United States Naval Postgraduate School

THESIS

The Effects of Sleep Loss and Demanding Work/Rest Cycles: An Analysis of the Traditional Navy Watch System and a Proposed Alternative

by

William Charles Stolgitis

October 1969

25

The Effects of Sleep Loss and Demanding Work/Rest Cycles: An Analysis of the Traditional Navy Watch System and a Proposed Alternative

by

William Charles Stolgitis
Lieutenant, United States Navy
B.S., United States Naval Academy, 1962

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
October 1969

Author ______________________________

Approved by: ______________________________
Thesis Advisor

____
Chairman, Department of Operations Analysis

____
Academic Dean

ABSTRACT

An analysis of the traditional Navy watch system and a proposed alternative is presented. Current research on sleep deprivation and the effects of demanding work/rest schedules is documented and discussed as a basis for key assumptions in the analysis. Methodology is also presented for determining the relative ability of the two schedules to meet the assumed minimum sleep requirements. The results favor the alternate schedule as the more efficient for allocating available time resources to meet established sleep requirements.

TABLE OF CONTENTS

I. INTRODUCTION

A present-day shipboard sailor attentively listens to the striking of the ship's bell. As it rings out seven times, he smiles with the pleasant assurance that he is nearing the end of his 4-hour "watch". He is tired and he needs sleep. During the voyage that resulted in the discovery of America in 1492, the sailors under the command of Christopher Columbus also listened to the ship's bell for identical reasons. "Time on the vessels of that day was measured by a half-hour glass... 8 glasses made a watch... the ship's bell was the means of marking the glasses."[1] The custom of standing 4-hour watches can be traced even further back into history and is known to have been used on board ships as early as the 13th century.[2] This old and established Naval tradition has spanned the centuries until the present time.

In the present space era, technology and methodology are continually being changed or entirely replaced with new and more efficient systems. This thesis attempts to determine, through the findings of current research on sleep and work/rest cycles, whether a system of watch standing devised by the masters of ancient sailing ships is still valid in our time.

---

[1] American Heritage, p. 87, American Heritage Publishing Company, December 1955.

[2] Campbell, A. B., Customs and Traditions of the Royal Navy, p. 70, Aldershot, Gale, and Polden Ltd., 1956.

PRECEDING PAGE BLANK

II. STRUCTURE OF THE WATCH

As previously noted, the first mention of 4-hour watches occurs in the 13th century. The daily life of a seaman in that time consisted mainly of the back-breaking tasks common to all sailing ships. The practice continued and was justified as being a length of time quite long enough to keep a man active and alert. The British Navy continued the 4-hour system with the minor addition of the "dog-watches" which were a means of rotating the watch to ensure that all hands would not get the same watch every day. The United States Navy adopted the routines of the British Navy and continues traditionally to adhere to the following schedule:[3]

0800-1200	forenoon watch
1200-1600	afternoon watch
1600-1800	first dog watch
1800-2000	second dog watch
2000-2400	first watch
0000-0400	mid watch
0400-0800	morning watch

The above schedule is normally a three-section watch, i.e., the crew is divided into three equal sections and a section is rotated through every third watch.

This conventional routine is utilized by virtually all units of the surface Navy, although there are no regulations that require its use.

---

[3] Blue Jackets Manual, 18th ed., United States Naval Institute, Annapolis, Md., 1968.

United States Navy Regulations Chapter 10, Article 1002.1 give the Commanding Officer great freedom in his allocation of duties. "The Commanding Officer shall establish such watches as are necessary for the safety and proper operation of the command." Taking advantage of the leniency of the above article in Navy Regulations, some units of the surface Navy and especially the Nuclear Submarine Force have individually derived different standards of duty allocation. The most common alternative to the 4-hour, three-section, watch system has been a 6-hour, three-section system. This thesis will specifically analyze the standard 4-hour versus the less common 6-hour watch systems.

