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SLEEPINESS AND SLEEP IN A SIMULATED "SIX HOURS ON/SIX HOURS OFF" SEA WATCH SYSTEM

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Ships are operated around the clock using rapidly rotating shift schedules called sea watch systems. Sea watch systems may cause fatigue, in the same way as other irregular working time arrangements. The present study investigated subjective sleepiness and sleep duration in connection with a 6 h on/6 h off duty system. The study was performed in a bridge simulator, very similar to those found on ships. Twelve officers divided into two groups participated in the study that lasted 66 h. Half of the subjects started with the 06:00–12:00 h watch and the other half with the 12:00–18:00 h watch. The subjects alternated between off-duty and on-duty for the remainder of the experimental period. Approximately halfway through the experiment, the 12:00–18:00 h watch was divided into two 3 h watches/off-duty periods. The effect of this was to reverse the on-duty/off-duty pattern between the two groups. This enabled all subjects to work the four possible watches (00:00–06:00 h, 06:00–12:00 h, 12:00–18:00 h, and 18:00–24:00 h) in an order that was essentially counterbalanced between groups. Ratings of sleepiness (Karolinska Sleepiness Scale; KSS) were obtained every 30 min during on-duty periods and if subjects were awake during off-duty periods. The subjectively rated duration of sleep was recorded after each off-duty period that preceded watch periods when KSS was rated. The results showed that the average level of sleepiness was significantly higher during the 00:00–06:00 h watch compared to the 12:00–18:00 h and 18:00–24:00 h watches, but not to the 06:00–12:00 h watch. Sleepiness also progressed significantly from the start toward the end of each watch, with the exception of the 06:00-12:00 h watch, when levels remained approximately stable. There were no differences between groups (i.e., the order between watches). Sleep duration during the 06:00–12:00 h off-duty period (3 h 29 min) was significantly longer than during the 12:00–18:00 h period (1 h 47 min) and the 18:00–24:00 h period (2 h 7 min). Sleep during the 00:00–06:00 h period (4 h 23 min) was longer than all sleep periods except the 06:00–12:00 h period. There were no differences between groups. In spite of sufficient opportunities for sleep, sleep was on the average around 1–1 h 30 min shorter than the 7–7 h 30 min that is considered "normal" during a 24 h period. This is probably a consequence of the difficulty to sleep during daytime due to the alerting effects of the circadian rhythm. Also,

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sleepiness during the night and early mornings reached high levels, which may be explained by a combination of working close to or during the circadian trough of alertness and the relatively short sleep periods obtained. An initial suppression of sleepiness was observed during all watches, except for the 06:00–12:00 h watch. This suppression may be explained by the "masking effect" exerted by the relative high levels of activity required when taking over the responsibility of the ship. Toward the end of watches, the levels of sleepiness progressively increased to relatively high levels, at least during the 00:00–06:00 h watch. Presumably, initially high levels of activity are replaced by routine and even boredom.

Keywords Subjective sleepiness, Sleep, Watch standing at sea, Shift-work simulation, Maritime shift schedules

INTRODUCTION

As in many other industrial sectors, irregular work hours within shipping may cause fatigue and thereby endanger safety. Fatigue at sea has been raised as an important issue by the International Maritime Organization (IMO, MSC/Circ.1014, 2001). Furthermore, fatigue has been put forward as an important factor contributing to accidents and incidents at sea. Although fatigue has been found to be involved in several cases, the role of fatigue may be underestimated (Phillips, 1998). Several different sea-watch systems are used to make around-the-clock operations possible. Normally, two or three officers alternate on duty around the clock for weeks or even longer periods. Sea watch systems, although rapidly rotating, also give opportunities to sleep during free-watches in close proximity to work periods, which is in contrast to many other industrial settings. Generally, peer-reviewed studies of fatigue on ships bridges are few. Colquhoun et al. were the most active researchers in the area (e.g., Colquhoun et al., 1988; Condon et al., 1988; Plett et al., 1988). Colquhounalso authored two reviews on the topic (Colquhoun & Folkard, 1985; Colquhoun, 1996). The studies mainly describe changes in circadian physiological and behavioral rhythms as a function of the duration of the journey. Mainly longer sea voyages were studied and the watch-systems were 4 h on/8 h off. Such systems demand three officers alternating on the bridge. However, as it is considered economically more favorable to have only two officers with alternating watches on the bridge, the 6 h on/6 hours off system is becoming more frequent. This is especially true for smaller merchant ships and shorter journeys. However, studies on 6 h on/6 h off systems are few (for a review see, Colquhoun & Folkard, 1985).

