Too tired to work? A study into the effects of shiftwork in a group of health physics monitors.

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Abstract. Shiftwork has been shown to have an adverse effect on workers sleep behaviour, alertness, fatigue levels and susceptibility to errors and accidents at work. There has been a lot of research into the effects of shiftwork in general industry and its impact in some specific service areas such as the fire service and nursing but little has taken place in the nuclear industry. The two most serious accidents involving radiation, Three Mile Island in 1979 and Chernobyl in 1986 both occurred during the night shift and the decision making processes of the operators were cited as major factors contributing to the disasters. In 1993 an exploratory study into the impact of shiftwork at a nuclear power plant concluded that the results have practical implications for work scheduling in high hazard industries. A further study in 1995 also reported an abrupt fall off in alertness levels during the evening shift as well as the night shift in a group of nuclear workers. This study examines the work-related effects associated with shiftwork in a small group of health physics monitors in a nuclear repair/maintenance organisation. The study group is a mixture of serving military personnel and civilian staff working two separate and distinct shift patterns. The control group is the health physics personnel who work a normal working day pattern and are a mixture of serving military and civilian workers. The survey was carried out over an eight-week shift schedule using repeated survey questionnaire and vigilance test data. Fatigue as a result of shift work and a proneness to work related errors are indicated to be present in the shift workers. The night shift is the most problematic in terms of decreased alertness levels, sleep quality and sleep length. Evidence was also collected that supported the ‘self-selection’ process for shiftworkers, particularly amongst the civilian staff. This study both supports and challenges some of the findings of previous research into shiftwork. The results may have implications for the production of risk assessments and work scheduling in health physics safety critical roles.

Disclaimer. This paper is the work and findings of the author and does not necessarily reflect the thoughts and policy of the Royal Navy.
1 Introduction

1.1 Man has evolved with a diurnal routine of activity and sleep. These routines are controlled by circadian rhythms. These circadian rhythms are body clocks that influence or control physiological functions such as core body temperature, blood pressure and time of sleep and behavioural variables such as alertness and mental performance. Some biochemical synthesis and secretions are also controlled by circadian rhythms, the hormone melatonin being a good example.

1.2 It is estimated that in any urban economy about 20% of the working population is employed outside the regular 0800 -1700 working day [1]. It has been well documented and research has proven that shiftwork can have a detrimental effect on the health of individuals [2][3]. Shiftworkers often report experiencing insomnia, digestive problems, irritability, fatigue, depression and a lower quality of life in general through fatigue caused by sleep deprivation. In addition to these health effects, shiftworkers who rotate shift on a weekly basis also have more accidents at work and have a lower productivity output [4].

1.3 In the nuclear industry great emphasis is put on safety case justifications prior to operations commencing and during the subsequent continuation of those operations [5]. These justifications and subsequent reports cover engineering processes and standards, fault analysis and external factors but generally the only human input is a requirement that the workforce is 'suitably qualified and trained'. There is little or no recognition of work routines such as shiftwork. In practice it is not uncommon for some nuclear safety critical work to be carried out during the evening and at the weekends. The justification for this is that the consequence of any accident is less and the potential for an accident is reduced because there are fewer people on site during these times. However, research into shiftwork has shown that the risk of an error at work resulting in accidents is increased during operations at these times [4].

1.4 This study looked at a small number of workers in the nuclear industry responsible for radiological safety. The group is made up of a mixture of serving Royal Navy personnel and Ministry of Defence civilian staff. Two separate shift systems were in use, one for the navy and the other for the civilian staff. The civilian shift schedule is a 'traditional' 3 week cycle with rest days between shift change over and the naval schedule is over 6 weeks with two 3 day breaks at weeks 1 and 3 or 2 and 4. At the end of the 6 weeks there is 2 weeks leave. This is a long shift cycle and has been of some concern to the shiftworkers for some time, most notably the inflexibility of the shift and the amount of time spent at work. This study looked at the impact of the 2 shift systems on fatigue and alertness levels and the potential for work related errors in a role with critical radiological safety responsibilities.

2 Shiftwork and The Nuclear Industry

2.1 Physiological functions increase during the day when we are active and decrease at night when we are sleeping. However, studies have shown that these rhythms persist if we suddenly reverse our activity pattern and sleep during the day and are active at night. Attempting to sleep at times of decreasing melatonin levels and increasing body temperature will often result in disturbed sleep in the from of shorter sleep episodes and more awakenings [1].

