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The impact of partial sleep deprivation on military naval officers' ability to anticipate moral and tactical problems in a simulated maritime combat operation

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ABSTRACT

The current research investigated how long-term partial sleep deprivation influenced naval officers' ability to generate anticipations of potentially critical problems at the entry of an operation. The study was organised as a balanced experimental design, testing the officers both in a rested and a sleepless condition during a complex naval simulator exercise. The results showed that lack of sleep severely impaired the officers' ability to foresee important problems within both the moral and tactical domain of the operation. These findings indicate that lack of sleep may obstruct planning and preparations in maritime operations in a way that may increase the risk of accidents and fatal errors, which again underscores the importance of sleep and rest as an integrated element of maritime operations and leadership.

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Key words: sleep deprivation, anticipation, moral, tactical, planning, navy

INTRODUCTION

The ability to foresee problems has long been recognised as an important element in preparing for difficult situations in both military and commercial maritime operations. This is supported by Clark [1] and Verganti [2], who find that anticipation of problems serves several purposes: 1) it enables the avoidance of (avoidable) problems before they occur, 2) it reduces the impact of problems by attending to the problems before they escalate, 3) it warns stakeholders about (unavoidable) future threats in order to enable mental and practical preparations to be made in time, and it subsequently enables the effective repairing of problems that do occur. The relevance of this process is also supported by findings showing that anticipation of problems is embedded in successful planning and subsequent performance in different work settings [3].

In complex maritime operations lack of sleep is a well-documented challenge to safety on board [4] and several studies find that watchkeepers suffer low quality and fragmented sleep, accruing sleep debt and exhibiting critical fatigue behaviours [5]. Such sleep deprivation has been demonstrated to impair performance of a wide range of cognitive tasks and sensory functions, such as logical reasoning, meta-cognition and vigilance [6]. Tasks that are dependent on the prefrontal cortex (PFC) are found to be particularly sensitive to lack of sleep [7], indicating a neuroanatomical localisation of the observed cognitive impairments. Notably, functions where the PFC seems to play a central role are the ability to plan [8] and to think creatively [9], but only a handful of studies have explicitly investigated how and whether sleep deprivation affects such cognitive functions [10, 11].

According to military operational doctrines, morals and tactical issues are among the most critical concerns in modern military operations [12]. A "tactical" problem is related to techniques for using weapons or military units in combination for engaging and defeating an enemy [12], and a moral problem is related to the ability to meet the following criteria [13]: (1) Distinction (acts of war should only be directed at enemy combatants), (2) Proportionality (the military advantages must clearly outweigh incidental civilian injuries and damages), (3) Minimum force (utilize as little

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force as possible to achieve military defeat of the enemy), (4) Fair treatment of prisoners of war (humane treatment). Only 2 previous studies address how sleep deprivation influences moral reasoning. Killgore et al. [14] found that sleep deprivation led to an overall increase in judging difficult courses of action to be appropriate, and Olsen et al. [15] found that partial sleep deprivation caused qualitative impairment of moral reasoning, but to our knowledge no studies have investigated the effect of sleep loss on the ability to anticipate moral or tactical problems in a naturalistic setting.

In the present study, we therefore addressed the following questions: (1) how does sleep deprivation influence the ability to anticipate moral and tactical problems? And, (2) are there differences in how these 2 types of problem anticipation are affected by sleep deprivation?

METHODS

SAMPLE

The participants in the present study were recruited from among 69 first-year officer cadets at the Royal Norwegian Naval Academy (RNoNA). All of them had a minimum of 1 year of military service before entering the RNoNA (M = 2.7 years of service), and they were all screened to ensure good physical and mental health, and cognitive aptitude prior to admission. Their mean age was 23.6 ± 4.09 (range 21–32) years and 4 of them (6%) were women. Seven did not participate in the study due to external service demands (n = 2), medical issues (n = 2), or unwillingness to participate (n = 3).

MEASURES

The Stanford Sleepiness Scale (SSS) was utilised to assess the subjective degree of sleepiness. SSS is a 1-item scale, where participants are instructed to rate their present sleepiness on a 7-point scale ranging from 1 (“feeling active, vital, alert or wide awake”) to 7 (“no longer fighting sleep, sleep onset soon, having dreamlike thoughts”). High scores indicate greater sleepiness [16]. The scale is widely used as a state measure of subjective sleepiness, and it has consistently been shown to be sensitive to acute sleep deprivation [17].