The present study aimed at investigating subjective sleepiness across and within the four possible watches of the 6 h on/6 h off system. Specifically, the study sought to determine if the mean level and the development of sleepiness within watches differed between watches. In addition, the authors were interested in the amount of sleep that could be obtained

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during off-duty periods depending on the time of day. The aim was further to control for the sequence of watches and accumulative effects due to the length of the journey. This was made possible by using an experimental approach in a bridge simulator.

METHODS

Subjects

Twelve healthy male subjects with a mean age of 39 years (age range, 26–51 years) participated. All were trained navigators. Six were recruited from the merchant marine (including two sea pilots) and the remaining six were naval officers.

Design

The watch system studied was a 6 h on /6 h off system. The design of the study is depicted in Figure 1. The subjects were assigned to one of the two watch teams, the sequences of watches for which are shown in the figure. Team 1 started their first watch at 06:00 h; team 2 started at 12:00 h. The watches alternated with off-duty watches. However, the period 12:00 to 18:00 h in the middle of the experiment was divided into a 3 h watch and a 3 h off-duty period, the order of which differing for the two teams. Following these "dogwatches," the two teams resumed the 6 h on/6 h off pattern—but now in a reversed pattern from before the dogwatches. The dogwatches were introduced in order to allow all subjects to work all four watches during the short time available for the study. The resulting design was counterbalanced between teams, although not completely (see Figure 1).

Simulator and Simulated Task

The simulator was a Navi trainer professional 2000/3000 (Transas Marine). The simulator belongs to the Swedish Maritime Administration.

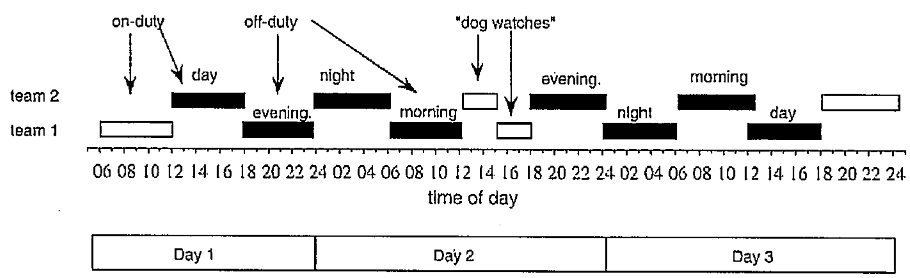

FIGURE 1 Study design. Boxes show the timing of watches on the bridge. Black boxes are the watches used for analyses of sleepiness; periods between watches are the off-duty periods.

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The simulator has three bridges: one large bridge and two smaller ones. The bridges are essentially copies of bridges common on modern merchant ships. The ship simulated was a chemical tanker with a displacement of 8,000 tons. The task was to continuously navigate the Irish Sea along a pre-determined route. The three bridges operated separately and independently of one other. Apart from the routine navigational task, a typical and realistic event was introduced once every hour (e.g., another ship intersecting, or the failure of the radar system). Care was taken to have a similar workload across all 6 h watches. However, the simulator could not be programmed to have similar environmental lightning conditions. Hence, there were day-night differences in lightning.

The simulator was located in a separate building. Sleeping quarters for six persons were arranged in a lecture room as well as a "mess room" in an adjacent room. Six separate "sleep cubicles" were arranged in the lecture room to allow as much privacy as possible. The subjects were instructed to use the sleeping quarters only when they intended to sleep. If they chose not to sleep during off-duty periods, they were to spend their time in the mess room. The mess room contained a television set with the possibility of showing videos and had newspapers, magazines, and other ways to pass time. Food was also served in the mess room: breakfast, 05:30–06:30 h; lunch, 11:30–12:30 h; and dinner, 17:30–18:30 h. There was also a refrigerator containing snacks and beverages. Coffee was also available but limited to one cup per off-duty watch for each subject. There were two main reasons why the intake of coffee (and beverages containing caffeine) were limited and offered only to the off-duty periods. First, a free intake of coffee, although being close to the normal situation on-board, would have meant that different subjects would had used stimulants in an uncontrolled way. Secondly, beverages and food were not allowed on the bridges in the simulator for technical reasons. To achieve a "ship-like" environment, all the windows in the building were covered, and the subjects were not allowed to leave the building during the study period (66 h). The windows were blinded by white fabric. The reason was not only to control the natural light, but also to shield the subjects from everything that was going on outside the building. The subjects were at all times supervised by two experimenters: one responsible for the navigational task, and one for administrating the subjective ratings.

