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Comparision of alertness levels in ship crew. An experiment on rotating versus fixed watch schedules

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ABSTRACT

A short pilot study was conducted during a shipboard training deployment to compare alertness levels in the same crew members while working a fixed watch schedule, and then a rotating watch schedule. Alertness levels were assessed before and after each duty watch using measurements of oculomotor function (Fitness Impairment Tester). Saccadic velocity was shown to have the greatest correlation with duration of sleep deprivation and was significantly slower (indicating decreased alertness) in the crew working the rotating watch schedule than the crew working the fixed watch schedule. This pilot study corroborates previous studies' recommendations that fixed watch schedules allow better acclimatization of sleep patterns, thus minimizing fatigue and increasing operational alertness.

INTRODUCTION

Crew on board naval ships are required to maintain a high state of alertness while working in shift-cycles for prolonged periods of time. Some issues that have been recognized are: the short duration and interrupted nature of sleep, and the difficulties in maintaining alertness during periods of the day when energy levels are at a low because of diurnal rhythms.

Although working in short shifts throughout the day may be necessary, the planning of the shift schedule could be optimized to take into account sleep duration and diurnal alertness patterns.

After extensive research, the US Coastguard has recommended that crewmembers should obtain at least 7 to 8 hours of uninterrupted sleep per 24-hour period, or at least 6.5 hours of sleep and a 2-hour nap. They also recommend that schedule rotations should be minimized to avoid body clock and sleep cycle de-synchronization, and that crew should maintain the same work-rest cycle for at least 2 continuous weeks [1].

However, some navies prefer a rotating watch schedule, where the timing of shifts rotates from day to day.

AIM

The aim of this study was to compare sleep duration and alertness levels in crew working a rotating watch schedule and a fixed 1-in-3 watch schedule during a training deployment.

MATERIALS AND METHODS

The study was conducted on board a naval ship during a training deployment in February 2007. Twenty-four ship crew volunteers from the bridge and engine room watch stations were divided into 3 watches (A, B, and C).

In the first phase of the study, which lasted 4 days, the participants worked a fixed watch schedule: 4 hours on, 8 hours off; thus working 2 shifts in a 24-hour cycle (Table 1).

There was a washout period of 6 days, during which the volunteer crew were exempted from shift duties and kept regular daytime hours.

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Table 1. Fixed 1-in-3 watch schedule

0000--0400	0400--0800	0800--1200	1200--1600	1600--2000	2000--2400
A	B	C	A	B	C

In the following second phase of the study, which lasted 4 days, the participants worked a counter-clockwise rotating watch schedule in which the start-of-shift timings rotated earlier from day to day (Table 2). In this schedule, the evening watch (4 pm to 6 pm) was split into two to facilitate a daily anticlockwise rotation of shift timings between the 3 watches.

During the study phases, Fitness Impairment Tester (FIT)-2000 measurements of oculomotor function were taken immediately before and after each duty watch. FIT (Pulse Medical Instruments, Inc.) is a self-contained, fully automated, computer-controlled, commercially available optical tracking and recording system. Each FIT measurement is a 30-seocnd non-invasive test that measures:

a. saccadic velocity (speed of side-to-side eye movement);
b. pupil diameter at rest;
c. latency (time from flash of a light source to pupil constriction);
d. amplitude (amount of constriction).

The sequence of measurements in the FIT 2000 is shown in Figure 1.

Oculomotor functions have been shown to be predictive of sleep deprivation-induced operational performance degradation [2]. Of the four measurements in the FIT, saccadic velocity is the most sensitive for measuring sleep deprivation-induced impairment. Saccadic velocity decreases with increasing levels of sleep deprivation. A decrease in saccadic velocity and increase in papillary diameter after sleep impairment have been significantly correlated with

Table 2. Anticlockwise rotating watch schedule

	0000-0400	0400-0800	0800-1200	1200-1600	1600-1800	1800-2000	2000-2400
Day 1	A	B	C	A	B	C	A
Day 2	B	C	A	B	C	A	B
Day 3	C	A	B	C	A	B	C

