The effects of Booster Breaks during a sedentary night shift on physiological, psychomotor, psycho-physiological, and cognitive performance over a 3 night shift habituation phase

BY

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THESIS

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ABSTRACT

Despite extensive research into shift work, workers working under rotating shift conditions are still plagued by the effects of the desynchronisation resulting from working against their natural circadian rhythms. Additionally, modern industries are shifting towards tasks requiring greater cognitive demand with less manual labour incorporated into the tasks. Research into operator based tasks, and hence those of a sedentary cognitive base both during day and night shifts, has been focusing on the effectiveness of the standard rest/break schedule. Research indicating that the standard rest break schedule is often ineffective in eliminating operator discomfort and performance deterioration, with these affects argued to be more pronounced during a night shift schedule

Therefore current research set out to investigate alternative rest break schedules, incorporating a short bout of physical activity and stretching exercises which are proposed to enhance performance and subjective mood, while eliminating operator discomfort for sedentary based cognitive tasks. Three conditions were tested during a three day habituation shift cycle within a laboratory, incorporating two night shift groups (control and experimental) and a control day shift group. Twelve subjects made up each group, with the two night shift groups completing the shift schedule together. The control groups followed a typical 8 hour shift schedule while the experimental group performed a booster break (exercise and stretches) activity for 7.5 minutes every hour during the night shift schedule. Over the course of the shift, subjects completed a battery of six tests providing data on physiological measurements (heart rate and temperature), performance criteria (reaction time responses, memory and neurobiological) and subjective measures.

Responses obtained for all the different parameters measured indicated a strong circadian influence for the majority of the variables, indicating the course of natural down regulation within physiological and performance criteria over the night shift. The booster break significantly improved reaction time performance, subjective ratings and

resulted in a high sustainable activity level. Day shift comparisons indicating that within subjective measures and reaction time performance, the booster break resulted in similar responses to those of the day shift workers, while the control night shift groups reported significantly lowers results. Additionally, the booster break had positive influences during the circadian nadir, significantly improving parameters of performance and subjective ratings of sleepiness.

The results of this study indicating which variables are strong predictors and indicators of the oscillations in performance and subjective ratings due to the circadian changes. The booster break interventions had positive effects on subjective ratings and reaction time performance, while also being argued to decrease the burden placed on the cardiac system as a result of increased sympathetic tone during the night shift, while additionally resulting in similar responses to those of day shift workers. Further studies are required, however, to provide conclusive evidence particularly within a working situation over a longer shift schedule.

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CHAPTER I

INTRODUCTION

BACKGROUND TO THE STUDY

While 24-hour operations have long been a part of emergency occupations, the need for continuous around the clock production and operations has increased dramatically within a range of industries. Shift work and night work have become inevitable within today's global expanding market, and this augmented 24-hour demand has led to the escalation in research geared at improving both on the job performance and off the job recovery. While no best fit solution is possible, a best cause solution comes in the form of assessing methods to increase adaptation to shift work and decrease the extent of the negative consequences potentially imposed on the worker as a result of the desynchronisation. Advances in modern technology have brought about a shift in task requirements, moving towards increased automation within previously high manual materials handling jobs, thus changing the nature and requirements of many tasks. With that workers are now being exposed to more sedentary based tasks with increased cognitive and psychomotor requirements.

It has been well reported and documented that shift work, and in particular the night shift components have undesirable effects on many workers, the result of which being due to the fact that humankind has evolved as a diurnal species that is habitually active during the daylight hours and sleeping at night (Folkard, 1992). According to Costa (2005), shift and night work are conditions that challenge the human adaptability to temporal changes both from the biological and social perspectives. With reference to the adverse effects, night work has been documented to have unfavourable impacts on health, as it interferes with 'physical, mental and social wellbeing', perturbing the psychophysical homeostasis (circadian rhythms, sleeping and eating hours), decreasing vigilance and performance (errors, accidents), hampering family and social relations, and being a recognised risk factor for gastrointestinal, psychoneurotic and cardiovascular disorders (Atkinson and Devenne, 2007; Costa, 2005; Costa and Sartori, 2007; Folkard and Tucker, 2003; Loudoun, 2008).

In addition to the adverse health effects of shift work, researchers hypothesise that undesirable eating habits, increased caffeine intake, and lack of physical activity, further exacerbate the already problematic situation (Åkerstedt **et al**., 1984 and Ludovic **et al**., 2001). Furthermore, many employers do not take special consideration as to the design or redesign of rest breaks during the night shift, resulting in rest breaks not being fully effective in eliminating operator discomfort and performance deterioration (Douwes **et al**., 1994 and Zwahlen **et al**., 1984), which are often pronounced during the night shift and now further compounded by the higher cognitive, sedentary working tasks of the modern industry.

Research attempting to alleviate the negative effects of shift work is primarily focused on costly intervention strategies aimed at enhancing adaptation through the use of drugs or exposure to timed bright light (Claustrat **et al**., 1995; Lewy **et al**., 1996; Sharkey and Eastman, 2002). The speed and direction of shift rotation and the length of the shift cycle have been the focus of researchers for many years (Barton **et al**., 1995 Knauth, 1996), assessing variation of direction and speed of shift cycles in combination with exposure to drugs and/or lighting. Both methods, while providing valuable information, are often impractical requiring extensive resources to implement and maintain, with workers expected to follow set guidelines outside of the working environment.

A less researched area is that surrounding the scheduling of rest/activity breaks during shift and night work, with particular reference to the more sedentary operator based working tasks which predominate within many work settings today. Tasks involving high physical demands often require breaks during which time the worker can recuperate from the physiological and biomechanical strain being placed on them during task completion. With increased automation leading to increased cognitive demands and sedentary activity, careful consideration needs to be taken when considering both the frequency and duration of rest breaks and additionally the activity performed during said rest breaks.

While standard shift schedules might offer longer rest periods and longer periods of continuous production time, they pose the threat of workers waiting until they experience musculoskeletal discomfort or cognitive fatigue before taking a forced rest break (Henning **et al**., 1997). A night shift laboratory study performed by Tucker (2003) indicated that even small changes in the activity/rest schedule may imply large changes in physiological and psychological responses and that fatigue and performance can benefit from shorter more frequent rest breaks. Neri **et al** (2005) reported hourly 7 minute breaks during a night flight to be an effective means of temporarily counteracting declines in physiological and subjective measures of arousal and fatigue.

In addition to increasing the frequency of rest breaks, the activities performed during the rest breaks is of concern during high cognitive, sedentary based tasks. Balci and Aghazadeh, 2004 and Henning **et al** (1997) found that physical activity incorporated into the breaks increases productivity growth, discomfort reduction and improves worker well-being. Taylor (2005) developed the Booster Break which entails a simple combination of stretchers and exercise for an approximate duration of 7.5 minutes, to be performed every hour during the shift cycle. Numerous authors have proposed similar designs for alternative break schedules (Balci and Aghazadeh, 2004; Henning **et al**., 1997; and Tucker, 2003) all proposing to increase vigilance and mood, and decrease fatigue levels and musculoskeletal strain associated with prolonged office and sedentary work.

Numerous studies have assessed the influence of lighting, napping and stimulates such as caffeine on performance, subjective mood and cognitive functioning across a shift. Minimal research appears to have however, examined the effects of altering the work/rest schedule during the night shift while incorporating light physical exercise into the break periods.

The study set out to assess the impact of hourly 7.5 minute booster breaks during a 3 night habituation shift cycle against a standard night and day shift schedule. In an attempt to avoid the possibility of dissimilar working conditions between the day and night shifts, both conditions were undertaken within a controlled laboratory setting wherein the physical and social environmental factors could be rigorously controlled and standardised. This permitted a valid comparison of results between the day shift and both conditions comprising the night shift.

The present study examined psychomotor performance criteria, physiological and psychophysiological responses, and cognitive and performance parameters over 3 conditions. The design consisted for a 3-way independent sample group, with each subject completing a battery of 6 tests over the course of each shift cycle. The battery of tests were administered at predefined intervals over the course of the 8 hour shift, this was to provide information regarding the changes in response across the course of the shift.

This study employed an inter-disciplinary approach of a simulated working environment in an attempt to identify trends in measures and potential areas associated with night work. The results might prove valuable in terms of subsequent development of ergonomic intervention strategies designed to minimise the conflict between aberrant work hours and the diurnal nature of man, and to ultimately optimise working performance within highly sedentary and cognitive demanding working environments. Additionally, the interventions secondary motive is to increase physical activity levels of predominantly sedentary individuals and highlight the benefit of even light physical activity.

STATEMENT OF THE PROBLEM

Shiftwork is invertible within today's globally expanding market, with an ever increasing demand for longer hours and higher production. Over the course of the last few years there has been a growing shift towards increased automation, moving from jobs requiring high physical demands to those of sedentary, high cognitive requirements. Additive to the already well documented problems associated with shift work, is the decreased physical activity levels and increase obesity rates facing a larger portion of the population every year. A variety of performance and subjective measures are known to be driven and influenced by the circadian rhythm, and hence are adversely affected by the down-regulation of the circadian system and its desynchronisation during night shift work. Following this is a known decrement in performance, subjective feelings and physiological characteristics. Methods geared at enhancing on-the-job performance and subjective feelings need to be devised, particularly those geared towards higher cognitive-sedentary office based tasks. The proposed intervention is that of a regularly repeated booster exercise break performed during the night shift which is hypothesised to enhance performance measures, subjective mood and decrease the extent of the down-regulation of the circadian system.

Thus the present study included a condition incorporating hourly 7.5 minute physical activity breaks into the night shift to contrast the adverse effects associated with night work. The intervention incorporated a simple set of stretches and aerobic stepping moves, which are designed for large group participation and ideal of *in situ* environments. The subject group was divided into three groups, namely the control day shift, the control night shift and the experimental night shift group (performing the booster break), all of whom were exposed to the same working and environmental conditions, as well as the same battery of tests

RESEARCH HYPOTHESIS

By conducting a simulated shift work study focusing on the effects on hourly booster breaks during the night shift cycles, it was expected that the proposed intervention strategy would result in reduced negative subjective feelings, enhanced performance and decrease the adverse effects associated with the down-regulation of the circadian rhythm during night shift work.

Additionally, it was expected that the intervention would increased adaptation to night shift work as measured through the performance criteria and physiological responses over the course of the three night shift cycles.

STATISTICAL HYPOTHESIS

The battery of tests incorporated four group variables, namely physiological responses (Heart rate and heart rate variability, and tympanic and skin temperature), psychomotor performance (Simple reaction time, high and low precision reaction time, saccade latency, and critical flicker fusion frequency), psychophysiological measures or subjective mood profiles (Wits and Karolinska sleepiness scales), and cognitive performance (Probed memory recall). Additionally an inter-break performance measures was recorded as weight of beads produced between each test battery (beading performance).

The statistical hypotheses were framed around three statistical analyses. The first analysis was a 3-way ANOVA incorporating the four primary tests batteries occurring during the 8 hours working shift comparing the controlled night shift to that of the experimental group, and hence providing a statistical analysis of the overall effect of the condition over the course of the three night habituation phase. The second analysis assessed the final day effect by comparing the data between the two conditions over the third shift. The third analyses dealt with the end of shift effect, taking into account the test battery that occurred between 04h15 and 05h00 to evaluate the final effect the condition had over the course of the three shifts.

The various tests of the above expectation, that the proposed intervention would improve performance and subjective measures and decrease the adverse effects associated with the down-regulation of the circadian system, were framed in the following null hypotheses.

1. Over the course of the three night shift habituation phase, the measures criteria would remain the same for the controlled night shift and the experimental night shift groups. The hypothesis addresses the four group tested variables.

   a) H_o: $\mu GTV_{Control} = \mu GTV_{Experimental}$

      H_a: $\mu GTV_{Control} \neq \mu GTV_{Experimental}$

Where:

- GVT = the group test variables - physiological responses, psychomotor performance, psychophysiological measures or subjective sleepiness profiles, and cognitive performance
- Control = controlled night shift
- Experimental = experimental group exposed to booster break

2. The null hypothesis states that the control group and experimental group would respond and produce the same measures during the third night of the three night habituation phase. The hypothesis addresses the four group tested variables.

a) H_o: $\mu GTV_{Control} = \mu GTV_{Experimental}$

H_a: $\mu GTV_{Control} \neq \mu GTV_{Experimental}$

Where:

- GVT = the group test variables - physiological responses, psychomotor performance, psychophysiological measures or subjective sleepiness profiles, and cognitive performance
- Control = controlled night shift
- Experimental = experimental group exposed to booster break

3. Over the course of the 3 shift cycle, the circadian effect would remain the same for the final (fourth) early morning test with there being no significant differences between the days (shifts) for the control night shift compared to the experimental night shift.

a) H_o: $\mu GTV_{Control}$ (T4 All days) $=$ $\mu GTV_{Experimental}$ (T4 All days)

H_a: $\mu GTV_{Control}$ (T4 All days) $\neq$ $\mu GTV_{Experimental}$ (T4 All days)

Where:

- GVT = the group test variables - physiological responses, psychomotor performance, psychophysiological measures or subjective sleepiness profiles, and cognitive performance
- Control = controlled night shift
- Experimental = experimental group exposed to booster break
- All days = Night 1, night 2 and night 3 of the shift schedule
- T4 = final test measure occurring between 04h15 & 05h00

DELIMITATIONS

The research sample group consisted of a student population, aged between 18 – 26 years of age. The pool of subjects comprised 36 subjects, half male and half females. Subjects completed the morningness-eveningness questionnaire providing information regarding chronotype. The permutation of subjects into three groups of twelve was controlled for by gender, chronotype and number of years at university. This was done to ensure an even distribution across the three different conditions, those being control night shift; control day shift (SDS) and experimental group exposed to the booster break intervention.

During the recruitment phase subjects were delimited based on the exclusion criteria of non smokers with no prior history of shift work, no sleep related disorders and no current consumption of alertness enhancing medication. Additionally subjects were required to be in good health and maintaining a regular sleep pattern of at least 7 to 8 hours of sleep a night.

The first phase of data collection involved a verbal explanation of the testing procedures, administrations of the Horne and Ostberg (1979) morningness-eveningness questionnaire, as well as written informed consent forms. Information of subject's age, mass and stature, and number of years of education were recorded at this stage.

The second phase occurred at the Biopharmaceutical research institute (BRI) laboratory where testing was to occur. During this phase subjects were familiarised with the laboratory and then a demonstration of the battery of tests was provided. Subject then had a chance to perform all tests which were to occurr during the data collection phase.

The experimental data collection phases ran in cycles of 3 nights, amounting to a total of 9 nights of testing followed by 3 days of testing. The night shift cycles began at 21h00 and ended at 07h00, with the day shift cycle starting at 07h00 and ending at 17h00. All shift cycles were performed within the BRI laboratory in an attempt to control conditions and ensure all subjects were exposed to the same condition throughout the duration of their shift cycle.

The night shift cycles incorporated both the controlled night shift group and the experimental groups running concurrently. The scheduling of breaks differed between the two conditions. The control gourp had one long 30 minute break at 01h45 and two shorter 15 minute breaks at 23h45 and 04h00. During the work breaks both the control groups of subjects retired to a recreational room where their activities were monitored. Subjects were not permitted to nap during breaks and were required to sit quietly and read or converse among themselves. For the experimental condition, subjects were exposed to hourly 7.5 minute booster intervention breaks. Subjects were exposed to a pre shift and post shift battery of tests, with four batteries of tests being administered at approximately 2 hours intervals throughout the night shift (see appendix B1). The day shift only consisted of one control conditions, with subjects being exposed to a standard scheduling of breaks (see appendix B2) and a similar design of battery of tests as during the nights shift design. Throughout the entire shift cycle a continuous measure of heart rate were obtained.

The nutrition provided to subjects during the breaks remained constant across all conditions, with subjects receiving no caffeinated and no alcoholic liquids. Subjects were provided with food during predetermined times, with the control groups having a break from work while they had their food and the experimental group remained working while eating their meal.

The tasks being performed during the inter-break and inter-testing periods were controlled with subjects required to pack 40 application packets per shift and subsequently perform a simple beading task. The task selection was designed to ensure minimal arousal effects to allow the natural circadian oscillation and effects of condition to be evident. The rate of beading was not prescribed but was used as an inter-test battery performance indicator. While subjects were free to converse they were required to remain seated and working when not on break or performing a test battery.

The experiment focused on the physiological, psychomotor, psychophysiological, cognitive, and, performance responses across 6 batteries of tests, assessing differences between SNS, SDS and BB conditions. Dependent variables were delimited to heart rate and heart rate variability, infrared emission detection of tympanic and skin temperature, simple reaction time tests, high and low precision tests, target deviation for high and low precision tests, saccade latency, critical flicker fusion frequency, Karolinska sleepiness and Wits sleepiness scales, positive and negative affects scale, and probed memory recall.

LIMITATIONS

When investigating physiological, psychomotor, psychophysiological and cognitive response across 3 independent sample groups it is impossible to control all impinging influences as there is such a broad network of causality with such a wide range of variables. Therefore, when examining the implications and subsequent conclusions from these experimental results, cognisance must be taken of the following limitations.

A relatively small sample size comprising 12 subjects per subject group (n = 36) was used in this research due to logistical restrictions. These entailed a limited time frame afforded for the use of the BRI laboratory, limiting the duration of each shift cycle and the number of subjects within each experimental group. The 3 day shift cycles, while providing valuable information on trends in performance, are potentially too short to provide indication of habitation effects or the extent of cumulative fatigue.

While all attempts were made to control subject day time activity during the night shift cycles, it was impossible to ensure subjects adhered to the guidelines provided and hence actions such as day time napping or caffeine ingestion might have influenced subject responses. The sleep diaries provided limited information regarding this, as validation of information was not possible.

While subjects were confined to the BRI laboratory for the duration of the 8 hour shift cycle in an effort to lessen the effect of extraneous variables, the differences between the day and night conditions could not be fully controlled. The ambient temperature differences might have influenced skin and tympanic temperature measures. In an attempt to alleviate the extent of extraneous variables influencing subjects during the night shifts, a cross over design was used with both controlled and intervention groups making up part of each 3 night shift cycle.

Subjects reported experiencing no major sleep problems and no prior knowledge of any sleep disorders. As the researchers had no means of testing for sleep disorders, the information provided by the subjects was taking at face value. Should any subject in fact suffer from a sleep disorder, their results potentially might not be a true representation of responses under either of the night shift conditions.

Period or cycle of the female subject's menstruation was not taken into account within the sample. It is a known factor to influence a range of circadian oscillators, however due to ethical reasons researchers did not enquire about phase of menstruation or stipulate restriction on subject participation surrounding this element.

The length of each shift constituted the need to provide subjects with a nutritional source (food), which the researchers were able to control, within means. In order to ensure subjects consumed similar meals, researchers provided all nutrition during the shift cycles. While efforts were made to ensure meals were of similar standards, the macronutrient composition of each meal could not be fully controlled. Additionally, varying dietary preferences meant not all meals were matched on a macro nutritional level which might have influenced glycemic index and thus indirectly, performance and mood. Furthermore, some subjects opted not to eat during the late night shift meals. A potential effect being subjects were not fully matched in regards to total nutritional intake which might have an effect on arousal, performance, and potentially mood. Additionally, it should be noted that had all dietary demands been matched across all conditions and subjects, the potential still exists for different response between subjects with regards to mood, performance and arousal due to the diet.

CHAPTER II

REVIEW OF LITERATURE

INTRODUCTION

According to Hennig **et al** (1997) shiftwork has become an essential component of daily life in the modern societies, with the need for 24-hour essential services requiring many of the work force to reverse their normal diurnal sleep/wake schedules (Santhi **et al**., 2005). Numerous forms of shift work exist, with a variety of definitions and understandings. Costa (2003) broadly defines shift work as scheduled work that is completed outside the parameters of the traditional day shift, with the research within the shift work area generally focusing on the night component.

Night work, while potentially valuable and often essential within a range of industries, exacts a substantial cost in terms of health and degraded performance (Santhi **et al**., 2005). It has been well reported and documented that shift work, and in particular the night shift components have undesirable effects on many workers, due to the fact that humankind has evolved as a diurnal species that is habitually active during the daylight hours and sleeping at night (Folkard, 1992). According to Costa (2005), shift and night work are conditions that challenge the human adaptability to temporal changes both from the biological and social perspectives. With reference to the adverse effects, night work has been documented to have unfavourable impacts on health as it interferes with ‘physical, mental and social wellbeing’, perturbing the psychophysical homeostasis (circadian rhythms, sleeping and eating hours), decreasing vigilance and performance (errors, accidents), hampering family and social relations, and being a recognised risk factor for gastrointestinal, psychoneurotic and cardiovascular disorders (Atkinson and Devenne, 2007; Costa, 2005; Costa and Sartori, 2007; Folkard and Tucker, 2003; Loudoun and Allan, 2008).

ELEMENTS AND CHARACTERISTICS OF SHIFTWORK

The adverse effects associated with shift work and more specifically, night work upon the individual, are well documented and understood. Kostreva **et al**., (2002) points out that with the steady demand for shiftwork and the continuing evidence of difficulties experienced by its workers, much focus has been placed on designing shift systems that would minimise the adverse effects of shiftwork on human health and performance. Ultimately the adverse effects and mismatched schedules of workers results in decreased performance and has a negative consequence on the final output. As shift work and night work are inevitable, the best solution comes in the form of assessing methods to increase adaptation to enhance or maintain performance under standard conditions, without increasing the already inadequate working condition.

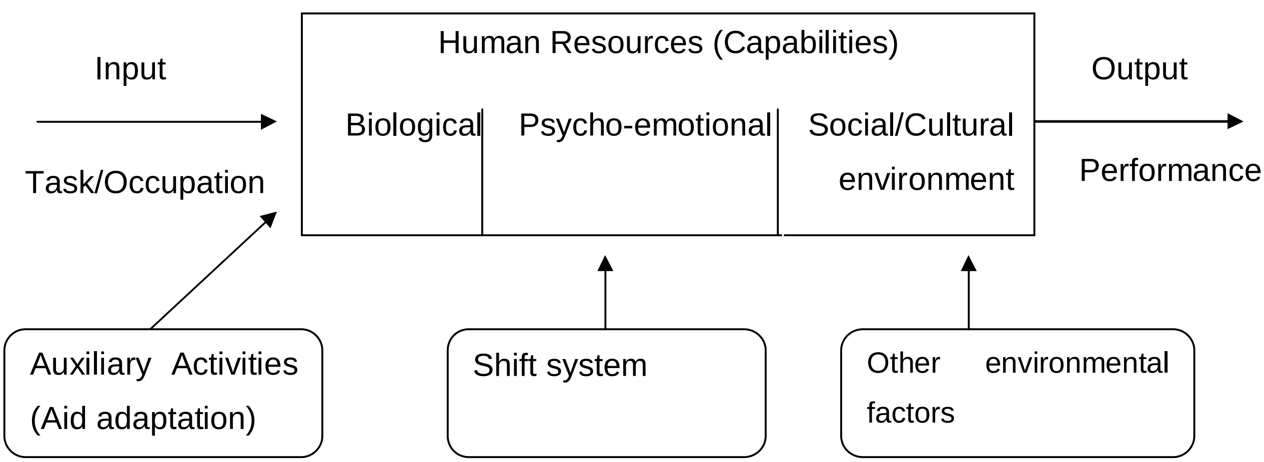

Figure: 1 General overview associated factors impacting individuals and their subsequent output.

Figure 1 is a theoretical schema developed by the author of all the proposed elements that potentially influence the final output and performance on a task requirement. The auxiliary activity forms part of the proposed intervention schedule, with the theoretical idea being that the intervention will have a greater influence than the shift system and other environmental factors in order to ensure the output of performance is not affected by the human resource (capabilities) elements.

SHIFT SCHEDULES DESIGN

Folkard (1992) suggest that there is no best shift system, as any design is a trade off between accommodating the workers social needs and health and safety aspects. A review of available literature on shift schedules highlights Folkard (1992) point, in that while some shift designs are preferential to others, no consensus on the ideal shift system is agreed upon. Knauth (1996) identifies the three most widely used shift schedules as; permanent night shifts, weekly rotating, and rapid rotating. Each of these shift schedules has its pros and cons, which are summarised in table I.

Rapidly rotating systems typically require workers to never spend more than one, two or at most three, successive days on night shift before they rotate to spend similar periods either off duty, on morning shift, or on afternoon shift, before returning to the night duty, and so on (Wilkinson, 1992). Several authors suggest that rapidly rotating shift systems are preferable, when compared to that of slow rotating systems. Knauth (1996) and Fischer **et al** (1997) agree and point out the main reasons to be; the attenuation of sleep deficits and decrease of the intensity and frequency of disturbances of sleep that lead to internal desynchronisation (least disturbance of circadian physiological functions), and the need to improve the works social relations and keep a diurnal orientation that would help promote health and well-being among shiftworkers is seen to be maintained better under this shift schedule.