III. SLEEP

All human beings have a biological need for sleep. A basic drive in man's life is the acquisition and maintenance of a warm and secure location where he will contentedly spend one-third of his existence. In 1969, the exact nature of sleep remains a mystery. "It is still unclear why humans sleep and why they need as much as they do." [Foulkes 1966]. However, why humans must sleep is not important here. The essential fact is that they do and must achieve an adequate amount of sleep to function at their best. "The effects of sleep deprivation are well known: a loss of efficiency in mental and physical functioning, irritability and tendencies toward perceptual distortion and ideational confusion." [Foulkes 1966]. How much sleep then is necessary for a sailor at sea to function in an acceptable manner? It is this question that will be investigated.

Sleep is conventionally classified into 5 electrically discriminable stages: i.e., stages 1, 2, 3, 4, and 1-REM (rapid eye movement). Stage 1 and stage 1-REM, which is normally associated with dreaming, are commonly thought of as "light sleep." Stages 2, 3, and 4 are considered to be a "deep sleep" period. The differentiation of these stages is accomplished by continually recording the electrical activity of the brain with an electroencephalograph (EEG). While a knowledge of the exact electrical nature of these sleep stages is not essential to this discussion, it is necessary to establish that these different stages of sleep do indeed accomplish distinct recuperative processes in the body. This fact has led researchers to redirect their attention from the question of "how much sleep should one obtain?" to the more pertinent question of "how much of what kind of sleep should one obtain?" [Williams et al. 1967].

The method used to recognize the precise physiological and psychological aspects of the various sleep stages is partial and differential sleep deprivation. Partial sleep deprivation is the reduction of an individual's sleep to 4 or 5 hours if his normal sleeping time is 8 hours. Differential sleep deprivation is the denial of a specific stage of sleep. Subjects are allowed to obtain a normal night's rest with the exception of the specific stage which is to be investigated. Whenever the subject enters the investigative stage as determined by the EEG, an electrical stimulus is administered forcing the subject to abandon the stage under observation. Upon completion of the sleep cycle, the subject is exposed to a battery of mental and physical tests in an attempt to detect and define the results of this selective deprivation. The majority of the work on differential sleep deprivation has been largely concerned with stage 1-REM and stage 4 sleep.

A loss or deprivation of stage 4 sleep is characterized by a general sense of ill-feeling. Wilkinson (1968) noted that subjects deprived of stage 4 sleep exhibited marked depressive and hypochondriacal reactions. These symptoms have been substantiated by the findings of Williams et al. (1967), who note the hypochondriacal symptoms aggravated by personality withdrawal, and a lessening of the aggressiveness in the individual's normal behavior. Lethargy, exhaustion, and reduced functioning have also been a major effect. A loss of stage 4 sleep for more than 5 days has been likened to a full night's sleep loss [Johnson 1967]. After several nights of total stage 4 deprivation, almost continuous stimulation is required to prevent a subject from entering stage 4 sleep. It is evident, although not completely apprehended, that some undefined function of this particular stage is virtually essential to the recuperative processes of the body. Another indication of the validity of this conclusion is the "recovery effect." Any reduction in the duration of stage 4 sleep is compensated by a marked increase in stage 4 during subsequent sleep periods. This phenomenon has been noted by all sleep researchers without exception.

The "recovery effect" has also been established to hold for stage 1-REM sleep deprivation. Individuals deprived of this dream stage will increasingly attempt to enter it. The effects of REM sleep deprivation appear to differ from stage 4 deprivation indicating a separate recuperative function. Williams et al. (1967) observed "... the subjects were becoming less well integrated and less interpersonally effective. They tended to show signs of confusion, suspicion, and withdrawal. These subjects were labelled as anxious, insecure, introspective and unable to derive support from other people." The physical consequences of these psychological changes manifests itself by lapses in performance rather than steady declines [Wilkinson 1968]. The performance of partial sleep deprived individuals becomes inconsistent and highly unpredictable.

In addition to having variant effects, stages 1-REM and 4 also have unique positions in the sleep cycle. A normal uninterrupted night's sleep is composed of several cyclical transitions through the five various sleep stages. The preponderance of stage 4 sleep occurs during the initial hours of this sleep. Tune (1968) noted, "in young adults, more than 70 per cent of all stage 4 sleep occurs in the first third of the night." Williams et al. (1967) submitted that young adults took approximately 75 per cent of their stage 4 sleep in the first three hours and by the end of five hours had acquired virtually 97 per cent of all stage 4 sleep. Conversely, stage 1-REM is predominately centered in the last 3 hours of sleep and rarely appears t all in the first 3 hours. The implication is that the body gives precedence to the recuperative effects of stage 4 to the exclusion of stage 1-REM.

