Effect of acute sleep deprivation on concentration and mood states with a controlled effect of experienced stress

Učinek kratkotrajnega pomanjkanja spanja na koncentracijo in počutje z nadziranjem doživetega stresa

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Abstract

Background: Sleep is a biological function, which enables and allows regeneration, rest and preparation for further activity and also allows for previous activity and experience to organize and merge with our pre-existing experience. Sleep deprivation impairs several aspects of human functioning and the main purpose of our article was to verify if acute one night sleep deprivation (already) leads to changes in concentration and mood with a controlled effect of stress.

Methods: We applied an attention test (TP – test pozornosti) before and after acute sleep deprivation in nine healthy young males. We measured their mood states with a BRUMS (Brunel Mood Scale) profile and monitored the level of cortisol throughout the entire experiment. We also compared the results of the participants with the results of a control group to verify the effects of the experiment.

Results: Our results show that acute sleep deprivation did not cause any significant changes in concentration. However, acute sleep deprivation did cause mood changes–our subjects reported feeling more tired and less vigorous at the end of the acute sleep deprivation. Cortisol preserved the same circadian rhythm following the period of sleep deprivation.

Conclusions: As previous studies have shown, mood changes rather than decreased concentration occur after acute sleep deprivation – cognitive abilities seem to be more resistant to sleep deprivation. Further studies with longer sleep deprivation should show how long it takes to disrupt our concentration and higher cognitive abilities.

Izvleček

Izhodišča: Spanje je biološka funkcija, ki omogoča regeneracijo, počitek in pripravo na nadaljnje dejavnosti, pri tem pa omogoča, da na novo pridobljene izkušnje povežemo z že obstoječim znanjem. Pomanjkanje spanja vodi v zaspanost,[1] več študij[2,3,4,5] pa je opisalo vedenjske, kognitivne in psihofizične posledice pomanjkanja spanja. Na kognitivnem področju opažajo upad osnovnih funkcij, kot so budnost, pozornost in hitrost odzivanja,[2,6,7,8,3,9] pa tudi slabšo učinkovitost pri kompleksnih kognitivnih nalogah, kot so inhibicija odgovora, načrtovanje, odločanje, učinkovitost pri reševanju aritmetičnih nalog in logično sklepanje.[9,10] Da bi učinkovito opravljali dejavnost, kot so vožnja ali nadzorovanje naprav in komunikacijskih tehnologij, je potrebno dobro vzdrževanje pozornosti,[11] saj so včasih lahko usodni že majhni in redko pojavljajoči se dražljaji.[12] Tudi v tekmovalnem športu je pomemben kognitivni vidik, še posebej ob dolgih in napornih tekmovanjih, pri katerih ni dovolj časa za počitek (npr. pri jadranju preko Atlantskega oceana). Študije pričajo tudi o tem, da pomanjkanje spanja vpliva na posameznikovo počutje;[10] navajajo celo, da pomanjkanje spanja močneje vpliva na počutje kot na kognitivno ali motorično delovanje.[9] Pomanjkanje spanja se

navadno kaže s povečano razdražljivostjo, nepotrpežljivostjo, povečano anksioznostjo in depresivnostjo,[3,9,13] pri depresivnih bolnikih pa vpliva na izboljšanje počutja[14]. Nekateri avtorji menijo, da je slabše kognitivno delovanje posledica stresa, ki ga povzroča pomanjkanje spanja.[7,15,16,17] Še vedno pa ne vemo natanko, kako dolgo obdobje brez spanja že vpliva na slabše počutje in neučinkovito izvajanje dejavnosti. S pričujočo raziskavo smo tako želeli ugotoviti, ali akutno pomanjkanje spanja, ki traja eno noč, že povzroči spremembe v koncentraciji in počutju ob nadzorovanje učinkov stresa. Preveriti smo želeli veljavnost hipoteze, da ena noč brez spanja že vpliva na koncentracijo in počutje.