The weekly rotating shift schedule is argued to be the most commonly found schedule, in which the period of rotation conforms to the working week (Wilkinson, 1992). This schedule is seen to offer the most adaptation of the circadian systems; however several nights in a row are likely to result in a bigger cumulative sleep deficit towards the end of a span of night shifts (Fischer **et al**., 1997 and Knauth, 1996). A shift schedule that is most positively seen to favour adaptation of the circadian system is that of permanent night shift. According to Wilkinson (1992) this requires periods of weeks, or even months on the night shift, with of course, intervening days off duty throughout, and with the whole interleaved with corresponding long, or longer, periods of continual day shift work. It is generally argued that shift schedules that minimise disruption to the circadian system are preferable; and permanent night shifts systems are associated with greater circadian adaptation and therefore less disruption (Barton **et al**., 1995). While adaptation is increased with permanent shift schedules, most workers value leisure time during evenings and therefore this design has major social implication (Knauth, 1996).

Table I: Simplified summary of arguments for or against certain types of shift systems Adapted from Knauth (1996)

Shift system	**Permanent night shift**	**Weekly rotating**	**Rapid rotating**
Disruption of circadian rhythm	Yes	Yes	Least disruption
Accumulation of sleep deficits	Yes	Yes	No
Weeks without free evenings	Yes	Yes	No
Performance during night shifts	Somewhat better	Reduced	Reduced

Shift systems which first move from morning shift to evening shift and then to night shift, have a forward rotation (phase delay, clockwise rotation), whereas the counter clockwise rotation (night to evening to morning shift) is called backward rotation or phase advance (Knauth, 1996). The forward rotation is argued to prolong the day of change from one shift to a different type of shift and therefore corresponds better to the endogenous circadian rhythm, which has a period of more than 24hours (Wever, 1979).

While variations in shift systems offer alternative means of aiding in the entrainment of circadian rhythms, the implementation of different systems is often costly and impractical, requiring extensive planning and long phases of implementation. Researchers ultimately need to consider simpler methods which require minimal alterations with maximum benefits.

THE BIOLOGICAL CIRCADIAN RHYTHM

Life on earth evolved around two key variables, space and time. The spatial features of each organisms biotic and abiotic environments are to a certain extent more familiar concept to most people, while that of the temporal features remain more abstract and often goes unnoticed (Dunlap **et al**., 2003). Within the last century or so, it has become progressively clear that adaptation to the temporal structures of the geographical environment is as important as adaptation to spatial factors, more so for organisms living in periodically fluctuating environments (Roenneberg and Foster, 1997).

One of the earliest observations that the living organism contained endogenous rhythms was an 18th century botanical commentary made by Jean-Jacques d'Qurtous de Mairan (Moore-Ede **et al.,** 1982). In his experiment, De Mairan isolated a heliotrope plant from the influences of the sun and found that even when shielded from periodic influences of the environment, the plant continued to exhibit its cyclical pattern of opening during the day and closing at night (Boivin and James, 2004). Since that time, the ubiquitous presence of a master pacemaker has been observed across most living organisms.

Since the initial findings in the 18th century, vast studies have been conducted to indicate that organisms living on earth exhibit daily rhythms in both physiology and behaviour (Zee and Manthena, 2007). Sharma and Chandrashekaran (2005) indicate that the earth spinning on its axis approximately once every 24 hours exposes living organisms to highly predictable daily rhythms of light and temperature, and that humans and most other organisms have evolved an internal 'clock' that regulates functions of the organism in a manner appropriate to the time of day (Zee and Manthena, 2007). Hence even when organisms are isolated from the influences of periodic environmental factors – by maintaining them under constant laboratory conditions with light, temperature and sound constant – a large majority of them display biological rhythms with a near 24 hour free running period (Sharma and Chandrashekaran, 2005). These psychophysiological measures that vary with a periodicity of approximately 24 hours are referred to as "circadian rhythms" - *circa = approximately, dies = days*- (Neubauer, 1992; Sharma and Chandrashekaran, 2005; Myers and Badia , 1995; Zee and Manthena , 2007).

Under entrained state, circadian clocks adjust their phase and/or period to synchronise their 'internal time' with the phase and period of the geophysical world, and thus acquire a stable phase relationship with the environment (Sharma, 2003). The circadian clock or rhythm, which cycles approximately every 24 hours is governed by neuro-logic mechanisms (biologic clocks) that respond to internal and external stimuli. According to Grossman (1997), specialised retinal receptors sense external stimuli (sunlight and darkness) and trigger the hypothalamus to control the body's own circadian rhythm pacemaker.

The primary region in the hypothalamus involved in circadian rhythms is the suprachiasmatic nuclei (SCN). Experiments preformed by Stephan and Zucker (1972), and Moore and Eichler (1972), demonstrated that the SCN exhibited two important properties of the master circadian clock: lesions of the SCN abolished circadian rhythm, and lesions of input to the SCN abolished entrainment of the clock to environmental signals (Zee and Manthena, 2007). Therefore, indicating that the SCN and the hypothalamus are the controlling structure of the master circadian rhythm.

The SCN works to ensure that even when human beings are isolated from external time cues, they will continue to present rest/activity cycles that are organised around near 24 hour biological days. It is well established that the overt rhythms of a variety of physiological and behavioural variables, including the endogenous components of core body temperature, neuroendocrine secretion, sleep organisation and propensity, subjective alertness and moods, cognitive performance, short term memory and clock genes expression, are comprised of an endogenous circadian component that continues to oscillate even in the absence of periodic fluctuations (Boivin and James, 2004 and Grossman, 1997; and Zee and Manthena , 2007)

Studies performed in underground bunkers showed that the human circadian rhythm for most people has a day length that is about 25 hours, with individuals ranging from about 24 -26 h hours (Eastman, 1990), with more recent studies indicating that the average period of the human circadian rhythm is approximately 24.1 hours (Khalsa **et al**., 2003). Consequently when humans are isolated from environmental time cues, their circadian rhythms become out of phase with the 24 hour clock, and these individuals are said to be “free running”. The reason for this is that these rhythms are considered endogenous and are therefore self-sustained and generated within the organism (Myers and Badia, 1995).

According to Boivin and James (2004) a phenomenon called “circadian entrainment” operates each day in order to maintain a stable phase position between the endogenous circadian pacemaker and the environment, therefore implying that synchronisers from the environment are forcing humans to adjust their oscillations to that of the geophysical world. So although the circadian clock has the capability to run automatically, in its natural state it regularly receives environmental signals, and these environmental signals act to entrain the circadian clock such that the rhythms do not “free-run” and remain synchronised to the 24 hour day period (Eastman, 1990).

The entrainment of the circadian clock is achieved through 24 hour ‘Zeitgebers’ or time-cues. According to Eastman (1990), these zeitgebers entrain circadian rhythms by producing the required daily corrective phase-shifts. Sharma and Chandrashekaran (2005) specify that the circadian clocks can synchronise with zeitgebers merely by passively responding to them, with evidence from studies over the past decades indicating that circadian clocks possibly use several time cues simultaneously in order to occupy temporal niches in the natural environment. The range of entrainment of each zeitgeber depends on its strength relative to the strength of the oscillator controlling the circadian rhythm, with a larger range of entrainment to be expected from stronger zeitgebers (Aschoff,and Wever 1981, and Van Someren and Riemersma-Van Der Lek, 2007).

Night shift workers are required to work, sleep and eat at the ‘wrong’ phase of their circadian cycle and during consecutive night shifts, their internal circadian rhythms gradually shift to adapt to the new schedules, but full adaptation is rarely achieved (Eastman, 1990). The phase of the circadian cycle or clock can be adjusted or entrained by external stimuli such as the daily cycle of light-dark (LD), as well as by internal stimuli such as information related to the physiological and behavioural status of the individual (Yannielli and Harrington, 2004). Importantly even under slow shift cycles or permanent night work, complete adaptations or entrainment of circadian cycles rarely occurs.

Burgress et al (2002) and Eastman (1990) points out that this is primarily due to workers reverting to ‘normal’ sleeping hours on days off, and that even if their sleep and work schedules are shifted, other 24 hour zeitgebers are not and these might act to oppose the shifting of the internal circadian rhythms.

ZEITGEBERS (TIME CUES) FOR THE CIRCADIAN CLOCK

The relationship between circadian rhythms and various stimuli or zeitgebers are described using phase response curve’s (PRC’s). According to Burgess **et al** (2002) and Johnson (1999), a PRC is a plot of phase shifts of a circadian rhythm as a function of the circadian phase that a stimulus, or zeitgeber, is given and thus it is derived by administering a stimulus at many different times or circadian phases and measuring the effects on the phase of the circadian clock. Stimuli include light pulses, temperature, or pulses of drugs or chemicals (Johnson, 1999).

Light/dark cycle and melatonin rhythms

The light/dark cycle is argued to be the strongest and most important zeitgeber for the circadian clock, and it is well established that appropriately timed light and dark periods can phase shift human circadian rhythms (Boivin and James, 2005; Johnson, 1999; Myers and Badia, 1995; Czeisler **et al**., 1989; Dijk **et al**., 1995; Eastman **et al**., 1999). Light entrains circadian rhythm largely by action during the subjective night and generally does not alter the phase of the circadian rhythm when presented during the subjective day, but during the subjective night it is argued that detection of light, signals the clock to reset (Johnson, 1999 and Yannielli and Harrington, 2004).

According to Zeitzer **et al** (2000) the response of the circadian pacemaker to light varies both with the time and intensity of the photic stimuli. With regards to both timing and intensity, Boivin and James (2005), Eastman (1990) and Zeitzer **et al** (2000) found that bright light exposure late in the subjective evening delays the circadian oscillation to a later phase position (phase delay), bright light exposure early in the morning advances the circadian oscillation to an earlier phase position (phase advance), and that bright light administered in the middle of the day has minimal effects on the circadian oscillation (figure 2). It is believed that through the above mentioned mechanisms, the endogenously generated circadian rhythm maintains entrainment with the endogenous light/dark cycle (Johnson **et al**., 2003; and Yannielli and Harrington, 2004).

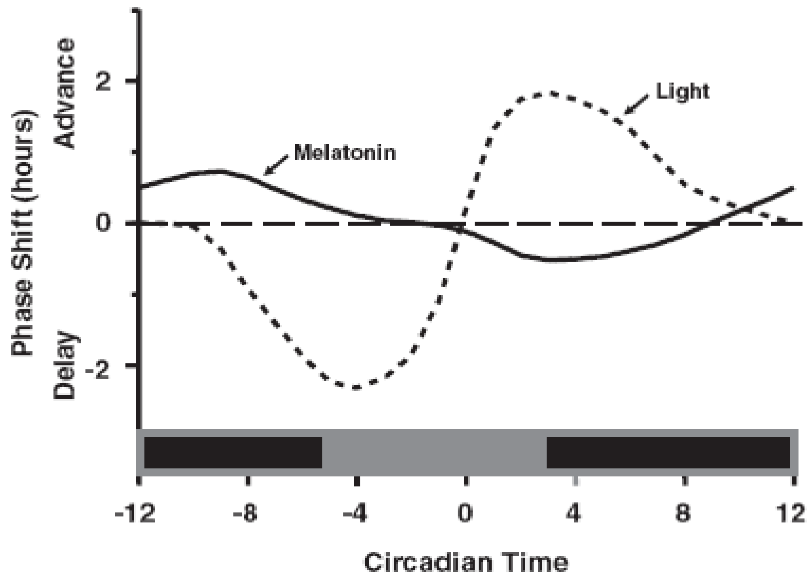

Figure 2: Schematic representation of the phase response curve to light and melatonin (adapted from Zee and Manthena 2007).

The mechanism behind the phase shifting effects of light exposure deals with the suppressing effect light has on pineal melatonin production, such that in the presence of light, the output from the retinohypothalamic tract inhibits the melatonin synthesis, whereas darkness stimulates it (Claustrat **et al**., 1995). Burgess **et al**., 2002 and Zeitzer **et al** (2000) suggest that any exposure, at any time will have some suppressing effect on melatonin production. In fact, the melatonin rhythm is entrained to the dark periods and it can be acutely interrupted by light exposure during the night (Claustrat **et al**., 1995). In humans, melatonin supplies the night information to the brain, and can therefore be described as the sleep hormone. Melatonin also plays the role of an endogenous zeitgeber on core body temperature or sleep-wake cycle (Claustrat **et al**., 1995).

Adaptation to shift work and in particular that of night work is most affectively achieved through the entrainment of the circadian rhythm with the use of the light-dark cycle. Appropriate use of nocturnal high intensity light can increase the rate of circadian adaptation even further than simple shielding from the external light-dark cycle (Burgess **et al**., 2002), with the magnitude of the resetting response increasing with the illuminance in a non-linear manner (Zeitzer **et al**., 2000). Boivin and James (2005) suggested that coupling high intensity light exposure during the night shift and avoidance of day time light exposure, might lead to an almost complete adaptation, however complete adaptation is almost never achieved as workers revert to normal schedules on time off (Eastman, 1990).

The melatonin rhythm generated by the endogenous clock located in the SCN of the hypothalamus is highly influenced by the light/dark cycle (Claustrat **et al**., 1995). The light/dark cycle functions such that in the presences of sufficient light intensity and duration (2500 Lux for 2 hours between 02h00-04h00) the output from retinohypothalamic tract inhibits the melatonin synthesis, whereas darkness stimulates it (Lewy **et al**., 1992).

As with bright light exposure, melatonin administration must be carefully scheduled. Endogenous melatonin is only produced during night time darkness, while exogenous melatonin causes phase shifts similar to those produced by exposure to darkness (Lewy **et al**., 1996; and Sharkey and Eastman, 2002). Lewy **et al** (1998) generated a PRC to melatonin in humans that demonstrated circadian phase advances with melatonin administration in the late afternoon and evening and circadian phase delays with administration in the later hours of sleep and morning (Sharkey and Eastman, 2002).

When looking at bright light and melatonin in combination, Lewy **et al** (1996) indicates that in accordance to the PRC, bright light should be scheduled in the morning and melatonin administered in the afternoon in order to provide a corrective phase advance and in order to provide a corrective phase delay, bright light should be scheduled in the evening and melatonin should be administered in the morning.

Temperature rhythms

Sharma and Chandrashekaran (2005) stipulate that besides the light-dark cycles, temperature cycles are undoubtedly the most important zeitgeber for circadian clocks, with Johnson (1999) pointing out that temperature plays a supporting role to the light-dark cycle. Temperature step-ups and step-downs as well as temperature pulses evoke phase advances and phase delays in a phase-dependent manner, and temperature pluses entrain circadian rhythms in a manner similar to the light-dark cycle (Moore-Ede **et al**,. 1982b).

Additionally, there is a close relationship between the plasma melatonin peak and the minimum of core body temperature, including entrained conditions. This phase relationship is also observed in a constant routine condition, when a light pulse is given around the nadir temperature, melatonin and temperature phase display an equivalent shift, which suggests a common control of both rhythms by the same clock (Claustrat **et al**., 1995).

FACTORS ASSOCIATED WITH SHIFTWORK TOLERANCE

Individual factors

According the Costa (2005), epidemiological studies indicated that the critical age for reduced tolerance to shift work is reported between 40 – 50 years of age. There are several factors that suggest that the changes in daily rhythmicity and in sleep quality associated with aging are the result of changes in the circadian system itself. In addition to the age-related alterations in amplitude, advanced phase shifting, and a shortened period of temperature, melatonin, and sleep-wakefulness (Baehr **et al**., 2002; Costa, 2005; Harma, 1996; and Myers and Badia, 1995), there are also reported age-related morphological changes evident in the SCN and in the pineal gland (Myers and Badia, 1995).

Weinert and Waterhouse (2007) point out that a decrease tolerance occurs as the circadian rhythms break down and organisms lose their ability to adapt to their periodically changing environment.

In older age the phase of circadian rhythms becomes more advanced relative to the environment (Baehr **et al**., 2002), and there is also a considerable decrease in the amplitude of the temperature rhythms and a diminution of night melatonin levels (Myers and Badia, 1995). The result of these factors is with increased age, individuals tend to have poorer quality of night time sleep, early sleeping and waking hours (increased morningness), decreased tolerance to shift and night work and the ability to synchronise with the periodic environment is impaired (Costa, 2005; Harma, 1996; Myers and Badia, 1995; Weinert and Waterhouse, 2007).

Lundberg (1996) indicates that women's occupational roles have changes with concomitant changes of the traditional responsibility for home and family, and this can contribute to stress and long-term health risks. Female workers are known to experience a "double burden" resulting from their simultaneous engagement in paid employment, plus a greater share or complete responsibility of the domestic load, with the primary concern being the responsibilities of the female worker during day time hours, during which sleep should be occurring.

Camerino **et al** (2006) reported that due to the social effect associated with the double burden, females are reported to have a significantly lower working ability index (WAI) compared to that of their male counterparts. The WAI or 'working ability' is a complex construct reflecting the individual and occupational factors influencing a person's ability to cope in working life (Illmarinen, 1999). The importance of taking into consideration the WAI differences for males and females has to do with shiftwork tolerance and adaptation.

Personality related factors

The notion of shift work tolerance was conceptualised by Audlauer **et al** (1979) when they suggested that a common subjective health complaint could be used as an indicator of individual differences in the ability to adapt to shift work without adverse effects (Tamagawa **et al**., 2007). The factor of concern here that has been shown to be associated with individuals differences in shift work tolerance includes each individuals innate circadian type; in particular their degree of eveningness or morningness (Tamagawa **et al.**, 2007; and Wilkinson, 1992).

Monk and Folkard (1992) and Neubauer (1992) include morningness-eveningness in their three broad classifications of personality associated with “circadian type”. The first circadian type involves the differentiation between “morning larks” and “night owls”. The larks are commonly referred to as “morning types” (M-types), while the owls are known as “evening types” (E-types). M-types tend to have early bedtimes and wake times, are more alert during the morning, are considered conscientious, trustworthy and emotionally stable; while E-types are more aroused later at night and experience difficulty in waking early (Cavallera and Giudici, 2008; Kerkhof, 1985; and Neubauer, 1992). Self-assessment questionnaires, such as that devised by Horne and Ostberg (1979), are commonly used for indentifying morningness and eveningness characteristics (Caci **et al**., 2008; and Cavallera and Giudici, 2008).

These diurnal types are known to differ in their sleep-wake pattern as well as in biological rhythms (Neubauer, 1992), such that data from studies has indicated that adaptation of the circadian rhythms depend critically on whether an individual is a morning or evening type (Wilkinson, 1992). Regarding general adaptation it has been found that M-types generally find adaptation difficult, opting for day shifts as performance measures tend to drop during night working hours (Monk and Folkard, 1992; and Wilkinson, 1992). Monk and Folkard (1992) suspect the difficulty with adaptation to be linked to three factors. Firstly, M-types find it extremely difficult to stay awake at night, or sleep late in the morning, which Neubauer (1992) hypothesised to be due to the fact that M-types body temperature shows a steeper increase in the morning, and therefore morning types reach their peak temperature earlier in the day than the evening types. Secondly, M-types appear to be more susceptible to environmental zeitgebers. A third possible reason is that when M-types are isolated from all time cues, they exhibit “free-running” circadian rhythms with an approximate length of 24.3 hours in comparison to E-types who tend to have slower rhythms of approximately 25.5 hours.

A study by Horen **et al**., (1980) demonstrated that extreme M-types show a decrease in performance efficiency over the day, while extreme E-types demonstrated a general improvement in performance as the day progresses. For this reason, E-types show better adaptation to night shifts and generally opt for evening work (Wilkinson, 1992).

It is mostly accepted that night work is best suited to those individuals with a longer running period, as this leads to a phase delay in behaviour, for example a later bed time. Eastman **et al** (1995) stipulates that phase delay shifts of circadian rhythm are more likely in E-types compared to M-types, and Baehr **et al** (2002) hypothesises that evening types better ability to adapt their circadian phase is driven by social pressures (e.g. pressure to get up early in the morning to go to work) to adopt an earlier sleep-wake schedule than their circadian clocks produce naturally.

The second circadian type reviewed by Monk and Folkard (1992) entails the quantification of individual differences along the dimensions of introversion-extroversion, which according to Neubauer (1992) might be linked to morningness-eveningness. The general consensus within the literature is that the arousal rate in both introverts and extroverts increase over the day, with there being a greater rate in the latter personality group (Blake, 1971).

As with other personality traits, that of morningness-eveningness is influenced by gender, age, occupation, culture and more anecdotally season of birth and puberty (Caci **et al**., 2008).

Caci **et al** (2008) reported that previous research regarding gender and morningness-eveningness personality were inconsistent, however recently through the use of larger samples most studies confirm that males have a higher eveningness preference. In the relevant research by Chelminski **et al** (1997) involving 1617 subjects a significant association between scores on the morningness-eveningness scale and gender were found, with females showing a stronger tendency towards the morningness dimension (Cavallera and Giudici, 2008). Natale and Danesi (2002) reported findings that suggested that the percentage of evening types in men was greater than that of women, while the percentage of morning types in females was greater than that in males.

Studies by Kim **et al** (2002) and Takeuchi **et al** (2001) provide contradictory finds in that both studies found no significant gender differences in the morningness-eveningness dimensions.

With respect to age, older age correlated with morningness preference as Tankova **et al** (1994) and other studies in recent years in young and adults have confirmed an important shift towards morningness preference occurs towards the age of 50 and a shift towards eveningness preference has been observed towards the age of 13 (Kim **et al**., 2002 and Smith **et al**., 2002). Furthermore, Carrier **et al** (1997) found that increasing age was related to earlier habitual wake time, earlier bedtime, better mood, and alertness at wake time (parameters corresponding to the morningness personality). Over all studies indicate that rhythmicity of the circadian system among people over 50 shifts towards morningness (Caci **et al**., 2008 and Cavallera and Giudici, 2008).

Horne and Ostberg (1979) developed a 19 item questionnaire concerning rising and bed time, preferred times of physical and mental performance, and subjective alertness after rising. This known as the morningness-eveningness questionnaire (MEQ) is a wildly accepted and utilised questionnaire in order to grade individuals in a chronotype category. Horne and Ostberg's (1979) MEQ defines five chronotype levels namely, extreme morning type, morning types, intermediates, evening types, and extreme evening types.

ENVIRONMENTAL FACTORS

Physical environment

The physical environment, including noise, lighting, temperature, work space and vibration can either enhance or impair performance. Human are particularly vulnerable to extreme conditions in the physical environment, with fatigue and impairment of performance as net results of unsuitable working conditions. These results may be exacerbated when working at night, particularly if the worker has accrued a sleep debt.

Social environment

A critical environmental component that is known to influence performance is that of "social facilitation" or, the effect of an audience. This social environment, which may include co-workers, management staff, customers or spectators, often impacts on an individual's performance in either a positive or negative manner.

IMPLICATION OF PHYSICAL ACTIVITY

General wellbeing

The benefits of regular physical activity have long been recognised. These include the prevention of heart disease by decreasing hypertension and blood cholesterol levels, as well as a reduction in occurrence of musculoskeletal injuries such as lower back pain via an increase in flexibility and muscular strength.

The escalation of automation within the previously highly manual materials handling sectors of the modern workplace has significantly changed the demands and lifestyle of the workers, who now tend to be less subject to physical demands, and are more taxed or stressed additionally due to advancements in technology, increasing the cognitive component of tasks.

The consensus among expert reviewers (Harrington, 2001 and Waterhouse **et al**., 2007) is that shift work is associated with greater health problems than normal day work. These health effects of shift work include a reduction in quality and quantity of sleep, chronic fatigue, anxiety and depression, adverse cardiovascular and gastrointestinal effects and reproductive effects in women (Atkinson and Davenne, 2007).

One of the recognised problems associated with shiftwork is that of passivity following a reduced, or lack of, regular participation in physical activity (Åkerstedt **et al**., 1984). This state of hypokinesis appears to stem primarily from the disruption of the workers social and recreational lifestyle due to the continuous alteration of work hours. Time off work tends to be used predominantly for sleep and family contact with limited time remaining for participation in physical activity. Many shiftworkers wish to, but cannot, perform leisure activities at the same times as day workers and for these workers participating in team activities or competitive sport, a restriction in convenient leisure-time may become one of the major factors in causing them to leave shiftwork (Herbert, 1983).

Harrington (2001) identifies the importance of physical fitness and activity in helping workers reduce the problems associated with shiftwork. Atkinson and Davenne (2007) further stipulate that physical activity is one of the few leisure activities which may mediate long term favourable changes in physiologic functions as well as alter the fatigue levels of the shiftwork.

Physical activity performed at least twice a week is usually included in guidelines for improving shiftwork tolerance (Harrington, 2001, Knauth and Hornberg, 2003) but the usefulness of exercise during shiftwork is poorly understood and there is evidence that shiftworkers find it difficult to follow advice regarding exercise training (Wedderburn and Scholarios, 1993).