A 1968 study of 240 adults conducted by Tune (1968) and held over a 2 month period disclosed the mean duration of sleep under normal conditions to be 7.5 - 8 hours. This is in accordance with the universally accepted standard. Tune also noted that the younger (20-39) population took more sleep than the older group (40-59) and that males took more sleep than females. For the population to be investigated, (young, male, sailors) this would indicate that they could be expected to be slightly above the mean in their requirements, or about 8 hours of sleep being normal. Any reduction of this amount of rest will of necessity deprive the individual of increasingly larger segments of stages 1-REM and 4 sleep. With only slightly reduced duration of sleep, stage 1-REM alone will be affected; but when sleep becomes reduced to less than 5 hours, the majority of stage 1-REM will have been lost, and a reduction in stage 4 will commence.

It is near the critical area of 5 hours, or less, that performance and performance capacity appear to deteriorate. Wilkinson et al. (1966) record, "...less than 5 hours sleep on a single night impairs vigilance..." and, "the reduction of sleep by about half can produce a significant fall in working efficiency." A rather important additional conclusion of Wilkinson is the implication that it is only after 3 hours of sleep that vigilance testing shows improvement over a 0 hour level of sleep, i.e., less than 3 hours of sleep did not contain the undefined regenerative capacity to improve signal detection, or related vigilance type tasks. Wilkinson's stated conclusion is that the properties of 1-REM sleep are implied to be more important in vigilance and the appearance of this sleep does not occur until after the 3rd hour with the majority revealing itself after the 5th hour. Naitoh et al. (1968) cite an experiment in which the shortening of sleep by 40 per cent (approximately 5 hours total sleep) resulted in a significant loss of efficiency. Webb and Agnew (1965) note a performance decrement "... even though the subject had undergone only a very limited amount of deprivation of stage 4 sleep." The inference is clear. Performance decrements can be detected when an individual's sleep is reduced below 5 hours. When the sleep taken is above this level, any deviations from the norm, if they exist, have not yet been detected and will in all likelihood prove very subtle in any but the long run effects. It is reasonable to conclude however that the biologically built-in demands of the body (in this case a rather universal norm of 8 hours sleep) constitute a very real function for body regeneration and any aberrations from this norm can only decrease the body's performance capability.

If the sleep stages could be artifically manipulated, it might conceivably be possible to induce a concentration of stage 4 and 1-REM sleep into the first hours of the cycle resulting in the ability to achieve the required amounts of stage 1-REM and 4 sleep and consequently the ability to function quite well with a reduced amount of sleep. Such control is not forthcoming at this time. Sleep patterns do not compress and miniaturize the total sleep cycle when the individual is acclimated to a restricted sleep period. Williams et al. (1967) restricted a group of subjects to 3 hours a day. The expected result was a shortened cycle with amounts of each stage proportional to that which resulted from a normal night's sleep. This did not occur. The subjects' sleep cycle remained the same as normal. "...they slept as if they were going to obtain a full nights sleep." The body is not equipped to anticipate shortened sleep cycles and to adapt accordingly. Dr. Laverne C. Johnson, reporting in Naval Research Reviews August 1967 on the results of a sleep symposium conducted in San Diego May 20-21 1966, reported that conference members agreed on the difficulty of manipulating the sleep cycle, "... sleep patterns appear to be locked in biologically and are indeed difficult to shift." Since it is presently impossible to humanly regulate the amounts and times of occurrence of the various sleep stages, the sole means of ensuring adequate amounts of the various sleep stages is the allowance of time for sufficient uninterrupted sleep.