Procedure

The study was conducted during two weeks in November 2002. Each week, six subjects participated, three belonging to team 1 and three to team 2. The subjects arrived during Monday afternoon, and the afternoon and evening was spent preparing for the study, including an extensive training on how to operate the bridge. The following morning, the subjects

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arrived at the simulator building. At 06:00 h, team 1 started their watch, whereas team 2 was off-duty. The subjects alternated working on the bridges as described in Figure 1, until 24:00 h Thursday night. The subjects were then allowed to leave the simulator building and sleep the night in a nearby hotel. After a full night's rest, the experiment was over, and the subjects were allowed to leave. During their off-duty periods, the subjects were free to sleep as much as they wanted.

Measurements

Every 30 min, the subjects were required to rate their subjective sleepiness using the Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990). The KSS is a nine-point scale ranging from 1 ("very alert") to 9 ("very sleepy, an effort staying awake, fighting sleep"). Ratings were obtained during off-duty watches only if the subjects were awake. Ratings were given verbally via telephone or intercom. After each off-duty watch, the subjects were asked to fill in a sleep diary (i.e., the Karolinska Sleep Diary [KSD]; Åkerstedt et al., 1994), if they had slept. The subjective sleep duration was recorded during the off-duty periods immediately before the duty periods that were used for the analyses of sleepiness.

Statistical Analyses

Data were analyzed using ANOVA for repeated measures with the team (two levels) as the between factor and across watches (four levels) and during each watch (twelve levels) as within factors. Level of significance was set to .05, and p values are given after Huynh-Feldt correction when appropriate. Pair-wise comparisons were made using the Bonferroni/Dunn procedure. Statistical tests were performed using Statview 5.0.1 for Macintosh (SAS Institute, Cary, North Carolina, USA). The last watch for team 1 and the first watch for team 2 were omitted from the data analyses (see Figure 1) to achieve data from the four possible watches and to avoid possible start-up and end-spurt effects.

Ratings obtained during off-duty periods were compared with those obtained during on-duty periods at the points in time when both types of ratings were given, which occurred on seven occasions across the experimental period. The analyses of the differences were made using ANOVA for repeated measures with off-duty/on-duty (two levels) and time (seven levels) as within factors. Because the seven points in time were not equally distributed across watches or within watches (see Figure 2), no analyses could be made using watch or time within watch as factors.

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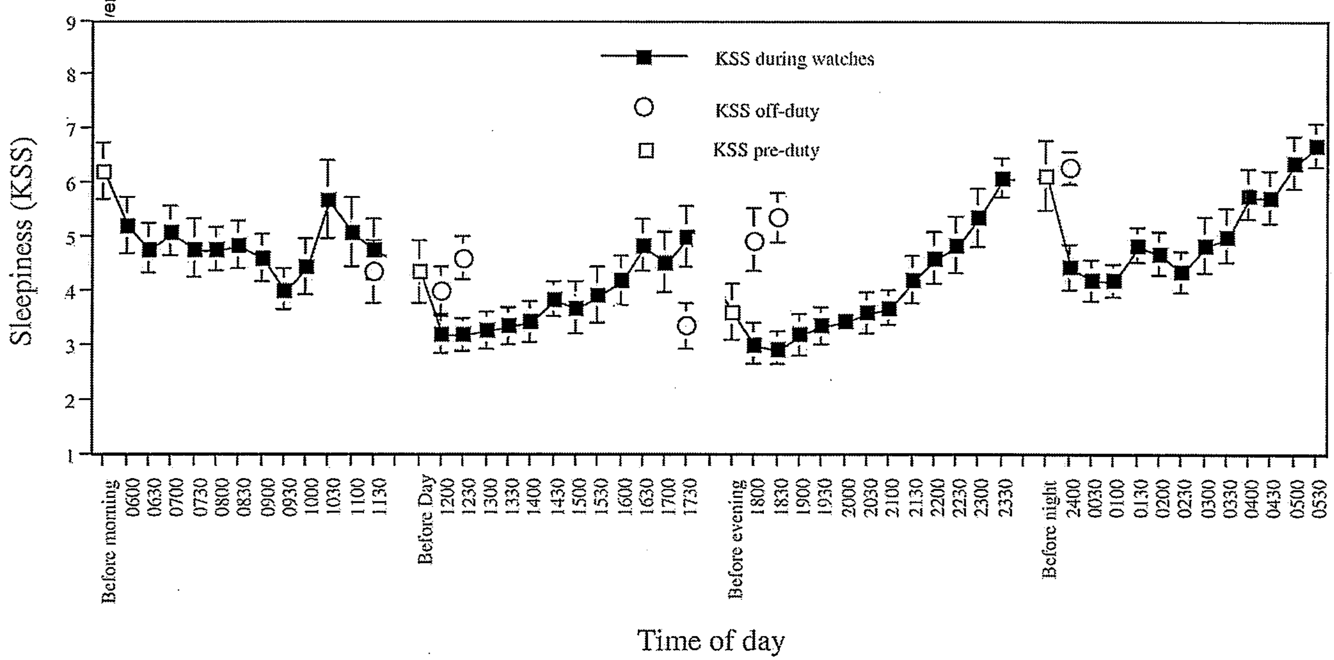

