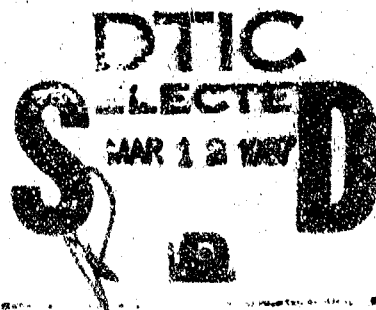


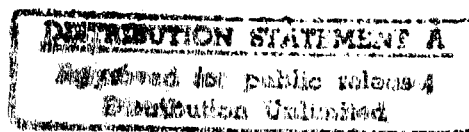
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SLEEP MANAGEMENT FOR MAINTENANCE OF HUMAN PRODUCTIVITY IN CONTINUOUS WORK SCHEDULES

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To expedite communication of our research, this is a preprint of a paper submitted to the 7th International Symposium of Night- and Shift-Work.

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SUMMARY

Sleep management provides the guidelines for planning the time of sleep to maintain behavioral efficiency in completing the assigned job, especially when the workload is so high as to demand all personnel work continuously with minimal sleep. As a part of an effort to establish sleep management and sleep doctrine, the effects of starting time, exercise, time-on-the-job, and sleep duration on task performance were evaluated, using three groups of young (early twenties) and physically fit U.S. Marine Corps volunteer subjects. These groups of volunteers started a 45 hour long continuous work period at 0800 (morning group), 1300 (noon group) and 2400 (midnight group). This 45 hour long period was divided into the first 20 hour long continuous workday (CW1), followed by a five hour long break period which included three hours of nap, then a second 20 hour long workday (CW2). The times for the three hour nap differed for these three groups; for the morning group the nap was between 0400 and 0700, for the noon group between 0900-1200, and for the midnight group between 2000-2300. One half of the subjects in each group were randomly assigned to walk on a treadmill for half an hour of every working hour, exercising at 30% of their maximal aerobic power. All of the subjects's performance was evaluated by the Naval Health Research Center Performance Assessment Battery. In this report, the results of three tasks from this battery, the Simple Reaction Time task, the Four Choice task, and the Visual Vigilance task, are discussed.

The significant results can be summarized in terms of four aspects of sleep management: 1) Starting time of the workday made a critical difference in the maintenance of performance effectiveness; the subjects in the noon group showed slower and poorer psychomotor performance than the other groups. Starting time, therefore, should be chosen, if possible, so that the end of the continuous workday will not coincide with the circadian performance trough of the 0400-0700 time period. The key elements to be considered in choosing starting time are time-on-the-job, time-of-day, and the interaction between these two factors. 2) The physical workload of 30% of maximal aerobic capacity slowed down the response speed for those tasks given in the post-physical work period (the second half hour of every working hour). Task performance during the physical work period (the first half hour) remained unaffected in terms of reaction time and accuracy of signal detection. This indicates that physical work in itself, at least at this 30% workload, does not directly affect task performance. 3) After the subjects have gone for 20 hours continuously (CW1) and then slept for only three hours, their performance in the

second 20 hours (CW2) was significantly degraded. This shows that three hours of nap is not long enough to sustain the baseline level of performance observed in the first 20 hour workday. 4) Subjects can maintain performance for the first 12 hours of the first continuous (CW1) workday without showing significant degradation.

INTRODUCTION

Society demands continuous services. The burden of continuous services is commonly met by formation of 'shifts' where the work done is shared by sets of workers starting at differing time periods throughout the day. In some cases (e.g., major natural disasters) however, all available people must work continuously with minimal or no sleep until some control is achieved. A sudden collapse of shift work schedule due to unexpectedly high workload also forces all available workers to be on the job for extended periods of time.

The period of all-out effort produces logistic problems of housing, transportation, supplying water/food and sleep. Maintaining water/food supply may be difficult. However, once they are made available, workers can quickly satisfy their need even 'on the run'. Sleep need is fundamentally different from the need for water or food. For most, sleep need can be met fully only by a slow process of sleeping for an average of 7 to 8 consecutive hours per 24 hour period, i.e., a long period of 'time-out' to satisfy this sleep need. There seems to be no biomedical methods to intensify sleep to make short sleep as recuperative as 7 to 8 hours of sleep. Sleep need is also different from water/food need in that sleep can neither be commanded to start at will nor stored.