One final consideration is the rapid physical and psychological recovery from the effects of sleep loss. The symptoms and effects of sleep deprivation seem to disappear with the modest acquisition of one period of uninterrupted sleep [Hartman and Cantrell 1967]. The possibility of the undetected existence of some detrimencal effects caused by chronic sleep deprivation is not disputed, but apparent performance capacity and uniformity is seen to promptly return to its pre-deprivation level. Tune (1968) observed the phenomenon of a sleep "debt", or a backlog of required sleep resulting from the cumulative effects of curtailed sleep. He noted that this "debt" was paid off by the individual sleeping an average additional hour when time and occasion permitted. The necessity for repayment of this debt is evidenced by the persistent attempts to oversleep and is analogous to the earlier mentioned "recovery effect" of differential deprivation studies.

The Military problem then is the allocation of sufficient sleep to ensure the individual a capacity for reliable and consistent performance. The penalties resulting from a failure to do so are psychological instability, physical decrements, and lapses in performance. A sailor may appear and feel quite astute yet remain unreliable at his job. As the helmsman stands the mid-watch, it is expected that he will react swiftly, accurately, and consistently to verbal orders from the Officer of the Deck. It is expected that the lookout will visually sight and report all contacts and hazards to navigation. The reliability of both should be above reproach, but it is seen that these are the traits and talents of rested individuals and not the capabilities of sleep-deprived men. On the basis of the above discussion and for the purposes of this thesis, it will be assumed:

1) The performance decrement as pertains to vigilance does not disappear with less than 3 hours sleep.

2) A minimum of 5 hours sleep is required to enable the individual to maintain an acceptable level of consistent and reliable performance.

3) The physical and psychological recovery from the effects of sleep loss is accomplished by the acquisition of a normal uninterrupted sleep period.

IV. WORK/REST CYCLES

An obvious question when comparing the relative advantages of two distinct work/rest cycles (in our case 4/8 and 6/12) is whether the duration of the longer work period is in itself a stress that lessens the benefits of the correspondingly longer sleep period. The answer to this question is elusive.

The major portion of the research accomplished on work/rest cycles has been directed towards the aerospace industry. The main objective has been the determination of minimum crew manning levels required to operate a given system at a specified level of performance. Many alternative work/rest cycles have been investigated, e.g., 2/2, 4/4, 6/6, 16/8. The applicability of this research as a direct measure or standard for a ship's crew performance is doubtful. The models for all the experiments concerned with work/rest cycles that appear in the bibliography do not extend themselves as representative of actual shipboard conditions in at least two major respects. First, the subjects in all the studies are allowed total rest during the non-working periods, i.e., a 4/8 subject would work 4 hours and then have 8 hours rest for a total of 16 rest-hours per day. Similiarly, a 4/4 subject would have 12 hours of rest per day. Although this schedule can be considered reasonable for the confines of a space capsule, it does not accurately depict normal shipboard routine. Consider the following time schedule which is typical of a 4/8 watch schedule daily routine and which would occur every third day.

0000-0400	watch
0400-0600	rest
0600-0800	clean ship/breakfast

0800-1100	ship's work
1100-1200	lunch
1200-1600	watch
1600-2000	rest/dinner/rest
2000-2400	watch

It is quite evident that off-watch periods are rigorously utilized and that the requirements imposed on the individual are much more extreme than would be reflected by an absolute 4/8 work/rest cycle.

Secondly, motivation of the individual is of prime importance. All twelve of the individual experiments cited by Chiles et al. (1968) used college students or commissioned officers as subjects. The inference obtained from such subjects might not readily be extended to a crew of not so highly educated, motivated, or receptive sailors. It is commonly known that a high stimulus or motivation will readily override the detrimental effects of sleep loss on performance for a short period of time. A very good current example is that of the Astronauts Collins and Armstrong in Apollo 11 who in the last hours of the moon flight actually "could not" sleep and yet exhibited outstanding performance. The differences in motivation between the caliber of subject described and the average sailor can then be seen to be a very real problem making the task of comparison very hazardous.