FIGURE 2 Ratings of sleepiness (KSS) during the watches (filled squares), immediately before the watch (open squares), and during off-duty periods (open circles). Values shown are means and standard errors. The ratings immediately before the watches are not based on all 12 subjects but are included for illustrative purposes.

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Ethical Considerations

The study was approved by the ethical committee of the Karolinska Institute (Dnr 02-244) and followed the ethical principles of the journal for human research, as stated in Touitou et al. (2004).

RESULTS

Subjective Sleepiness

Ratings of subjective sleepiness are presented in Figure 2. Two types of sleepiness data are included in the figure. Filled squares are half-hourly ratings obtained when subjects were standing watch. Open circles show sleepiness rated during off-duty watches and represent means for points in time when all 12 subjects had been awake and rated their sleepiness. There was no significant difference between watch teams ($F\ 1/10 = 1.85$; ns), nor was there a significant interaction between watch team and the timing of the watch ($F3/30 = 0.03$; ns); that is, the order between watches did not affect sleepiness differently. Mean sleepiness differed significantly between watches ($F\ 3/30 = 5.30$, $p < 0.005$). Post-hoc tests (Bonferroni/Dunn) showed that sleepiness during the night watch was significantly higher than during both the day and evening watches ($p < 0.003$ and $p < 0.007$, respectively).

Sleepiness ratings across watches varied significantly across the 12 half hours ($F\ 11/110 = 13.22$, $p < 0.0001$). Also, the interaction between the timing of watch and the time within watches was significant ($F\ 33/330 = 2.41, p < 0.005$). An inspection of Figure 2 shows that sleepiness increased from the beginning to the end of each watch, except for the morning watch (the latter may explain the significant interaction).

The statistical tests that were performed on the differences between self-rating data obtained during off duty watches (open circles) and on-duty watches at coinciding points in time, when there were ratings for all 12 subjects, showed a significant ($F1/10 = 7.44$, $p < 0.03$) effect of off-duty versus on-duty sleepiness. Sleepiness was on average higher during the off-duty span. It should be noted, however, that the comparisons were mainly made during the start and the end of watches/off-duty watches, and that five out of the seven points in time coincided with the start of the watches.

Subjective Sleep Duration

For subjects who did not sleep during a specific off-duty watch, 0 h of sleep were entered before analyzing the sleep duration data. Subjective sleep duration (see Table 1) varied significantly between off-duty

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TABLE 1 Subjective Sleep Duration During Off-Duty Watches

Watch team	Morning (06:00–12:00 h)	Day (12:00–18:00 h)	Evening (18:00–24:00 h)	Night (24:00–06:00 h)
First	4.24 ± 0.39 (6)	1.42 ± 0.29 (6)	2.11 ± 0.52 (5)	4.05 ± 0.21 (6)
Second	2.74 ± 0.90 (6)	2.10 ± 0.59 (5)	2.10 ± 0.51 (5)	4.71 ± 0.13 (6)
Mean, both teams	3.49 ± 0.52	1.76 ± 0.33	2.11 ± 0.35	4.38 ± 0.15

Values are means ± standard errors. Figures within parenthesis denote the number of subjects that slept during each off-duty watch.

watches ($F\ 3/30 = 11.76$, $p < 0.0001$) but did not differ between watch teams ($F\ 1/10 = 0.02$, ns). The interaction term was not significant ($F\ 3/30 = 2.07$, ns). Post-hoc tests (Bonferroni/Dunn) showed that sleep duration was significantly longer during the morning compared to the day ($p < 0.002$). Sleep during the night was significantly longer than both during the day and the evening ($p < 0.0001$ and $p < 0.0001$, respectively).