Harma **et al** (1982) concerned with general fitness, found that physically fit day workers had lower heart rates, less perceived exertion and faster recovery of heart rate both during the day and at night as compared to workers of average fitness. These differences coupled with larger amplitude in circadian rhythm, which results in greater stability of circadian rhythms and which are beneficial in coping with frequently changing disturbances (Atkinson **et al**., 1993), led these authors to conclude that physically fit individual should tolerate shift work better than less fit individuals (Bonnet, 1990).

Function of exercise in aiding entrainment

Atkinson **et al** (1993) suggest that the changes in amplitude which occur with physical training are a result of physiological adaptations to the endogenous clock itself, with the habitual activity of training over regular and frequent periods acting as a zeitgeber. Youngstedt **et al** (2002) point out that while light exposure is considered the most important regulator of the mammalian circadian system, studies on rodents and humans have indicated that physical activity and exercise also have a profound influence on circadian timing.

According to Barger **et al** (2004), the primary problem with most studies is that the extent of exercise responsible for phase shifting is unclear as subjects are generally exposed to light levels that are already known to phase shift the circadian pacemaker. A study by Edwards **et al** (2002) demonstrated similar concerns in concluding that their findings of a phase shift might of been attributable, in part, to light exposure rather than of the exercise routine. These concerns were alleviated by Barger **et al** (2004) in their study where they controlled lighting by keeping subjects under near dark conditions (≈ 5 lux), and were able to show exercise to facilitate a phase shift.

Evidence from human studies indicates that exercise can in fact shift circadian rhythms in constant conditions (Van Reeth **et al**., 1994 and Buxton **et al**., 1997), and accelerate entrainment to a shifted sleep-wake schedule (Eastman **et al**., 1995), or a shortened sleep-wake period (Miyazaki **et al**. 2001). With suggestions being that in fact exercise may provide an alternative or adjuvant phase-shifting stimulus with similar potency as bright light (Youngstedt **et al**., 2002).

Holding the point of light as a zeitgeber entraining the circadian pacemaker, workers attempting to entrain their rhythms to night shift schedules might find the early morning and day time light exposure to decrease alignment of their circadian pacemaker to night schedules. Youngstedt **et al** (2002) hypothesises that alteration in physical activity levels might attenuate or defeat attempted phase shifting by bright light exposure, thus appropriately timed bouts of physical activity might potentially enable night workers to maintain entrainment for greater periods of time, therefore decreasing the degree of misalignment leading to difficult working schedules.

Earlier research looking at the entraining effect of timed bouts of physical exercise suggests that the sensitivity of the human circadian timing system to exercise is not constant across time of day (Barger **et al**., 2004 and Buxton **et al**., 2003), and that it is in fact dependent on the time of day when physical activity is performed (Miyazaki **et al**., 2001). In summary; the direction and magnitude of a shift caused by exercise is dependent on the internal biological time that the stimulus is presented.

THE SCHEDULED WORK BREAKS WITHIN SHIFT SYSTEM DESIGN

Whether or not rest breaks should form part of a schedule and thus be controlled or whether the worker themselves should select the appropriate time for a rest break during the shift is argued among researchers. The arguments revolve around the potential disruption to schedules and task performance and additionally to the question of whether or not the individual is able to select appropriate times for breaks that will be most beneficial and afford the most recovery. Bechtold **et al** (1984) and Janaro (1985) stipulate that although it may appear that taking a rest break is intuitive; studies have shown that workers will not always select an optimal rest break schedule, and performance may be improved significantly by using systematically schedule breaks. Left to their own devices, individuals often tend to work beyond the point at which their performance begins to decline, perhaps continuing until subjective feelings of fatigue become intolerable (Tucker, 2003). According to Murrell (1979), rest breaks taken after the point at which performance has begun to decline are likely to be less effective in promoting recovery, with only temporary respite from the decline in performance being achieved. An alternative argument to this was put forward by Tucker (2003) who suggested that the requirements for a pre-determined rest schedule means that rest periods will not necessarily coincide with the individuals perceived need for a break (i.e. at times of heightened fatigue). An important issue regarding rest breaks in most types of work therefore is the individual’s ability to monitor their own level of fatigue.

One of the viewpoints seems to be that the greater the discretion given to a worker to control the pace of their work, the better able they will be to regulate both the effects of fatigue on their performance, and the experience of stress, by taking micro breaks. However, Bechtold **et al** (1984), Janaro (1985), McLean **et al** (2001) and Tucker (2003) concluded, workers may not always be the best judges of the most appropriate rest schedules. Additionally, when such rest breaks are regulated on a discretionary basis by the workers it becomes questionable whether such breaks are of sufficient duration (Bechtold **et al**., 1985) or occur frequently enough or early enough in the working period to prevent the ensuing fatigue (Henning **et al**., 1989).

In investigating the conventional rest break schedules (mid-morning, lunch, mid-afternoon), researchers have indicated that these schedules are not fully effective in eliminating operator discomfort and performance deterioration (DouCFFF **et al**., 1994 and Zwahlen **et al**., 1984). Tucker (2003) in reviewing early studies by Jones (1919) and Wyatt and Fraser (1925) found that by dividing the total rest time within a work period into more frequent shorter breaks, productivity was increased. Indications being that while 'standard ' shift schedules might offer longer rest periods and longer periods of continuous production time, they pose the threat of workers waiting until they experience musculoskeletal discomfort or cognitive fatigue before taking a forced rest break (Henning **et al**., 1997).

Experiments conducted in field settings and recent laboratory studies indicate that workers productivity and well-being can benefit from short breaks (Tucker, 2003). According to Rohmert (1973), short rest breaks capitalise on the rapid rate of recovery that occurs during the initial portion of a rest period and do not compromise a workers adaptation to work. Others have implied that excessive short break will have more of a disruptive effect on productivity and a balance needs to be obtained in order to ensure productivity does not suffer (Tucker, 2003). Henning **et al** (1997) suggested that care be taken to integrate the breaks with task demands because when breaks are too frequent, they may disrupt the work flow. Optimal rest break scheduling therefore is a function of the task demands, cycle time and total duration of the task (Bechtold **et al**., 1984 and Fisher **et al**., 1993). Caution however does need to be taken with mental work tasks as transition between activity and rest may cause some loss in concentration and thus be disruptive and hence requires additional consideration and knowledge of task requirements

According to Tucker (2003), evidence from a range of industrial settings appears to suggest that fatigue and performance can benefit from relatively short breaks. In fact the frequent use of rest breaks has been proposed by many authors as an effective means of reducing musculoskeletal discomfort, mood disturbances, static loading of the musculoskeletal system as well as repetitive strain injuries (Henning **et al**., 1997).

Rohmert (1973) noted that an exponential increase in fatigue which potentially occurs over the work period can be prevented by short, frequent rest breaks.

In looking at work-rest schedules, Mathiassen (1993) concluded that even minor changes in the exercise/rest schedules may imply large changes in physiological and psychophysical responses, with evidence from laboratory studies suggesting that the nature of the activity undertaken during the rest breaks may be crucial in determining the amount of recovery afforded (Tucker, 2003). Research indicates that productivity growth and discomfort reductions can be achieved with as few as two 5 minute breaks with exercise in addition to the normal rest breaks both in the mid-morning and mid-afternoon during an 8 hour work day shift (Henning **et al**., 1997).

Frequent, short rest breaks, both those involving exercise and those not, have proven to increase productivity, improve worker well-being and eye, leg, and foot comfort (Balci and Aghazadeh, 2004 and Henning **et al**., 1997). Research assessing both day and night shift workers indicated that risk of injury immediately following a break to be reduced to levels close to those observed at the start of the preceding period of work (Tucker, 2003). These finding provide evidence that regular rest breaks are an effective means of controlling the accumulation of risk and ensuing fatigue.

Dooley (1981) found that in review of the NIOSH guidelines, recommendations for breaks during a range of tasks are provided. NIOSH recommends a break of 15 minutes for every 2 hours of work under moderate demands while performing at a computer, and every hour under higher demands (Tucker, 2003), while recommendations from the Occupational Health and Safety Branch of Ontario Ministry of Labour suggests that a 5 minutes break be taken for each hour of work where computer or desk work is involved (Occupational Health and Safety Branch of Ontario Ministry).

In considering work of a more manual nature with increase physical demands, recommendations within the literature suggest a ten minute break each hour to be more productive and less fatiguing than one fifteen minute break every ninety minutes (Bhatia and Murrell, 1962) Indications from the literature are that considerations need to be taken regarding the type of task and the schedule of rest breaks. The evidence supports the fact that additional rest breaks may enhance productivity under certain conditions. Careful considerations need to be taken regarding the length and timing of these schedule rest breaks. Tucker (2003) writes that the effectiveness of a particular rest break schedule will be influenced by the nature of the work routine and will therefore vary from one working environment to the next. Potentially what Tucker (2003) is indicating is the fact that scheduling of rest breaks is task specific in that within certain working environments breaks have to be schedules around production as stopping production for a short break is impractical and expensive. Alternatively, within a self paced working environment individuals can more freely stop working without affecting productivity.

Henning **et al** (1989) stipulated that should the break or micro break be too short, performance might worsen on certain tasks as subjects terminate the break before the restorative effects occur. Boucsein and Thum (1997) reported a schedule of 7.5 minutes rest after 90 minutes of work to be effective in improving emotional well-being of workers, with the rating of perceived discomfort being less for those work periods with short pauses or breaks, compared to those working periods without. Overall, careful consideration needs to be taken as optimum rest schedules are likely to be specific to the nature of the work activity being undertaken (e.g. task demands, workers control of pacing, consequences of failure) as well as differences in both the individuals state (e.g. ability, motivation, sleep debt) and trait (e.g. circadian type).

Rest breaks on night shifts

A substantial body of evidence has identified the ways in which alertness, mood, cognitive functions and various other functions vary as a function of time of day and, in particular, as a result of circadian rhythms (Reilly and Waterhouse, 2009 and Wright **et al**., 2002). Recommendation based on break schedules for night shift work therefore requires additional consideration to account for differing responses to those of the day shift counterparts. Eilers and Nachreiner (1990) recommend that additional breaks be provided to counteract more pronounced decrements in night-time performance. While a more recent study looking at flight crews found that a hourly 7 minute break during a 6 hour night flight were an effective means of temporarily counteracting declines in physiological and subjective measures of sleepiness, with strongest effects occurring near the circadian trough (Neri **et al**., 2005). The physiological responses were however, not sustained throughout the entire inter-break period and there were no beneficial effects of rest breaks on vigilance performance The use of short rest break periods during the shift cycle have shown positive responses across a range of job type, however the effectiveness of the rest period across the inter-break period has not been well documented, with those documented cases indicating a poor maintenance of responses across the inter-break period (Neri **et al**., 2005).

It is hypothesised that by not only increasing the frequency of breaks but also the nature of activity performed under such breaks, that the breaks might have longer lasting impacts due to changes in heart rate, blood pressure, core body temperature and stress hormones, enhancing the alertness state of the individual, potentially for a longer period of time than a simple rest break.

Taylor (2005) proposed an alternative method which is geared at ensuring the short rest break has a more positive inter-break effect. His proposed method involved incorporating a series of short exercises and stretches into the break period in an attempt to enhance alertness, decrease musculoskeletal discomfort, and provide alternatives to sedentary rest breaks. Taylor (2005 p. 462) defines the booster break as "organised, routine work breaks intended to improve physical and psychological health, enhance job satisfaction, and sustain or increase work productivity". The booster break consists of a simple combination of stretchers and exercises for an approximate duration of 7.5 minutes every hour during the shift cycle (Taylor, 2005).

The rationale behind such designs as the booster break are firmly rooted in the traditions of public health and the behavioural sciences, which include an emphasis on preventing disease and injury and promoting health and well-being through population-based solutions (Taylor, 2005). A literature review regarding the implementation of Taylors (2005) proposed booster break indicated that it has primarily been implemented within working situations as an aid to decrease smoking (Sarna **et al**., 2009) and obesity rates (Yancey **et al**., 2007), and as tool to make individuals aware of their current health status (Yancey **et al**., 2006). An extensive review of the booster break implementation did not however indicate any studies utilising the break schedule under shift work or night work conditions.

One such mechanism of booster breaks that has shown promise in the literature is the effect of a light exercise session on whole body and core body temperature. Matsumoto **et al** (2002) points out that by using physical exercise to combat sleepiness in circumstances in which wakefulness has to be maintained, one might unconsciously be employing a heat-production effect. A Study performed by Leproult **et al** (1997) showed that night time exercise around the nadir of core body temperature could alleviate subjective sleepiness, while in a study by Matsumoto **et al** (2002) it was found that increased physical activity during one night of total sleep deprivation counteracted the major early morning peak of subjective sleepiness, while the objective measures of performance remained unchanged.

The rate of heat production is dependent of the metabolic rate, duration of activity, sweating rate, environmental condition, clothing, and major muscle groups used (Reilly and Waterhouse, 2009). Reilly and Brooks (1990) found that with light/moderate exercise, the onset of sweating occurred after 7 minutes, with this homeostatic mechanism designed to decrease core body temperature. The ideal circumstance with the booster break is to increase the core body temperature slightly, particularly near the nadir (discussed in detail further on). With approximately 80% of the energy utilised during exercise contributing to heat production (Reilly and Waterhouse, 2009), the hypothesis for a short, 3 minute, exercise session being to simply increase temperature with major muscle group utilisation while avoiding the hypothermic mechanisms of sweating.

SLEEP AND MECHANISMS OF SLEEP

Sleep is a state that comprises a complex combination of physiological and behavioural processes. Santos **et al** (2007) indicate that sleep has some manifestation, such as a cyclic pattern, relative immobility and in increased threshold to external stimuli. The grave importance of sleep becomes evident during sleep deprivation since deprivation promotes several alternations, including a marked increase in production of stress hormones such as catecholamine's and cortisol, a reduction in cognitive capacity and a reduction on the state of alertness, among other things (Carskadon and Dement, 2005).

Measurements of electroencephalogram (EEG) and eye movements (electro-oculogram, EOG) are used to categorise the different stages of sleep. EEG monitors brain activity with the eye movement measures from EOG correlating to that of brain activity and hence providing an indication of the level of sleep (Carskadon and Dement, 2005 and Driver and Taylor, 1996)

Sleep can thus be divided into two stages: the phase in which the EEG records a synchronised tracing known as non-rapid eye movement (nREM) phase, and the phase in which the electroencephalogram (EEG) records signals similar to those in the wake period, associated with rapid eye movement, known as rapid eye movement (REM) sleep (Santos **et al**., 2007).

NREM sleep is conventionally subdivided into 4-stages (1, 2, 3, and 4), which are relatively precisely, although somewhat arbitrarily, defined along one measurement axis, the EEG; with the EEG pattern for nREM sleep commonly described as synchronous (Carskadon and Dement, 2005). Driver and Taylor (1996) describe the 4 stages under nREM phase; stage 1 sleep is a light transitional phase from waking to sleep, with the first appearance of the deeper stage 2 normally being considered as the true onset of sleep or 'sleep onset latency'. From stage 2, sleep gradually becomes the deeper stages 3 and 4 of nREM sleep, this is collectively being referred to as 'slow-wave sleep' (SWS), and is characterised by high amplitude, low frequency waves (slow wave) on the EEG. The SWS or deep sleep which occurs during stages 3 and 4 of nREM sleep is thought to be the most restorative of all the sleep stages, with most of its activity occurring in the first two sleep cycles (Cauter **et al**., 2008).

At the end of the slow-wave period, a sleeper then moves back through the lighter stages and into REM sleep, which is characterised by EEG activity similar to that of stage 1 nREM but with very low muscle tone and the characteristic rapid eye movement (Carskadon and Dement, 2005 and Driver and Taylor 1996). Unlike nREM sleep, REM sleep is generally not divided into stages, although tonic and phasic types of REM sleep are often distinguished for research purposes.

According to Atkinson and Davenne (2007) and Driver and Taylor (1996) there are approximately 4-5 nREM/REM cycles during a typical night's sleep, each lasting approximately 90 minutes depending on the number of cycles and total length of sleep. Sleep cycles consist of an episode of nREM sleep followed by a period of REM sleep, with SWS dominating the nREM sleep portion of the sleep cycle towards the beginning of the night, while REM sleep tends to be greatest in the last one third of the night (Carskadon and Dement, 2005 and Driver and Taylor 1996). The understanding is that the preferential distribution of REM sleep towards the latter portion of the night, within normal adults, is thought to be linked to a circadian oscillation, which is often gauged by the oscillation of body temperature (Carskadon and Dement, 2005).

According to Krueger **et al** (1998) two hypothesis attempt to explain the mechanisms involved in sleep regulation, the one addresses circadian markers while the other is related to the homeostatic effects of sleep (Santos **et al**., 2007)

MARKERS OF THE CIRCADIAN RHYTHM

Physiological variables such as body temperature, endogenous melatonin and cortisol, and sleep-wakefulness are considered to be strong markers of the circadian temporal organisation (Myers and Badia, 1995; and Weibel **et al**., 1995). Changes in these markers across successive 24 hour periods are assumed to reflect changes in the circadian systems. The two primary markers are those of temperature and melatonin which are inversely related and tend to change in unison, as is evident from figure 1 (Johnson, 1999).

Body temperature and more specifically core body temperature is the most frequently used marker due to ease with which it can be recorded and non-invasive nature of the measurement. According to Myers and Badia (1995), care must be taken when using body temperature measures as several activities – food intake, photic stimulation, and physical activity – alter (mask) the underlying rhythm.

Melatonin has been used more recently by researches as a circadian markers as it is generally unaffected by extraneous factors like activity and sleep, therefore making it a more reliable markers (Myers and Badia, 1995). Melatonin is synthesised and released in the pineal gland primarily during the night time hours (whether awake or sleep) in a prominent on/off pattern following a parabolic curve (Myers and Badia 1995).

PSYCHOPHYSIOLOGICAL ASSESSMENT

Extended wakefulness is thought to cause various impairments of high brain function, with studies confirming that sleep deprivation can decrease performance in terms of alertness, memory, psychomotor skills, reaction time performance or throughput in cognitive tasks (Åkerstedt, 2007 ;Matsumoto **et al**., 2002; and Scott **et al**., 2006). In order to assess the impact of sleep deprivation caused by the implemented shift work schedules a variety of performance measures were selected.

Periods without sleep, typical to night shift workers, have been demonstrated to have significant adverse effects on subjective mood (Scott **et al**., 2006), with significant correlations having been found between self-reported mood and performance. The suggestions stemming from this are that mood-state might be a useful predictor or performance in sleep deprived subjects (Mikulincer **et al**., 1989).

Subjective sleepiness profiles

Subjective sleepiness profiles are utilised to provide an indication of the degree of sleepiness the subject is feeling. Like most subjective ratings individuals are able to provide their own projections, however the use of these scales forms the functions of assessing if subjects are able to monitor their own fatigue and hence the potential for performance deteriorations.

The Karolinska sleepiness scale is a 9-graded scale originally developed to constitute a one-dimensional scale of sleepiness. It has been validated against alpha and theta electroencephalographic (EEC) activity as well as slow eye movement electroculographic (EOC) activity (Åkerstedt and Gillberg, 1990). The 9-graded KSS scale had been widely used in the past few years, producing reasonable results in studies of shift work (Axelsson et al, 2004; Harama et al, 2002; and Sallinen et al, 2005), while also demonstrating that falling asleep at the wheel in a driving simulator to be preceded by increasing KSS scores. Several studies indicated that KSS scores rise with increasing periods of sustained wakefulness (Åkerstedt and Gillberg, 1990) and strongly correlate with time-of-day (Kecklund and Åkerstedt, 1993).

Blatter and Cajochen (2007) validated the use of the KSS during shift work against cognitive performance, a probed memory recall test and psychomotor vigilance performance. The authors found a common trend among the measured variables with an increase in sleepiness based on the KSS being associated with a decline in all the test parameters.

Maldonado **et al** (2004) argue that while the more popular scales such as the KSS and Stanford sleepiness scale (SSS) might be quick and easy to administer a degree of literacy and comprehension is required. Therefore making the use of such a scale across all population groups is a challenge. Maldonado **et al** (2004) thus developed and validated the Wits sleepiness scale (WSS) with the 5 pictorial faces to which subject merely point to indicating their level of sleepiness.

NEUROBEHAVIORAL MEASURES

According to Van Dongen **et al** (2003) the biological clock which modulates hour-to-hour waking behaviour, as reflected in fatigue, alertness and performance, generates a circadian rhythm in almost all neurobehavioral variables. Thus it predicted that the neurobehavioral responses will following the natural endogenous circadian rhythm, peaking and waning over the course of 24 hour day.

Critical flicker fusion frequency

The critical flicker fusion frequency (CFFF) threshold is defined as the frequency at which a flickering light is indistinguishable from a steady, non-flickering light (Wells **et al**., 2001). The CFFF threshold is the lowest frequency of flickering light (measured in Hz) that is required to produce the appearance of steady light to the observer (Jensen, 1983; Luczak and Sobolewski, 2005; Wells **et al**., 2001). Hence, when a light is flickered at rates equal to (or greater than) the CFFF threshold, the individual flashes cannot be resolved and the light is indistinguishable from a steady, non flickering light, and this would represent the threshold and signify the end point of the test.

Both ascending and descending thresholds are distinguishable in CFFF. Luczak and Sobolewski, (2005) specify that the ascending (fusion) threshold is an indicator of human sensitivity to the perception of the end of light flickering. This is measured with the lowest frequency of the flashing light (in Hz), at which the subject perceives a steady light instead of a flickering one. Alternatively, the descending (flicker) threshold is measured with the highest frequency of the flashing light when the flicker appears. Previous work by these authors indicates that the ascending and descending thresholds should be treated as different phenomena (Luczak and Sobolewski, 1995).

The physiological basis for human perception of flicker/fusion light flashes is based within the cerebral cortex of the brain (Walker **et al**., 1943), with the perception of fusion flashes depending on the arousal level off the retina and on the processes occurring there (Luczak and Sobolewski, 2005). The Cerebral cortex area of the human brain is a structure within the brain that plays a key role in memory, attention, perceptual awareness, thought, language, and consciousness, with Rammsayer (1995) stipulating that the CFFF is a valid and reliable indicator of the level of cortex arousal and activation. Hosokawa **et al** (1997) further points out that CFFF has been used to assess central nervous fatigue since the early 1940's and has continues to this day.

The belief among researchers is that the frequency at which an individual can perceive the flicker may be regarded as an index of the fidelity and efficiency of their visual sensory system (Jensen, 1983), and thus the CFFF is useful for assessing the temporal characteristics of the visual system (Wells **et al**., 2001). Iwasaki **et al** (1989) and Curran **et al** (1990) indicated that, the CFFF value might be used as a measure of quantification, not for fatigue at the periphery of the visual system, but for fatigue at the centre of the visual systems or mental fatigue. Additionally, in the field of fatigue research, it is said that the decrease in the CFFF value is correlated with the appearance of mental fatigue and the deterioration of the arousal and consciousness levels of the brain (Baschera and Grandjean, 1979 and Weber **et al**., 1980). Luczak and Sobolewski, (2005) additionally indicate that CFFF is an accepted indicator of fatigue and workload caused by many different types of occupations and that this is so because there is a relationship between changes in CFFF and fatigue.

Literature indicates that the threshold of CFFF is characterised by different types of rhythms, with one of these rhythms being that of the circadian CFFF rhythm. Luczak and Sobolewski, (2005) reported that experiments indicate a circadian CFFF rhythm that was especially clear for shift workers and that was shift dependent. Studies reported by these authors indicate extremely low CFFF values during the night shift (between 04h00 and 06h00 hours), where after the CFFF values are shown to increase. Matsumoto **et al** (1978) continues by saying that the CFFF values recorded at the end of the night shift were lower than at the beginning of the a day shift. Overall the results indicate that CFFF is a function of work fatigue as well as an affect of the circadian rhythm of the overall arousal level (Luczak and Sobolewski, 2005).

Additional Kogi and Saitio (1971) noted that the effect of the time of day had more influence on the CFFF value than worker fatigue. Furthermore Landis and Hamwi (1954) found a daily pattern of CFFF changes that correlate with the circadian rhythm of oral temperature and that there is an individual difference in the pattern of the circadian CFFF values (Kogi and Saitio, 1971).

Contradictorily, Costa (1993) in his assessment of air traffic controllers, found that while fatigue increased pre to post shift, the behaviour on both CFFF and reaction time showed no differences between the beginning and the end of the three shift cycles (morning, afternoon and night). This study did however have differing intensities of workload being reported across shifts, with night shift having the least air traffic and hence the propensity for boredom (Costa, 1993).