Sleep management or sleep logistics is proposed in this paper to show the importance of planning for time of sleep. Sleep management can also assist in deciding on the manpower resource allocation. Knowing sleep duration, time-on-the-job, physical workload, and time-of-day when the continuous work period started, sleep logistics can estimate the hours of effective performance remaining in the workers, and recommend when they should be replaced by a new group of freshly rested workers.

The purpose of the present paper is to show the important factors in sleep management for those involved in continuous work schedules. This paper is particularly concerned with the impact on performance for the work periods starting at 8 AM, noon or midnight. Morgan and Coates (1974) found that the subjects (Ss) who started the 36 hour long continuous work period at 1400 showed a minimal performance deterioration compared with those Ss in the 0600 or 2200 starting groups.

MATERIALS AND METHOD

This paper describes the results from the series of studies in which the task performance, mood and fatigue of U.S. Marine Corps volunteers were observed during a

laboratory simulated sustained operation held at the Naval Health Research Center (NHRC).

Subjects: These Marine Corps volunteer Ss were young, physically fit males, who were accustomed to some sleep loss and strenuous physical work. They were studied in three groups: the morning (8 AM; Number of Ss = 22), noon (1 PM; N = 16) and midnight groups (N = 16). Average ages of these three groups were 20.6, 22.1 and 20.2 respectively. The nature of the study and the risks involved were explained verbally and given in written form to all Ss prior to their voluntary consent to participate. All Ss had the right to withdraw from the study.

Data Collection Protocol: The abbreviated protocol is shown in Table 1.

Table 1: Data collection protocol

	Orienta- tion	Adapta- tion Sleep	Baseline Work	Baseline Sleep	CW1	NAP	CW2	Recovery
Morning	(08-22)*	(23-07)*	(08-22)*	(23-07)*	(08-03)*	(04-07)*	(08-03)*	(04-12)
Noon	(08-12)*		(13-03)*	(04-12)*	(13-08)*	(09-12)*	(13-08)*	(11-19)
Midnight	(08-19)*	(20-04)*	(05-14)*	(15-23)*	(00-19)*	(20-23)*	(00-19)*	(20-04)
*Time needed to go from one phase to the next phase								

Morning Group On Monday (Day 1) a pair of Ss were given graded maximum exercise tests to assess maximal oxygen uptake with simultaneous measurement of heart rate. Then, the Ss were familiarized with the tasks in the study. One member of each pair was randomly assigned as an exercising subject (S) and the other as non-exercising S. Both Ss performed the same tasks at the same time throughout the experiment. The only difference between the Ss was that during the first half hour of each hourly session, the exercising S performed a visual vigilance task while walking on a motorized treadmill. In contrast, the non-exercising S performed this task while seated in front of a computer video monitor. Treadmill speed was adjusted to be at 30% of individual's maximal aerobic power. During the last half hour of each hourly session, both Ss worked at the computer to complete various psychological tasks, questionnaires and physiological measurements. The baseline work segment started at 0800 Tuesday (Day 2) and ended at 2115 of the same day, consisting of 12 one-hour sessions with meal breaks of 30-45 min every four hours. The first 20 hours long continuous workday (CW1) began Wednesday (Day 3) at 0800 and ended at 0300 Thursday (Day 4). After the end of CW1, each S was given a 3-hour nap, 0400-0700 Thursday. After being awakened from the nap, the Ss were given breakfast

and then at 0800 Thursday, the second 20-hour long continuous workday (CW2) started, this ended at 0300 Friday (Day 5). After the end of CW2, the Ss slept until 1200.

Noon Group The data collection protocol remained basically the same as the morning group. However, the schedule was shifted so as to start the CWs at noon (1300; see Table 1). Another change in this and the Midnight Groups was the use of spirometer readings of expired air, vice heart rate, of the exercising S on the treadmill to control the physical workload.

Midnight Group The data collection protocol remained basically the same as in the other groups. However, the schedule shifted so as to start the CWs at midnight (see Table 1).

Psychological Tasks The NHRC Performance Assessment Battery (NHRC-PAB; see Ryman, et. al. 1984) was used to evaluate a wide range of human abilities. In this report, the performance of three tasks in the NHRC-PAB, a visual simple reaction time (SRT) task, an alphanumeric Visual Vigilance task, and Four Choice serial reaction time task are discussed. The SRT task was developed by Lisper and Kellberg (1972) initially for an auditory signal. The Visual Vigilance task was developed at NHRC (see Hord, 1982). The Four Choice serial reaction time task has been described by Wilkinson and Houghton (1975).