With due attention to the above inadequacies, there still remains some substantial evidence that longer work cycles do not offset the associated advantages of longer sleep cycles. Hartman et al. (1967) compared 4-hour shifts with 8-hour shifts and reported no significant difference in performance capabilities. Moreover, the "natural" routine of 16 hours awake with 8 hours of uninterrupted sleep was evidenced by repeated consistency of performance, while the 4/4 cycle with its consequential interrupted sleep schedule was characterized by large individual differences and lapses in performance. The individuals following the "normal" routine were more dependable and predictable in their output. Hartman(1967) noted, "...it appears that interrupted sleep is in and of itself a stress, possibly because individuals do not get the usual amounts of each stage of sleep." Colquhoun et al. (1968) have examined several different shift lengths including those of 4 and 8 hours duration. Commenting on the longer 8 hour shift, they noted, "there was no clear evidence of fatigue due to the increased length of the working spell." Using performance level as a criterion they concluded that the optimal shift, "...should be a single spell of 8 hours, not two of 4...."

For the purpose of this study, it will be assumed that the difference in fatigue levels arising from the extra 2 hours of work on the 6 hour shift is not significant.

V. ANALYSIS

The basic assumptions for this analysis as developed earlier in the thesis are:

1) The fatigue differential caused by the additional two hours between 4-hour and 6-hour watches is not significant.

2) The performance decrement as pertains to vigilance does not disappear with less than 3 hours of sleep.

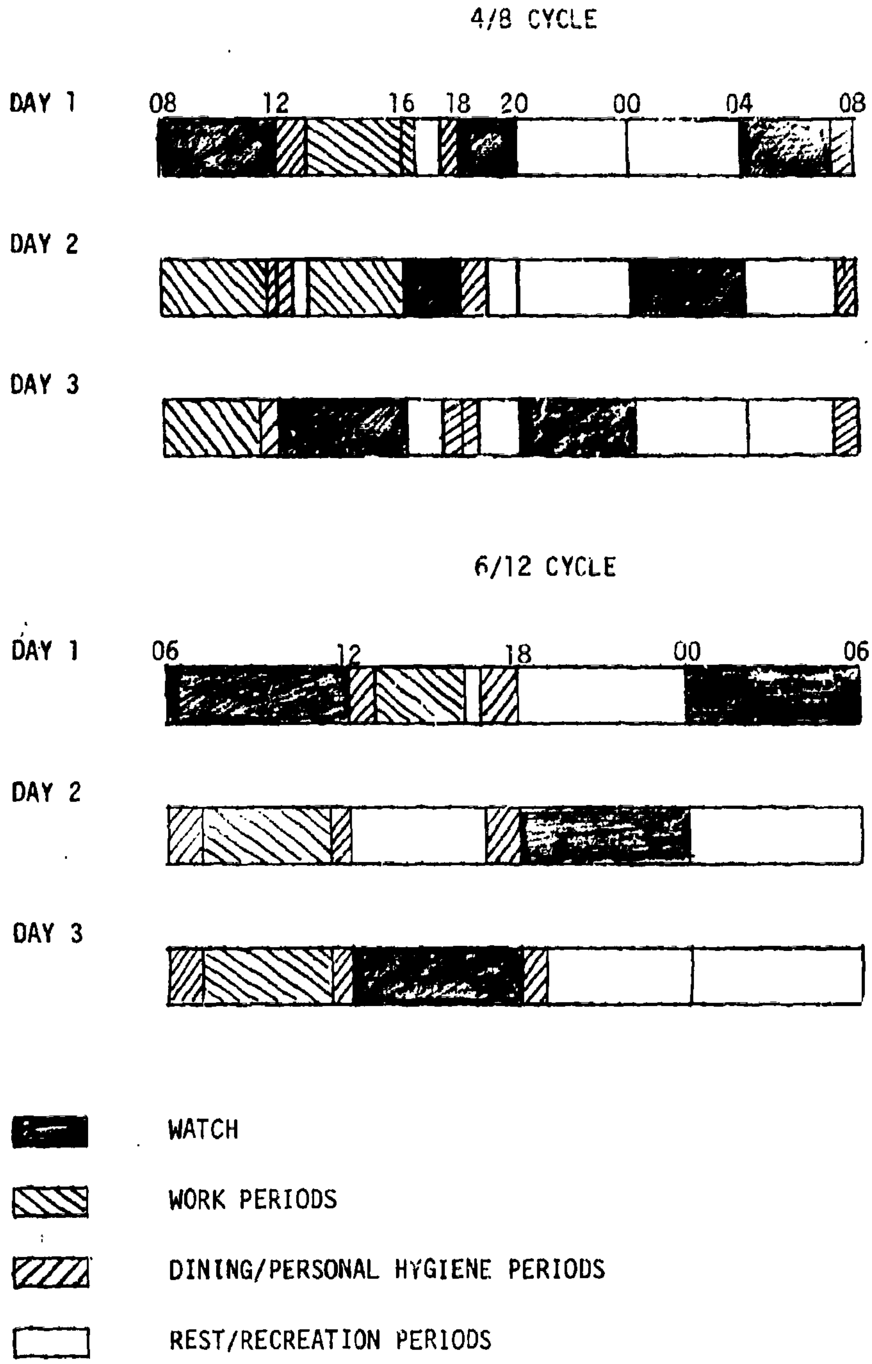
3) A minimum of 5 hours sleep is required to enable the individual to maintain an acceptable level of consistent and reliable performance.