Metode: V raziskavi je prostovoljno sodelovalo 9 zdravih moških (starost M = 29,22; SD = 3,99), ki so bili vsaj trikrat tedensko telesno aktivni, pred začetkom raziskave pa so tri tedne izpolnjevali dnevnik spanja in v tem obdobju niso utrpeli pomanjkanja spanja; 4 tedne pred preizkusom niso uživali psihoaktivnih snovi. V kontrolni skupini, ki se po starosti ni statistično značilno razlikovala (F = 0,02; p (F) = 0,89), je bilo 13 zdravih, redno telesno aktivnih moških. Izobrazbena struktura obeh vzorcev je bila enaka. Za merjenje koncentracije in počutja smo uporabili test pozornosti TP[18] in Brunelovo lestvico počutja.[19] Raziskovalni protokol je trajal 56 ur; prvo noč smo spanje v laboratoriju merili s klasično polisomnografijo, nato pa sta 40-urno obdobje brez spanja nadzorovala dva zdravnika, ki sta zagotavljala, da so preiskovanci ostali budni. Počutje preiskovancev smo ugotavljali z baterijo testov, ki so vključevali tudi preverjanje delovanja motorike in avtonomnega živčnega sistema. Po končanem obdobju brez spanja smo v laboratoriju izmerili še spanje v naslednji noči. Koncentracijo in počutje smo prvič izmerili zvečer po noči normalnega spanja in nato še 24 ur kasneje, po neprespani noči. Za nadzorovanje učinkov stresa smo vsake 4 ure odvzeli vzorce krvi in preverjali raven kortizola; meritve so bile opravljene z radioimunološko metodo v Lyonu v Franciji. Za kontrolo smo uporabili vzorce, ki smo jih odvzeli v času, ki je bil najbližji psihološkemu testiranju, tj. ob 19. uri. Opravili smo analizo variance in izračunali Spearmanov korelacijski koeficient, za statistično pomembnost smo izbrali raven $p < 0,05$.

Rezultati: Rezultati niso pokazali razlik v ravni kortizola ob prvem in drugem merjenju ($t = -0,74$; $p = 0,48$), ki je med obema merjenjema ohranila enak cirkadiani ritem. Pri testiranju koncentracije smo ob drugem merjenju dobili nekoliko boljše rezultate, pri preverjanju počutja pa smo ugotovili, da se je po neprespani noči povečala utrujenost in znižala živahnost. Glede pojavnosti jeze, zmedenosti, depresivnosti in napetosti ni bilo sprememb. Ob primerjavi rezultatov kontrolne in eksperimentalne skupine smo ugotovili, da je v obeh skupinah pri testiranju koncentracije prišlo do podobnega učinka vaje (razlike v prvem testiranju $F = 0,44$; $p = 0,51$ in v drugem testiranju $F = 0,02$; $p = 0,90$). Preverjanje morebitnih korelacij med kortizolom, koncentracijo in počutjem ni pokazalo nobenih statistično značilnih povezav.

Zaključki: Ljudje se na nove in zahtevne situacije pogosto odzovemo s povečanim stresom. 40-urno obdobje brez spanja je zagotovo stresna situacija, še posebej glede na število meritev in testov, ki so bile opravljene. Kot kazalnik stresa smo izmerili količino kortizola v krvi. Ugotovili smo, da se tudi po pomanjkanju spanja količina tega hormona ni povečala, kar pomeni, da na naše rezultate ni vplival večji stres, ampak gre dejansko za učinek kratkotrajnega pomanjkanja spanja. Kortizol je tudi ohranil enak cirkadiani ritem. Kot kazalnik kognitivnega delovanja smo izmerili koncentracijo, pri kateri ni prišlo do zmanjšanja funkcije, temveč celo do boljših rezultatov. Ob primerjavi rezultatov eksperimentalne in kontrolne skupine smo ugotovili, da je v obeh skupinah prišlo do enako obsežnega izboljšanja rezultatov. Zaključimo torej lahko, da se po kratkotrajnem pomanjkanju spanja koncentracija in aktivno spremljanje okolja, ki je njen predpogoj, ne poslabšata. Do razlik pa je prišlo pri preverjanju čustvenih stanj; preizkušanci so namreč poročali o večji utrujenosti in manjši živahnosti, kazala pa se je tudi nagnjenost k večji zmedenosti, kar je v skladu z ugotovitvami nekaterih drugih avtorjev.[9,13] V nasprotju z nekaterimi predhodnimi raziskavami[3] pa pri naših udeležencih nismo zasledili povečanja depresivnosti.