2.2 These rhythms are internally controlled but their timing synchronises and coincides with external environmental cues. So if we persist with a reversal of sleep and activity after a period of acclimatisation the body's circadian rhythms will have reversed and become synchronised to the new set of exogenous cues. Individuals differ considerably in how quickly they can reverse their rhythms. It can take 5-7 days for some people, up to 14 days for others and at the extreme some people may never be able to achieve a complete reversal.
During this period of change over the body's functions are in a period of 'internal resynchronisation', which is very stressful and accounts for much of the exhaustion, malaise and lassitude with changing work shifts [6].

2.3 Psychological functions also follow a well defined circadian rhythm. Most psychological functions are performed most effectively when the body temperature is at its highest and least effectively when it is lowest. This links with the periods of activity and sleep patterns.

2.4 There has been a lot of research into the effects of shiftwork in general industry and its impact in some specific service areas such as the fire service [7] and nursing [8] but little has taken place in the nuclear industry [9]. There is probably nothing more publicly emotive and concerning than a nuclear accident or a serious radiation incident. Two serious nuclear accidents, Three Mile Island in 1979 and Chernobyl in 1986 both occurred during the night shift and the decision making processes of the operators were cited as major factors in contributing to the disasters [9].

2.5 Under normal conditions circadian rhythms are aligned so as to set wakefulness during the day and sleep at night. These rhythms in turn work in combination as to shut down some functions at night allowing a restful night sleep and warming up other functions so as to regain alertness and activity during the day. It is argued that the desynchronization of circadian rhythms combined with the sleep deficit and fatigue associated with shiftwork may significantly impair work efficiency making the worker more vulnerable to error [10][11][12]. In particular the night shift performance capabilities have been shown to deteriorate [11][12][13][14] but the results of research on the number of work errors and accidents between shiftworkers and day workers is inconsistent [10]. Some studies report an increase in shift related events but others do not and it appears the devil is in the confounders. These differences reflect the different shift patterns in different industries and the management philosophy contained in their approach to shiftwork, making it necessary to research the impact of shiftwork on certain safety implicated industry rather than to rely upon general research. What is consistent though in the studies is the seriousness of errors and accidents.

2.6 An exploratory study by Smith and Folkard in 1993 [9] into the impact of shiftwork at a nuclear power plant stated that the night shift is the most problematic in terms of alertness, sleep duration and quality of sleep. He concluded that his results have practical implications for work scheduling in high hazard industries. A later study in 1995 [15] not only further supported Smith's [9] findings with regard to reduced alertness and enhanced sleepiness of the night shift but also reported an abrupt fall in the alertness of the evening shift with an increased distractibility at the end of this shift. He concluded that the evening as well the night shift constitutes a serious threat to the operational safety of the facility in his study. Both of these studies support the general hypothesis of reduced alertness levels and increased sleep disturbance on the night shift.

3 Safety and Performance

3.1 Although the 1991 research paper about the classification of accidents [16] did not deal with shift work or times of accidents it did reveal some interesting data associated with errors and accidents at work that are relevant to shift patterns. Of the eight identified contributing factors to fatal accidents at work five of them can be influenced by shift work particularly the evening and night shift. The five factors are Work Practice, Supervision, Task Error, Medical and other of which the main components are alcohol and drug involvement. Three of these are affected by fatigue and alertness levels; work practice, task error and medical. It has already been said that there is less supervision on night shift work [10]. Alcohol and drug use have been identified as contributing factors to fatal accidents at work and it has been shown that fatigue and sleep deprivation can induce the same behaviour as alcohol. After about seventeen to nineteen hours of wakefulness the vigilance and accuracy performance of individuals is equivalent to or worse than that with a 0.05% blood alcohol
concentration (BAC). This increases to an equivalent BAC of 0.10% and greater past the 23rd hour of wakefulness [17][18]. Tepas [19] and Folkard [20] reported that 50% of shift workers spend at least 24 hours awake on their first night. It is worth noting here in this section that the blood alcohol legal limit for driving in the UK, USA and Canada is 0.08%, with Australia and Sweden even lower at 0.05% and 0.02% respectively.

3.2 A study on the German working population looked at the risk of an accident at work as a function of both hours at work and time of day [4]. Published papers, which consistently reported that the risk of accidents at work is a function of time at work brought this about. Folkard [21] demonstrated that the risk of an accident was approximately the same for the first eight hours of work but increased greatly beyond the ninth hour, doubling at the twelfth and trebling after the fourteenth. This calls into question the practice of overtime beyond the eight hour day and in particular the common practice of double shifts particularly through absence of another worker [22] and the safety with which the work can be carried out either in terms of performance or work related errors. Further to this, other studies have shown that there is a significant difference in the accident rates of night shift workers and their daytime counterparts [23]. This then leads to the hypothesis that not only is the hour at work a function of accident risk but so is the time of day. Fatigue and wakefulness are affected greatly by shift work and it has been shown that the level of alertness is linked to sleep deprivation and fatigue. Hänecke's [4] study showed a clear, statistically significant association between time of day and hour at work and accident risk. For example there is a marked difference in accident risk at 1500 hours between a worker in his 10th hour following a 0600 hour start time and a worker who started his shift at 1400 hours. The difference is in the order of a tenfold increase in that the early worker is more than likely to have an accident than his afternoon shift colleague.