Age has shown to have an impact on CFFF values with a negative correlation being observed between age and the CFFF value (Hosokawa **et al**., 1997). In their study assessing a portable fatigue meter (CFFF), Hosokawa **et al** (1997) concluded that age must be considered when interpreting CFFF values, particularly when looking across a wide range of age differences, with smaller CFFF values being reported in the middle-aged (26 – 31 years of age) group compared to that of the younger group (19 – 25 years of age).

Saccade latency

Eye movements promise to be an informative measure of fatigue because the eyes are constantly moving and many parameters of eye activity are not under voluntary control and hence by looking at different parameters of eye movements, the impact of fatigue on different brain functions might be distinguished. According to Zils **et al** (2005) eye movements during wakefulness usually occur as 1 or 2 types: pursuit or saccadic movements. Pursuit movements have the purpose of smoothly following a moving target or fixing the gaze on a target during head movement, alternatively, saccades are changes of gaze direction toward a target (Zils **et al**., 2005). For the purpose of fatigue research the saccadic eye movements are of importance as saccades are considered as an indicator of fatigue (Schleicher **et al**., 2008).

Saccades are defined as fast eye movements which are used to rapidly catch an image of interest on the fovea (Crevits **et al**., 2003). Two main types of saccades have been identified, reflexive/reactive or exogenous and voluntary or intentional saccades. Reflexive saccades are externally triggered by a target suddenly appearing in the environment and are elicited in reaction to the sudden appearance of a salient visual element, while voluntary saccades are internally triggered and are made with a goal, typically being triggered to redirect gaze between permanently visible objects (Cotti **et al**., 2007 and Crevits **et al**., 2003).

With regards to saccades and cognitive tasks, it has been anticipated from previous studies that voluntary saccades would be more affected than reflexive saccades after sleep deprivation (Crevits **et al**., 2003).

Jainta **et al** (2004) defines saccadic latency (or reaction time) of stimulus induced eye movements as the period between the sudden appearance of a new saccadic target and the start of the actual eye movement. More simply put, saccades are the fast movements used to change fixation rapidly, with the average human central nervous system responding with a saccade after a latency of approximately 200 to 250ms (Yang **et al**., 2002). Saccades are typically conjugate movements with the eyes moving equally and in the same direction. The latency is regarded as the period of neural motor programming, in which two parameters of the eye movement (direction and amplitude) are extracted from the visual input and determined to start the ballistic movement (Jainta **et al**., 2004).

According to Yang ***et al*** (2002) several processes take place during the latency period, these being a shift of visual attention to the new target, the disengagement of oculomotor fixation, and computation of the metrics of movement.

Saccades, unlike the movements of other body parts, are not under conscious control (Snyder **et al**., 2001 and Van Beers, 2007), with there being no voluntary control over their kinematic properties such as speed and duration (Becker and Jurgens, 1990). Therefore, saccades are stereotyped movements whose kinematic properties are determined by the amplitude, a phenomenon known as the main sequence (Bahill **et al**., 1975). The importance of the involuntary control of saccades is that the validity is therefore not hampered by variability in the subject's voluntary control (Van Beers, 2007). Additionally, another advantage of using saccades is that they are too quick to be corrected based on sensory feedback received during the movement (Becker and Jurgens, 1990). The latter two points provide strong validations for the use of saccades as a fatigue measure as they are not under the conscious control of the subject and subjects are unable to influence the speed and duration of the saccadic movement.

COGNITIVE FUNCTIONING

When studying the effects of night and shift work on alertness and cognitive performance, it is often complex due to the fact that performance can vary both with circadian and homeostatic factors, and can also suffer from the effects of sleep deprivation and other consequences of desynchronisation of the circadian system. Cognitive performance has most closely been linked to the endogenous rhythm of core body temperature, within most shift work studies (Reilly and Waterhouse, 2009).

Performance comprises, for the purpose of this review, cognitive functions ranging in complexity from simple psychomotor reaction time and precision to probed memory recall tasks. The diurnal pattern of performance, alertness and memory processing are regulated by the biological clock in SNS (Åkerstedt, 2007), thus following a similar rhythm to that of other endogenous diurnal patterns. Van Dongen **et al** (2003) indicate that the rhythms of performance of these variables mirror the rhythm of subjective sleepiness and are argued to mimic the circadian rhythm of core body temperature, which has been demonstrated to be a good marker of the biological clock.

Diurnal variations in speed and accuracy of cognitive performance have been noted within a number of circadian related studies (Blatter and Cajochen, 2007). It has generally been observed that variation appears to be dependent upon the diurnal rhythm in body temperature (Monk **et al**., 1996), and that a spontaneous or induced change in body temperature is reflected in a change of reaction time in the opposite direction. Furthermore, it has been demonstrated that an increase in body temperature, independent of internal biological time, is correlated with improved performance and alertness (Wyatt **et al**., 1925). Thus, the performance parameters are hypothesised to follow the natural biological rhythm of core body temperature with performance peaking during higher temperature recordings and dipping around the temperature nadir. Additional Wyatt **et al** (1999) points to methods that increase core body temperature, potentially will circuitously improve measures of performance and alertness.

Monk **et al** (1996) discussed that fact that the temperature rhythm is informative of changes in physiological milieu that are profound, and which may themselves influence performance independently of the endogenous circadian pacemaker. Ultimately, it is suggested that temperature changes may reflect changes in metabolic processes which could facilitate performance by speeding up the rate at which information is processed.

Additionally, Scott **et al** (2006) indicated significant correlations between self-reported mood and performance, suggesting that mood-state may be an additional (in combination with core temperature measures) useful predictor of performance in sleep deprived subjects.

Tasks that involve sustained attention, like vigilance performance, reaction time performance or cognitive tasks such as probed memory recall, result in marked reduction of capacity during the late night hours (Åkerstedt, 2007), with this being argued to reach a minimum around the temperature nadir (Reilly and Waterhouse, 2009)

Of the numerous measures of psychomotor ability used to assess the effects of sleep deprivation and circadian desynchronisation as a result of shift work, reaction time, both simple and choice are most frequently reported (Scott **et al**., 2006). Simple reaction time being the response to a single stimulus such as the presentation of a dot on a screen, while choice involves possibly a graphical depiction or auditory stimulus. Sleep deprivation has been associated with longer reaction time and reduced force on simple and choice reaction time tests (Wlodarczyk **et al**., 2006), with sleep deprivation resulting in decreased performance indexed by increasing lapsing, cognitive slowing, memory impairment, decreased vigilance and reduced attention and shift in optimum response capabilities (Scott **et al**., 2006).

PHYSIOLOGICAL PARAMETERS

Heart rate and heart rate variability

During the past few years, evidence from shift work research looking at the evaluation of an elevated cardiovascular risk in people working in shifts has become more convincing (Van Amelsvoort **et al**., 2001). Investigations focusing on the area of cardiovascular health have been finding elevated risks of coronary heart disease morbidity and mortality among shiftworkers (Freitas **et al**., 1997 and Murata **et al**., 2005). With the mechanisms behind the increased risk being unclear; however, authors predict that measures of heart rate might provide insight into mechanisms involved (Van Amelsvoort **et al**., 2001).

Methods of assessing the autonomic function and variations over a period of time are vital in assessing circadian cardiovascular control, particularly in shift work oriented studies. A non-invasive technique currently used in the investigation of cardiovascular autonomic control is that of heart rate variability (HRV), which is quantified by analysis of variations of the intervals between consecutive normal heart beats (Pumprla **et al.**, 2002), and reflects cardiovascular control exerted by both parasympathetic and sympathetic nervous systems (Mourot **et al.**, 2004). Numerous authors agreeing that HRV provides an accurate reflection of the autonomics activity (Pumprla **et al.**, 2002 and Sluiter **et al.**, 2009), and is reliable for evaluation of cardiac autonomic functions (Ito **et al**, 2001), providing a useful indicator of the overall output of the sympathetic and parasympathetic branches of the autonomic nervous system (Van Amelsvoort **et al.**, 2001 and Boneva **et al.**, 2007). Van Amelsvoort **et al.**, (2001) specify that HRV and its spectral components reflect the dynamics of cardiac parasympathetic and sympathetic outflow, providing details on their activation and deactivation.

In normal populations, autonomic activity shows a circadian pattern, which is similar to that of cardiovascular events. The sympathetic activity being prevalent during the day and in the early waking hours is responsible for the functioning of the body under stressed states, while the parasympathetic components which controls the more vegetative states, predominates at night (Freitas **et al.**, 1997 and Pumprla **et al.**, 2002). During periods of shift work, empirical data from studies have indicated that working nights causes a shift of the autonomic balance towards sympathetic dominance (Van Amelsvoort et al, 2001), which is hypothesised to lead to increased burden on the cardiovascular system.

As with heart rate, it has been found that the circadian pattern of HRV to be predominantly related to the sleep-wake rhythm and to be independent of the night-day cycle, with the cardiac autonomic control as measured by HRV displaying a marked circadian rhythmicity (Freitas **et al.**, 1997).

Spectral analysis of 24-hour recordings of heart rate and heart rate variability have shown that in normal subject's low frequency (LF) and high frequency (HF) expressed in normalised unit exhibits a circadian pattern (Malik **et al.**, 1996). Studies having assessed the effects of shift work on heart rate indicate that heart rate increases during working time and decreases during sleeping time, regardless of the different working hours (Ito **et al.**, 2001). During normal rest/activity cycles, the autonomic control of heart rate shifts between the sympathetic and parasympathetic regulations, these typically following a circadian rhythm of increased sympathetic activation during the day and increased parasympathetic activity at night. Malik **et al** (1996) suggesting that this shift is evident within the HF and LF domains such that higher values of LF being more pronounced during the daytime and HF at night.

The parasympathetic influences on heart rate are mediated via the release of acetylcholine by the vagus nerve, while the sympathetic influences on heart rate is mediated by the release of epinephrine and norepinephrine (Malik **et al**., 1996). Levy (1971) indicates that under resting conditions, vagal tone prevails and variations in heart period are largely dependent on vagal modulation, additionally it is stated that the vagal and sympathetic activity constantly interact.

The efferent vagal activity is the major contributor to the HF component, with the more controversial LF component being argued to be a marker of both the sympathetic and vagal influences (Malik **et al**., 1996).

Van Amelsvoort **et al** (2001) and Ito **et al** (2001) in focusing on the autonomic control of heart rate agree that either, alterations or disturbances in the circadian cardiovascular autonomic control pattern caused by altered active/rest cycles of shift work, might be responsible for the cardiovascular risk, psychological, and other medical problems related to shift work. This being such that working at night when the physiological system anticipates rest and recuperation, causes a mismatch, placing extra burden on the cardiovascular system and the output of the intrinsic circadian pacemaker (Van Amelsvoort et al, 2001).

Performance relative to endogenous components

Body temperature has long been believed to be correlated with performance measures, with Kleitman (1963) indicating the human performance was best between 12H00 and 18H00, just before body temperature was highest, and worst when temperature was lowest (between about 04h00 and 06h00). Alternatively, it has also been claimed that subjective alertness, memory-loaded performance and cognitively complex tasks are controlled by oscillator's independent from those that drive the body temperature and sleep/wake cycle (Johnson **et al**., 1992), and therefore do not fluctuate in the same manner. A study performed under constant routine by Johnson **et al** (1992), assessing various measures in relation to core body temperature found that patterns of subjective alertness and simple cognitive performance paralleled that of body temperature, thus indicating that in fact the same pacemaker that drives the endogenous circadian rhythms of body temperature and a number of physiological variables, controls patterns of subjective alertness and simple cognitive performance (Johnson **et al**., 1992). These results were however obtained under constant routine and therefore the extrapolation, to simulated night shift studies where subjects are not under constant 24 hour conditions, needs be taken carefully.

Considerable research has been done into assessing the relationship between temperature and human performance. Kleitman **et al** (1963) early on proposed that body temperature was an underlying mechanism regulating performance. Wright **et al** (2002) and Kleitman **et al** (1963) point out that if the effect of temperature indicates the dealings with a chemical phenomenon then there are two interpretations of the relationship between temperature and reaction time. The first deals with mental processes representing chemical reactions themselves and the second that the speed of thinking depends on the level of metabolic activity of the cells of the cerebral cortex, and by the raising of the latter through an increase in body temperature, one can indirectly speed up the thought process.

Kleitman **et al** (1963) original hypothesis has been support by later studies with Reilly and Waterhouse (2009) noting that there is a wealth of evidence that the rhythms of human mental and physical performance follows a time-course of the rhythm of core temperature, with simple reaction time performance and alertness eliciting a circadian rhythm similar to that of core temperature (Dijk **et al**., 1992 and Reilly **et al**., 2007).

Under constant condition, body temperature and neurobehavioral performance levels exhibit a circadian pattern with higher levels during the habitual waking day and lower levels during the habitual sleep time at night (Johnson **et al**., 1992 and Wright **et al**., 2002), thus performance follows the circadian rhythm of temperature.

Studies of shift work, indicated that better performance has been associated with higher body temperature levels, independently of circadian phase and time spent awake (Campbell, 1995, Czeisler **et al**., 1990 and Leproult and Persson, 2002), while those focusing on forced desynchronisation, performance tends to be lowest during the biological night near the temperature nadir regardless of the duration of prior wakefulness (Dijk **et al**., 1992 and Hull **et al**., 2000).

Contradictorily, Wright **et al** (2002) reports that it is unclear from prior studies whether performance is directly affected by body temperature or whether body temperature and performance simply mirror the circadian phase.

According to Rouch **et al** (2005) the study of effects on night and shift work on measures such as alertness, cognitive performance and reaction time are complex due to the fact that research has found that these performances vary both with circadian and homeostatic factors and can suffer from the effects of sleep deprivation and other consequences of desynchronisation of the circadian system. Therefore it is important to acknowledge while temperature has be indicated to be a strong indicator, it is highly influenced by a variety of elements and suffers from the masking effects of endogenous hormones as well as type of activity being performed

CHAPTER III

METHODOLOGY

INTRODUCTION

Circadian disruptions associated with shift work are documented to result in a reduction in quality and quantity of sleep, chronic fatigue, anxiety, depression, adverse cardiovascular, and gastrointestinal effects (Atkinson and Devenne, 2007). Researchers investigating the adverse health effects associated with shift work hypothesise that undesirable eating habits, increased caffeine intake, and lack of physical activity exacerbate the situation, placing shiftworkers at even higher risk (Åkerstedt **et al**., 1984 and Ludovic **et al**., 2001).

The shift towards increased automation within previously high manual materials handling jobs and a subsequent increase in office based work (increased cognitive demand and sedentary work) has changed the requirements placed on many shiftworkers. New techniques and interventions are required to alleviate the negative consequences associated with poor eating habits and the passivity following a reduction in, or lack of physical activity as a result of both task requirement and the shift schedule.

Overall a lack of entrainment of the circadian system to the shift cycle, poor nutrition and physical activity levels and undesirable break scheduling results in performance decrements, fatigue, injury, health issues and negative subjective feelings.

RESEARCH CONCEPT

The nature of night shift work and the problems associated with the circadian disruptions, health concerns and sedentary conditions under which most workers find themselves, calls for consideration as to the scheduling of work breaks and additionally to the nature of activity undertaken during these work breaks. Research indicates that within a range of industries and occupations, fatigue and performance can benefit from shorter more frequent rest breaks (Tucker, 2003), with exercise incorporated into the breaks increasing productivity growth, discomfort reduction and improved worker well-being (Balci and Aghazadeh, 2004 and Henning **et al**., 1997).

Therefore, the authors' focus falls onto the night shift component of shift work and the incorporation of alternative rest break schedules, with particular reference to the activities under taken during these breaks. Numerous night shift laboratory studies have indicated that even small changes in the activity/rest schedule may imply large changes in physiological and psychological responses (Mathiassen 1993 and Tucker, 2003). With particular reference to shorter breaks indicating that productivity growth and discomfort reductions can be achieved with short exercise breaks in addition to normal rest break. The positive consequences associated with short, frequent exercise breaks and the adverse health effects associated with night shift work, lead to the development of the booster exercise break (Taylor, 2005).

The exercise booster break Taylor (2005) described entails a simple combination of stretches and exercise's for an approximate duration of 7.5 minutes every hour during the shift cycle. Numerous authors have proposed similar designs for alternative break schedules (Balci and Aghazadeh, 2004; Henning **et al**., 1997; and Tucker, 2003) all proposing to increase vigilance and mood, and decrease fatigue levels and musculoskeletal strain associated with prolonged office and sedentary work.

The framework of the research study therefore being to determine the effect of short more frequent breaks, incorporating exercise, during a simulated night shift on physiological and perceptual responses, mood states and basic psychomotor performance, in the form of simple reaction time and precision performance. Additionally, heart rate and heart rate variability were recorded throughout the shift cycle, with measures of tympanic and infrared forehead temperature being recorded during the battery of tests to assess any circadian related fluctuations. Reduction or changes in alertness and arousal levels were proposed to be identified through the measure of saccade latency utilising a modified Fitt's tapping task and a simple reaction time task.

EXPERIMENTAL DESIGN

Alternative scheduling and increased need for breaks during the night shift has been shown in laboratory studies (Tucker, 2003), with field working studies pointing to the fact that traditional rest break schedules pose the threat of the worker working beyond the point of musculoskeletal discomfort or cognitive fatigue before taking a forced rest break (Henning **et al**., 1997). No “golden-standard” exists for the optimum design of breaks due to the complexity and variety of working situations and task demands, as well as individual differences. The introduction of physical activity into the break period prompts an increase in stress hormones and arousal levels, which in the researchers opinion, will provide positive feedback within an office based design where sedentary activities predominate. However, it should be born in mind that while the implementation of physical activity within such a working environment might yield positive consequences, within highly a manual materials handling task and hence a task requiring high energy expenditure, the implementation of physical activity into the rest break schedule might yield more negative resource depletion consequences. The design therefore is built around office based work of a sedentary nature where the introduction of the booster breaks during the night shift will aid performance and not result in resource depletion.

The research design thus set out to determine what alternative scheduling of work breaks and the activity performed during such work breaks would have on the shift worker, with the primary focus being that of night shift workers.

In essence the research design consisted of 3 conditions over a 12 day period. That being, 3 different simulated shift schedules or arrangements. The standard night shift condition or controlled night shift followed a similar design to a standard 8 hour night shift, where workers were permitted to 3 evenly distributed work breaks over the course of the shift, amounting to a total time of 1 hour. The second night shift condition was that of the intervention condition, under this condition workers were exposed to hourly 7.5 minute booster breaks and one 15 minute standard rest break, amounting to a total of 1 hour over the shift (see appendix B1). The final condition was that of a day shift which followed the same design as the night shift (see appendix B2). Table II provides a breakdown of the design for the three conditions.

Table II: Break down of the three different conditions.

CONDITION	DESIGN	TOTAL TIME REQUIREMENT
1	Standard night shift	3 nights (3 x 8 hours)
2	Intervention shift	3 nights (3 x 8 hours)
3	Standard day shift	3 days (3 x 8 hours)

THE SHIFT CYCLE AND STRUCTURE

The research project spanned over 12 days, with the first 9 nights constituting the nights shift portion and the final 3 days the day shift schedule. The 9 nights were divided into 3, such that one shift cycle consisted for 3 consecutive nights. The night shifts began at 22h00 and ended at 06h00, with subjects required to report to the Biopharmaceutical research institute BRI laboratory at 21h00 for pre shift procedures. The day shift schedule alternatively required subjects to report at the BRI laboratory at 07h00 for pre shift procedures with the shift starting at 08h00 and ended at 16h00. Four shift cycles made up the research project with each shift comprising 12 subjects. The group of 12 subjects consisted of 4 standard night shift subjects, four subjects exposed to the booster break intervention and 4 subjects exposed to a nap condition. The nap condition formed part of a collaborative study in which subjects were exposed to a 1 hour nap between 00h00 and 03h00 during the night shift cycle. Within the day shift portion of the study, all 12 subjects formed part of the control group, with no intervention exposure during the day shift cycles. The day shift simply acted as a controlled condition.

In order to assess the impact of the different conditions, a battery of tests was designed. This battery of tests consisted of four stations which were to be completed within 15 minute cycles. With each shift cycle consisting of 12 subjects, three 15 minute testing session constituted one test battery (see appendix B1 and B2), with 4 subjects making up one testing group. Subject assignment to each testing group was considered to ensure a mixed distribution of controlled subjects, napping subjects and booster break subjects (Table III). The battery of tests were staggered, following the same pattern each time with testing group 2 starting testing followed by group 3 and completing the cycle of tests with group 1. The assignment of subjects to testing groups within the day shift portion of the study was more randomly done as all subjects were equally exposed to the same conditions with no interventions being implemented.

Table III: Assignment of subjects to testing groups.

Testing Group 1	Testing Group 2	Testing Group 3
1 Booster Break Subject	2 Booster Break Subjects	1 Booster Break Subject
2 Control night shift	1 Control night shift	1 Control night shift
1 Nap Subject	1 Nap Subject	2 Nap Subject

Key: Number indicates the number of subjects from each condition within a particular testing group

The inclusion of 3 conditions with each cycle was done so that any changes in ambient conditions or working conditions would be distributed across all three groups. This ensured that should conditions change, subjects from each condition would be equally exposed and thus any changes elicited in responses as a result, would be experienced by subjects from all 3 conditions. Additionally, the staggered designs of the testing batteries were designed to provide indications of the effect of the intervention or lack thereof across the inter-break period, and therefore assess a time cause relationship. An unmixed testing group and non-staggered design of testing might potentially have resulted in response differences between conditions simply being due to differences in time of tests and not the exposure to the intervention or lack thereof during the inter-test periods.

The Intervention Strategy

The night shift intervention strategy consisted of hourly 7.5 minute breaks – termed 'Booster Breaks'. Taylor (2005) coined the term Booster Breaks and defines them as "organised, routine work breaks intended to improve physical and psychological health, enhance job satisfaction, and sustain or increase work productivity". The Booster break developed for the current research was altered from a review of work breaks in promoting health by Taylor (2005) and a study performed on flight crews by Neri **et al** (2002).

The basic design for the Booster Break involved a 2 minute simple whole body stretch, a 3 minute aerobic step session, a 2 minute light cool down and a 30 second relaxation period. The criteria for the Booster Break was three fold; firstly the exercise intensity was to be of low to moderate intensity with subjects maintaining a heart rate less than 60 – 70 % age predicted maximum heart rate (220 - age). Secondly, the group of subjects were to be instructed by a research assistant and thirdly the speed of stepping controlled by a metronome ranging between 125 – 135 beats.minute^{-1}. No music or any other arousal measures where used during the aerobic step class. The research assistant instructing the subjects maintained the desirable speed of stepping through the use of the metronome, using voice commands to provide details of chances in stepping actions.

Three different Booster Break regimes were designed, this was to maintain subject interest and prevent boredom through performing the same routine over and over. The stretching exercise (figure 3) varied each time; however the primary goal of whole body stretching was maintained. Subject feedback regarding stiff body areas was used to guide the stretching exercise, particularly in the later Booster Break sessions once subjects had been working for longer periods of time.

The design of a 3 minute stepping session remained the same throughout the Booster Breaks, aerobic step routines varied with slight changes in the tempo ranging between 125 – 135 beats.minute^{-1}. During the later booster breaks (between 02h45 and 05h00), the tempo of the aerobic step sessions increased to a constant level of 135 bt.min^{-1}.

Literature indicates that between these times, core body temperature reaches a nadir (Reilly and Waterhouse, 2009), with a variety of performance criteria showing a marked decrease around this nadir (Dijk **et al**., 1992 and Reilly **et al**., 2007). Therefore, the increased tempo rate aimed to increase the intensity slightly and elicit an increase in core body temperature due to the physical activity and hence counteract the extent of the decrease in core body temperature around these times.

For the aerobic stepping section of the break, the complexity of sets increased slightly as subjects became more comfortable and efficient with the step exercise. Ultimately, the design of each booster break followed the same trend and maintained the criteria outline earlier.

The aerobic step height was maintained at 200mm from the floor to the top of the step, with all subject's utilising the same steps. Both the stretching and step exercises occurred on a carpeted floor, with subject able to exercise with or without shoes depending on preference. Subject returned to the same step for each of the booster breaks over the 3 night.

Figure 3: Group of subjects performing the booster break activity with the aerobic stepping and light stretching cool down.

The Night shift

The night shift incorporated both a control group and an intervention group running concurrently, with each group of 8 subjects consisting of 4 control subjects and 4 subjects being exposed to the intervention strategy. The night shift groups were required to arrive at the BRI laboratory at 21h00 and report directly to the recreational room. Upon arrival, subjects received their heart rate belts. Female subjects proceeded to the bathrooms with a female research assistant to fit their heart rate belts while male subjects remained in the recreational room with a male research assistant. Once all subjects' belts were fitted and activated, the pre-shift meal was served.