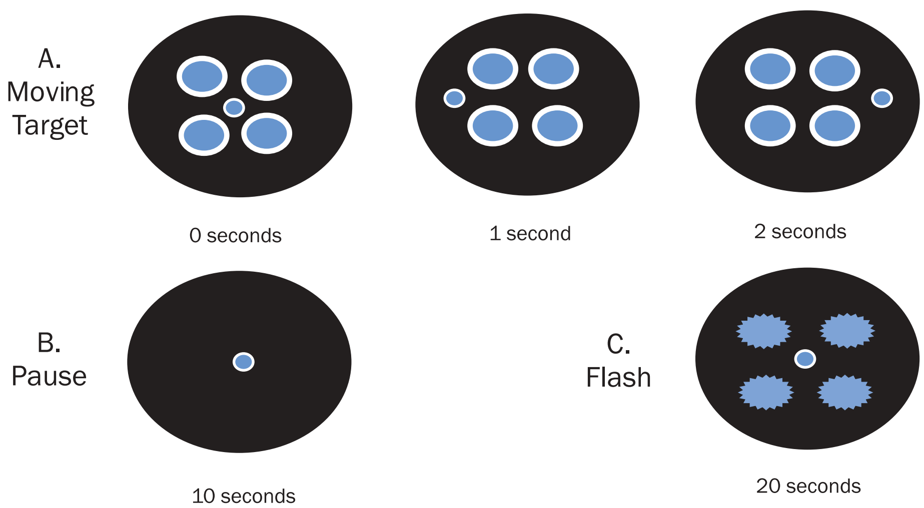

Figure 1. Sequence of Measurements in the Fitness Impairment Tester-2000 (courtesy of Pulse Medical Instruments, Inc)

increased incidence of driving accidents and impaired simulated driving performance [3]. Saccadic velocity is also resistant to changes in ambient light and time-of-day effects [4].

In addition to FIT-2000 measurements, participants also maintained a sleep and nap diary, and recorded the quantity of caffeinated drinks consumed and the duration of any physical exercise done during the study phases.

RESULTS

SLEEP AND NAP TIMES

The main sleep period of the day was defined as the longest period of uninterrupted sleep; while the total sleep time is defined as the total duration of the main sleep period and nap periods.

There was no significant difference in the length of the crew's main sleep period between the fixed watch schedule (4.95 hours of sleep per day) and the rotating watch schedule (4.99 hours per day).

However, the participants were able to get more nap time in the fixed watch schedule, leading to a significant difference increase in total sleep time in the fixed watch schedule (6.04 hours per day) compared to the rotating watch schedule (5.43 hours per day).

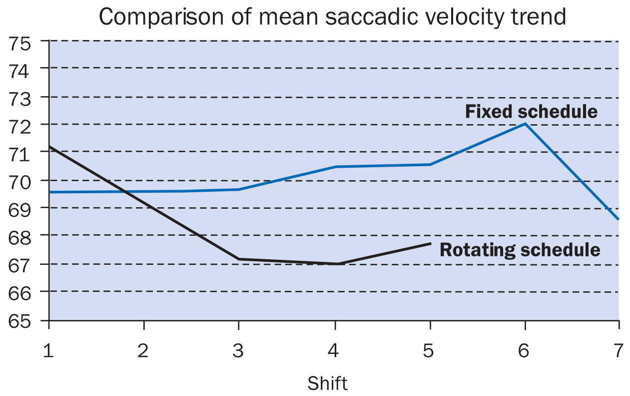

Figure 2. Comparison of mean saccadic velocity over time between fixed and rotating watch schedules

Of note, in both watch schedules the main sleep period and total nap time were less than the recommended seven hours of sleep, suggesting that both watch schedules may result in chronic sleep debt.

COMPARISON OF OCULOMOTOR FUNCTION

Saccadic velocity was found to have the most significant correlation with increasing fatigue with time, as was found in previous studies.

In both the fixed and rotating watch schedules, there was no significant change in oculometric measurements for the first 36 hours of commencing a shift work.

However, the mean saccadic velocity measured after the 4th duty watch performed by each watch group was significantly slower in the rotating watch schedule than in the fixed watch schedule. This suggests that the fatigue level after about 36 hours was higher in the rotating schedule than in the fixed schedule.

The mean saccadic velocity measured before and after the 5th duty watch for each watch group was also lower in the rotating watch schedule than in the fixed schedule, but this did not reach statistical significance.

Unfortunately, the second phase of the study was terminated prematurely by the ship's command, so analysis of oculomotor function after the fifth duty watch could not be made. However, the trend over time of saccadic velocity in each of the schedules strongly suggests that the rotating watch schedule was associated with a higher level of fatigue (Figure 2).

In both the fixed and rotating watch schedules, there was no difference in the oculomotor parameters between the 3 watches, A, B, and C. In the fixed watch schedule, there was no evidence that the "middle watch" (working 12 midnight to 4 am, and noon to 4pm), which is believed to be the least physiological, was more fatigued than the other watches, using the ANOVA post-hoc Scheffe test (Figures 3 and 4).