Anticipation of tactical and moral problems. The ability to anticipate tactical and moral problems was measured at the start of a mission by having each officer answer in writing the oral instruction: “Explicate all relevant tactical and moral problems that could occur in the operation ahead of you.” The answers were categorised by 3 expert raters, blinded to the condition (rested or sleep-deprived) of the participant, into a moral and a tactical category, and transformed into the following 3 index categories: (1) number of anticipations (i.e., moral and tactical), (2) anticipation of moral problems index (Ampi), and anticipation of tactical problems index (Atpi), and (3) quality of anticipation index (i.e., moral and tactical). The indexes were calculated in a 5-step process. In the first step, the cadets’ answers were validated as either tactical or moral, and answers outside these categories were rejected (e.g., “the instructors will delay the exercise”, or “how can we get food after the exercise”). A moral problem was categorised in accordance with the principles of just war. Typical answers were: “minimise civilian casualties if we use our artillery”, and “we will not be able to obtain target data that ensure discrimination between enemies and the locals”. A tactical problem was defined as a factor that might affect the military effectiveness of the operation. Typical responses in this category were: “get into the target area undetected”, and “achieve good coordination between the FPB’s during the attack”. In the second step, the number of problems explicated in the tactical and moral domain was counted. In the third step, the probability of the issues/problems occurring during the operation was rated on a 3-step Likert scale (1 = unlikely, 2 = may happen, 3 = highly likely). In the fourth step, the severity of the potential consequences of not overcoming the problem, either moral or tactical, was assessed on a 3-step Likert scale (1 = marginal; 2 = significant, 3 = large). Subsequently, the Ampi and Atpi indexes were calculated by adding the raw scores from steps 3 and 4 (i.e., accumulated relevance). Thus, a high score indicates that the identified problem is of high operational importance (i.e., will probably occur and cause large negative consequences if not dealt with effectively). Finally, in step 5, controlling for the number of anticipations registered by each officer, a quality assessment was calculated by dividing the Atpi and Ampi indexes by the number of anticipated problems (i.e., average quality measure).

PROCEDURE

The study was approved by the Royal Norwegian Navy’s Head of Education. Participants were informed that participation was voluntary and that they could withdraw from the study at any time. They were informed that the results were for research purposes and that individual results would not be made available to the RNoNA. The participants then took part in an experiment with a repeated measures design consisting of 2 combat simulation training exercises carried out in 6 interconnected navy navigation simulators. In 1 condition, the combat simulation training took place in a rested state, and in the other condition the participants were tested in a sleep-deprived state. The exercises started with a mission briefing, including an intelligence briefing. After the briefing, the squads were given 20 min to plan the operation. Then, as the crews stood ready to execute at the bridge, the participants were handed pen and paper, and were instructed to anticipate individually all potential tactical and moral problems they found to be associated with their present assignment. After 10 min, the cadets handed in their responses and the operation started. In order to control for the circadian influence on performance, both conditions of the experiment were conducted between 1 and 2 p.m. In the sleep-deprived condition, the cadets had slept an average of 2 and a half hours per day for 5 consecutive days. This amount of sleep was reported independently by staff who acted as observers during the combat simulation training. Prior to this, the cadets were not under any sleep restriction regime imposed by their military units, but performed regular daytime duty for about 8 hours per day. A counterbalanced design was used to control for a potential order effect, whereby half the sample completed the first exercise in the rested condition 1 week prior to completing the second part in the sleep-deprived condition, and the other half completed the exercise in the rested condition 1 week after completing the exercise in the sleep-deprived condition. Two different exercise scenarios were utilised. They were counterbalanced across the sleep-deprived/rested conditions. Sleepiness was recorded in both conditions. Data were manually transferred to SPSS 18.0 for statistical analysis, and all questionnaires were coded in order to achieve anonymity.