At 21h15 testing group two proceeded through to the testing area to begin the pre-shift tests, during this time the rest of the subjects remained in the recreational room, either eating their meal or relaxing. Once testing group 2 completed their pre-shift test, they returned to the recreational room and testing group 3 entered pre-shift testing. Testing group 1 followed after group 3, with the ending of their testing marking the start of the shift at 22h00. Subjects in the recreational room were at this time called through to the working area to start their shift.

While in the working area, subjects were required to fulfil their time by performing a set of predetermined tasks. This involved a simple packing and beading task. Thus during working times subjects were required to pack 5 application packets an hour and then continue with the beading task. Subjects were free to select when they packed the application packets as long as they completed 5 every hour. This remained the same for both night conditions and the control day shift.

Throughout both the night and day shifts, subjects were exposed to a total of one hours break per shift and six 15 minute testing batteries. The tests comprised a pre shift test, four testing batteries during the shift and a post shift test (see appendix B1 and B2).

At 06h00 the post shift testing began, again starting with testing group 2 and ending with testing group 1. Once subjects completed post shift testing they removed their heart rate belts and handed them in before returning home. Subjects were reminded to complete their daily sleep logs before leaving.

The Day Shift

The controlled day shift was the final shift cycle taking place on the last 3 days of the testing. Subjects assigned to this group were required to report to the BRI laboratory at approximately 07h00. Before starting the shift subjects were fitted with the heart rate memory belts, as in during the night shifts. Those subjects assigned to testing group 2 were then taken through for the pre-shift testing at 07h15, while the remainder of the subject had their pre-shift meal in the recreational room. All subjects went through their pre-shift testing before starting the shift a 08h00. As this was a controlled condition, no intervention was implemented and all 12 subjects were exposed to the same conditions throughout the 3 day shifts.

The schedule of testing maintained the same staggering as from the night shift design. During break periods, all subjects retired from the working area and moved across to the recreational room to receive their snacks. Subjects were similarly exposed to reading materials and encourage at this time to converse amongst themselves.

The subjects were exposed to the same working task requirements during the working periods as the night shift workers. The shift ended with a post-test, where after subjects removed and handed in their heart rate belts to a researcher and returned home after being reminded to complete their daily sleep logs.

Task Requirements

The current research design considered the effects of low arousal, sedentary based working tasks which often predominate during the night shifts following the move towards more automated based tasks. The tasks provided to the subjects thus needed to elicit similar arousal levels while ensuring subjects remained sedentary. Simple tasks requiring minimal equipment and costs were sort out in order to mimic low arousal sedentary based tasks.

Of the numerous tasks looked at, the following received the most consideration based on the criteria above. A simple data capturing or typing tasks was considered, as while providing a low arousal based tasks, it also could function as a performance based task.

This would of provided information regarding inter-break performance and allowed subjects to remain sedentary and perform a monotonous task typical to many office based working tasks. This task was however not utilised as the acquisition of twelve computers was not possible and logistically the space provided within the BRI laboratory could not facilitate such equipment.

Alternatively, allowing subjects the chance to complete academic based work or studying during the working time was considered due to the fact that a group of University students made up the sample. Again these tasks were rejected, this being based on the fact that the researchers could not monitor workload and ensure all subjects in fact had work to complete during the research time. Simple board game playing was further considered, as this is a low cost method and simple to implement. This task was however not utilised as the affect of socialising while playing the game might potentially act as an arousal effect and thus is did not fulfil the criteria of the task.

Therefore, after considering numerous tasks, two low arousal low concentration repetitive tasks were selected to be performed during the working periods. The first of these was a simple packing task involving an A4 document, envelopes and booklets which needed to be assembled. The second task was a simple beading design task.

The Rhodes University Student Bureau required a vast amount of ‘application pack’ for potential students in 2010 to be packed. Through the liaison with the Student Bureau these unmade application packets were acquired and the assembly requirements explained. Subjects needed to fold an A4 document in half, place this into the booklet and slide that into an envelope. Once all documentation was in the envelope, subjects removed a sticky label and sealed the envelope before placing it next to them on the desk.

Subjects were assigned to pack a total of 40 application packets per shift, amounting to 5 an hour with this amount being decided on based on the total number of application packet received. Throughout the study a total of 4320 Rhodes University application packets were packed. It was up to the discretion of the subjects as to when, during the hour they packed the 5 required application packs. Once packed, a research assistant would remove the packed envelopes and replace them with 5 booklets, envelops and A4 documents at the start of the new hour.

The beading task involved medium sized glass beads of varying colours. Six different colours were provided to each subject. The beads were 8/0 in size which equates to 12 beads per inch. Subjects were provided with 1m lengths of cotton yarn, which had a pre tided end bead on. For the threading process, an 8cm long length of Aculon was provided; this was folded in half with the cotton yarn threaded through (appendix/figure). Aculon or “tiger tail” was used in place of a beading needle as it offers a cheaper and safer alternative. Subjects were left up to their own discretion regarding the patterns of beading. No pre defined lengths or colour sequences were provided, however most subjects opted for making necklaces using most of the 1m length of cotton yarn.

During the battery of testing, subject were required to bring all their beading from that shift with them. It was weighed and used as an indicator of performance during the time between testing sessions.

The task requirements, while simple, provided the subjects with incentive based work as they were producing an end product and not simply performing a mundane task which might possibly induce excessive amounts of boredom. Due to the nature of the study it is of utmost importance not to elicit any unnecessary arousal within the subjects as this might potentially influences the testing procedures. Hence a repetitive task of this nature was selected as not to induce unwanted levels of arousal and ensure all subjects performed at a steady rate throughout the working periods.

Within the task requirements the subjects were not imposed to a performance target with the beading performance being self regulated and the packing of 5 application packs an hour inducing the minimalist of strain. Importantly a slowing down from a certain level of beading or rate of packing would not facilitate performance as both tasks required minimum attention and effort thus no trade off of performance was possible.

NUTRITION

At predefined times throughout the night and day shift subjects were supplied with food. The first meal subjects received was the pre-shift meal, the content of which differed between the night and day shift. For the night shifts, upon arrival at the BRI laboratory at 21h00, subjects received a selection of white and whole-wheat rolls. Three combinations were supplied namely salad rolls with tomato, cheese and lettuce, a chicken and mayonnaise roll or a tuna and mayonnaise roll. Subject were free to select according to preference which roll they wanted and had between 21h00 and 22h00 to eat the pre-shift meals. Alternatively, during the day shift subjects reported to the BRI laboratory at 07h00 where they received two assortments of breakfast cereal, these being Kelloggs cornflakes and rice krispies with milk and sugar provided. Quantities for food and sugar were monitored but not strictly regulated, as to mimic a subject's normal breakfast meal. Subjects had between 07h00 and 08h00 to eat their pre-shift breakfast before starting the shift. Throughout the shift cycle, including the pre shift meal and during the shift meals, the subjects were free to either eat or chose not to eat when food was provided. Subject did so with the knowledge that they could only eat at predetermined times and could not store food or request food to be eaten at their own leisure. Subjects were allowed to eat according to hunger, particularly during the pre shift meals, this was to ensure that each subject either consumed what was deemed to be a sufficient amount to maintain them between eating periods or alternatively should they not require food then not to force feed them and induce a possible fatigue effect. Feeding periods were predetermined in order to ensure, particularly during the shift that subject action were controlled and they were all equally exposed to the same activities and requirements depending on their condition.

At three predetermined times (see appendix B1 and B2) throughout the shifts subjects received light meals or snacks. During feeding time, the control groups retired from the working and went into the recreational room where they received their meals. The intervention group however, was required to continue working during feeding periods; they were only permitted to take a formal break from work during the second feeding session between 03h45 – 04h00 and thus consumed their meals while continuing with work.

During the “tea break” a selection of sandwiches and water were provided to the subjects. The option for toppings was apricot jam and peanut-butter with a combination of the two depending on subject taste. With all feeding sessions, subjects were not required to eat should they not feel hungry; however, subjects were not permitted to store food after the predefined feeding periods or order food outside such periods. This ensured that all subjects where eating at approximately the same time.

The second feeding session consisted for a 30 minute break for the control shift and a 15 break for the intervention group. Subjects were provided with the option of juice and an apple plus a sandwich snack with topping of tomato and cheese, or any combination of the two. This constituted the mid shift meal where subjects received their longest break from work and their largest snack of the shift. For all sandwiches there was a selection of brown or white bread. At no time during the shift did subject receive substances containing caffeine or high sugar amounts; this was done in order to control arousal levels as a result of the diet provided.

SUBJECTS

Prior to the study, basic demographical and anthropometric data were collected on all of the participants. This included measures of age, stature, mass, ethnicity, education level and information regarding their level of morningness-eveningness. Education level, measured as number of years at university, was recorded as it was believed to be important in the randomisation of groups to ensure an even distribution across all groups. This was considered owing to the memory task performance, as uneven distribution might skew the data. The race of the subjects was also recorded. Again, as with education level, race was considered as another factor to consider when randomising the sample groups.

A total of 36 subjects, half male and half female, were recruited to participate in the research. Subjects were all recruited from the Rhodes University student population, aged between 18 – 26 years of age. Table IV provides the mean data scores for the 36 subjects. The information of primary interest for the research study was that of education level and morningness-eveningness type and these two values were used to group subjects to ensure homogeneity among groups. Subjects were predominantly moderate morning-eveningness types with a similar education background. The more specific break down of individual informal is available in the appendix.

All subjects indicated having no pervious sleeping disorders, no physical disabilities or current medical conditions. All subjects were non-smokers, with no previous experience in shift work, and currently maintained a typical sleep pattern. These criteria were all stipulated within the exclusion criteria of the study, all pin pointed in the advertisement for subject recruitment. To confirm subject habitual sleep/activity patterns a daily sleep and activity dairy was completed 3 days prior to testing, during testing and 3 days post testing.

Table IV: Subject characteristics, grouped data and male and female differences.

	n	**Age (years)**	**Education level** (Socre based on years of education)	**Morning-Evening Score** (Horne and Ostberg scale)
Control night shift	12	21 (± 1.4)	13.75 (± 1.4)	52.4 (± 8.15)
Experimental night shift	12	21.6 (± 1.9)	13.8 (± 1.5)	55.8 (± 9.1)
Day shift	12	21.5 (± 1.2)	13.6 (± 1.2)	55 (± 8.3)

DEPENDENT VARIABLES

The collaborated nature of this study meant that the napping sample, the standard night shift and standard day shift were identified as independent variables. Heart rate variability, precision performance, reaction time, memory performance, tympanic and skin temperature, critical flicker fusion frequency threshold, saccade latency, subjective sleepiness and mood were the dependant variables.

Physiological analyses

Heart rate and Heart rate variability Heart rate shows a variation over the rest/activity cycle with circadian rhythms being evident. Simple heart rate data (bt.min^{-1}) indicates changes between activity and rest, and appears to be unaffected by different working hours. Under normal daily rhythms the autonomic control of the heart shifts between the sympathetic and parasympathetic nervous systems altering with the rest activity cycle, and maintaining the body in the correct activity level (Malik **et al**., 1996).

Alterations or disturbances in the circadian cardiovascular autonomic control pattern caused by altered active/rest cycles of shift work might be responsible for the cardiovascular risk, psychological, and other medical problems related to shift work (Van Amelsvoort **et al**., 2001 and Ito **et al**., 2001). The altered rest/activity cycle of shift work causing a shift in the autonomic control such that sympathetic activity predominates during the night shift, with this being hypothesis to increase the burden placed on the cardiovascular system (Van Amelsvoort **et al**., 2001).

Heart rate measures and heart rate variability (HRV) are non-invasive methods of investigating the cardiovascular autonomic control of the heart over a period of time. It has been proven to provide an accurate reflection of autonomic activity (Pumprla **et al**., 2002 and Sluiter **et al**., 2009), providing a useful indicator of the overall output of the sympathetic and parasympathetic branches of the autonomic nervous system (Van Amelsvoort **et al**., 2001 and Boneva **et al**., 2007). Thus through the monitoring of heart rate and HRV over the period of the shift, indications of rest/activity and shifts in the autonomic control can be assessed.

The Suunto T6 heart rate memory belt was used to record cardiac responses, at a 1000Hz rate, during the entire shift cycle. An electrode strap was placed around the mid-chest at the inferior border if the pectoralis major muscle, in line with the apex of the left ventricle. The electrode which is responsible for detecting the electrical activity of the heart, is stored on the micro-chip inside the belt. The belts provide a detailed beat to beat analysis as well as R-R intervals and ratios which are important in determining heart rate variability.

All data were stored in the belts memory and download through the use of a docking station and Suunto training manager 2.2.0.8 software a few hours after the shift finished. Once the heart rate information is transferred into the Suunto training manager software basis analysis can be performed. The data which were statistically analysed was taken during the periods of the test batteries where subjects maintained a seated posture in order to eliminate changes in heart rate response as a result of postural changes.

Infrared Emission Detection of Body Temperature

The human thermoregulatory system follows a circadian rhythm varying under normal condition about 1ºC either side of 37ºC (Reilly and Waterhouse, 2009 and Wright **et al**., 2002). The fluctuations of core body temperature are believed to mirror the feelings of subjective and objective sleepiness with maximum sleepiness occurring during the several hours around the minimum core body temperature (Matsumoto **et al**., 2002). While impacting sleep and sleepiness, core body temperature measurements have additionally been shown to provide an indication of human performance and mood. Numerous authors have pointed to the fact that measures of neurobehavioral performance, reaction time, mood and other performance criteria follow a similar pattern to that of circadian core body temperature (Dijk **et al**., 1992; Johnson **et al**., 1992; Reilly **et al**., 2007; and Wright **et al**., 2002)

The non-invasive measurements of body temperature, particularly those mirroring core body temperatures provide valuable information regarding circadian rhythms of the body. Infrared emission detection thermometers calculate body temperature by measuring infrared radiation from either the tympanic membrane of the ear, or that radiating from the surface of the skin. Two infrared emission detection thermometers where utilised to obtain a measure of forehead skin temperature and tympanic temperature.

A Braun ThermoScan ExacTemp® with a fitted disposable lens filter was utilised to obtain a measure of tympanic temperature. The ThermoScan was set in “equals” mode, as to measure ear temperature without adding an offset (Chamberlain **et al**., 1995). The

ThermoScan ExacTemp® scans by taking 8 measurements per second and displays the highest temperature down to one decimal point in degrees centigrade (Manual for Braun Pro 3000 ThermoScan ExacTemp®).

Additionally a handheld infrared thermometer provided a noncontact forehead temperature measurement. An Infrared thermal imaging camera (Flir Systems: ThermaCAM i series) was used to obtain a measure of the subject's forehead temperature.

Psychomotor performance analyses

Reaction Time Test

According to Scott **et al**. (2006) of the measurements of psychomotor ability used to assess the effects of sleep deprivation, reaction times tests, both simple and choice, are most frequently reported. Of the psychomotor performance tests used within the battery of tests here, simple reaction time tests as well as a high and low precision test were utilised. The tests were designed to assess changes in motor responses and cognitive functioning over the course of the shift cycle.

The simple reaction time test was a computer based test designed to measure reaction time responses to a visual stimulus. The task involved subject responding to a stimulus presented on the computer screen by clicking the mouse as fast as possible in response to the appearance of the stimulus. No auditory stimulus was presented. The stimulus was a yellow dot with a diameter 150mm presented against a dark green back ground. A total of 11 trials/stimuli were presented with the first trials being excluded, thus a total of 10 trials were considered for analysis. The stimulus presentation varied between 1000 and 2000ms. From the time the stimulus was presented, the subjects had 1000ms to respond, after which time that trial would not be considered and an additional trial would be added. Should a subject forestall a response, prior to the presentation of the yellow dot, that trial would also not be considered. The test was only completed after 10 successful trials, with the duration of the test typically lasting no longer 25 seconds.

Precision task performance

The scope of the study, while primarily based around working tasks of a sedentary nature, still needs to consider the impact working against the natural circadian rhythm on tasks requiring accuracy and precision. In order to assess these components a precision based task was incorporated into the test battery. This was done to monitor any changes in reaction time and precision performance over the course of the different shifts and assess if the intervention strategy of hourly booster breaks would have favourable impacts or not.

For the precision performance task a computer-based Fitts' Test using a 17" LG touch screen was employed. The reaction test involved subject responding to variations of different sized yellow dots on a dark green back ground. Subjects had to respond by touching the yellow dot with their index finger as fast as possible once the stimulus was presented. The test encompassed two settings, a high precision task (small targets) and a low precision task (large targets). The Index of Difficulty (ID), with this referring to the ratio between movement distance and target size (Schmidt and Lee, 2005) was constant for high precision task (ID=5.66) and for the low precision task (ID=3.44). The set ID values were corresponding to Ngcamu (2009) in order to allow comparison of data with the impact of awkward body postures. The subjects performed each of the two tasks six times throughout a single shift. Each task performed consisted of 25 targets. The task with which the subject began alternated each time the test was administered, thus if the subject began with the low precision task and ended with the high, the next test battery the subject would begin with the high precision test and end with the low precision test.

Exclusion criteria were set for both the high and low precision tests as with the simple reaction test. The working field was set to 220mm by 220mm. The yellow dot varied is size between 20mm and 40mm in a random order according to movement distance (in order to provide a constant index of difficulty), with the time between presentations varying from 500 to 1000 ms. The first trial was excluded, including any trials with a reaction time less than 0.1 seconds, this constituted a double tap on the screen, and any reaction time greater than 1.5 seconds. Additionally, any target deviations greater that 100mm were excluded, with the test being completed after 25 successful trials.

Saccade Latency

The Dikablis Eye Tracker System consists of three subunits: the head unit, which is equipped with two cameras in order to capture the images of the eye and of the visual field. The head unit sends all video information to the receiving unit which again sends the signals to the recording unit (Figure 4 and 5).

Figure 4: The three sub-units of the Dikablis eye tracking system.

The head unit fits on the subject's head, with the weight of the device being supported by the nose. The eye detection camera is located above the left cheek and the field view camera is located just above the nose support, this camera provides a coloured wide angle picture depicting the user's field of view. The eye camera detects the cornea reflex and identifies the pupil, providing information on the pupil's movements.

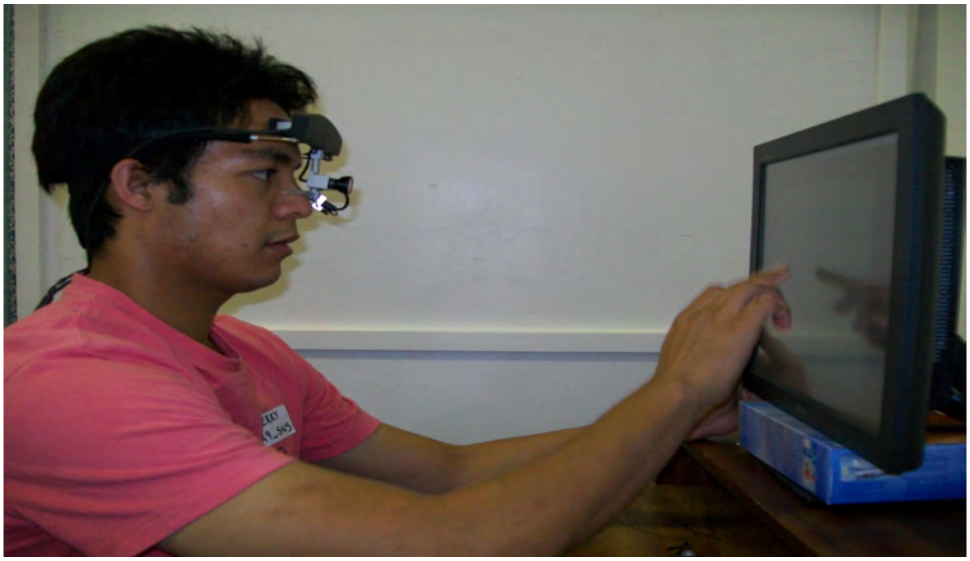

Figure 5: Subject fitted with eye tracking system.

The field camera, focusing on the monitor in front of the subject, provides the field view of the Fitts test the subject performed. The eye camera, focusing on the pupil, provides an indication of the time from the presentation of the target stimulus (fitt's test) to the commencement of the saccade (Darrien **et al**., 2001). The time between two saccades is generally called fixation duration (Schleicher **et al**., 2008), and basically represents the time between stimulus presentation and movement of the pupil in response. The fixation duration or saccade latency is a reliable indicator of fatigue.

Critical Flicker Fusion Frequency (CFFF)

The analysis of fatigue of the centre of the visual systems and mental fatigue was assessed through the measurement of critical flicker fusion frequency (CFFF). Research indicates that decreases in CFFF values correlate with the appearance of mental fatigue and the deterioration of the arousal and consciousness levels of the brain (Baschera and Grandjean, 1979 and Weber **et al**., 1980), with CFFF being an acceptable indicator of fatigue (Luczak and Sobolewski, 2005). Refer to chapter II under neurobiological measures for greater detail.

A modified pair of binoculars was used to measure the CFFF threshold. The binoculars were modified with the ends blocked with covers such that no ambient light could enter. One white light–emitting diode (LED) was placed in the right visual field of the binoculars; subjects therefore had a monocular observation of the flickering white light through the right eye only. The left eye simply viewed total darkness. The flickering of the LED was controlled by the researching in a one trial ascending method, thus the frequency (Hz) value was increased until such time as the subjects perceived the flickering light to be indistinguishable from a steady, non-flickering light.

PSYCHOPHYSIOLOGICAL ANALYSES

Subjective perceptions vary as a function of motivation and fatigue over the period of a shift, with there being high inter-individual differences. The individual's perception and motivation has an impact on performance and there is a possibility that it might fluctuate over the cause of a shift and over success shifts. In order to assess subjective rating of perceived sleepiness and subjective mood the following measures were implemented to assess the psychophysiological aspect of the night shift cycle.

Karolinska Sleepiness Scale (KSS)

Through the use of the KSS, subjects indicate on the 9-graded scale the description-step that best reflects the psycho-physical state they were experiencing at that current moment. The KSS scale ranges from 1 equalling extremely "alert" to 9 being "very sleepy, great effort to stay awake, fighting sleep" (appendix). Subjects simply pointed to the value which best described their level of sleepiness at the time of test administration. The use of the KSS within similar shift work settings has been validated by Blatter and Cajochen (2007) in measuring similar parameters as in the present study (cognitive performance, probed memory recall test and psychomotor aspects). The results indicated from the Blatter and Cajochen (2007) study provide the backing for using such a measure within the scope of the present study.

Wits Sleepiness Scale (WSS)

The Wits Sleepiness Scale (WSS) which is a validated pictorial scale using 5 cartoon faces (Figure 5), provides a subjective measure of instantaneous perceived sleepiness similar to the KSS, with sleepiness referring to the degree of difficulty in staying awake while completing a task (Milia, 2006). It has been validated within a South African context, as well as against established scales (Maldonado **et al**., 2004). The use of cartoon faces ensures a small level of literacy and comprehension needed, plus allows of comparisons across languages as no word association appears on the scale. Practical attention was paid to the eyes and the faces such that they are devoid of gender and ethnic features (Maldonado **et al**., 2004). By simply pointing at the cartoon face that best describes how subjects are feeling at the time, an indication of the level of sleepiness is obtained.

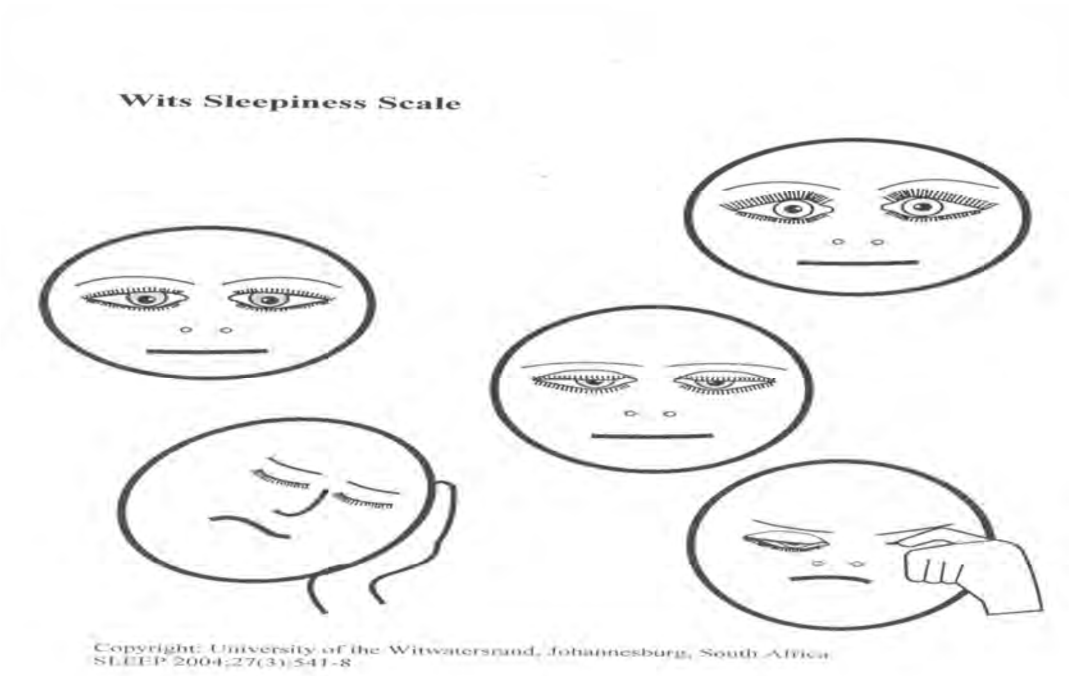

Figure 6: Pictorial sleepiness scale based on cartoon faces (WSS)

COGNITIVE ANALYSES

Probed Memory

A probed memory recall test, utilising 12 unrelated words, was used to indicate the circadian variations, impact, and fluctuation of short term memory recall. The probed memory recall test was selected for the current research based on a study by (Blatter and Cajochen, 2007) where the authors found strong correlations between subjective and performance measures over the course of a night shift cycle with measures of memory performance based on the probed memory recall test.