3.3 Peak accident times appear to be between 1000 - 1100 hours and 1300 - 1600 hours. However, Costa [10] argues that this probably reflects peaks in work activity since performance capabilities due to circadian rhythms should be relatively high at these times.

4 Fatigue and Alertness

4.1 Fatigue has generally been correlated with time on task and time at work rather than time of day. However, shiftwork researchers have found that time of day does have a profound affect on fatigue and that work start time affects sleep in addition to the time at work. For most workers the amount of sleep on non workdays is longer than the amount of sleep on workdays. Also on non workdays most people sleep at night, following the circadian rhythm aligned to day/night. Work schedules such as those imposed by shift working affect the sleeping pattern: night shift workers sleep the least, with afternoon/evening shift workers sleeping the most and day shift people less than the evening but more than the night shift. Tepas [24] states that the primary problem with regard to sleep and the night shift is a reduction of sleep rather than the night shift disturbing sleep. Night shift workers often report difficulty in falling and staying asleep.

4.2 These changes in sleep length have an effect on the shiftworkers subjective state including fatigue. Paley [7] cites Johnson's [25] suggestion that partial sleep loss has the same features as total sleep loss. Therefore, irritability, fatigue, inability to concentrate and periods of misperception should feature quite significantly in night workers.

4.3 Paley's [7] study group worked a similar shift pattern to the Royal Navy personnel in the Health Physics Group. A rotational 0800-1600, 1600-2359 and 2359-0800 with similar times on each shift i.e. 2 weeks day shift, 2 weeks evening shift and 2 weeks night shift. He reported significant differences in sleep patterns for the three shifts (F(2,38) = 31.39, p <0.001) with mid shift cycle mean sleep times of 309.473, 442.105 and 430.263 minutes for night, day and evening shifts respectively.
He also found that responding to call outs affected the fire-fighters' sleepiness. The call outs had an arousing effect on the fire-fighters' with a reduction in their subjective sleepiness.

4.4 This last point seems to be supported to a certain degree by Bonnet [26]. He found that verbal and physical activity consistently produced a characteristic EEG arousal response and a return to wakefulness for a period of time directly related to the magnitude of the physical arousal. Standing and sitting upright also supported a return to wakefulness although only for short periods of time. The study was also consistent with the hypothesis that alertness is based upon time awake, circadian effects and level of arousal. Sustained wakefulness has also been found, to have a significant effect on performance [17] most notably during the 23rd to 27th hour of wakefulness.

5 Shift Duration and Shift Systems

5.1 All shift systems have advantages and disadvantages. No single shift pattern is an answer to all problems across industry but there are shift patterns that are better than others in the context of physiological, psychological and social recommendations. However, all these need to be considered alongside the output requirements of the employer. In the nuclear industry this includes the safe production of energy.

5.2 Knauth [27] said that when only a few nightshifts are worked such as one or two there is little disturbance to the circadian rhythm and that the realignment of physiological functions is more apparent the greater the number of consecutive nights worked. The realignment of physiological functions is supported by other research where permanent night workers were studied [28] but Knauth [27] quotes Folkard who challenges this theory by stating that that most people do not adjust very well but some may.

5.3 Three important factors in shift work are the speed with which the shift rotates, the orientation of that rotation and the length of time on shift. The shift rotation pattern can either be slow or rapid, the orientation can be forward or backward moving and the time on shift can vary but is normally 8 - 12 hours or a combination of those hours.

5.4 Rapidly rotating schedules have the advantage in that the circadian rhythm is kept to its day time synchronisation and has not had enough time to adjust or to desynchronise [27]. Consecutive night shifts can also lead to an accumulation of sleep deficit thus increasing fatigue and decreasing alertness. The third advantage of quick rotation is that socially the worker will have free evenings each week in order to undertake family and other social events as is our diurnal make up. However, the disadvantage of rapid rotation is that workers generally 'tough out' the night shifts and experience increased fatigue during their shift and a decrement in performance [29]. In contrast slowly rotating shifts over 3 to 4 weeks allow physiological synchronisation and adaptation to the new routines and as a result performance is more consistent [29].

