation, there is a general impairment of orienting processes or a selective one. Aim of the present study is highlighting the effects of sleep deprivation on the three subcomponents of orienting of attention: disengagement, moving and engagement (Posner and Raichle, 1994). The ANT-R (Fan et al., 2009) was administered following two sleep conditions: Baseline - a regular night of uninterrupted sleep, and Deprivation - 24 hours of total sleep deprivation. We have found a significant slowing down of the disengagement component, while engagement and shift components were virtually unaffected by sleep deprivation. Our data show that sleep deprivation selectively affects the three subcomponents underlying covert orienting of attention. Hence, they suggest that performance deficits following sleep curtailment should no longer be accounted for in terms of a general reduction of alertness or global attentional deficits.

Keywords: Attentional networks; Orienting; Disengaging.

Introduction

As a consequence of lifestyles and occupations in modern societies, many people experience fewer hours of sleep or even sleep loss. Several studies found that sleep deprivation could lead to a variety of cognitive deficits, including poorer attention. One of the most consistent results in sleep research is that sleep loss impairs performance on simple cognitive tasks such as signal detection and reaction time (RT) tests (Drummond, Paulus, & Tapert, 2006; Van Dongen, Baynard, Maislin, & Dinges, 2004; Wimmer, Hoffmann, Bonato, & Moffitt, 1992). However, it remains unclear to what extent attention is impaired by sleep loss. In fact, most studies refer to performance deficits following sleep deprivation as general reduction of alertness or generic "attentional deficits".

One current conceptualization of attention divides it into three functions defined in anatomical and functional terms: executive control, alerting and orienting (Posner & Raichle, 1994). Executive control is the capacity to detect and resolve conflict among responses. Alerting is defined as achieving and maintaining an alert state. The orienting network is defined as rapid or slow shifting of attention among objects within a modality or among various sensory modalities. Orienting could be overt, associated with head or eye movements, or covert, related to attentional movements without a change in eye position. In the present study, we focused specifically on the covert orienting of attention. Covert orienting is subdivided into three different elementary operations: disengaging attention from its current focus, moving attention to the new target or modality, and engaging attention at the new target or modality (Posner, Walker, Friedrich, & Rafal, 1984).

One way to examine the orienting of attention is manipulating the validity of a spatial cue (Posner, 1980). A valid cue indicates the location in which a subsequent target will appear. If the cue is invalid, the target appears in a different location, opposite to the location indicated by the cue. The benefit in terms of target processing efficiency achieved by valid cues is less in magnitude than the cost associated with invalid cues.

The attentional networks can be investigated using the revised Attentional Network Test (Fan et al., 2009) that is designed based on the original ANT (Fan et al., 2002). Unlike the original version, the ANT-R includes manipulations of the cue validity that allow to examine the three subcomponents of covert orienting.

Recent studies using the original ANT to investigate covert orienting of attention following sleep deprivation found either a negative or a null impact (Jugovac & Cavallero, 2012; Martella, Casagrande, & Lupiáñez, 2011). Thus, it is still unclear whether there is a general or a selective impairment of orienting processes following sleep deprivation. In the present study, we use the ANT-R to investigate whether and how the three subcomponents of orienting are impaired after a night of total sleep deprivation. In particular, we expect that the disengagement component is selectively affected by sleep deprivation.

Methods

Partecipants

Forty-three students (14 men, 29 women; mean age 23 years; range 20-26 years) took part in this study. All of them were right-handed and reported normal or corrected to normal vision. They had no history of brain injury, no sleep or circadian disorder, as assessed by questionnaires. The participants completed the Morningness-Eveningness Questionnaire (MEQ; Horne & Ostberg, 1976) and only the intermediate circadian types were included in the study. They reported to have good habitual sleep, between 6 h and 10 h in duration daily. A written informed consent was obtained from each participant prior to the experiment. They received course credits for their participation in the study.

The revised Attention Network Test (ANT-R)

The ANT-R (Fan et al., 2009) is a task that "combines a cued reaction time task (Posner, 1980), a flanker paradigm (Eriksen & Eriksen, 1974) and a location conflict (Simon) paradigm (Simon & Berbaum, 1990)".

Stimuli consisted of a row of five horizontal black arrows (one central target and four flankers, two on each side), with arrowheads pointing leftward or rightward. Participants' task is to identify the direction of the central arrow (left or right). In each trial, a cue that is a flashing box presented for 100 msec may be shown and after a variable cue-target interval (0, 400, 800 msec) the stimulus is presented. The cue validity manipulations (valid, invalid, double, no cue) are used to investigate the orienting subcomponents and the interactions between the attentional networks. Furthermore there are two flanker congruency (congruent, incongruent) and two location congruency (congruent, incongruent) conditions.