The tests comprised 36 cards, each containing 12 unrelated words. The utilisation of the 36 different cards followed that there were 6 testing session per shift, with the subject completing 2 trials under each test. Therefore, at testing each group was exposed to card 1 followed by card 2 for the first testing battery. Once the all subjects had passed through the testing station cards 1 and 2 were removed and cards 3 and 4 were taken out to be used for the second test session. During one shift a total of 12 cards would be used for the 6 tests, and with a 3 shift cycle a total of 36 different cards were needed. At no time was a subject exposed to the same card with all subjects being exposed to the same combination and ordering of test cards.(picture of cards for PRM)

Similar to Dinges **et al** (1993) validated probed recall memory task, the subjects were permitted 30 seconds to memories the 6 paired words. A 5 second delay followed after which subject recalled as many words as possible by writing them down in the 30 second period. Once subjects time was up or they could no longer recall any more words they received a 45 second break before repeating the same process over again with a different set of cards.

The scoring of the probed memory recall test involved a point for each correctly recalled word. This involved the correct spelling of the word, with incorrectly spelt words being regarded as incorrect. From the two trials, the average value of correct answers was calculated to represent the score for that testing session.

PERFORMANCE PARAMETERS

Bead Weight

The bead weight performance measure was designed to assess the intra individual difference in performance between testing sessions and over the course of the entire shift. The total bead weight over the shift was considered to assess changes over the three shifts as well as the changes during inter-break testing periods in order to assess variations in performance, mood, motivation and fatigue levels over the course of the shift cycle. This measure, while only providing an intra individual variation, provides an indication of performance between testing sessions, while all other measures provide information more closely linked to performance during a particular testing session.

EXPERIMENTAL PROCEDURE

Subject recruitment

Prior to subject recruitment, ethical approval for the study was received from the Human Kinetics and Ergonomics ethical committee. Full disclosure of procedures and subject requirements was provided to the ethic's committee before ethical approval was granted (see appendix A6). This included the methodological consideration, letter of information and informed consent which subjects were to receive and a written format of the information subjects received during habituation.

Subject recruitment took the form of advertisement through posters, e-mail and through student networking and a local student newspaper. A general break down of the research was provided, including exclusion criteria from participation in the study. Potential subjects, fulfilling the criteria outlined, were asked to contact the researches to set up a date where the subjects would attend the first of two habituation sessions. Subjects contacted researchers via e mail, texted messages and calls, all concerns and questions were dealt with before arranging the first meeting which was to take place in the Human Kinetics and Ergonomics department. Subjects were informed that they would be remunerated on an hourly basis, in the instance that should an individual withdraw from the study before completing the 3 shift cycles, they would still be remunerated for the work they had completed.

Habituation

The first habituation session took place in the Human Kinetics and Ergonomics department, taking approximately one hour. Subjects attended in small groups. A presentation outlining the purpose and aims of the research, risks and benefits, and break down of the intervention strategy and testing equipment was provided at this stage. All information was provided in written (letter of information) and oral format. Additionally, subjects were fully informed of the fact that they were under no obligation to stay in the study and that should they at anytime feel uncomfortable or unhappy with the requirements of the study, they were fully within their rights to withdraw and discontinue from the study. Once subjects were aware of this, a letter of informed consent (see appendix A5) was handed out; subjects read this and signed it indicating their willingness to take part in the research.

The testing procedure was explained, detailing all the equipment which was to be used. At this stage subjects were not exposed to the tests, this occurred during the second habituation session. All equipment and tests where explained verbally by the researchers in the most simplistic of ways, so as not to confuse the subjects. All questions and concerns were dealt with as this stage before moving on.

Once the presentation finished and all questions had been answered, the subjects received the Horne and Ostberg (1979) morningness-eveningness questionnaire (see appendix A3). A detailed explanation of the questionnaire and the reasons behind its use was provided. Upon completion of the questionnaire, subjects provided details regarding age, gender, race and current level of education. All information was used in the assignment of the subjects to groups; this was to ensure a homogenous distribution of subjects across conditions. The design worked such that within each group – intervention group, control night and controlled day group – there was an even split of males and females, a similar distribution of morning types and evening types and similar group education levels. This was to ensure that variations between groups could be more accurately accounted for due to differences in conditions and not manipulated by an uneven distribution of subjects on the basis of morningness-eveningness types and education level.

Before leaving, subjects indicated when they would be able to attend the second habituation session which was to occur a week later at the Biopharmaceutical research institute (BRI) laboratory where the testing would occur.

Subjects attended the second habituation session in small groups. Upon arriving at the BRI laboratory subjects received a tour of the laboratory, followed by an explanation of what was going to occur during the session. Subjects were informed about which shift they were to attend, however, they were not informed at this stage as to whether they were going to be exposed to the intervention strategy or controlled group, this only occurred once subjects arrived for their first shift. The reasoning behind this was to ensure subjects maintain as normal as possible routine prior to starting their shift and were not potentially influenced by the knowledge of which conditions they would be exposed to.

A detailed explanation and demonstration of the booster break intervention was explained to all the subjects during the second habituation session. A second demonstration and practice was provided on arrival to the first shift for those in the intervention groups to ensure that they were aware of the proceedings and able to perform the simple step exercises.

Following this subjects, were taken into the testing section of the main room and the procedure of each test which they were to be exposed to during testing was explained in detail again. After that, each subject had a chance to practice each test and ensure that they were comfortable with the requirements from the testing battery and able to utilise all equipment. Once all subjects were familiar with the test batteries, they went into the working area of the room where they were informed of the working tasks which they would be performing during the shift cycle. All questions and concerns were answered before subjects departed.

MEASUREMENTS OF DEPENDENT VARIABLES

Test Battery

Subjects were tested in groups of four, with each subjects starting at the same station every time and moving in a clockwise direction until they had completed all four testing stations. Not all the stations required the same amount of time, therefore should one station finish before the next; subjects took a seat next to that station and waited until they could start the next test. The testing batteries took between 12 – 15 minutes to complete, after which time subjects returned to the working area. Once all four subjects had completed the battery of tests, the researchers called the next group to come through for testing and the procedure was completed again. Each subject completed the test battery a total of 6 times, this included both the pre and post shift tests.

Station 1:

Station 1 consisted of three tests; two perceptual scales and the simple reaction time test. The first test was the Karolinska Sleepiness Scale (KSS), followed by the Wits Sleepiness Scale (WSS) and finally the computer based simple reaction time test. Subjects spent approximately 3 – 4 minutes at this station before proceeding to station 2.

The KSS and WSS were visually displayed on the left hand side of the desk (see appendix B3 and B4). By pointing at each scale – first the KSS and then WSS – subjects indicated how they felt at that current time. Once completed, the subject turned to face the computer to begin the simple reaction time test. Upon completion of the final test the subject move to their right to station two.

Station 2:

Station 2 consisted of four measurements, the bead weight performance measure, critical flicker fusion frequency (CFFF), and infrared emission detection thermometer reading of the tympanic membrane temperature and forehead skin temperature.

When called in for testing, each subject collected the total beading work, both completed and what they were currently working on, and brought it through to testing. The total amount beaded was recorded each time the subject entered the testing battery, with the difference in values between subsequent tests being of interest. Subjects placed the beads on the zeroed digital platform scale and the researchers recorded the value on a data sheet.

Next the subjects performed the CFFF test with the modified binoculars. The binoculars were held by the subject and placed against their face such that no ambient light entered. Once subjects were comfortable the researcher turned on the LED and subjects adjusted the binoculars such that the flashing light was in centre view. The researcher turned the frequency gauge to maximum so that the subject was aware of what the constant non-flickering light looked like, once subjects were comfortable the test started. From a low frequency, the research slowly increased the Hz rating until such a time that as flickering light became indistinguishable from a steady non-flickering light. Once this occurred, subjects verbally prompted the research to stop. The value was recorded from the frequency gauge meter and the test was complete.

The next measurement involved a noncontact forehead temperature measurement by a handheld infrared thermometer. Subjects were required to look directly at the researcher while the infrared camera was held perpendicular to the forehead at an approximate distance of 10cm. Once the researcher had focused the camera and was recording steady readings a snap shot picture of the subject's forehead was taken. The picture was then reviewed to obtain the temperature in degrees centigrade.

The final measure for station 2 involved the measure of tympanic temperature. For standardisation purposes the left ear was used for each test throughout, with a probe cover being fitted to the barrel. No additional techniques were use while measuring subject's tympanic temperature, such as a posterosuperior ear tug, with the same researcher performing the measure each time. A single measure was obtain and recorded in the thermometers memory before subjects moved onto the next testing station.

Station 3:

Station 3 involved the assessment of saccade latency through the use of the Dikablis eye tracking system and the high and low precision reaction tasks. The saccade latency data collection formed part of a collaborative research project with all data collection and reduction being performed by Robertson (2009). Subjects were required to sit on a chair facing the touch screen in a comfortable position. A researcher placed the eye tracker onto the subjects head by extending the elastic strap over the back of their head and resting the forehead pad and nose piece in place. Once the eye tracker was resting comfortably on the subjects head the researcher turned the system on and got the subject to assume the position in which the testing would be preformed. The eye camera was then adjusted to provide a clear video image of the pupil, while the field camera was adjusted to ensure a clear view of the touch screen.

While performing both the high and low precision tests, the subjects were instructed that once they had responded to the stimulus presentation by hitting the yellow dot with their index finger, they were required to move their hand down to the bottom corner of the screen. Once the next stimulus was presented, subjects then moved their hand to the yellow dot, hitting it with their index finger and returning their hand to the bottom of the screen. This ensured that the field camera was able to clearly pick up the presentation of the yellow dot, without being blocked by the subjects hand and therefore could accurately measure the time between stimulus presentation and pupil movement. Secondly, this ensured a level of standardisation between tests.

The task with which the subject began alternated each time the test was administered, thus if the subject began with the low precision task and ended with the high, the subject would then begin the next test with the high precision task and end with the low precision task.

The test started with the researcher verbally informing the subject of the start of the test and which task they would be performing. Once the subjects complete the first task, there was a short break before starting the next task. If any changes to the camera angles were needed, they were performed during this break. Upon finishing the test, the researcher removed the eye tracker from the subjects head before they moved off to station 4.

Station 4:

Station 4 involved the probed memory recall test. Subjects sat at a desk and when ready received their first card of 12 random words. When instructed to the subjects turned the card over and the researcher started recording time. Once the 30 seconds had passed, the researcher removed the card and allowed for 5 additional seconds to pass. When instructed to the subject started to recall the words by writing them down onto a recall sheet. Subjects received 30 seconds to recall words after which the research removed the recall sheet and the subject received the second card face down. After a 45 second break the subject repeated the process.

CONTROLLED VARIABLES

Extraneous variables and factors have negative impacts on the validity of data, therefore to ensure maximum integrity of the data certain factors need to be controlled to ensure all subjects are exposed to similar conditions and subsequently changes in data responses can be better inferred to changes between controlled and intervention conditions. The staggered nature of the testing batteries and mixed sample groups within each night shift cycle ensured that any environmental changes would be evenly distributed across the same 12 subjects for either the controlled or intervention groups.

The BRI laboratory enabled constant controlled exposure of lighting to all subjects involved in the night shift cycles. Through ceiling florescent lighting, the lighting was constant at 500 lux throughout the testing, exercising and recreational areas.

The intake of food, and in particular larger meals, has been shown to have impacts on the circadian rhythm, acting as an entrainment factor. Under that logic, the food intake and more specifically the caloric intake of the subjects was controlled and held constant across the shifts, both night and day. Additionally, limitations and guidelines were set on caffeine consumption leading up too, and during the shift cycles.

Total exposure to break times during the shifts was of equal duration, with only the frequency and duration of each individual break varying between the controlled and intervention groups. The testing times, although staggered (appendix), remained constant for each group over the 3 night/day shift cycle. Therefore exposing subjects to the same regime each night and allowing the effects of the shift cycle and intervention to have effect.

A simple set of working tasks were selected to allow a degree of freedom within the working period and to ensure a similar level of arousal among all subjects. The working tasks remained the same across all shifts, with the only leeway being the freedom to pack the application pack at any time within the hour provided. The nature of the intervention booster break remained constant across each shift, with all groups of intervention subjects being exposed to the same design of exercises with the shift cycle.

STATISTICAL ANAYLSIS

All statistical analyses were performed using statistica (version 8) with all data inputted calculated from a references value. The reference data was calculated from the average of the pre test occurring between 21h15 – 21h45 and the first test (22h15 – 23h00) for each of the individual shifts. Therefore, all data is representative against this average value and expressed in a ratio.

Three-way factorial ANOVAs were performed to draw conclusions for the overall effect of the three shift condition, assessing the differences between conditions. In order to assess the roll over effect between conditions a two-way ANOVA was performed incorporating two test batteries (test battery 1 and 2) over the three shifts. To draw conclusion based on end of shift measures (test battery 4) over the three nights and between conditions a two-way ANOVA analysis was performed. All primary assessment compared the control and experimental conditions over the course of the three shifts. Individual analyses were preformed in order to assess the effect of condition occurring at a set point during a specific shift. A one-way ANOVA analyses were performed in order obtain the effect of condition at that level. Throughout all statistical analysis a confidence level of $p < .05$ was used to indicate a significant effect.

CHAPTER IV

RESULTS

INTRODUCTION

The diurnal nature of man results in predictable and expected patterns in physiological, psychophysical and psycho-emotional behaviours and responses over the course of the 24 hour day. The introduction of shift work and in particular that of night shift work, desynchronises the circadian rhythms of workers, consequently resulting in adverse effects on performance within a range of domains. Researchers, in attempting to alleviate the extent of performance decrements prevalent during the night shift, have developed a range of intervention strategies. Many of these interventions are however costly and often highly impractical, requiring extensive monitoring and often impractical off the job requirements.

The present study set out to assess if shorter more frequent rest breaks incorporating simple stretches and exercises every hour throughout the night shift would decrease the extent of performance decrements, improve subjective feelings and aid in increasing the speed of adaptation to night shift work.

The three night shift habitation phase entailed three 8 hour shifts with two groups of subjects performing the same tasks and test batteries. One group forming the control condition followed a standard shift schedule while the other was exposed to the booster break intervention. The study aimed to assess if implementation of alternative rest break schedules incorporating physical activity would enhance performance and subjective ratings over the course of the night shift and enable individuals to adapt faster to the desynchronisation associated with night shift work.

KEY CONSIDERATIONS

Throughout the results and discussion sections, the *conditional*, *circadian* and *habituation* effects will be referred to. The *effect of condition or the conditional effect* referring to difference between condition, typically between the control night shift and that of the experimental night shift, where subjects were exposed to the booster break intervention. Where stipulated, the difference between conditions might included the standard day shift subjects for comparison against the night shift groups (control and experimental).

The *circadian effect* indicates the changes occurring over the course of the shift, and hence from one measures (test) to the next. The circadian effect following the natural biological rhythm which fluctuates in a systematic way through a period that is close to a 24 hour cycle peaking and waning at certain times. Oscillations in circadian rhythm will be discussed pertaining to a particular night or day and will therefore indicate the fluctuation in responses occurring over the course of a particular shift.

Alternatively, the *habitation effect* refers to the changes which occur over the course of the shift cycle and therefore looks at changes occurring from one day to the next. A habituation effect typically entails an improvement in responses or performance as subjects become habituated to the abnormal shift schedule, and thus habituation typically represents a positive response to the shift schedules (these being within the night shift schedules). Indications of a habituation to the shift schedule will typically involve an improvement in respons time for example, with there being a significant improvement in overall responses time from shift one to shift three.

References made to the *final effect* are those pertaining to the final measure (test) occurring between 04h15 – 05h00 for the night shift and 15h15 – 16h00 for the day shift. This effect deals with the end of shift performance, generally comparing the variables over the course of the three days/nights taking into account the differences between the conditions. Assessment of the final affect is of importance as the test battery typically occurs around the period of the circadian nadir.

A statistical assessment was performed on all data, for each of the three shifts in order to calculate the point of worst performance or lowest score during each shift. This was done for both the control and experimental conditions in order make comparisons between conditions. Significant differences in lowest values or worst performance are discussed within the chapter with all references being made to table 16 in the appendix.

The data were exposed to a reference value in order to make the data set relative. The reference data were calculated from the average of the pre test occurring between 21h15 - 21h45 and the first test (22h15 – 23h00) for each of the individual shifts. Therefore, all night shift data are representative against this average value, with the general trend remaining similar between the referenced values and those of the raw data sets. It must be noted that within all figures, the values represented on the y-axis are those of the referenced data and not the raw data scores. In viewing all graphs it must be noted that the referencing expresses all values as a ratio to the reference value and thus the values presented are not the raw scores but a relative ratio to the referenced values.

The final statistical consideration is a *covariate analysis* to assess the impact of chronotype's within the condition in order to ascertain if certain chronotypes are more significantly affected by certain conditions. In essence this will potentially indicate if one type of chronotype (moderate evening type, moderate morning type or intermediate) is more affected by the condition of exposure or simply by the abnormal working schedule. A four-way ANOVA analysis assessing overall effects was performed in order to look for an interactional effect between condition and chronotype.

HEART RATE AND HEART RATE VARIABILITY

The heart rate data were obtained over a continuous period of 8 hours during the shift cycle, following which a spectral analysis was performed. The data was analysed in 15 minute intervals, taken during the periods subjects were performing the battery of tests. This assessment was performed in order to obtain an indication of the autonomic control during the test batteries so that inferences might be made pertaining to the data obtained during the various tests. The data represented is the mean of twenty second intervals during the fifteen minute periods. The data of concern, in order to obtain an indication of sympathetic and parasympathetic activity, are those of the heart rate frequency, low frequency/high frequency ratios, and the low frequency bands and high frequency bands.

The results will be represented in isolation to assess general trends within each parameter and later discussed in conjunctions to indicate the autonomic shifts between the sympathetic and parasympathetic systems over the course of the shift, taking into account all the data represented within this section.

Table V: Summary of 3-way ANOVA analysis of spectral heart rate data for the controlled and booster break groups

Note: X = A significant effect at a level of 0.05

Measures	Condition				Circadian effect				Habituation				Circadian effect*Condition			
	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D
HRF	X			X	X			X					X			X
LF/HF RATIO								X								
HF BAND					X			X								
LF BAND					X			X								

Key: **All T; D 3** = all tests over the three days (Final day effect), **T 4; All D** = Final test for each day (End of shift effect), **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days(Overall effect)

Heart rate frequency (HRF)

Heart rate frequency or heart rate (beat.min^{-1}) provides a general indication of the activity level of the subject and that of the autonomic system as heart rate (bt.min^{-1}) fluctuates. The overall statistical analysis indicated in table V indicates a significant ($p < .05$) difference between conditions, a circadian effect, and an interactional effect between circadian rhythm and conditions.

The graphical representation of the heart rate (figure 7) data indicates that during the first night shift, subjects displayed similar heart rates, with both groups of subjects' heart rate declining over the course of the shift., The booster break group displaying significant ($p <.05$) elevations during the shift, between 00h15 – 01h00 and 04h15 – 05h00 indicating a higher level of arousal. During the second night shift, the booster break group's average heart rate remained relatively stable, there was however a significant peak in heart rate near the end of the shift (04h15 – 05h00), around the point suggested to be the circadian nadir. The control group once again follows a more circadian pattern, with on average a decline in heart rate over the shift, with significantly lower heart rate during the final stages of the shift.

The booster break group depicted similar average heart rates during the third night, with a general continuation of average heart rate over the shift. The control group however, depict a significant decline over the course of the shift, with this being speculated to be the influence of the circadian down regulation of the autonomic systems and the strong influence of the parasympathetic nervous system.

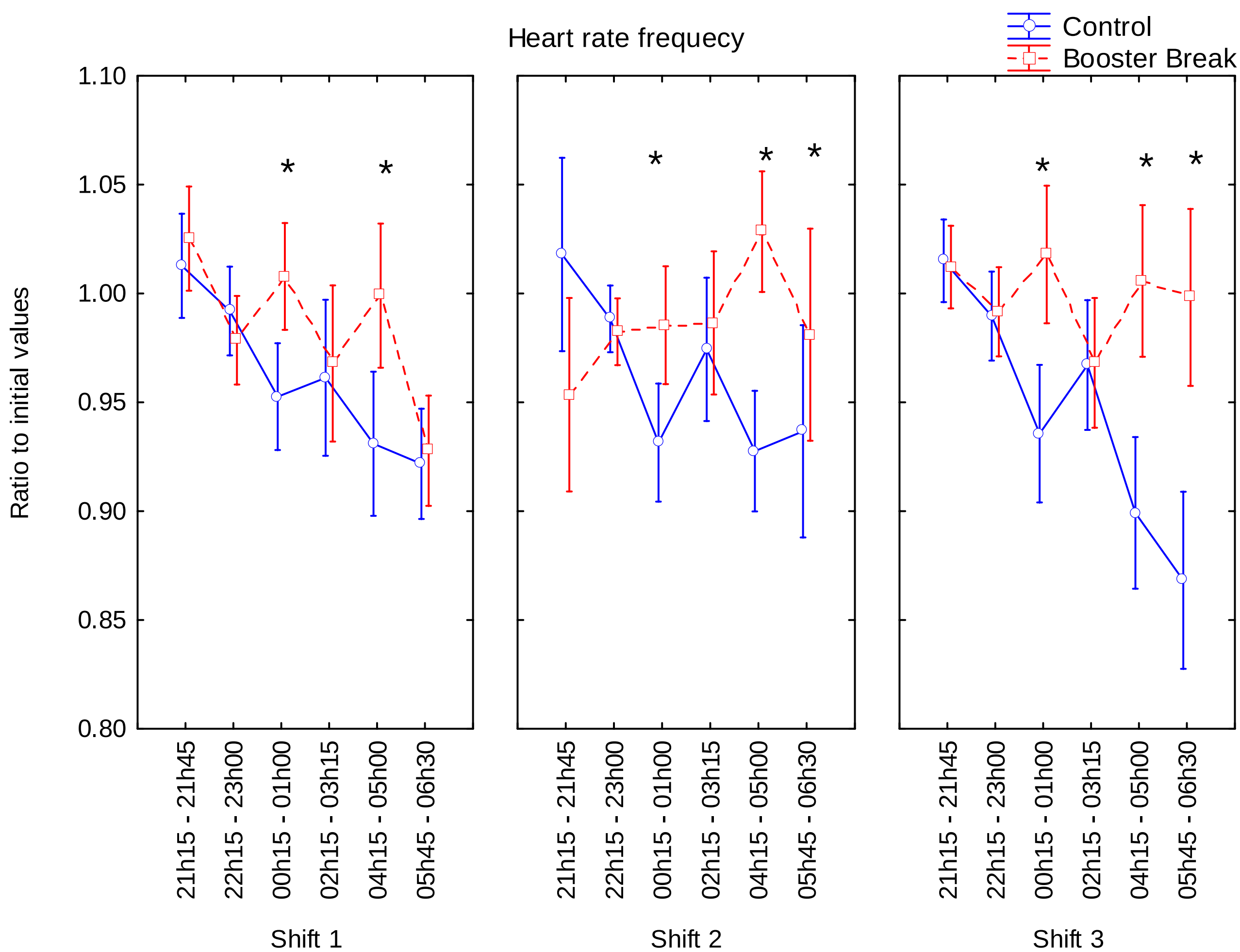

Figure 7: Heart rate frequency for the control and booster break groups over the three night shifts. Note: figure 7 corresponds to appendix table C1

(* denotes a significant difference, $p < .05$)

Alternatively, from the heart rate data here it could also be speculated that the booster break group was more under the influence of the sympathetic branch of the autonomic system, potentially as a result of the interventions, as indicated by the higher average heart rates over the three night shifts. The strength of these two systems becomes more apparent during the second and third night shift, where the significant ($p < .05$) interactional effect between circadian rhythm and condition become apparent as the heart rates for the two conditions deviate.