4) The physical and psychological recovery from sleep loss is accomplished by the acquisition of a normal uninterrupted sleep period.

To investigate the differences in the 4/8 and 6/12 watch schedules, it is necessary to examine their respective distributions of watch, work, and rest times across a complete 3-day cycle. Figure 1 diagrams this allocation of time. The daily schedule utilized is taken from the standard ship's routine as specified by Bluejacket's Manual (1968).

The time spent on watch is the same for both systems. With the 4/8 schedule, there are 7 watch periods while on the 6/12, there are 4 watch periods. Each schedule totals 24 hours of watch per cycle for an average 8 hours of watch per day. The 4/8 schedule allows for 13 hours of ship's work per cycle, or an average 4.33 hours per day. A total of 11 hours for an average 3.67 hours per day is provided by the 6/12 schedule. The average time involved in daily watch and work duties is 12.33 hours for the 4/8 cycle and 11.67 hours for the 6/12 schedule. For either system, it is seen that approximately 12 hours of labor per day are demanded of the sailor making both systems equal in this respect. It is with the time allocated for rest that the two systems differ.

Figure 1. Diagrams of 4/8 and 6/12 watch schedule



Applying assumption (2) to the 4/8 cycle, the benefits derived from available sleep periods of extremely short duration are considered negligible, e.g., the 1630-1730 and 1830-1930 periods of day 3. The validity of this assumption is reinforced by the fact that these particular periods are those of intense social activity aboard ship, and the quiet atmosphere conducive to rest is not easily achieved. This provides a potential daily sleep schedule of:

day 1	2030-0330	7	hours
day 2	1900-2330	4.5	hours
day 3	0000-0600	6	hours
daily average		5.83	hours

Assumption (2) is not pertinent to the 6/12 cycle since by its structure, such short sleep periods are not scheduled. The available sleep periods arising from this schedule are:

day 1	1830-2330	5	hours
day 2	1300-1730	4.5	hours
	0000-0600	6	hours
day 3	1900-0530	10.5	hours
daily average		8.66	hours

It is assumed that approximately 3 hours per day are for eating, dressing, personal hygiene, etc. Combined with work and watch times, this would total 15.33 "active" hours during the 4/8 watch schedule leaving 8.67 hours for rest and recreation. Similarly, the 6/12 schedule would provide 9.67 hours for rest/recreation. It is noted that only a 1 hour difference in rest/recreation periods exists between the two schedules. By virtue of the more uniform and lengthier apportionment of the 6/12 schedule, a greater percentage of the daily rest/recreation time is available for sleep which meets the criteria of the second and third assumptions. Sleep Cycle Efficiency (S.C.E.) will be defined as the ratio of average potential daily sleep to the average daily rest/recreation periods.

$$S.C.E. = \frac{\text{average potential daily sleep periods (hours)}}{\text{average daily rest/recreation periods (hours)}}$$

By this measure of effectiveness, sleep cycle efficiency is .673 for the 4/8 schedule and .895 for the 6/12. The 6/12 schedule is thus seen to be approximately 1.33 times as efficient as the 4/8 schedule in converting available off-duty periods into potential sleep periods.