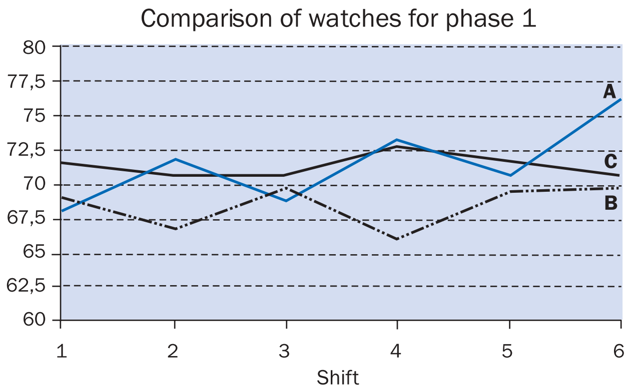

Figure 3. Comparison of mean saccadic velocity between watches A, B and C in fixed watch schedules

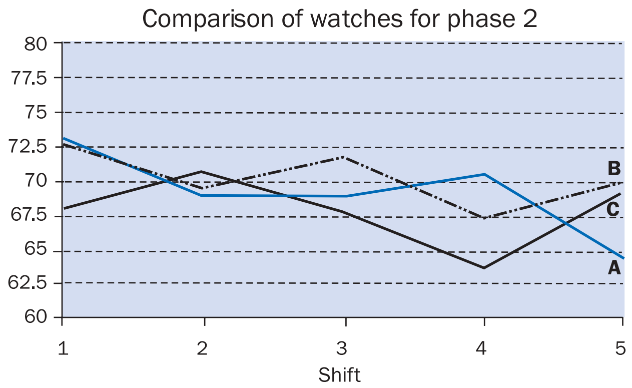

Figure 4. Comparison of mean saccadic velocity between watches A, B and C in rotating watch schedule

DISCUSSION AND CONCLUSION

Seafarer fatigue is a huge safety concern not only in the military but also across the shipping industry, and previous reviews on the subject have stressed the need for increased attention and adherence to shipboard manning regulations [5].

The traditional rotating watch schedule is practiced in some units because it avoids one watch having to permanently work the unpopular “middle watch” (midnight to 4 am, and noon to 4 pm). Because of shorter watch periods from 4 to 6pm, it allows all watches some time for social and recreational activities in the evenings.

However, recent studies have enumerated the problems associated with a rotating watch schedule. When sleeping and waking times change on a daily basis, a biological circadian rhythm cannot be established, leading to decreased alertness and disruption of sleep patterns [6].

Additionally, in an anticlockwise rotating schedule, when the start-of-shift timings become progressively earlier, there is progressive reduction of sleep and accumulation of sleep debt [7], much like chronic “jet-lag”.

The premature termination of the study precluded observation of the differences between the two watches over a longer period, as would be seen in operational deployments. However, the trend of decreasing saccadic velocities in the rotating schedule suggests that there may be an increased effect of fatigue, compared to the fixed schedule.

Another limitation of this study is the small sample population, which raises the possibility of a sampling error. However, as the distribution of baseline saccadic velocities in the study group taken before the first phase of the study approximates a normal distribution, the rate of error is minimized (Figure 5).

In conclusion, despite its limitations, this short study conducted in an operational environment suggests that a rotating watch schedule results in a shorter rest time and increased fatigue, in comparison to a fixed schedule. Increasing the duration of this study and the number of participants may produce more significant evidence that a fixed watch schedule, which allows establishment of a diurnal sleep-wake pattern, may be superior in minimizing crew fatigue in prolonged operations.

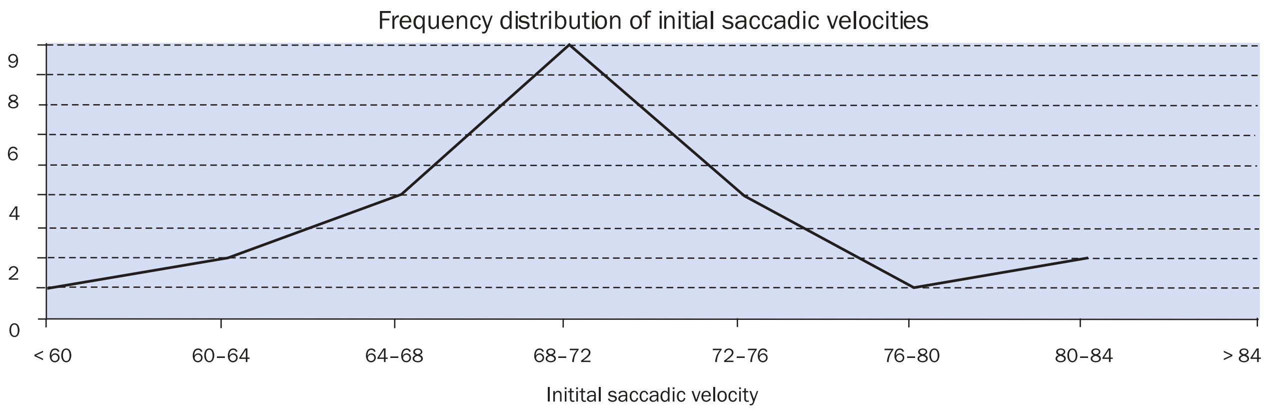

Figure 5. Frequency distribution of initial saccadic velocities in the study population

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