The efficiency of the alerting and orienting networks is assessed by measuring the degree to which response latencies are influenced by the presence or absence of the cue and the spatial cue position respectively, and executive control network efficiency is measured as the amount of interference induced by flanking stimuli.

To quantify the efficiency of the three subcomponents of orienting, individual differences in reaction times (RTs) are measured manipulating the cue validity conditions. The disengagement of attention can be assessed by comparing the RTs to targets following double cue and invalid cue presentation. One can estimate the moving of attention by comparing the RTs of double-cue and the RTs of valid-cue conditions. The engagement of attention at targets can be evaluated by comparing the RTs of invalid cue and valid cue conditions.

Procedure

The experiment was conducted in the Sleep Psychophysiology Laboratory of the University of Trieste. The evening before each test session, participants underwent an adaptation phase, so as to avoid the possibility of confounding effects due to learning. In the experimental phase, the task was administered at the same time of day, 9:00 a.m., following two different sleep conditions, in order to preclude circadian confounds.

Two subjective sleepness scales, the Stanford Sleepness Scale (SSS; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973), and the Global Vigor-Affect Scale (GVAS; Monk, 1989), were administered before the behavioral test, to verify participants' state of vigilance at the beginning of each test session.

The two sleep conditions were:

(a) Baseline – participants came to the sleep laboratory at 8:30 a.m. after a regular night of uninterrupted sleep in their own homes (at least 6 hours of a normal night of sleep). Compliance was assessed by wrist actigraphy. The test session started at 9:00 a.m., when the participants performed the ANT-R II.

(b) Deprivation – participants came to the sleep laboratory at 9:00 p.m. The participants received precise instructions not to nap during the day preceding the deprivation night and they were required to keep their regular bedtimes. Then, they spent the entire night awake in the laboratory under the continuous monitoring of an experimenter: as per standard sleep deprivation protocols, they were allowed to engage in non-strenuous activities such as reading, studying, watching television, and conversing. Throughout the entire night they were not allowed to drink beverages containing alcohol, caffeine and/or theanine. At 9:00 a.m., the test session took place following the same procedures used in the baseline condition. Overall, participants stayed awake for a total of 24 consecutive hours.

The two conditions were counterbalanced across participants with an interval of one week between the two – that is, participants were run in group sessions with half undergoing sleep deprivation first and the other half, in the opposite order.

Results

The subjective scales were used to verify that the experimental sleep deprivation condition manipulation had been effective. Data from the SSS showed that perceived sleepiness following deprivation (Mdn = 5) was reliably higher ($p < 0.001$) than in the baseline condition (Mdn = 2.4). Two one-way ANOVAs performed on the Vigor and Affect data from the GVAS showed that perceived Vigor level after sleep deprivation was significantly lower than it was at baseline (25 ± 18 vs. 64 ± 18, respectively; $F_{1,42} = 61.8$, $p < 0.001$) and the Affect index was significant lower after sleep loss than baseline (63 ± 18 vs. 72 ± 16, respectively; $F_{1,42} = 6.7$, $p < 0.05$).

For each subcomponent of orienting we performed a repeated-measure ANOVA on RT data by means of 2 (sleep condition) by 2 (cue condition) by 2 (flanker condition).

The disengagement component slows down significantly after sleep loss (11 msec, $F_{1,42} = 6.3$, $p < 0.05$). Instead, neither the orienting (-4 msec, $F_{1,42} = 2.3$, n.s) nor the validity (7 msec, $F_{1,42} = 1.86$, n.s.) components are significantly affected by sleep deprivation.

Discussion

Our results show that 24 hours of total sleep deprivation selectively affects the three subcomponents underlying covert orienting of attention. Only the disengaging component was significantly adversely affected by sleep deprivation. Instead, the other two components of covert orienting, that are the abilities to move attention to the new target and to engage attention at the new target, did not show negative effects of sleep deprivation.

Inconsistent results of previous studies investigating the attentional networks following sleep deprivation could be explained by the type of tasks administered, which did not allow evaluating the subcomponents of orienting (Jugovac & Cavallero, 2012; Martella, Casagrande, & Lupiáñez, 2011).

In conclusion, the results of the present study indicate that performance deficits following sleep loss should no longer be accounted for in terms of a general reduction of alertness or global attentional deficits.

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