5.5 The orientation of the way the shift rotates is important in assisting the realignment of the circadian clock. When a shift change occurs the employee is required to change his activity/rest cycle. These changes affect the circadian clock and hence have an adverse effect on alertness, fatigue and work effectiveness. In fact because of the similarity of the effects between shift changes and jet lag induced by flying across different time zones Kogi [30] refers to these effects as 'shiftlag'. Forward rotating shifts take advantage of the body's 'advancing clock' in that it is easier to adjust to a longer day and to delay going to bed for 3-4 hours. However, to reverse the shift rotation ie days-nights-evenings is like flying from west to east and to be in perpetual 'jetlag' [31].
5.6 Duration of shift is as controversial as shift rotation. Many studies have been carried out to examine the effects of 8 hour and 12 hour shifts but the overall opinion is that long days and shift overtime should be discouraged [2]. The effects of alternating 8 and 12 hour shifts within a shift system on sleep and performance have been reported by Axelsson [32]. The aim of the study was to look at the effects of 12 hour shifts at the weekends with 8 hour shifts on the weekdays. This is a similar pattern to that of the health physics group naval staff who carry out this type of schedule. However, the similarity ends there as Axelsson's study limits the number of 12 hour shifts to six and the number of weekends worked to two in six. This is to minimise the risk of accumulated fatigue. Whereas the naval personnel in this study work four weekends in six and twelve 12 hour shifts in six weeks. Axelsson concluded that 12 hour shifts do not cause increased sleepiness or decreased performance or disturbed sleep when compared to 8 hour shifts. He based this conclusion on the fact that the differences he found in sleepiness between the shifts was related to the difference in sleep length for the morning shift and to differences in physical effort at work for the night shift. Workers tend to prefer 12 hour shift cycles as this tends to lead to less time at work in days and permits more social and family life during the time off work. Whilst this generally promotes the well being of employees and their general lifestyle there are considerations relating to the 12 hour shift that some of the hazardous industries need to consider. Mitchell [33] states that whilst the general well being of the worker may be markedly improved with a 12 hour shift system there are an increased number of work related errors toward the end of the shift. This suggests that 12 hour shifts are valid for some industries but need careful consideration before their introduction. Smith and Folkard [34] support the notion of improved employee well being but again call into question issues of fatigue and safety associated with long working hours. This is again consistent with the findings of Tucker's research [35].

5.7 Lowden [36] challenged the theory that 12 hour shifts affect alertness and subsequently safety at work in a study where workers changed from 8 to 12 hour shifts. Lowden found all the benefits experienced by the workforce such as well being, more time off work, less non work fatigue to be consistent with the general hypothesis and findings of previous research. However, it was discovered that the quick change over to 8 hour schedules exacerbated sleep problems and fatigue and these were alleviated by the 12 hour shifts. It was also noted that the alertness levels went up on the 12 hour shift system but were still less than those of their day time colleagues. There was no marked difference in the 2 shift cycles for risk perception and reaction time performance.

6 Age and Shiftwork Experience

6.1 As people get older their sleep requirements and patterns change. Part of these changes in sleep patterns is reflected in an increased dissatisfaction with the quality of sleep. Two major influences on sleep satisfaction are living and working conditions. An in-depth study into shiftwork, age and sleep was carried out by Marquié and Foret [37]. Shiftworkers reported more problems with falling asleep and early awakening than non shiftworkers. However, the study did not support the hypothesis that shiftwork has a permanent effect on sleep. Age resulted in a continuous frequency of sleep disturbances peaking at age 52 for both never and past shiftworkers. The age score for sleep disturbances for current shiftworkers was 42 but subsequently this declined steadily.

6.6 The study also supported the hypothesis of a self selection process that excludes workers who are no longer able to cope with the demands of shiftwork. Colquorn et al [38] reported that about a fifth of workers leave shiftwork due to an inability to tolerate the schedules and only a tenth positively enjoy it, with the remainder tolerating the disbenefits and upsets of changing work times.
7 Objective

7.1 The primary objective of this study was to explore the general work related effects of shiftwork upon health physics monitors responsible for radiation protection duties within a nuclear maintenance environment. This was supported by the following aims:

a. To focus on within and between shift differences in reductions in sleep length associated with shiftwork and the changes in sleep as a function of shift and age.

b. To report the changes in fatigue and energy levels associated with shiftwork and the changes in energy levels as a function of shiftwork and shift type.

c. To assess the within and between shift alert levels of shift workers and to identify the changes in alertness as a function of shift type and shift work.

d. To assess the susceptibility of shift workers to work related errors.