Hypotheses and Statistical Analyses Four hypotheses were examined: (1) whether the workday starts in the morning, noon or midnight, the task performance level will remain the same for a 20 hour workday; (2) the task performance level of the exercising Ss will be at the same level as those non-exercising Ss; (3) the recuperative power of three hours of nap taken after a 20 hour continuous workday will be as powerful and long lasting as 8 hour long nocturnal sleep taken after a normal 8 hour workday; and (4) task performance levels will remain the same at least for a period of 12 hours if the Ss had 8 hours of sleep before the start of the first continuous workday. These four hypotheses were statistically evaluated by four way univariate analysis of variance (ANOVA; BMDP, 1983). The factors were Starting Time (3 levels; Morning, Noon and Midnight), Exercise (2; Exercise and No Exercise), Workday, (2; CW1 and CW2) and Session. Session factor varied from comparing the first four sessions of workday with the last four sessions of the same workday, to comparing the first session with the last session of the workday.

RESULTS

Does Starting Times Have the Same Effects on Performance?

SIMPLE REACTION TIME TASK

MEAN REACTION TIME SLOWEST 10% RESPONSES

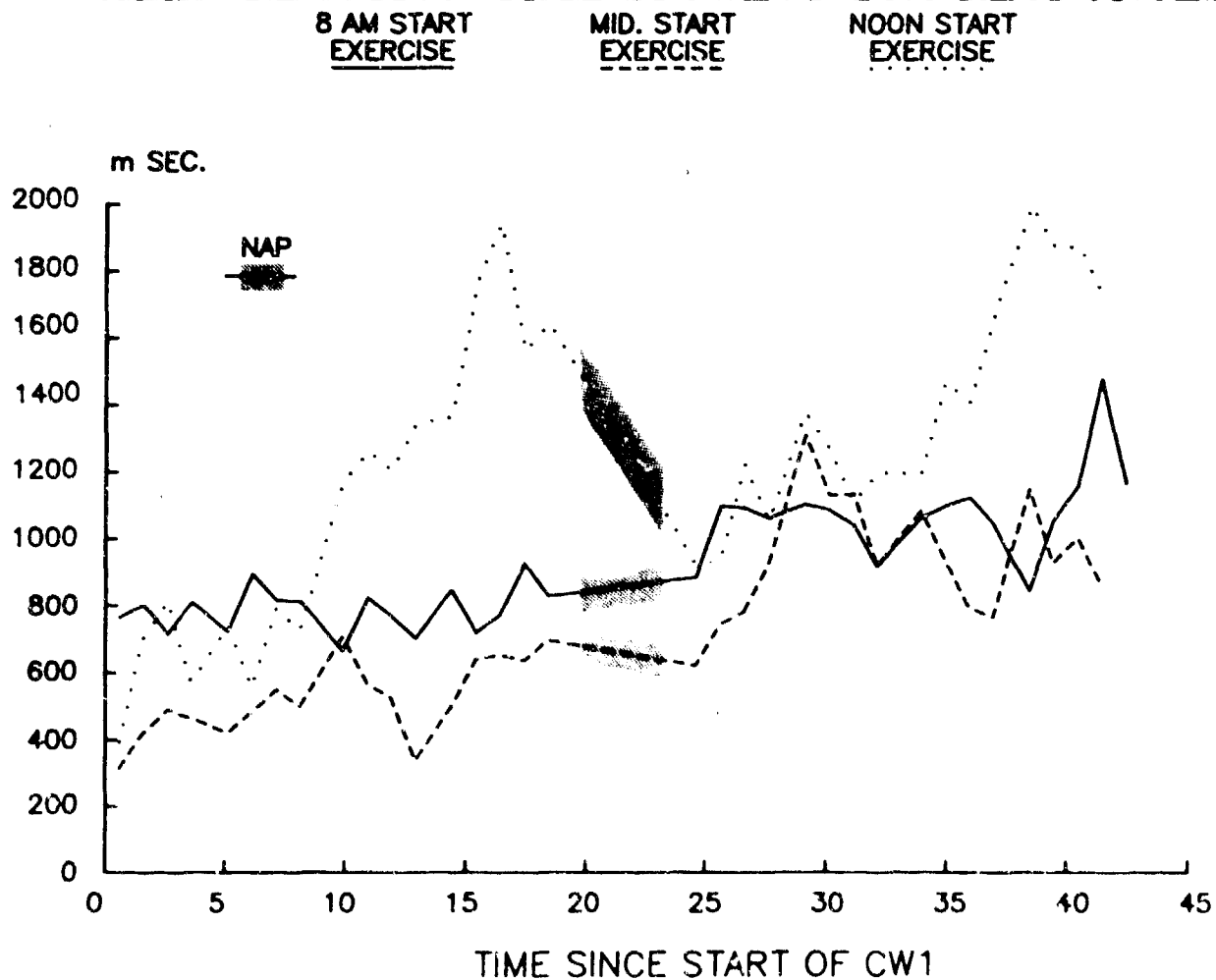


Figure 1. SRT task performance of the Exercising Ss.