DISCUSSION

As might be expected, the mean level of sleepiness during the night (00:00–06:00 h) watch was higher than both during the day (12:00–18:00 h) and the evening (18:00–24:00 h) watches. There was, however, no difference between the night and the morning (06:00–12:00 h) watches. The latter might seem surprising, but high levels of sleepiness during shifts with early starting times have been observed earlier in other shift-work settings (e.g., Kecklund et al., 1997). An inspection shows that the high mean level of sleepiness during the morning watch was mainly explained by the high levels during the initial hours. In "normal" shift work, similar findings have been attributed to the failure to phase advance sleep enough to obtain sufficient sleep in combination with the early morning circadian trough in alertness (Kecklund et al., 1994). In fact, restricted sleep might have been involved, as the subjects on average slept only 6 h and 8 min during the 24 h period prior to the morning watches (day plus night sleep; see Table 1).

There was a clear time-on-watch effect on sleepiness during all watches, except for the morning watch. Sleepiness was higher during off-duty periods compared to the beginning of the day, evening, and night watches, respectively. This, together with the lower levels during the start and the progressive increase in sleepiness toward the end of these watches, indicate that work on the bridge might have suppressed sleepiness. Taking over the responsibility for the ship in the beginning of the watch might have been activating, because the officer had to fairly rapidly get informed of the technical and the navigational state of the ship and to take control. The suppressive effect of activity on sleepiness

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is well acknowledged and termed "masking" (Waterhouse & Minors, 1994). Also, in recent publications, contextual variables have been found to affect sleepiness (Eriksen et al., 2005). The officers might later suffer from monotony toward the end of the watch when everything was "under control," which might have explained the progressive increase in sleepiness toward the end of the watch. Richter et al. (2005) found stronger time-on-task effects on sleepiness of a monotonous task compared to a more varied task. Similar monotony effects have been observed in studies on simulated car driving (Philip et al., 2005). An alternative explanation might be that fatigue gradually developed as a function of hours at work. There is, however, no support for this explanation in the literature, at least not for sedentary work for periods as short as 6 h.

The duration of sleep obtained during the present study was below the 7 to 7.5 h/day that one might expect as "average" in connection with normal day work. Restricted amounts of sleep were observed in spite of the fact that the off-duty periods could be used to sleep *ad lib*. Apparently, sleep was shorter during off-duty periods in the time span between 12:00 h and 24:00 h. This might be expected from the circadian effects on sleep duration (Åkerstedt & Gillberg, 1981; Czeisler et al., 1980). Hence, in spite of adequate time and practical opportunities for sleep, circadian factors affected sleep duration negatively.

The present study was a simulator study, and it should be remembered that such studies may not represent real life situations. The present study was performed in a simulator, as it allowed the control of external factors. This, of course, limited the influence of more "realistic" factors. The experiment was designed, however, mainly to study the effects of the timing of work periods, and therefore "realism" was sacrificed for "control." Philip et al. (2005) found that self-rated sleepiness was higher and reaction time performance slower during simulated car driving compared to actual car driving. Also, Gillberg et al. (2003) found subjective sleepiness during work to be higher in a simulated power plant compared to a real one. Hence, the levels of sleepiness observed in the present study might be higher than during actual watch keeping.

It is important to note that the present findings on both levels of sleepiness and duration of sleepiness probably were not affected by the sequence of watches or accumulation across the experimental period, as an essentially counterbalanced design was used. Although the sequence or cumulative effects cannot be completely excluded, the lack of significant differences between teams (i.e., sequence of on-duty periods) or interaction terms between teams and on-duty periods attest to the fact that the differences were mainly influenced by time of day (i.e., by the timing of the watches).

In summary, a 6 h on/6 h off sea watch system induces high levels of sleepiness during the night watch but also during the early morning

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watch. The explanation seems to be the circadian timing of these watches. Although the possibilities to sleep were adequate, sleep duration was shorter than "normal," presumably due to the circadian effects on sleep.

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