The average daily potential sleep for both schedules appears greater than the 5 hours specified by assumption (3), i.e., 5.83 and 8.67 hours for the 4/8 and 6/12 schedules respectively. These totals however represent the maximum time available for sleep and do not take into consideration such sleep-depriving events as night replenishments, special night work, social activities, insomnia, etc. All these factors combine to make actual available sleep a lesser total than that indicated by figure 1. In this respect, the 6/12 schedule proves superior to the 4/8 by its greater capacity to handle these additional challenges. The 6/12 schedule can accomodate an increased activity level that reduces its available sleep time by over 3 hours and can still provide an acceptable sleep level, while the 4/8 schedule can only afford an additional hour before reaching an unacceptable level of sleep deprivation. The 6/12 schedule is thus seen to be the better system in handling additional requirements within the framework of the schedule.

The 6/12 schedule also contains the important feature of providing one full nights sleep per cycle (1900-0530 during day 3). The consequence of the availability of an undisturbed full night's rest is furnished by assumption (4). This long sleep period effectively precludes long term physical and psychological decrements of a cumulative nature by ensuring sufficient sleep for a complete recovery from all existing effects of sleep deprivation. The 4/8 schedule does not permit such a recovery sleep.

Investigation of the 4/8 and 6/12 watch schedule has disclosed that each is approximately equal in its physical demands on the individual in terms of total hours spent on watch and ship's work. The two schedules differ in their allocation and distribution of rest and recreation periods. The 6/12 is analyzed as the more preferential due to:

1) increased efficiency in converting available off-duty periods into sleep periods of adequate duration.

2) greater flexibility in accomodating increased activity levels and maintaining acceptable levels of sleep.

3) provision of a long and uninterrupted sleep period capable of ensuring a complete recovery from the effects of sleep deprivation.

VI. CONCLUSION

The modern Naval ship is equipped with the most sensitive, elaborate, and sophisticated man-machine systems in history. Billions of defense dollars are spent annually for research leading towards the improvement of these systems, and yet, it sometimes appears plausible that the direction of advance is so heavily weighted towards the machine that it is exclusive of the equally necessary team member, man. The detection capacity of the most powerful sonar is directly related to the ability of the operator while the computerized fire control solution is only as accurate as the control officer's interpretation. Unlike many civilian enterprises where the machine can be allowed to function relatively unchecked, the military-purpose machine output must be diligently monitored and supervised. The penalty for machine irregularities in the first case would usually be economic in nature; the ramifications of a military man-machine system breakdown are of a more critical and possibly lethal nature.

This thesis has attempted to determine the relative capabilities of two watch systems to provide the adequate sleep necessary for enabling the ship's crew to reliably and consistently perform their daily routines. Excessive sleep loss has been shown to affect performance characteristics by a dual physical and psychological function. The physical nature of the sleep-deprived individual might well be manifested by performance lapses and vigilance deterioration with a consequential lessening of man-machine effectiveness. The psychological changes might tend to disrupt social interactions between individuals thereby breaching the crew's morale. Combined with inherent shipboard stresses such as constant motion, irregular schedules, and lack of privacy, the additional stress of sleep deprivation could not only cause a decrease in the individual's ability to perform his job but also a lessening of his motivation to do so.

An analysis of the 4/8 and 6/12 watch schedules has indicated the 6/12 system to be the better system for providing adequate sleep periods. It achieves this goal by establishing longer uninterrupted hours of sleep for the individual. With the 4/8 schedule, the longest non-watch period is 8 hours. Within this length of time, the sailor must allocate time for ship's work, meals, personal hygiene, social activities, etc. It is immediately clear that a normal 8 hour sleep is not possible with the above constraints. The 6/12 schedule by virtue of its 12 hour periods of non-watch provides a greater opportunity for the individual to accomplish his necessary duties and also allot time for sleep that is closer to the 8 hour norm than the 4/8 schedule. It is this characteristic of the 6/12 schedule that makes it preferential.