8 Materials and Methodology

8.1 Twenty-one workers from the health physics group aged 22 - 59 years (mean age - 36.76. SD 11.07) with a mean length of employment of 13.7 years (SD 13.15) and a mean length of 2.55 years (SD 1.59) in the current shift schedule have been investigated. The workforce is a mixture of serving Royal Navy personnel (n=14) and Ministry of Defence civil servants (n=7). Of these 6 RN personnel are employed in daytime office routines, and 8 RN personnel are in shiftwork. One MOD worker is employed in daytime office routines and 6 are employed in shiftwork. The office routines are a standard 5 day Monday to Friday working week starting at 0800 hours and finishing at 1630 hours. The shift schedules are split between RN and MOD staff. For the RN personnel each 24 hour workday Monday - Thursday is divided into three 8 hour work periods and Friday - Sunday is divided into two 12 hour periods. The day shift is 0800 -1600 hours, the afternoon/evening shift is 1600-2359 hours and the night shift is 2359-0800 hours, Monday - Thursday. The weekend 12 hour shifts are divided as 0800-2000 hours and 2000-0800 hours. The RN personnel are divided into 4 shift teams. A full shift cycle lasts 8 weeks and consists of 2 weeks of each day, afternoon and night shift. The final 2 weeks is shift leave. The MOD staff work a standard shift pattern of day, afternoon/evening and night, starting at 0600-1400 hours for days, 1400-2200 hours for the afternoon and 2200-0600 hours for the night shift.

9 Surveys

9.1 Five different types of survey were carried out. Fatigue Questionnaire - Office Day Workers, Shiftwork Fatigue General Questionnaire, Shiftwork Fatigue Questionnaire - Weekend Shift, Shiftwork Fatigue Questionnaire - Nightshift and a Symbol Digit Test.

Fatigue Questionnaire

This was used to gather the basic information about the office staff and their job characteristics. The information included living and travel to work arrangements, work load and sleep behaviour and fatigue evaluation.
Shiftwork Fatigue Questionnaire Weekend and Shiftwork Fatigue Questionnaire Nights

These were developed to measure the alertness levels of two particular shift schedules based upon items in the Survey of Shiftworker questionnaire (SOS) [39] and previous work by Folkard [9] using similar methods. The perceived alertness ratings of the night and weekend shifts were recorded at 2 hourly intervals from the start of the shift to the end by the shiftworker on a five point Likert Scale. The scale ranged from very sleepy to very alert with higher scores indicating a higher alert rating.

Symbol Digit Tests

The Symbol Digit Modalities Test (SDMT) was developed as a measure for screening cerebral dysfunction in adults and children [40]. In particular it is dependent on the ability to control attention. It involves the conversion of meaningless geometric designs into written number responses. Written responses are simple but are the end result of the integration of many neurophysiological processes underlying visual, motor and mental functions.

Scoring for the SDMT is corrected for age and education using the Symbol Digit Modalities Manual. Scores were recorded for this study as high, normal or low. Normal was within 1 SD for the age and education range, high was greater than 1 SD and low less than 1 SD. This is in line with the suggested interpretation of adult scores in the manual.

The SDMT is normally scored in terms of correct answers within the specified test time. However, in an attempt to assess whether this test is useful in assessing the number of mistakes shiftworkers make compared to their day time colleagues the number of incorrect responses was also recorded.

The SDMT was administered 3 times per week on the same day and at the same time. The first test of each week was 1000 hours on a Monday. This captured data from the office day workers and the RN and MOD shiftworkers on day shift. The second time was 1800 hours on the Monday, which captured from the evening RN and MOD shift. The last test was 1000 hours on a Friday, capturing data from the office day workers at the end of their working week and the dayshift RN and MOD workers at the beginning of their weekend shift. This design was chosen because between shift differences can be detected as can difference between day and shift workers.

10 Analysis

10.1 The data were analysed using analysis of variance (ANOVA) using the Statistics for Social Sciences (SPSS) software package. The repeated measure design allowed a full analysis of the affects of the shift schedule. The criteria for statistical significance was set at p <0.05, but lower p levels are recorded. All post hoc analysis were carried out using the Scheffé test.

11 DISCUSSION

11.1 The general biographical data collected revealed that there was a significant age difference between the job categories with the MOD shiftworkers being older than the other shift and day work study groups (p <0.001, 0.002 respectively). When humans get older their sleep patterns change and this may make it difficult to tolerate the demands of sleep disruption caused by shiftwork [37] [41]. There is also a hypothesis of self-selection for shiftwork [10] [24] [33] and age may play a crucial evidential role in this. It is quite probable that people with a preference or adaptability to shiftwork will be older than those with difficulties who will have left shiftwork at earlier opportunities especially those that have a poorer sleep structure and whose sleep quality is affected by variable work schedules.
11.2 Shiftwork experience differences in the years involved in shiftwork and the current shift system studied were very significant (p <0.001) in favour of MOD shiftworkers who had a mean experience of 26 years compared to the RN who only had 3.2 years. It is also worth noting that the RN workforce is transient and generally only remains in one type of employment for about two years before moving on to another ship or establishment. Therefore, it is not surprising that the length of time in the current shift system was significantly in the favour of the MOD workers. The MOD shiftworkers have a mean time in shiftwork of 26 years, which is the majority of their adult working life. This in terms of their mean age and the 'self selection' theory may indicate a tolerance to shiftwork among this study group.