Introduction

Sleep is a biological function, which enables and allows regeneration, rest and preparation for further activity, while also allowing for previous activity and experience to organize and merge with our pre-existing experience. Sleep deprivation is known to increase the degree of sleepiness.[1] The behavioural, cognitive and psycho-physiological effects of sleep restriction (> 24h) were described in different studies.[2,3,4,5]

Sleep deprivation leads to many deficiencies in cognition. It is associated with decrements in basic cognitive functions including alertness, reaction time, attention and vigilance,[2,3,6-9] as well as in higher and more complex cognitive functions, including response inhibition, planning, decision-making, arithmetic computation and logical reasoning.[9,10]

Maintenance of vigilance (sustained attention) is a fundamental prerequisite for safe and efficient performance[11] and is essential for numerous critical activities such as vehicle operation, equipment and communication monitoring. When engaged in such activities, failure to detect an infrequent but important stimulus can be critical.[12] In sport-related situations, alertness and vigilance are most important, especially when athletes engage in activities where the environment is constantly changing and one has little or no time to rest – such as competing in sailing competitions across the Atlantic Ocean.

Evidence also shows a strong effect of sleep deprivation on sleep-deprived persons' mood states. Some research even suggests that the most obvious change following sleep deprivation is to be seen in mood changes rather than in cognitive or motor performance.[9] while other studies implicate that the impact on mood is still unclear.[10]

Irritability, impatience, confusion, childish humour, lack of regard for normal social conversation and inappropriate interpersonal behaviour have all been described in experimental settings of sleep deprivation.[13,9] Several clinical studies demonstrate that the absence of sleep is closely related to occurrence of anxiety symptoms[2] and increasing depression rates[3]. Conversely, there is a relatively large amount of clinical literature pointing to the rapid mood-enhancing effects of sleep deprivation in depressed patients and sleep deprivation has even been proposed as a treatment for depression.[14] Although these findings could be dismissed as being relevant to depressed patients only, the effect is powerful and authors suggest that the milder effects could be expected with normal participants during sleep deprivation.

Some consider sleep deprivation can be stressful.[7] It is known that stress may impair normal cognitive functioning,[15-17] however, it is difficult to predict the duration of sleep deprivation necessary in order to evoke certain changes due to the lack of studies in this field, which would differentiate between long- and short-term sleep deprivation and their effects. One of the main reasons for this is also the procedural difficulty of such studies and unavailability of subjects.[1,2]

The main purpose of our article was to determine if one night's acute sleep deprivation (already) leads to changes in concentration and mood with a controlled effect of stress in healthy young males.

Our hypothesis, set in accordance with the above stated literature, was that one night's sleep deprivation leads to changes in concentration and mood.

Methods

Participants

9 healthy males (age data: M = 29.22; SD = 3.99) were enrolled in the study as volunteers. They were all either undergraduate students or university graduates. They were all regularly physically active at least three times a week. They all experienced normal sleep-wake cycle and fulfilled the sleep diary three weeks before entering the protocol. None of them worked as a shift-worker and they were not sleep deprived for at least 3 weeks before the study. They were all healthy non-smokers and restricted from the use of alcohol, caffeine and other psycho stimulant beverages during the study protocol. They were free of any medication for at least

4 weeks before the study. All subjects gave written consent before participation. The study protocol was approved by The Ethical Committee of the University of Ljubljana, Medical School.

A control group consisted of 13 male persons (age data: M = 29.00; SD = 3.56), the differences in age between the samples were not significant (F = 0.02; p (F) = 0.89), the educational structure of both samples was equal – also these med were healthy and regularly physically active.