STATISTICS

In order to identify differences in the ability to anticipate moral and tactical problems in the rested compared to the sleep-deprived condition, a series of paired t-tests were conducted. All significance tests were 2-tailed and the alpha-level was set to 0.05. To control for type-I errors, a Bonferroni correction was applied (which reduced the significance level to 0.017). Effect sizes (Cohen's d) expressing the difference between the 2 states in terms of pooled standard deviations were calculated. As an aid to interpreting effect sizes, Cohen [18] provided the following benchmarks for the behavioural sciences: a value of 0.2 represents a small effect, 0.5 a medium effect, and 0.8 a large effect. In order to estimate how many participants were needed in order to achieve an acceptable power (0.80), a power analysis was conducted based on G*Power version 3.03 [19]. For this analysis, power was set to 0.80, the significance level was set to 0.017 (2-tailed) and the expected effect size (Cohen's d) was set to 0.50, which is a conservative estimate based on previous meta-analyses of the effects of sleep deprivation. The results showed that 45 subjects were needed in order to obtain sufficient power to detected significant differences between the conditions.

RESULTS

LEVEL OF SLEEPINESS

SSS were analysed in order to verify that the 2 sleep conditions had actually produced 2 different states in terms of sleepiness. The results indicated a low degree of sleepiness in rested condition ($M = 2.00$, $SD = 0.48$) in contrast to a higher degree of sleepiness in the sleep-deprived condition ($M = 4.95$, $SD = 1.19$). This difference was statistically significant ($t = 17.24$, $df = 61$, $p < 0.000$), and the effect size ($d = 3.25$) was large.

ANTICIPATION OF TACTICAL PROBLEMS

A decrease was found in the ability to anticipate tactical problems from the rested to the sleep-deprived condition. The number of problems identified differed between the rested ($M = 4.70$, $SD = 2.86$) and the sleep-deprived condition ($M = 3.51$, $SD = 1.91$). This difference was significant ($t = 4.26$, $df = 57$, $p < 0.000$) with a medium effect size (d = = 0.49). Similarly, the relevance of the anticipated problems as calculated by the Atpi index, which assesses the probability and severity of consequences, was different in the rested ($M = 17.79$, $SD = 8.83$) compared to the sleep-deprived condition ($M = 11.66$, $SD = 6.93$). This difference was also significant ($t = 5.65$, $df = 61$, $p < 0.000$) with a large effect size ($d = 0.77$). The average quality of the anticipation of tactical problems also deteriorated from rested ($M = 5.01$, $SD = 0.18$) to sleep-deprived condition ($M = 4.40$, $SD = 0.23$). However, this difference proved to be non-significant ($t = 2.16$, $df = 61$, $p = 0.035$) (Table 1).

ANTICIPATION OF MORAL PROBLEMS

A significant difference was detected between the rested and the sleep-deprived condition in terms of anticipation of moral problems. The number of moral problems identified was higher in the rested ($M = 2.96$, $SD = 1.60$) than in the sleep-deprived condition ($M = 2.02$, $SD = 1.14$). This difference was significant ($t = 3.86$, $df = 55$, $p < 0.000$) with a medium effect size ($d = 0.67$). Similarly, the relevance of the anticipated moral problems as calculated by the Ampi index, which assesses the probability and severity of the consequences related to the problems, differed between

Table 1. Change in ability to anticipate tactical and moral problems due to sleep deprivation

Variable	Rested		Sleep deprived			
	M	SD	M	SD	df	T
Sleepiness (SSS)	2.00	0.48	4.95	1.19	61	17.24*
Anticipation of tactical problems (Atpi)	17.79	8.83	11.66	6.93	61	5.65*
Anticipation of moral problems (Ampi)	12.50	6.23	8.02	5.50	61	4.53*

*$p < 0.001$

the rested (M = 12.50, SD = 6.23) and sleepless condition (M = 8.02, SD = 5.50). This difference was also significant ($t = 4.53$, $df = 61$, $p < 0.000$) with a large effect size ($d = 0.77$). The average quality of the anticipation of moral problems deteriorated from the rested (M = 5.15, SD = 0.21) to the sleep-deprived condition (M = 4.48, SD = 0.29), but the difference proved to be non-significant ($t = 1.82$, $df = 61$, $p = 0.073$).

DISCUSSION

In the present study, naval personnel performed a true to life simulated naval military operation in both a rested and a sleep-deprived condition in order to investigate whether and how sleep deprivation might influence the ability to conduct proper mental preparations before starting a military operation at sea. In the literature, the ability to foresee problems has been emphasised as a prerequirement for being able to cope with a complex and unpredictable environment [3]. Thus, the ability to identify a wide spectrum of more or less likely problems could increase the likelihood that you will not be taken by surprise, unprepared, and that you subsequently respond more effectively to a problem if it actually occurs.