11.3 There was no difference between the perceived work load during the day for the occupation groups and job categories (p 0.07). However, there were differences between the day/evening, day/night and evening/night shifts (p 0.018, 0.001, 0.005 respectively). Shiftworkers considered the day shift to be the busiest and the night shift the lightest indicating that the majority of work is carried out during the day and supports the general opinion [10] of lighter work at night and the potential for more boredom to set in [9]. Industrial studies of the consequences of boredom at work have provided evidence suggesting an increase in errors over long work periods [9].

11.4 The shift system studied is in essence two systems running in parallel; one for the MOD staff and the other for the RN shiftworkers. There were significant differences between the RN and MOD work hours for day, evening and night (all p <0.001). During the evening and night shift the RN personnel work a 68 hour week compared to 38 - 40 hours for their MOD work colleagues. This is offset slightly during the day shift, which is 32 hours per week for the RN compared to 38.75 for the MOD shiftworkers. The RN shiftworkers work 336 hours during their 8 week cycle, using the formula in the European Working Time Directive [42] gives a mean working week of 42 hours. This is still less than the UK average of 44.7 working hours a week [43]. However, when the work hours are averaged for the six week working period of the shift schedules the real mean is 51 hours per week. The extended evening and night shift working weeks are concerning, particularly as two of the RN shifts work evenings and nights back to back giving 21 continuous working days totalling 204 hours. As well as shift work, fatigue is associated more with hours worked and in some cases this can be a prominent cause of chronic tiredness [37]. Therefore, there is a risk of chronic tiredness for the RN shift workers and a greater risk with half of the RN shiftworkers. Despite these long hours there was no difference between duration since the last rest day between the two shift teams. This seems to indicate that the MOD workers undertook more overtime than normal during this study period and hence themselves became susceptible to chronic tiredness as a result of long hours. The general results for sleep patterns and disruption for the shift workers generally support the findings of other research into this area.

11.5 There was no difference in the results for a pre-disposition to morningness in the study subjects but there was a difference between the office staff and MOD shiftworkers (p 0.042) in that the MOD workers felt more tired earlier in the evening. This does not fully support research that people aged over 47 move toward morningness [41] but there is an indication of chronic tiredness in the MOD workers in respect to the early evening tiredness results.
11.6 The mean reported sleep lengths for the shiftworkers was familiar to another study carried out on firefighters using a similar shift pattern [7]. Although there was some variability in the sleep length the pattern of results were familiar. The night shift sleep length reported the shortest sleep lengths for the shiftworkers. Although the evening shift reported the longest sleep length there was no significant difference between the mean day and evening shifts. This supports the general hypothesis that shiftworkers enjoy longer sleep lengths when on the evening shift and the least when on the night shift [7] [18]. Within shift analysis reported that the MOD shift workers had significantly shorter sleep lengths than both their RN shift colleagues and office workers during the day shift (p 0.006, 0.004). The MOD shiftworkers start at 0600 hours and the RN and office workers start later at 0800 hours thus enabling a longer night sleep for the RN personnel. There is also no statistical difference between the RN day shift and office workers (p 0.997). Therefore the difference in sleep length is probably due to the work start time [24].

11.7 Within shift analysis of the RN and MOD shiftworkers revealed no significant differences of difficulty when adjusting sleep routines to changing shift patterns, except when the change is from night shift to rest days (p 0.04). However, the results do consistently report less difficulty to adjusting sleep for the MOD shift workers overall. Previous research has shown that shiftworkers of the MOD mean age group report more sleep difficulties than the RN age group [37]. Therefore, their sleep pattern results in terms of changing shift cycles should show less tolerance to disruption than the younger RN shiftworkers. This demonstration of adaptability to alter sleep patterns by the MOD shiftworkers further supports the claim of a self selection process for shiftworkers. The greater degree of difficulty that the RN demonstrate over the MOD shiftworkers is further compounded by their long nightshift cycle. It takes up to 2 weeks to adjust the biological clock to realign the circadian rhythms to new exogenous clues. The RN night shift is 14 days long and allows for a change in the circadian rhythm to develop. Thereby, by the end of the shift cycle the RN workers circadian rhythms have adjusted to their new environment making it difficult to adjust to a 'normal' sleep pattern.