As mentioned in Chapter II, various units of the Nuclear Submarine Force presently utilize the 6/12 watch schedule. It is interesting and persuasive to note that they do so by crew's preference. The former Executive Officer of the USS STONEWALL JACKSON SSBN(634), A. G. Cicolani, LCDR, USN has stated that both the Blue and Gold crews of that ship have consistently voted in favor of following a 6/12 watch schedule. Other ships adhering to the 6/12 by ship's crew preference are the USS TECUMSEH SSBN(628), USS DANIEL BOONE SSBN(629), and USS ULYSSES S. GRANT SSBN(631) to name a few. The inference to be drawn is that what is preferred by the individual is "best" in that it will lead to higher levels of morale and performance, and these traits are certainly the best means to the achievement of the military mission.

The results of the thesis dictate the following considerations and recommendations:

1) under the assumptions of thesis, the 6/12 watch schedule is preferential to the 4/8 schedule in maximizing and stabilizing crew's performance capacities.

2) a shipboard study should be conducted to determine the relative characteristics of the two schedules under actual working conditions.

3) other alternate watch schedules should be investigated to determine their relative feasibility and optimality in maintaining crew's performance commensurate with the increased ability of man-machine systems.

BIBLIOGRAPHY

American Heritage, p. 87, American Heritage Publishing Company, December 1955.

Blue Jackets Manual, 19th ed., United States Naval Institute, Annapolis, Md., 1968.

Campbell, A.B., Customs and Traditions of the Royal Navy, p. 70, Aldershot, Gale, and Polden Ltd., 1956.

Chiles, W. Dean, Alluisi, E.A., Adams, O.S., "Work Schedules and Performance During Confinement," Human Factors, April 1968, p. 143-187.

Colquhoun, W. P., Blake, M.J.F., Edward, R.S., "Experimental Studies of Shift Work," Ergonomics, v. 11, p. 437-454.

Department of Psychiatry, University of Florida, Gainesville, Effects of Prolonged Stage 4 and 1-REM Sleep Deprivation, by Williams, R.L., Agnew, H.W., and Webb, W.B., 18 April 1967.

Foulkes, D., The Psychology of Sleep, Charles Scribners Sons, New York, 1966.

Johnson, L.C., "Sleep and Sleep Loss — Their Effect on Performance." Naval Research Reviews, Office of Naval Research, August 1967.

Naitoh, P. and Townsend, M.A., The Role of Sleep Research in Human Factors, Paper presented at the 21st Annual Conference on Engineering in Medicine and Biology, Houston, Texas, 19 November 1968.

Tune, G.S., "The Human Sleep Debt," Science, p. 67-71, December 1968.

USAF School of Aerospace Medicine, Report SAM-TR-67-99, MOL: Crew Performance on Demanding Work/Rest Schedules Compounded by Sleep Deprivation, by Hartman, B.O. and Cantrell, G.K., November 1967.

Webb, W.B. and Agnew, H.W., "Sleep: Effects of a Re ricted Regime," Science, v. 150, p. 1745-1746, 1965.

Wilkinson, R.T., "Sleep Deprivation: Performance Tests for Partial and Selective Sleep Deprivation," Progress in Clinical Psychology, v. VII, 1968.

Wilkinson, R.T., Edwards, R.S. and Haines, E., "Performance Following a Night of Reduced Sleep," Psychon. Sci., 1966, v. 5(12).

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Naval Postgraduate School
Monterey, California 93940

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

The Effects of Sleep Loss and Demanding Work/Rest Cycles: An Analysis of the Traditional Navy Watch System and a Proposed Alternative

4. DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Master's Thesis; October 1969

5. AUTHOR(S) (First name, middle initial, last name)

William Charles Stolgitis

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
October 1969	28	14

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

Naval Postgraduate School
Monterey, California 93940

13. ABSTRACT

An analysis of the traditional Navy watch system and a proposed alternative is presented. Current research on sleep deprivation and the effects of demanding work/rest schedules is documented and discussed as a basis for key assumptions in the analysis. Methodology is also presented for determining the relative ability of the two schedules to meet the assumed minimum sleep requirements. The results favor the alternate schedule as ~~the more~~ efficient for allocating available time resources to meet established sleep requirements.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6811

Security Classification

A-31408

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Work/Rest Cycles						
Sleep Loss						
Navy Watch System						

DD FORM 1 NOV 65 1473 (BACK)

S/N 0101-807-6821

Security Classification

A-31409