High frequency bands

Higher HF values are suggested, under normal daily rhythms to predominate at night and are thus more indicative of parasympathetic activation of the autonomic nervous system, typically associated with a vegetative state during sleep. Higher HF bands are hence associated with the down regulation of the body. Therefore during states of low arousal and increased sleepiness there are increases in HF activations, coinciding with increase acetylcholine production, a slowing of heart rate and an inferred decline in performance.

As indicated in table V there is a significant ($p < .05$) final day and overall circadian effect evident for both conditions. No significant conditional differences were calculated for the overall analyses of the three nights (3-way ANOVA). Due to the lack of significant conditional differences, the data will be discussed together with the trends of increased and decreased HF power being indicated within figure 8.

Within figure 8 it can been seen that the trends of increased and decreased HF power is similar for each of the three shifts with there being a constant switch between the weakening and strengthening of the parasympathetic brand over the course of the 8 hour night shift.

Figure 8 indicates that during the first period of the shifts, the general tendency is a decline in HF power occurring between the first and fourth test batteries (between 21h15 and 03h15). This is argued to be symptomatic of a decline in the strength of the parasympathetic activation that is typically strongest during the night time hours and is potentially the result of subjects remaining awake during a time when they are typically gearing for sleep or already sleeping. Additionally, it is speculated that the forced desynchronisation caused by the night shift schedule results in subjects fighting against the natural down regulation and therefore forcing a decline in parasympathetic activity in an attempt to maintain alertness and optimise general functioning. During the second and third night shift, the decline in HF power occurring up to this point is more pronounced, potentially indicating the cumulative effects of fatigue following the first night shift and the extra effort needed to work against the down regulation.

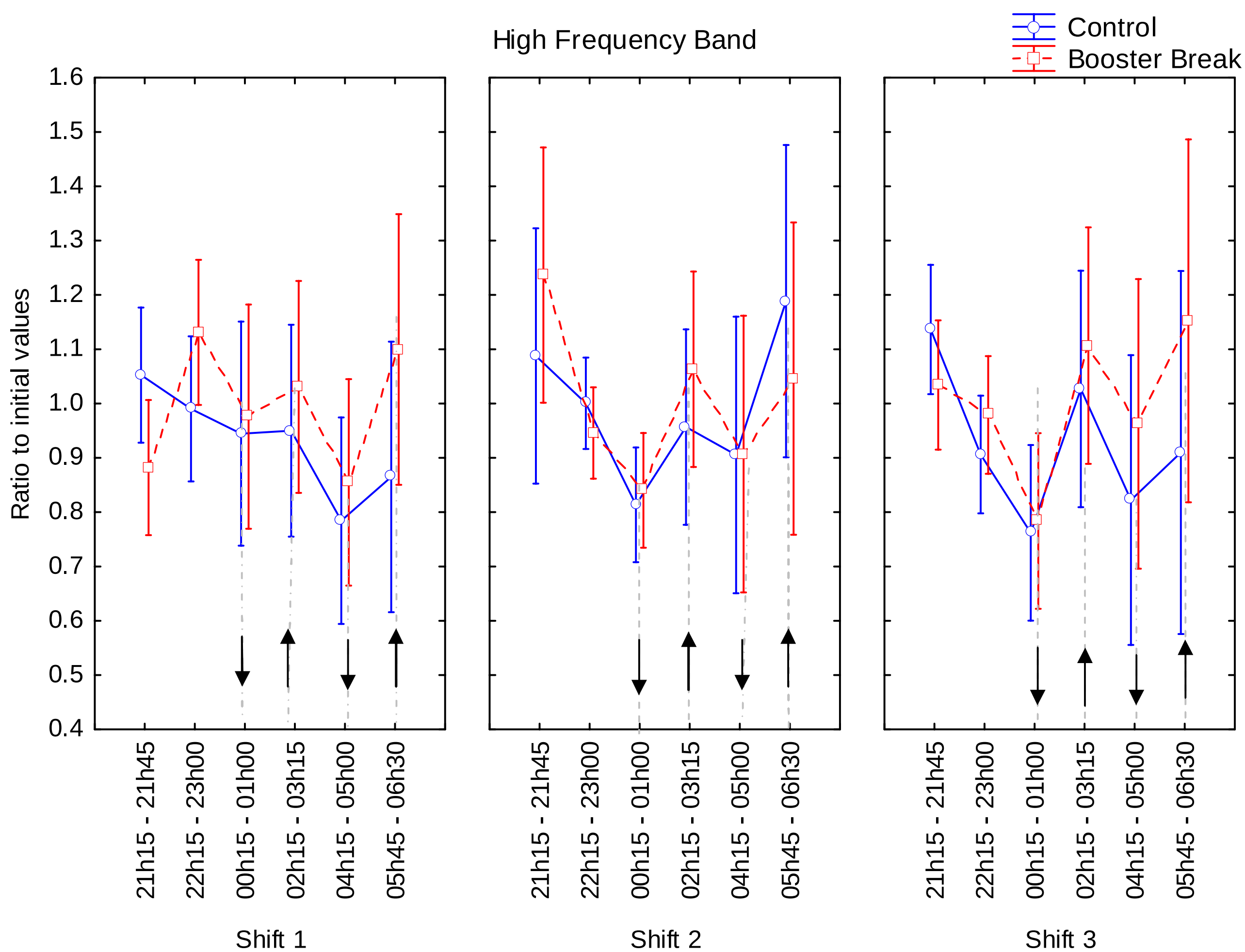

Figure 8: High frequency band analysis for the controlled and booster break groups over the three night shift cycle. Note: figure 8 corresponds to appendix table C1

As indicated in table V the strengthening of the HF power band occurring between 02h15 and 03h15 increases from the first shift through to the third shift (figure 8). As the increased power indicates a strengthening of the parasympathetic branch and thus an associated rise in sleepiness and decline in arousal and performance, it is speculated that over the course of the three nights the subjects experience a greater degree of down regulation from one shift to the next at during the time period. It is further hypothesis that the cumulative effect of fatigue and a lack of entrainment to the shift schedule are the cause of the increase HF power bands from the first to the third shift.

The decreased HF power which follows between 04h15 and 05h00 is suggestive of the subjects attempting to self regulate and increase their attentiveness and arousal level, resulting in a decrease in parasympathetic activation. This might function as a protective mechanism geared at attempting to ensure the most optimum performance and functioning during a period of time typically associated with nadir in circadian rhythm.

The increase HF power which results at the end of the shift, points to the fact that the subjects' sleep pressure had reached a point at which the natural down regulation became greatest and the subjects were unable to maintain the desired alertness levels. This might mark the point at which subjects become unable to work against the waning of the circadian rhythm.

In summary of the HF power data it would appear that over the course of the three night shifts, the extent of the strengthening and weakening of the HF power gradually increases and becomes more dramatic. Therefore, the peaking and waning of the circadian rhythm appears to become more unstable later into the forced desynchronisation and thus required greater effort from the subjects to simply maintain optimum functioning.

Low frequency bands

Higher LF bands are suggested to predominate during the day time hours (under standard conditions) where activity levels are higher and general functioning is greatest. The sympathetic branch of the autonomic system predominates during these times with increased level of catecholamine production (epinephrine and norepinephrine) increasing average heart rate, alertness and arousal levels.

Table V indicates that the HF bands had the same statistical outcomes of that of the HF power bands, with the strongest influence being that of the natural circadian rhythm during the final shift and overall. Due to the lack of significant differences the trends, as indicated with the figure will be discussed together.

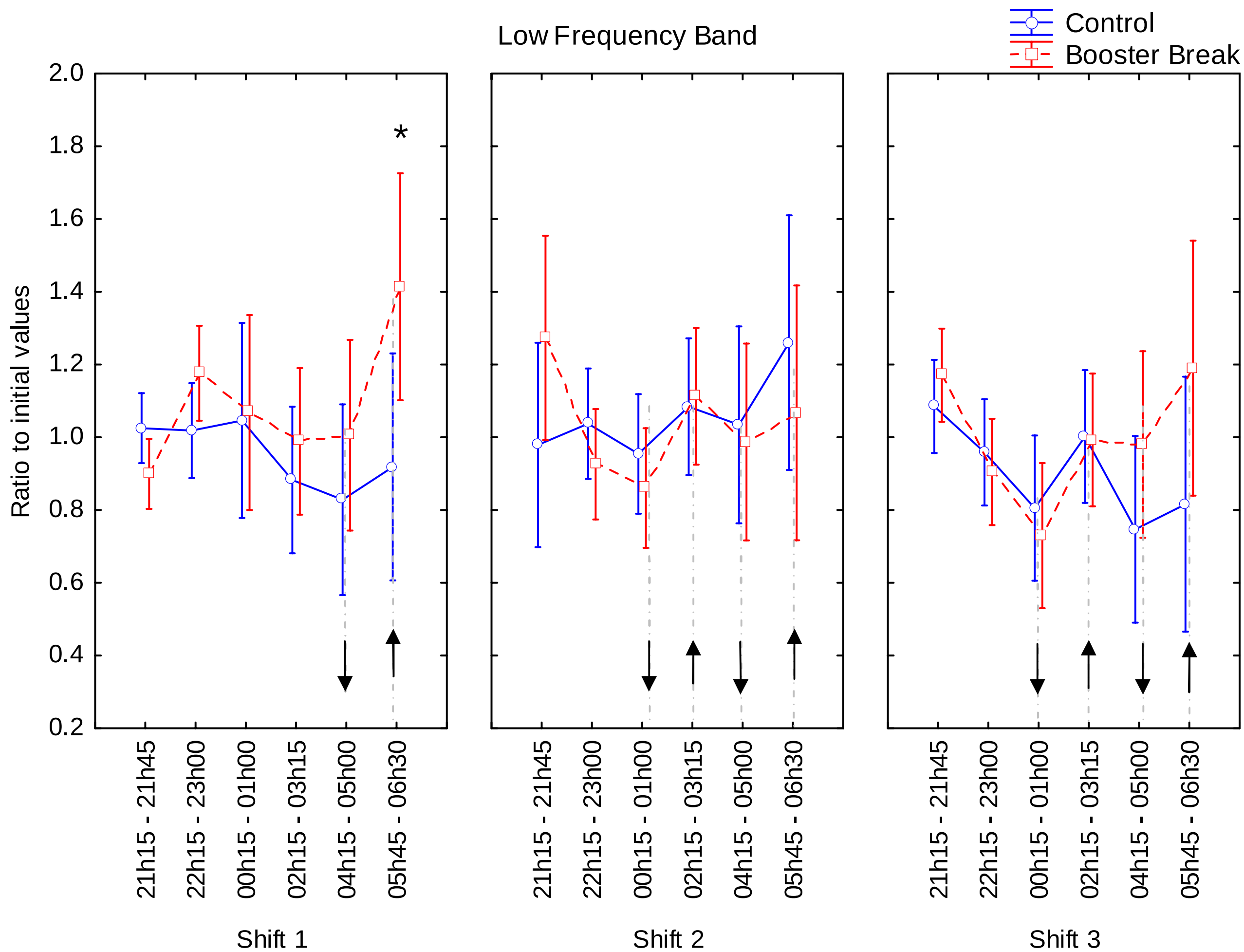

Figure 9: Low frequency band analysis for the controlled and booster break groups over the three night shift cycle. Note: figure 9 corresponds to appendix table C1

(* denotes a significant difference, $p < .05$)

Figure 9 indicates that the first night shift is generally marked by an average decline in LF power up until the final test battery occurring between 05h45 and 06h0. The declining power signifies a weakening of the sympathetic branch and thus a proposed increase in sleepiness associated with natural circadian down regulation occurring of a night. The end of the shift is marked by an increase in LF power indicating an increase in sympathetic activation and hence arousal and alertness. This might simply be due to the knowledge of the end of shift resulting in a misleading increase in arousal. Overall the first night is marked by an increased need for sleep and a predominating decline in HF power (figure 8).

The second and third night shifts follow a similar average trend with a decline in LF power during the first three test batteries up until 01h00. During this period of time it is speculated that the subjects are strongly influenced by the natural circadian down regulation with a weakening of the sympathetic branch during the night. During the same period of time, there was an average decline in HF power (figure 8). Indications being that although the sympathetic input is weakening, inducing sleepiness the fact that the HF power is also declining points to a mechanisms functioning to attempt to lessen the degree of fatigue by not increasing parasympathetic activation at the same time.

The next test battery between 02h15 and 03h15 is marked by an increase in LF power and hence a strengthening of the sympathetic activation. Again this is mirrored by an increased HF power (figure 8), and therefore there is an interplay between a strengthening of both the sympathetic and parasympathetic branches, in order to provide a balance and potentially function to ensure as steady a level of performance as possible.

The decline in LF power occurring during the period marked as the nadir in circadian rhythm (04h15 and 05h00) is more pronounced for the control group during the third night shift. This would suggest that the intervention resulted in a high maintenance of sympathetic activity during the period of strongest down regulation during the final night. However, it should be noted that the slowing of the sympathetic branch – indicated by decrease power of the LF band – is indicative of weaker sympathetic drive and thus an increase in sleepiness and associated performance and arousal. The fact that once again this decline is mirrored in the HF power band (figure 8) suggests that in an attempt to reduce the extent of this decline, the parasympathetic activation is weakened such that it counteracts the down regulation caused by the slowing of the sympathetic branch.

The end of shift increase in LF power is again hypothesised to be the product of the knowledge of the end of the shift and hence potentially produces a false or misleading shift towards increased sympathetic activation. Simply put the knowledge of going home functioned as an arousal tool enabling subject's temporary relief from the effects of the circadian down regulation.

With the LF component it should be borne in mind that this parameter is argued to include both sympathetic and vagal influences, therefore while the vagal influence slows heart rate, the sympathetic component increase catecholamine secretion working to increase heart rate. Therefore, utilisation of the LF/HF ratio information is suggested as it takes into account both branches of the autonomic nervous system and hence is potentially more representative of the sympathovagal balance

Low frequency/high frequency ratios

The LF/HF power ratio provides an indication of the balance of cardiac autonomic nervous activity by taking into account both the low frequency bands and high frequency bands. An increase or decrease in the ratio value reflects the normal circadian changes over a 24 hour period and provides an indication of the sympathovagal balance.

Table V indicates the only significant effect ($p < .05$) to be that of a circadian rhythmic effect occurring over the 8 hour night shift. No significant difference between the two conditions was calculated, with the day shift data producing similar trends in responses.

One-way ANOVA analysis performed to assess significant differences between conditions for each individual test battery indicated no significant differences and hence the data in figure 10 will be discussed together.

In order to attempt to simplify the analysis, the shift has been divided in three 'sections' as indicated in figure 10, where the ratio is either increasing or decreasing. Additionally the periods prior to the 22h15 test battery are not being considered for analysis due to the disruptions of the start of the shift causing misleading data profiles.

The general tendency during the first period of the night shift, incorporating the first two test batteries (between 22h15 and 01h00) is an increase in the LF/HF ratio. This is argued to signify greater sympathetic activation and a potential slowing of the parasympathetic branch. Potentially this entails a higher level of arousal and lower sleep pressure, and therefore more characteristic of day time activity.

Following this, during the test battery between 02h15 and 03h15 there is a decline in the LF/HF power ratio which implies a weakening in the sympathetic and strengthening of the parasympathetic branches of the autonomics nervous system. This is typically associated with an increased need to sleep and the down regulation of the circadian system, and is hypothesis to be associated with a dip in performance and increase in sleepiness ratings.

The final two test batteries are marked by an increase in the LF/HF ratio, once again increasing the sympathetic activation and hence the stress hormone production of epinephrine and norepinephrine. Speculations being that due to this period, typically being associated with the nadir in both circadian rhythm and temperature during which sleepiness peaks and arousal and performance dip and additionally due to the previous period of down regulation, the increased sympathetic activation is thus a mechanism geared to alleviate these negative affects and work against the down regulation. It is not clear however, whether or not this is consciously controlled by the subject through increased effort and concentration or simply the natural cycling occurring during forced desynchronisation.

The LF/HF power ratios indicate that there is a constant switching between the two branches of the autonomic nervous system, with the sympathetic branch taking over during the early morning periods of the shift, potentially as an aid in fighting off the increased sleep pressure which has built up over the course of the night shift.

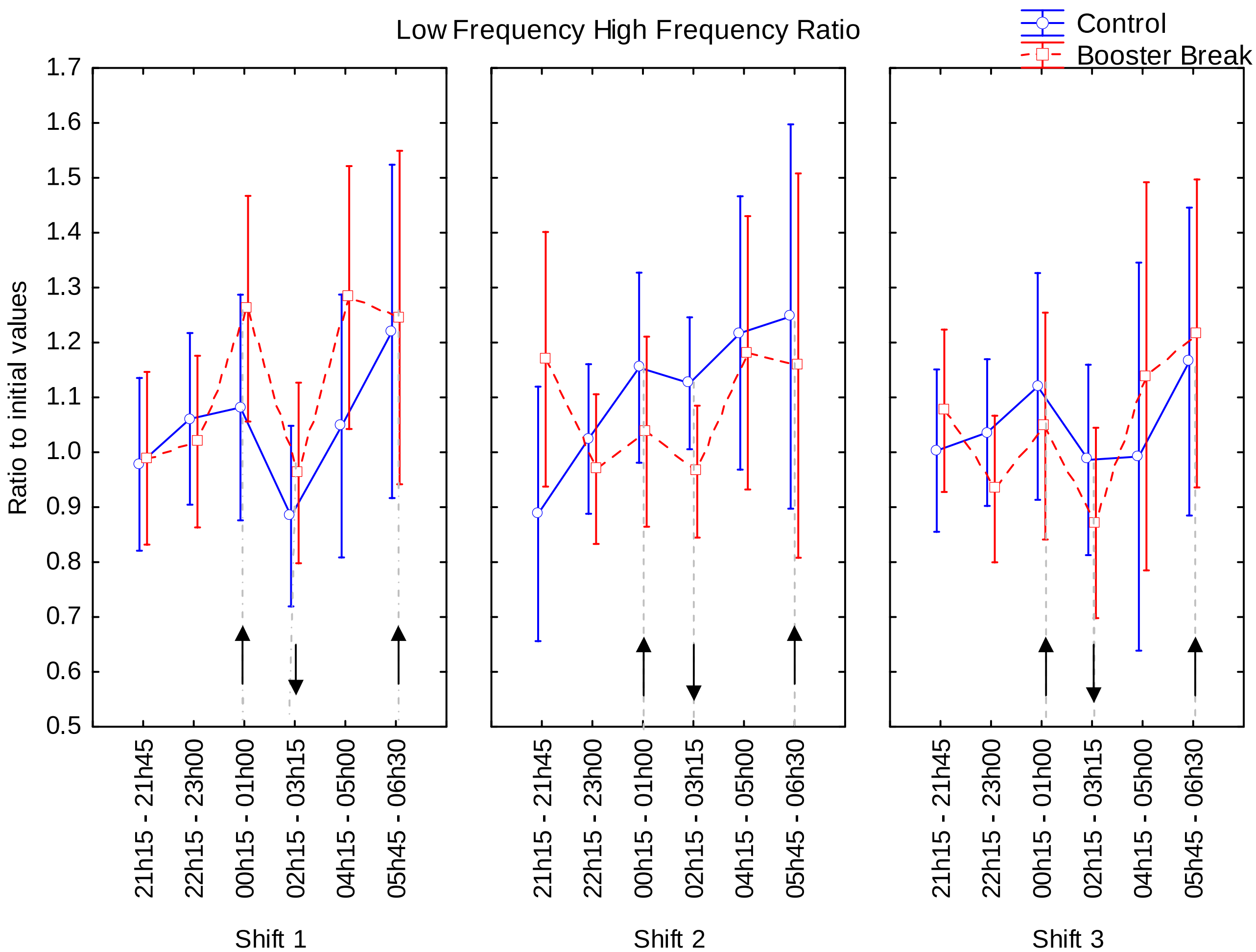

Figure 10: LF/HF power ratios for the control and booster break groups over the three night shifts. Note: figure 10 corresponds to appendix table C1

Summary of heart rate data

The high and low frequency power bands indicated interplay between the two branches of the autonomic nervous system. Increases in power within one band are mirrored by increases in the other band and hence a weakening of both the sympathetic and parasympathetic branches. The hypotheses being that while one system geared for down regulation is weakening the strength of the system required to maintain performance does not have to be so extensive. While this interplay seems to function to maintain a level of performance, it does not function in isolation such that as the parasympathetic branch increase inducing fatigue the sympathetic strengthens to counteract this. The fact that this does not appear to occur within this data suggests that the system interplay simply functions to maintain a steady as possible level, however the effects of the circadian rhythmic oscillations are stronger and ultimately result in a down regulation when working against the natural rhythm.

The LF/HF ratio data indicates the fluctuations occurring over the night and point to the fact that, following increased parasympathetic activation there is a mechanisms geared to increase the ratio power and thus the sympathetic branch. The general hypothesis is that it is either an unconscious mechanisms function to optimise performance under the desynchronisation phase or simple a conscious effect by the subjects to increase concentration and alertness in an effect to fight off the ever increase sleep pressure and fatigue.

TEMPERATURE MEASUREMENTS

Temperature measurements indicate the natural biological endogenous circadian rhythm occurring over the course of the night, indicating the peaking and waning of physiological measures. Inferences made from the waning in temperature measures can be associated with the expected decline in both performance measures, with regards to response time, and increased sleepiness and negative subjective mood profiles (Dijk **et al**., 1992, and Reilly **et al**., 2007).

Tympanic temperature

Tympanic temperature, measured in the canal of the ear, is argued to be a close representative measurement of core body temperature. The discussion around tympanic temperature measures and inferences made thereof are thus speculated to be representative of the core temperature rhythms of the individual.

Figure 11 provides a depictive representation of the tympanic temperature measures taken over the course of the three shifts. The general tendency is a gradual decrease in temperature values over the night, reaching a minimum during the final test occurring between 04h15 and 05h00. This period of time where the temperature reaches its minimum is argued to represent the circadian nadir and temperature nadir which is suggested to coincide with a decline in performance and increase in subjective sleepiness ratings.

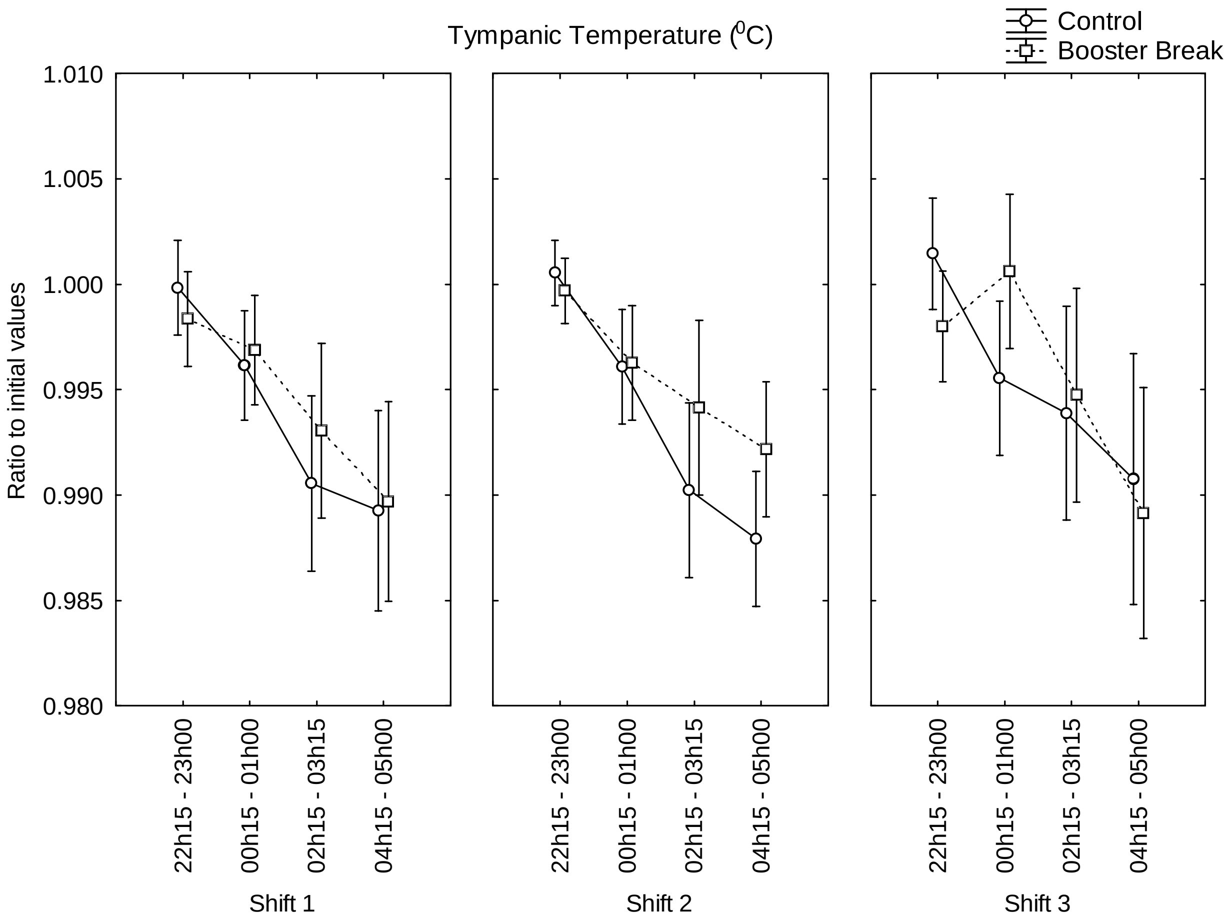

Figure 11: Tympanic temperature measures for the controlled and booster break groups. Note: figure 11 corresponds to appendix table C1

(* denotes a significant difference, $p < .05$)

The 3-way ANOVA analysis indicated in table VI indicates that a significant ($p >.05$) circadian effect was calculated, representative by the decline in temperature measures over the night shift cycle for both conditions. The decline in temperature recordings is indicative of the oscillating endogenous physiological rhythms, reaching a minimum during the final test between 04h15 and 05h00. While both groups indicated strong circadian effects, there were no differences between the controlled and booster break groups, with average temperature recordings following the same decline from one test to the next.