The plots in Figures 1 and 2 show the effects of the different starting times on SRT task performance. The period of nap is identified by shading (see Table 1). The plot to the left of the shading shows reaction time during CW1; the plot to the right, CW2. Figure 1 shows SRT performance of the exercising Ss; Figure 2 of the non-exercising control group.

SIMPLE REACTION TIME TASK

MEAN REACTION TIME SLOWEST 10% RESPONSES

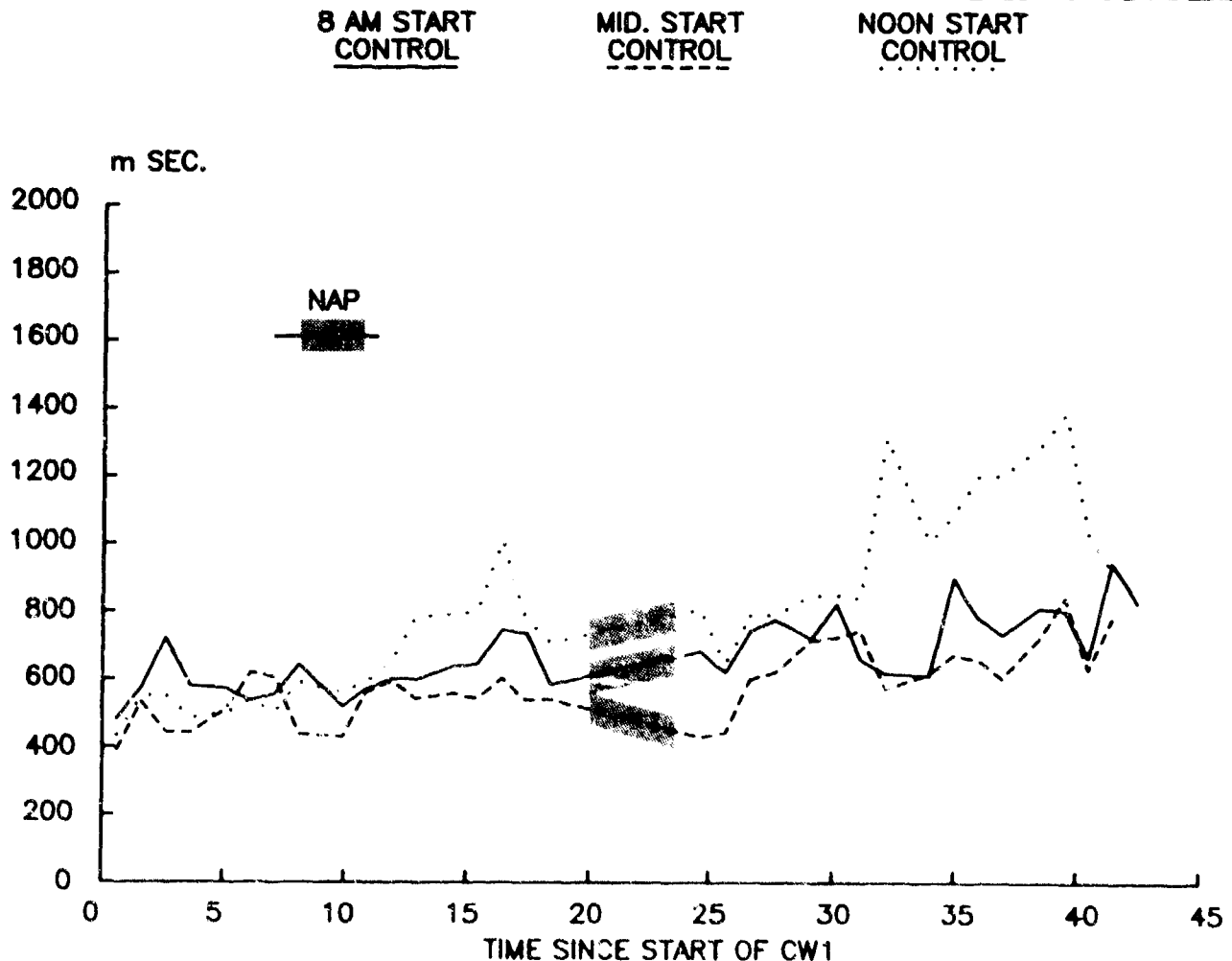


Figure 2. SRT task performance of the non-exercising control Ss.