Instruments

TP attention test (18), based on the Pieron – Toulouse attention test was used. Test consists of 40 rows (each containing 40 columns) of squares (side length is 2mm) with added lines in different places – above, below, on left or right side or in corners. The task of the participant is to find the number of squares in each row, which are the same as the stimulus square (which is indicated at the beginning of each row). Before the test task, participants are allowed a short practice of the task (the practice is not time-limited). For the test task they are given 5 minutes. The test is intended to measure attention, the ability to visually follow small elements and perceiving a certain symbol from a number of confounding symbols.

As additional test, the Brunel mood scale BRUMS[19] was used. The scale was developed to serve as a brief measure of mood states among adolescent and adult populations and is derived from the Profile of Mood States. The scale contains 24 simple mood descriptors, such as angry, energetic, nervous, and unhappy. Respondents indicate whether they have experienced such feelings on a 5-point scale. The standard response timeframe is "How you feel right now" although other timeframes, such as "How you have felt during the past week including today" or "How you normally feel" can be used. The BRUMS takes about 1–2 minutes to complete. The 24 items comprise the following six subscales: anger, confusion, depression, fatigue, tension and vigour. Each subscale contains four items. When responses from the four items in each subscale are summed, a subscale score in the range 0–16 is obtained. We decided to use only a few tests, since we wanted to keep the testing brief and stress-free.

Procedure

The research protocol lasted 56-hours. On the first night sleep was objectively recorded with classical polysomnography (PSG) in the sleep laboratory. PSG recording was performed on a commercial PSG system (Nicolet One nEEG, Viasys, Healthcare, Neurocare, Madison, WI, USA) using standard PSG settings,[20] and included EEG, EOG, chin and tibialis anterior surface EMG, ECG, nasal and oral flow (pressure), respiratory (chest and abdominal) movements, oxyhemoglobin saturation (pulse oxymeter) and continuous video monitoring. Polysomnographic recording night started at 23hrs when lights were turned off. There was no computer, TV, radio, or telephone in the room. Cell phones were not allowed. Polysomnography lasted until 7hrs when lights were turned on and subjects had to leave their bed. Subjects were kept under sedentary and constant environmental conditions where illumination was approximately 50 lux (measured by luxmeter Volcraft MS1300). During the 40-hours of sleep deprivation subjects were supervised by two physicians in order to keep them awake. Food intake was under control and meal schedule was the same for all participants. Subjects during the study underwent battery of other tests (testing the motorical skills and autonomic nervous system), which were under the strict control and the same timetable for all participants. At the end of sleep deprivation (day 1, night 2, day 2) at 23hrs on the 2nd day recovery sleep was recorded by the PSG in the sleep laboratory.

Concentration and mood testing were performed twice: first, in the evening of day 1, after a normal sleeping night in the sleep laboratory and 24 hrs later, after a sleep-deprived night and day 2, just before the recovery night in the sleep laboratory. Problem solving ability was also tested in addition to concentration and mood testing. Testing lasted about 30 minutes.

Table 1: Comparison of concentration and mood states prior to and following acute sleep deprivation

	Prior to deprivation		Following deprivation		T–test	
	M	SD	M	SD	t	Sig (t)
Concentration	29.67	4.06	32.33	4.15	-2.60*	0.03
Errors	2.11	1.69	1.44	1.13	1.26	0.24
Anger	1.44	2.13	1.33	1.87	0.18	0.86
Confusion	1.11	1.62	2.44	3.47	-1.63	0.14
Depression	1.11	1.69	1.11	1.54	0.00	1.00
Fatigue	3.33	1.58	8.00	3.28	-4.73*	0.00
Tension	1.00	1.66	1.44	2.65	-1.08	0.32
Vigour	9.67	2.59	7.11	3.52	2.48*	0.04

*Legend: M – mean; SD – standard deviation; Sig (t) – statistical significance of the t parameter; *– significance ≤ 0.05*

Blood samples for cortisol measurement were taken every 4 hours from the beginning of the protocol (even during sleep). Measurements were performed by radio immunological method (RAI) in the Centre of Radio analyse, in Lyon, France. The comparison of the cortisol levels was done with the time of measurement, which was closest to psychological testing, that is at 19 hrs.