11.9 Mean shift differences reported for the quality of sleep were not significant when examined between shift cycles and RN and MOD shiftworkers. According to age and shiftwork sleep research by Marquie and Foret [37] the MOD shiftworkers should have reported more problems than RN shiftworkers. There was, however, a significant difference between the MOD workers and the office workers p 0.036). The difference was probably because of the earlier start time for the MOD shiftworkers over the office staff and hence a reflection of their shorter sleep length the night before as previously reported. The RN shift and office workers have the same day time start time of 0800 and no significant difference is reported between these two groups for the same period thereby further supporting the previous statement. Office staff with the normal Monday to Friday 0800 hours to 1630 hours report the best quality sleep with a steady decline in quality through RN shiftworkers to the MOD shiftworkers. The mean results for sleep quality and age follow a slight increase in quality between ages 32-42 and a larger increase to age 52 but a drop off again in quality to age 62. Previous research [37] reported the peak age band reporting the most problems associated with sleep quality for shiftworkers is 32-52 with an increase in quality at 42-52. However, this increase in sleep quality peaking at 52 is still less than the sleep quality reported at age 32. This trend is not supported in this study, in the terms of sleep quality increasing from age 32 and peaking at 52 years. Sleep quality is the least for the MOD workers as an occupational group and due to the age differences would indicate that the quality of sleep is also age related to the MOD workers. Age banding the results proves this not to be the case. Therefore, the drop off in quality for the MOD workers is as a function of shiftwork.
11.10 Although the differences for sleep quality were not statistically significant there was a visible association between shift cycle, sleep quality and sleep length. The evening shift reports the longest sleep length and the best sleep quality, whereas the night shift reports the shortest sleep length and the poorest sleep quality.

11.11 The mean shift fatigueness reported significant differences between shift cycles for the day and evening shift (p 0.007) and the evening and night shift (p 0.002) with the evening shift reporting a lower fatigue rating in each case. There were no significance within shift differences although the RN night shift did report a greater problem with fatigue than the MOD workers, as did the MOD for the day shift over their RN colleagues. The RN reported fatigue differences for the night shift were probably as a result of the length of the shift cycle [37]. The difference in fatigue levels for MOD day shift workers is as a result to their early morning start and less reported sleep than their RN colleagues [24].

11.12 The study also revealed significant differences between the mean shift alertness for the weekend day and night shifts. The mean night shift alertness was significantly lower than the average day shift (95% CI -0.412, -0.639 p <0.001) and the mean 24 hour shift alertness dropped off significantly between midnight and 0600 (t 9.19, df 26, p <0.001). Significant mean alertness level differences were reported between the MOD and RN shift workers on 21 occasions over the study period from a total of 126 comparisons.

11.13 Perceived on shift alertness level unsurprisingly showed the night shift to be worse than the day shift. This was keeping in with other research into shiftwork and the night shift [4] [9] [34]. Significant mean alertness differences between the RN and MOD shiftworkers were reported throughout the study but became more prominent during the second week of the RN nightshift cycle. The minimum alertness rating required showing an acceptable level of alertness was 3 (from a five point Likert scale). Only 54% of the mean results met this figure. The peak alertness ratings are around 1400 hours on the Friday and Saturday and do not drop to levels of concern until 2200 hours and 2400 hours respectively during the night shift cycle. However on the third day of 12 hour shifts by 1600 hours the alert levels are dropping off and remain close to level 3 before rising at midnight and then dropping off through the night. Week two studies report similar results.

11.14 The differences in the RN alertness levels falling off so dramatically against the MOD scores for the second week of the night shift is probably related to the length of shift and hours worked and a result of chronic tiredness at the end of a long cycle. The final day of the two week night shift period is the last day of the RN cycle and the first day of the MOD cycle. This is also the worst shift for alertness ratings with no scores passing the minimum acceptable level between 2200 hours and 0800 hours. This is probably caused by fatigue and increased sleepiness in the RN shift and first night 'toughing it out' by the MOD shift. Both of these factors contribute to an area of great concern and the potential lack of suitable cover to support ongoing operations.

11.15 A reliable marker of the biological clock activity is the rhythm of melatonin and research has shown that with an increase in melatonin there is a decrease in alertness [1]. Plotting the mean 24 hour shift alertness scores over the melatonin rhythm [1] it can be seen in Figure 1 the drop off in alertness is related to the increase in melatonin concentration. Therefore, this study supports the hypothesis and previous research data that the circadian rhythms have an effect on the ability to sustain alertness during hours of work that are in conflict with the body's natural biological clock. The RN shift work contribution to the mean alertness levels were from 12 hour shifts and the increase in alertness at 2200 is in keeping in with another study that examined alertness in 12 hour shifts [14].
The results of the SDMT were examined between the office and shift workers as the occupational groups and again between the office, day and evening shift job categories. When corrected for age and education the office day workers scored higher than their day shift counterparts (95% CI -0.65, -0.09, p 0.005) but there was no difference in the evening shift workers and the other study populations. The higher office scores over the day shift workers would indicate a greater level of alertness and is in keeping with the earlier findings of the day shift experiencing greater sleep problems than the office workers. It has been shown that activity and stimulus [20] can influence these tests by increasing the arousal response. This would be for the same in both of the study groups and is therefore a consistent variable.