SRT TASK: Using the mean of the 10% slowest reaction time, an ANOVA revealed that the starting time, by itself, did not affect performance of the visual SRT task. However, a significant interaction between Starting Time and Session ($F(1/48) = 6.07$, $p < 0.02$) indicated that the effects of the starting time was not the same for all

sessions. An additional ANOVA of Starting Time x Workday (3 x 2) was calculated to clarify this interaction. The analysis results showed that the starting time did not affect the first four sessions of CW1 and CW2, but it did affect the last four sessions of these workdays. These findings suggested that the Ss in the morning, noon and midnight groups all started the sessions at a comparable level, but as the Ss in these groups neared the end of CW sessions of each workday, the Ss in the noon group slowed down significantly more than the Ss in the morning and midnight groups.

Four Choice Task: Using the mean of the 10% slowest responses, an ANOVA revealed that the starting time significantly affected the response speed ($F(2/46) = 5.26, p < 0.01$). Further analysis showed that the Ss in the noon group significantly slowed down during the sessions nearing the end of each workday more than the Ss in the morning and midnight groups. The percent correct measure for Four Choice task was also found to be significantly influenced by the starting time. The Ss in the noon group had the lowest percent correct ($F(2/46) = 4.68, p < 0.01$). The results indicated that the starting time significantly influenced Four Choice performance as the Ss neared the end of each workday.

Visual Vigilance: Percent correct measure of the alphanumeric visual vigilance task showed that the starting time significantly influenced the visual vigilance performance ($F(2/42) = 5.16, p < 0.01$). The Ss in the morning group had the lowest percent correct scores during the last four sessions.

Do Exercise and No Exercise Have the Same Impact on Performance?

SRT TASK: Using the mean of 10% slowest reaction time, an ANOVA revealed that the reaction time of the Ss who exercised were significantly slower than the non-exercising Ss ($F(1/48) = 7.00, p < 0.02$). Compare Figures 1 and 2 for exercise effects on SRT task.

Four Choice Task: Using the mean of the 10% slowest responses, an ANOVA revealed that the exercise significantly slowed down response ($F(1/46) = 24.98, p < 0.00$). Further analysis showed that the effect of slowing down of reaction time was significant only during the sessions near the end of each workday. The percent correct measure of Four Choice task performance showed similarly that the exercising Ss did significantly poorer than the non-exercising Ss ($F(1/46) = 4.82, p < 0.03$). The results meant that the exercising Ss performed the Four Choice task more slowly and less accurately than the nonexercising Ss.

Visual Vigilance: An ANOVA showed that there was no differences in the visual vigilance performance between the exercising and non-exercising Ss.

How Recuperative is a 3 Hour Nap?

Task performance during CW1 was compared with that during CW2 to evaluate the difference between recuperative power of 8 hour long sleep (after habitual 8 hour long continuous work) and a 3 hour nap taken (after a 20 hour long continuous work).

SRT TASK: The ANOVA of the mean 10% slowest responses revealed that performance during CW1 was significantly faster than during CW2 ($F(1/48) = 25.00, p < 0.00$).

Four Choice Task: An ANOVA showed that response time during CW2 was significantly slower than during CW1 ($F(1/46) = 6.59, p < 0.01$). The percent correct measure showed that performance during CW2 was not significantly poorer than that during CW1.

Visual Vigilance Task: An ANOVA showed that performance during CW2 was significantly less accurate than during CW1 ($F(1/42) = 8.28, p < 0.01$).

Do Performance Level Remain the Same during the First 12 Hours of a 20 hr Long Workday?

The visual SRT and Four Choice tasks were chosen for the detailed analysis.