In order to investigate whether the 2 conditions (rested and sleep-deprived state) actually gave rise to 2 different states in terms of sleep loss, the participants completed the SSS [16] in both conditions. The score was found to be significantly higher in the sleep-deprived than in the rested state, with a very large effect size (Cohen's $d > 3.0$), indicating that the experimental manipulation had the intended effect.

As regards the number of potential moral problems the officers were able to foresee, the results showed that the number was significantly higher in the rested than in the sleep-deprived condition. Moreover, the number of potential tactical problems the officers were able to foresee was significantly higher in the rested than in the sleep-deprived condition. Overall, these results suggest that sleep loss caused a loss in the divergent thinking ability of the officers who participated in the present study. It is thereby in line with previous laboratory studies showing that test scores for divergent thinking ability are reduced in a sleep-deprived compared to a rested condition [20]. The results are also consistent with findings reported by May and Kline [21] showing that 2 nights of sleep deprivation caused a significant deterioration in innovative thinking and the generation of spontaneous ideas among military personnel.

As regards the quality of the problem-anticipation process, this was evaluated by naive raters in terms of the probability of the problem occurring during the operation and in terms of the severity of the potential consequences of not dealing with the problem. With respect to tactical problems, the results indicated impairment of the quality of the judgments in the sleep-deprived compared to the rested condition. This finding is in line with the results found by Kobbeltvedt et al. [11], who showed that the planning of a military rescue operation was evaluated less favourably by external raters when the military officers were in a sleep-deprived compared to a rested condition. Moreover, in relation to the moral problems, the results indicated impairment of the quality of the planning in the sleep-deprived compared to the rested condition. This result is in line with Olsen et al. [15], who found that partial sleep deprivation caused qualitative changes in moral reasoning, including an increase in self-serving judgments. These results could supplement studies showing that the willingness to take risks increases with fatigue [22], and studies showing that sleep-deprived subjects are less concerned with negative consequences when faced with potentially high rewards [23].

Somewhat unexpectedly, the average quality of the anticipations did not change significantly between the rested and the sleep-deprived condition. This finding could be seen as a training effect. The most "obvious" tactical and moral problems, such as "how to get into the target area undetected" or "how to reduce collateral damage", could possibly be internalized through training to such a level that they are almost automatically explicated without high levels of cognitive processing being required. This may accord with previous studies showing that skills are more resilient to negative effects of sleep deprivation if they are drilled to a level of automatic response [11].

Overall, the results show that sleep deprivation causes impairment of the ability to "expect the unexpected" and to anticipate problems that could threaten the successful execution of a mission. The impairment was evident in both tactical and moral planning aspects. Although we did not assess any neuroanatomical/functional correlates to the planning impairments caused by sleep deprivation, previous studies have shown that the PFC is important in relation to planning ability [8], as well to the quality of moral reasoning [15]. This region of the brain has been shown to be particularly sensitive to sleep loss [19].

The present study is the first of its kind in that it assesses the impact of sleep deprivation on a realistic military operation and planning process. The ecological validity of the present study could therefore be regarded as high. Findings from other military settings suggest that partial sleep deprivation is very common. In 1 study, it was reported that military officers only slept for 4 hours per day for several months during international deployment [24]. This strengthens the ecological validity of our study and suggests that sleep deprivation in general might be a considerable problem in the military context [24].

As regards limitations, the present study did not register behaviour/performance on objective parameters, although such objective data could have corroborated our findings.

It should also be noted that we did not have any data on the participants' sleep prior to participation in the current study. However, the SSS score in the rested condition showed that the participants had low levels of sleepiness, indicating that the amount of sleep obtained before participation in this condition had been sufficient. It should be kept in mind that there is a gap between the pressure related to a simulation exercise like the 1 presented in the present study and actual combat operations. In the latter, life-and- death decisions are made, and it is possible that tactical (and self-serving) perspectives would have been prioritised at the expense of moral perspectives compared to the results from the present study.

The present study provides new empirical evidence that long-term partial sleep deprivation severely impairs the ability to anticipate tactical as well as moral problems in a naval military operational context.

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