Errors in the SDMT recorded a 62% greater mean mistake rate for shiftworkers over the office workers. Although statistical analysis failed to prove a definitive link between shift work and error rates a trend is indicated in the results. Office workers have the best corrected SDMT score and the lowest error rate. Of the day and evening shift study groups the day shift have greater error rate and the lower SDMT score. The error scores are consistent with the corrected scores by shift and indicate a proneness to errors in shift.

Errors in work can be ascribed to task error and work practice, both of which are affected by fatigue and alertness. It has been shown that the night and weekend shifts are prone to a significant drop off in alertness levels and the results for fatigue have proven that the day and night shifts suffer from sleep loss contributing toward chronic tiredness.

Time at work prior to undertaking the SDMT was not significant (p 0.367) for the number of errors but was for the corrected score (p 0.006). Time at work has been shown to be an important factor for accident rates at work [4]. The office workers were at work for 2 hours prior to taking the SDMT and the shift workers mean was 3 hours. Research into accidents at work has shown very little difference between 2-3 hours at work for an increase in accident rates, therefore, it is not unexpected to find no statistical evidence to support an increase in errors in the SDMT. However, accident rates are also a function of time of day [4]. Research into road accidents caused by fatigue show peak accident rates at 0200, 0600 and 1600 hours [44]. 1600 hours is the toward the end of the normal working day for most people and it is the initial increase in melatonin levels and 0200 and 0600 hours are during the peak excretion and concentration periods of the hormone.
12 Conclusion

12.1 The main aim of this study was to explore the general work related effects of shiftwork upon the health physics monitors. The work related effects of shiftwork were demonstrated through the study aims of sleep behaviour, fatigue, alertness and susceptibility to work errors. The results confirm that the health physics shift workers suffer much the same sleep deprivation problems as other shiftworkers and particularly so in the night shift.

12.2 Sleep disruption and long working hours have indicated chronic tiredness to be a problem with the RN shiftworkers. Alertness decreased dramatically on the night shift and in some cases to dangerously low levels that should be of great concern. The long night shift schedule should allow complete resynchronisation of the circadian rhythms but this was not clearly demonstrated in the study results in the terms of alertness levels. Any benefit gained by the length of the nightshift in terms of realignment and resynchronisation is probably eroded through the effects of chronic tiredness as the result of long working hours.

12.3 The study also showed that there are strong indications from the MOD shiftworkers that they are 'self selected' shiftworkers and support the hypothesis of an affinity to shiftwork. Although, they themselves are not without problems. They also show signs of fatigue and a drop off in alertness during the weekend and night shift schedules. The MOD day shift demonstrated problems with fatigue which is probably associated with short sleep lengths and poor sleep quality during this period of the shift schedule.

12.4 The drop off in alertness in the night shift has been shown to be associated with circadian rhythms and there were long periods of the nightshift where both the RN and MOD shiftworkers fell below the minimum alertness level in the study design. Although alertness can be stimulated through arousal it is unclear as to how long and what overall effect this arousal has, therefore these low levels should be of concern. Statistically susceptibility to work related errors was less obvious using the SDMT. However, by comparing the chronic tiredness, alertness and sleepiness results from this study to other research material there is an indication that the shiftworkers in this study group may be more susceptible to work errors and accidents than their day working office colleagues. This study group presents with the normal shift problems but in some cases are greater than expected and hence present a potential additional risk factor in radiological safety.

13 Post Study Note

13.1 Since this study was completed and reported upon more staff have been recruited into the department and the shift pattern has been changed. The new shift system is still based upon an 8 hour working day and forward rotating but is over a five week period with longer rest days between cycles. The start time for the day shift is now 0730 as opposed to 0600 and the length of the night shift is restricted to seven nights. There are no longer 12 hour shift patterns in the cycle.

13.2 Although a follow up study is yet to be completed anecdotal evidence from work related accident and work related errors, through the event reporting system, indicate a drop in the evening and night shift incidents. There has been an increase in the day time errors but equally there has been an increase in staff and the volume of work has also increased.
# REFERENCES


5. *Ionising Radiations Regulations 1999 Approved Code of Practice and Guidance*.