SRT Task: The visual SRT task was given 17 times during CW1 which continued on for 8 additional hours beyond the 12 hour work period. An ANOVA showed that these 17 sessions were significantly different from each other with conservative test ($F(1/46) = 6.99, p < 0.02$). However, only those sessions past the 12 hour mark and nearing the end of CW1 were significantly different from the other sessions. See Figures 1 and 2. **Four Choice Task:** This task was given six times during 20 hour long CW1. An ANOVA showed that these sessions were significantly different from each other with conservative test ($F(1/49) = 5.87, p < 0.0191$). Again, only those sessions past the 12 hour mark and near the end of CW1 were significantly slower than the other ones.

DISCUSSION AND CONCLUSIONS

The first hypothesis was rejected. The Ss who started the workday at 1300 had the most serious performance degradations compared with the Ss in the morning and midnight groups. The Ss in the noon group showed the degraded performance in the visual SRT and Four Choice tasks and the Ss in the morning group showed the lowest percent correct. This result does not agree with Morgan and Coates (1974), as they found that the Ss in the 1400 group showed minimal performance deterioration when compared with those Ss in the 0600 or 2200 starting groups. Morgan and Coates used one overall, combined, moving average measure of all tasks which may have obscured particular task changes at certain time periods. The performance degradation of the noon Ss suggests the importance of the interaction of time-on-the-job and time-of-

day. The Ss in the noon group were on-the-job for 15 hours when they began to enter into the period of the circadian trough (0300-0700). The performance degradation of the morning Ss indicated the importance of considering different sensitivity of tasks to sleep deprivation.

The detrimental influence of 30% submaximal exercise was reliably observed in performance of visual SRT and Four Choice tasks. Thus, the second hypothesis was rejected. Exercise resulted in slowed reaction times and increased inaccuracy of responses. It should be noted that these performance tasks were given after the exercise Ss' treadmill walk. Hence, the exercise per se might not have degraded performance, but post-exercise changes might have influenced the performance.

Another result of importance to sleep management is the minimal hours of sleep required per 24 hour period to maintain a baseline level of performance for 20 consecutive hours. The 3 hour nap taken after a 20 hour continuous workday was found to be too short to maintain the baseline level of performance. Thus, the hypothesis that a 3 hour nap taken after a 20 hour workday is as recuperative as an 8 hour sleep customarily taken everyday was rejected. The findings also indicated that a 3 hour nap taken at various times of the day (0400-0700, 0900-1200, or 2000-2300) were all equally ineffective in maintaining the level of performance which was assured by an 8 hour sleep, suggesting that time of napping (i.e., the circadian phasing of naps) might not be as important as the duration of the nap, when the Ss were not severely sleep deprived.

The last hypothesis that the performance level remained stable for the first 12 hour long workday was accepted.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) As part of a research effort evaluating task performance during sustained operations, three groups of young (early 20's), physically fit, U. S. Marine Corps volunteer subjects (Ss) were evaluated for effects of starting time, exercise, time-on-job, and sleep duration on their task performance. The Ss in the morning group (Number of Ss = 22) started a 45-hour long continuous operation at 0800. The Ss in the noon group (N=16) started the continuous operation at 1300, and the midnight group (N=16) at 0000. The 45-hour long work period was divided into the first 20-hour long continuous workday (CWT), followed by five-hour		

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20. Abstract: (continued)

long break period (which included a 3-hour nap), and then by the second 20-hour long continuous workday ~~(GW2)~~. Due to the different starting times, the nap times differed for the three groups; the morning group nap was between 0400 and 0700; the noon group nap time was between 0900-1200 and the midnight group took their nap from 2000 to 2300. One-half of the Ss in each group were randomly assigned to walk on a treadmill for half an hour of every working hour, at a speed corresponding to 30% of their maximal aerobic power. The Naval Health Research Center Performance Assessment Battery was used to measure the changes in psychomotor and cognitive efficiency. In this paper, the results of the Simple Reaction Time choice task and the Visual Vigilance task are reported.

The four major findings from these results were: 1) the Ss in the noon group showed significantly slower simple reaction and four-choice reaction times in comparison with the morning and midnight groups. Hence the starting time of the workday makes a critical difference in maintaining performance effectiveness; 2) exercise at 30% of maximal aerobic power significantly slowed the reaction time and caused more errors in the simple reaction and four-choice task times. Post-exercise psychomotor task performance was slower and less accurate for exercising as compared to non-exercising Ss; 3) the 3-hour long nap was not sufficiently long enough to assure continued high performance as compared to performance after a sleep of 8 hours in duration; 4) all Ss could maintain the same performance level up to 12 hours during the first workday.

These results are to be used in developing a sleep management doctrine.

Keywords: Sleep; Performance; Exercise; Reaction Time; Vigilance

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