Statistical analysis was done by the Graph Pad prism 4 programs. D'Agonist test was used for testing the random distribution of the variables. For cortisol, mood and concentration analysis of variance (ANOVA) was performed. Spearman correlation coefficient was used for the calculations of correlations. Results under $p < 0.05$ were taken as statistically significant.

Results

Cortisol values

Figure 1 shows mean values (± standard deviations) of serum cortisol during the study. The highest values were reached at 7 a.m., while the lowest values were measured at 11 p.m. There was no difference in cortisol values before or after the sleep-deprivation period. Cortisol preserved the same circadian rhythm following the period of sleep deprivation. There was no significant difference in the values of serum cortisol measured closest to the time of each testing, i.e. 7 p.m. ($t = -0.74$; $p = 0.48$).

Concentration testing shows a significant difference in concentration between the first and the second testing, the latter yielding slightly better results. Differences in errors made i n each testing were insignificant. Two significant mood changes occurred after the period of sleep deprivation, namely an increase in fatigue following sleep deprivation and a decrease in vigour. There were no significant changes in anger, confusion, depression or tension.

In order to determine how much of the improvement in concentration could be attributed to task-rehearsal and familiarity with the task, the results of the experimental group were compared with those of the control group, which was tested with the same tests twice within a 24-hour time period, but without undergoing sleep deprivation in between. The results show that the improvement also occurred in the control group and even though it was smaller in the experimental group, the difference is not significant. The effect of task-rehearsal was smaller in the control group, but the difference is negligible. The improvement in results for both groups was similar in both cases of concentration testing ($F = 0.44$; $p = 0.51$ and $F = 0.02$; $p = 0.90$ respectively for the first and second testing), and the same holds for the number of errors in both sleep-deprived and control group in both cases of testing

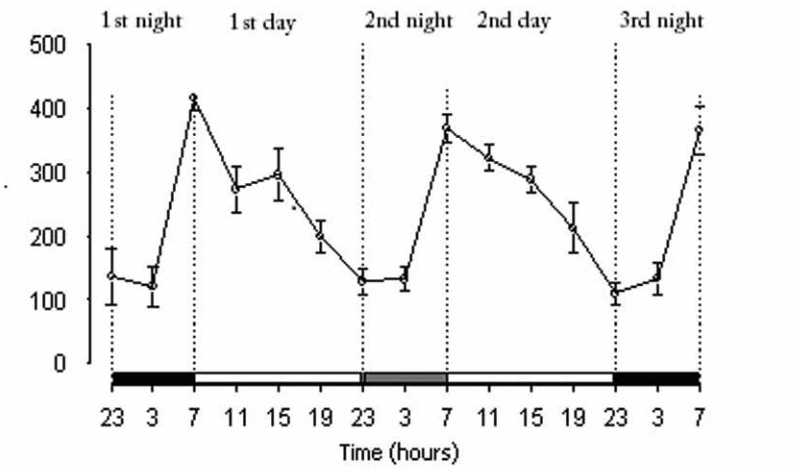

Figure 1: Mean values of serum cortisol (± standard deviations) measured every 4 hours during the entire protocol. On the first night (adaptation night) and the last night (black), patients were sleeping, while during the second night (grey), sleep was prohibited.

($F = 0.64$; $p = 0.43$ and $F = 0.00$; $p = 0.95$ respectively for the first and second testing).

Correlation testing of cortisol values with concentration and mood states in the first and the second testing shows no significant correlation between cortisol values with either concentration or mood states both before and after sleep deprivation at both times of testing, i.e. prior to the period of sleep deprivation at 19hrs of day 1 and 24 hours after the short-term period of sleep deprivation, again at 19 hrs. Only one statistically significant deviation was established, i.e. the correlation between the number of errors made on the first testing of concentration and the level of cortisol measured before the first testing ($r = 0.64$; $p = 0.06$).

Discussion

The main purpose of our study was to investigate the effect of (one night's) acute sleep deprivation on concentration, mood and resulting stress. Since sleep is a biological function, it is sensible to assume that lack of sleep cannot go "unpunished", however, humans have been known to withstand conditions far beyond normal and to thrive in far less than amiable circumstances. Our study focused on people's ability to concentrate and on their mood changes. So far, several areas have been thoroughly investigated as far as sleep-deprivation effects are concerned; the behavioural, cognitive and psycho physiological effects of sleep restriction or extended wakefulness (> 24h) are well known.[2-5]

People often react to new and difficult situations with increased stress[21] and being a participant in a sleep-deprivation study can certainly be described as a stressful situation, particularly in a case like ours, where several measurements and tests are taken, and this is undoubtedly not an everyday situation. Stress could be an element that causes an additional detrimental effect on the participants. Therefore, we decided to determine whether stress acted as an additional distracter. Cortisol (as a stress hormone) measurements were used and we found that cortisol values did not change after the period of acute sleep deprivation. Furthermore, we discovered that cortisol also preserved the circadian rhythm. We can thus assume that changes in mood and concentration are not the result of stress and are therefore consequences of short-term sleep deprivation.

Since concentration is one of the basic cognitive functions, deterioration in one's attention is heavily influenced by sleep deprivation.[8,9] However, our results have shown a significant improvement in the second testing. Since the test used provides no parallel version and we needed to control the effect of task-practice, we included a control group (equal in age and educational structure). Both, the experimental and the control group, were tested twice within a 24-hour time frame, the control group also showed improved results in the second testing. In general, the improvement in both groups was insignificant. We assume that our subjects' concentration did not deteriorate significantly after the period of acute sleep deprivation. In accordance with previous studies,[22,23] a short duration vigilance task was used in order to cause as little stress as possible to the participants.

It has been reported that maintenance of vigilance is a prerequisite for safe and efficient performance.[11] The results of our research show that our participants were able to maintain their vigilance and keep their concentration at a level that did not significantly differ from the level of concentration before sleep deprivation. We can thus conclude that acute sleep deprivation has no significant effect on concentration.

However, the way in which sleep deprivation affects mood changes remains unclear. Some authors[10] claim that mood changes are the most obvious type of change following sleep deprivation, rather than changes in cognitive or motor performance.[9,11] We found that acute sleep deprivation caused a change in mood states. Our subjects were significantly more tired after a short-term period of sleep deprivation and their vigour decreased. A minor, yet not insignificant change was an increase in confusion. Our results thus support the findings of authors,[9,13] who discovered irritability, impatience and confusion in subjects in experimental settings of sleep deprivation.

On the other hand, while some authors[3] reported increased rates of depression following the absence of sleep, our results show that acute deprivation had no such effect on the subjects. Mood changes seem to appear as a result of sleep deprivation, even that of a short-term nature, and after longer periods without sleep these changes could also affect other aspects of our functioning, such as reasoning, decision-making, response inhibition and other higher cognitive functions, since our emotional states are undoubtedly connected both with our cognitive and behavioural aspects.[24] Correlation of serum cortisol with both concentration and mood states (before and after short-term sleep deprivation) reveals that there are no significant connections. Still, we found one possibly significant deviation, i.e. in the close correlation between the number of errors made in the testing of concentration and the level of cortisol, which means that the number of errors made in the first testing was partly a consequence of stress. Thus the main contribution of this research is the exploration of short-term sleep deprivation, which is becoming a growing problem of the world, resulting from the "fast" lifestyle.

Conclusions

In conclusion, the results of our study have indicated that acute sleep deprivation did not have any significant effects on concentration. However, acute sleep deprivation did cause mood changes; our subjects reported feeling more tired and less vigorous at the end of the acute sleep deprivation period. Further studies with longer periods of sleep deprivation are needed to show the duration of sleep deprivation necessary in order to disrupt our concentration and higher cognitive abilities. Our hypothesis is thus confirmed as far as mood changes go, while we cannot support the assumption of concentration changes.

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