Table VI: Overview of tympanic and forehead skin temperature for significant effects within data

Note: X = A significant effect at a level of 0.05

Measures	Condition				Circadian effect				Habituation				Circadian effect*Condition			
	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D
Tympanic					X		X	X								
Skin					X		X	X		X		X				

Key: **All T; D 3** = all tests over the three days (Final day effect), **T 4; All D** = Final test for each day (End of shift effect), **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days(Overall effect)

A significant (p <.05) decline in temperature was calculated during the third shift, between the third and final test measures – this period suggested to be around the nadir in temperature. The results indicated in table VI, suggest that during the period close to the nadir and entering into the nadir there is a significant decline in temperature. It could be thus speculated that coinciding with the significant decline in temperature during this period there would be a significant decline in performance measures and significant increase in sleepiness and negative subjective mood.

Skin temperature

Skin temperature measures, while argued to provide an indication of oscillating endogenous temperature rhythms is affected by many extraneous factors such a ambient temperature. Ambient temperature, particularly during the night is known to decrease. Figure 12 depictions of forehead skin temperature recordings suggest that during the first and third night shifts, the temperature fluctuations were similar. Subjects from both groups, during these shifts, followed the same pattern. Overall, the circadian and final day effects (table VI) are more likely to be under the influence of the ambient temperature shifts than under the control of the endogenous oscillations of the circadian rhythm, evident from the tympanic temperature data for figure 11.

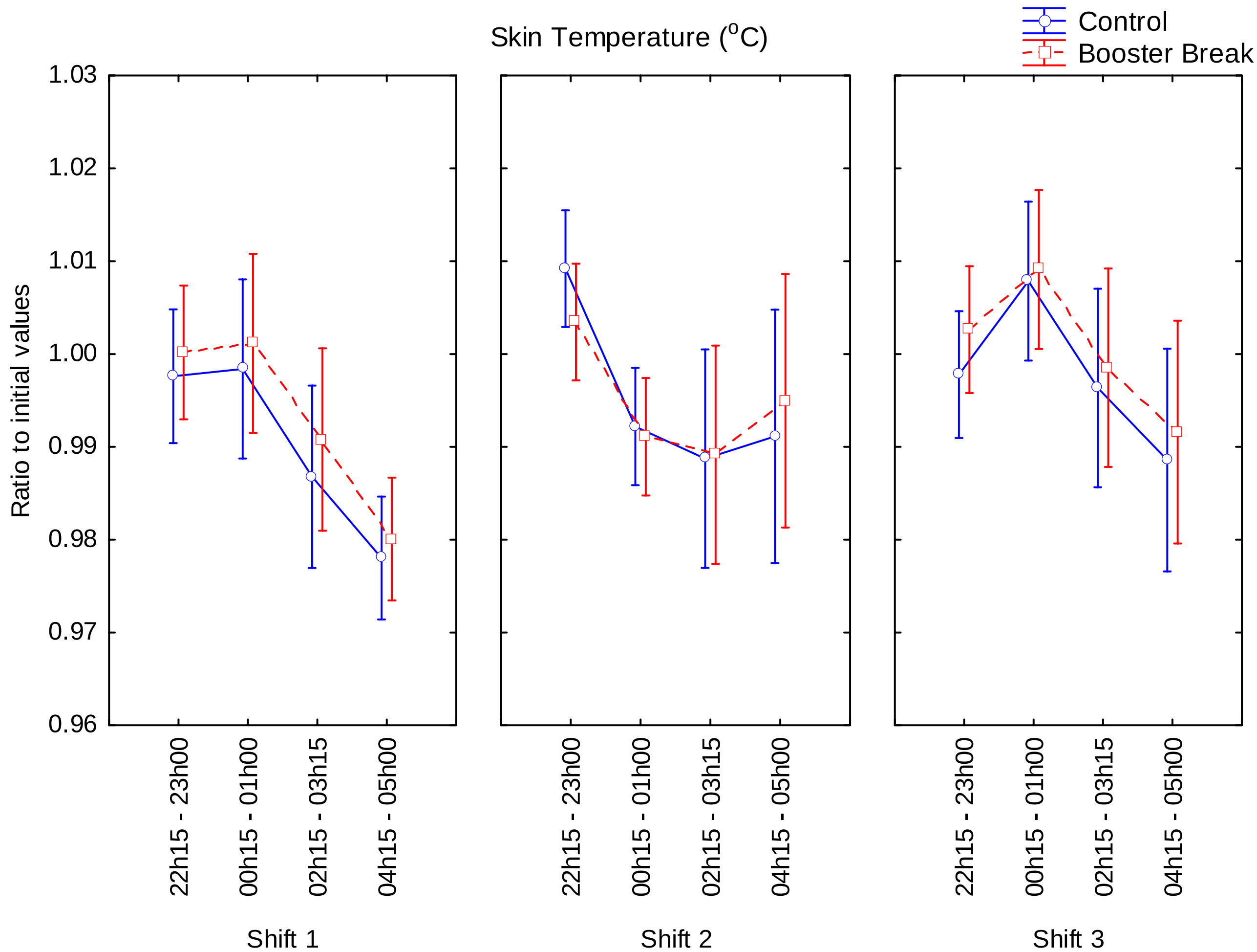

Figure 12: Skin temperature measures for the controlled and booster break groups.

Note: figure 12 corresponds to appendix table C1

* denotes a significant difference, p < .05)

The significant (p <.05) overall habituation effect, which suggests a differences in recording from one shift to the next – in the case of skin temperature, can be speculated to be the influence of ambient temperature changes occurring over the course of the 8 hour night shift and from one day to the next, and is therefore representative of the normal night/day shifts in ambient temperature. Overall the skin temperature recordings provided more insight into ambient temperature changes that it did to fluctuation in temperature as a result of the condition under which the subject was exposed to, and therefore is potentially a weak variable for use in a study of this nature.

Summary of temperature and expected outcomes

Skin temperature appears to be strongly controlled by ambient temperature fluctuations and less representative of changes resulting for circadian fluctuations. The tympanic temperature measures provided a more accurate depiction of the down regulation of temperature during the night. The marked decrease during the final period of the shift is believed to be indicative of the nadir during which time literature suggests there is a decline in performance and memory and an increase in perceived sleepiness (Johnson **et al**., 1992; Matsumoto **et al**., 2002; Wright **et al**., 2002).

SIMPLE REACTION TIME

The simple reaction time data presented is the mean value obtained from a 10 trial analyses measured in seconds. Each result represents the value of the mean of 12 subjects from either the controlled night shift groups or from the booster break group. An indication of performance was measures via the time to respond to the stimulus. Decreased performance was indicated by a slowing in response time (seconds) and improved performance by an increase in response time.

Figure 4.1 provides an indication of response time over the three night shifts for the control and booster break groups. During the first shift, the control group’s performance on average remained constant with there being no difference in response time from the start of the shift to the end of the shift. Similar trends are evident for the booster break groups, with start of shift performance being similar to that at the end of the shift. Large standard deviations (0.27) within the booster break and control group’s (0.22) response time were found during the tests occurring between 02h15 and 03h15. This potentially accounted for the significant increase in response time for the booster break group during this battery of test when compared to the control group, as outliers might be present within the data set.

The 3-way ANOVA analysis for all three shifts is indicated in table VII below. An overall significant circadian effect ($p < .05$) was calculated for response time between the two night shift conditions. The evidence of which is seen in figure 13. During the second and third night shifts it was found that there was a general tendency of slowing in response time over the course of the 8 hour night shift. An almost linear decline in response time for the control group can been seen, with performance decreasing from one test battery to the next, reaching the point of worst performance during the final test battery occurring between 04h15 and 05h00. Alternatively, the general tendency of response times for the booster break group was a decline in response time from the first to the second test battery followed by an improvement in response time thereafter. The significance of this being that while the control groups performance deteriorated over the course of the night, reaching the slowest response time at the end of the shift, the booster break groups worst average performance was recorded earlier in the shift followed by an improvement in reaction time response thereafter.

The general statistical analysis indicated no significant conditional influences for the overall analysis, the assessment of the final test battery for each day and for the third shift. The outcome of which being that the overall general average response times between the two conditions was similar with no conditions performing significantly better on average over the night. One-way ANONA analysis performed on each shift and test battery indicated two significant conditional differences as indicated in figure 4.1. The significant differences indicated during the first shift needs to be assessed with caution due to the large standard deviation values recorded and thus the potential remains for the significance to be accounted for due to an outlier in the data set. The significance indicated within the second shift must also be tentatively assessed, as the possibility for interpretation on a significance based on outlier is also probable.

While these significances are noted, the important analysis remain the overall effect and end of shift performance measures and thus with no significant conditional effects being recorded the data suggests that the subjects from the two night shift conditions, on average performed in similar manners.

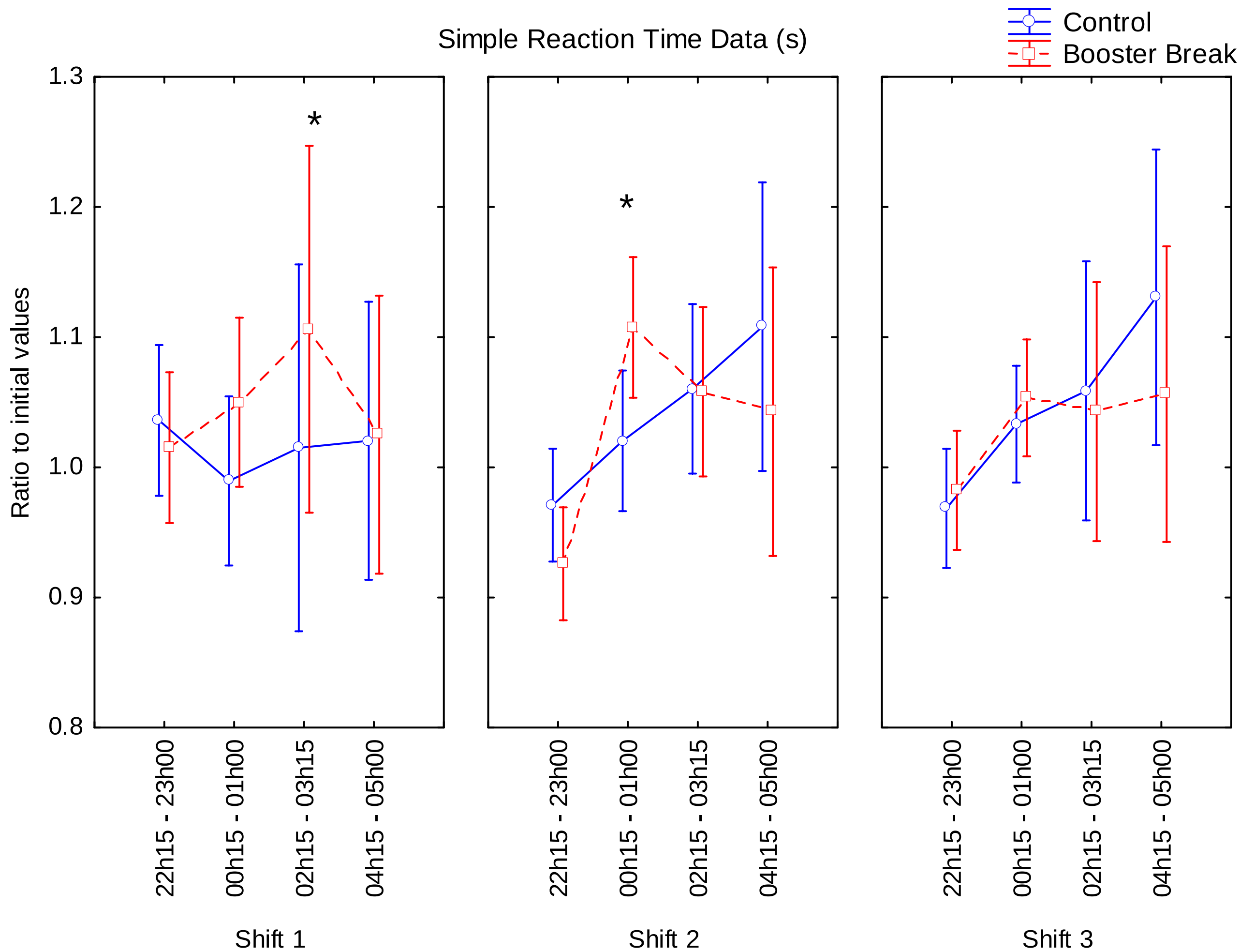

Figure 13: Simple reaction time responses for the controlled and booster break groups.

Note: figure 13 corresponds to appendix table C1

(* denotes a significant difference, $p < .05$)

Assessment of the extent of performance deterioration from the start of the shift to end of shift between the two conditions indicated the extent of differences between the start of the shift and end of shift as measured in a percentage decrease in response time or percentage change from the fastest to slowest response recorded during the shift. During the second night shift, the control groups reported a 76.55% deterioration in performance from the first test battery to the final battery compared to a 18.95% deterioration for the booster break group for the same test batteries. The percentage deterioration during the third night is not significantly different with the control group reporting a 62.62% decline compared to a 54.70% decline in the booster break group.

Table VII: Overview of Simple Reaction time (SRT) significant effects within data

Note: X = A significant effect at a level of 0.05

Measures	Condition				Circadian effect				Habituation				Circadian effect*Condition			
	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D
SRT					X			X								

Key: **All T; D 3** = all tests over the three days (Final day effect), **T 4; All D** = Final test for each day (End of shift effect), **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days(Overall effect)

Assessment of the final day and end of shift performance, suggested that the simple reaction time test was a weak indicator of performance differences between conditions under these circumstances with no significant conditional differences being calculated (table VII). However, although no significance was calculated the trend produced does point to the fact that the booster break group responded quicker nearing the end of the shift. A circadian effect was evident over the course of the three night shifts, when looking at both night shift conditions together. Thus, simple reaction time performance follows the natural cycle of circadian rhythm with there being an expected decline in performance over the course of the night shift. During the second and third shift this is in fact evident with performance deteriorating from the start of the shift to the end (figure 13). The circadian influence of reaction time responses appears to be strongest during the final night shift, with there being a significant ($p < .05$) difference in response times over the 4 measures (table VII and figure 13), for both conditions.

The covariate analysis assessing the effect of chronotype on performance between the two conditions produced no significant interactional effect between condition and chronotype. Therefore, the effects evident within the data are as a response of the condition and not the differences due to the subject's chronotype.

The simple reaction time test provided indications of differences between conditions – although not significant at a level of 0.05. The strongest influence on simple reaction time test responses was that of the circadian oscillation, affecting performance over all three nights.

PRECISION REACTION TIME

The precision reaction time test incorporated two testing components, the speed of response to a stimulus and the accuracy of hitting the stimulus target. The reaction time component of the task was the primary variable with the deviation values providing a secondary variable regarding precision of performance and the deterioration occurring over repeat measures taken during the night shift cycle.

Data represented for the precision reaction time tests are representative of the mean data of 25 trials with an index of difficulty set a 5.66 for the high precision task and 3.44 for the low precision task (Ngcamu, 2009). The task incorporated the Fitts test as a secondary measure to assess if accuracy is equally affected by circadian oscillation, and therefore takes into account the speed/accuracy trade off.

High precision

Figure 14 indicates that the performance over the first night for the high precision reaction time test was similar to that of the simple reaction time test (figure 13). Response times remained constant over the first shift with the average times remaining stable throughout the night shift. There was less than a 1% change in response time from the start of the shift to the end for both conditions.

The 3-way ANAVO analysis (table VIII) revealed an overall significant circadian influence which is most evident during the second and third night shift. During the second night shift, the control group’s end of shift performance was 10% slower than the start of the shift, while the booster break groups experienced a 3% improvement in response time from the start of the shift. The circadian rhythm appears to have had a greater influence on the control groups, as the down regulation caused a performance deterioration in an almost linear fashion over the shift. The significant circadian effect calculated for the third night shift (table VIII) influenced both groups of subjects in a similar manner with performance deteriorations being between 10.5% and 9% for the control and booster break groups respectively.

No overall significant differences were calculated between the two conditions. However a one-way ANONVA analysis indicated that during the second shift, the end of shift performance was significantly different (figure 14). This suggesting that the negative performance consequences, associated with the circadian down regular and nadir are more pronounced for the control groups, with the booster break group improving during the circadian nadir on night two.

Table VIII indicates an overall significant habituation effect, indicating that the pattern of response for the two conditions changes from one shift to the next. This is clearly seen in figure 14 with response patterns shifting over the three shifts. Examination of the figures suggests that the control group's performance decreased on average over the three nights. This indicates a cumulative fatigue effect with performance deterioration reaching its maximum during the final test battery on night three (figure 14). The effect of fatigue only appears to affect the booster break groups during the third night shift, as during the second night shift their performance improved at the end of shift with no changes evident during the first night shift. These measures, are not significantly different and thus overall the influence of conditions was less than that of the natural circadian rhythm.

The covariate assessment for chronotypes indicated no significant influences of chronotype on high precision reaction time responses, with the patterns of response between the three chronotype groups remaining similar over the three night shifts.

The high precision task provided a good indication of the cumulative effect of fatigue with performance profiles changing during the second and third night shift. The intervention appears to have a positive end of shift influences during the second night shift; however during the third shift the circadian effect produces an expected decline in response times for both conditions. The habituation effect presented in table VIII is more representative of a cumulative fatigue effect than a positive influence of habituation, evident by an overall deterioration in average performance from the first to third shift.

Table VIII: Overview High Precision (HP) and Low Precision (LP) reaction time responses significant effects within data

Note: X = A significant effect at a level of 0.05

Measures	Condition				Circadian effect				Habituation				Circadian effect*Condition			
	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D	All T; D 3	T4; All D	T3&4; D3	ALL T; ALL D
HP					X		X	X		X		X				
LP		X		X												X

Key: **All T; D 3** = all tests over the three days (Final day effect), **T 4; All D** = Final test for each day (End of shift effect), **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days(Overall effect)

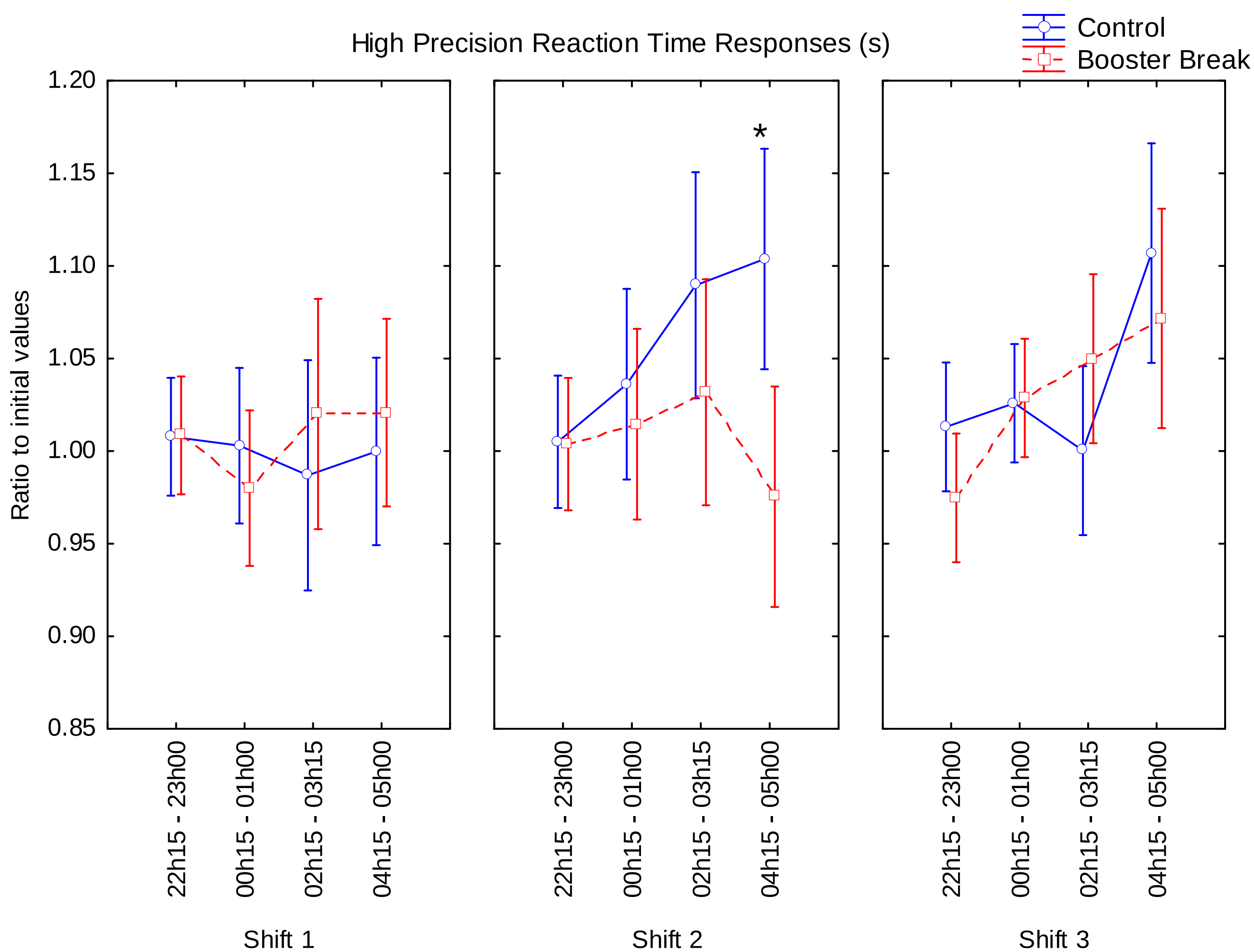

Figure 14: High precision reaction time performance for the controlled and booster break group. Note: figure 14 corresponds to appendix table C1

(* denotes a significant difference, p < .05)

The general habituation effect, which is suggestive of an improvement of performance from one shift to the next, appears to be more evident with the booster break group. The control groups typically responded on average the same at the start of the shift, with the worst performance value increasing from shift 1 and then remaining steady for shift 2 and 3. This indicates a lack of adaptation and hence habituation to the shift schedule and the significant impact of the circadian oscillator.

Low precision

A 3-way ANOVA analysis of the overall data from the low precision reaction time test indicated no significant circadian effects or indications of habitation occurring over the three night shift phase. The lack of significant circadian effects and the significant ($p < .05$) differences between conditions (table VIII) for the overall analysis indicated that the low precision reaction time responses are more strongly influenced by the conditions to which the subjects were exposed, and less to the peaking and waning of the circadian oscillator.

Figure 15 indicates that while the starting response times for each night are the same for the two groups of subjects, there is a deviation in reactions times typically occurring during the second half of the night. The average general tendency among the control group was a decrease in response time over the course of the night shift suggesting a strong circadian influence, while the booster break groups typically improved having a faster end of shift response time than that of the start of the shift. The significant conditional effects indicated in table 4.2 for the overall analysis and end of shift performance, provides strong evidence that the improvements in performance is not indicative of a learning effect and is in fact a result of the arousal effects from the intervention strategy. Additionally, the covariate analysis (see appendix C2) of chronotype further strengthens this point, indicating no significant interactional effect between condition and chronotype and hence stipulating that the significant differences between responses for the two conditions are in fact a result of the exposure to the intervention and not due to differences in chronotype.

The assessment of the percentage change in response times from the start of the shift to the end of shift indicates that the control groups, on average for the three nights had a 6% decline in response time while the booster break group had an almost 2% improvement from the start of the shifts to the end of the shifts.

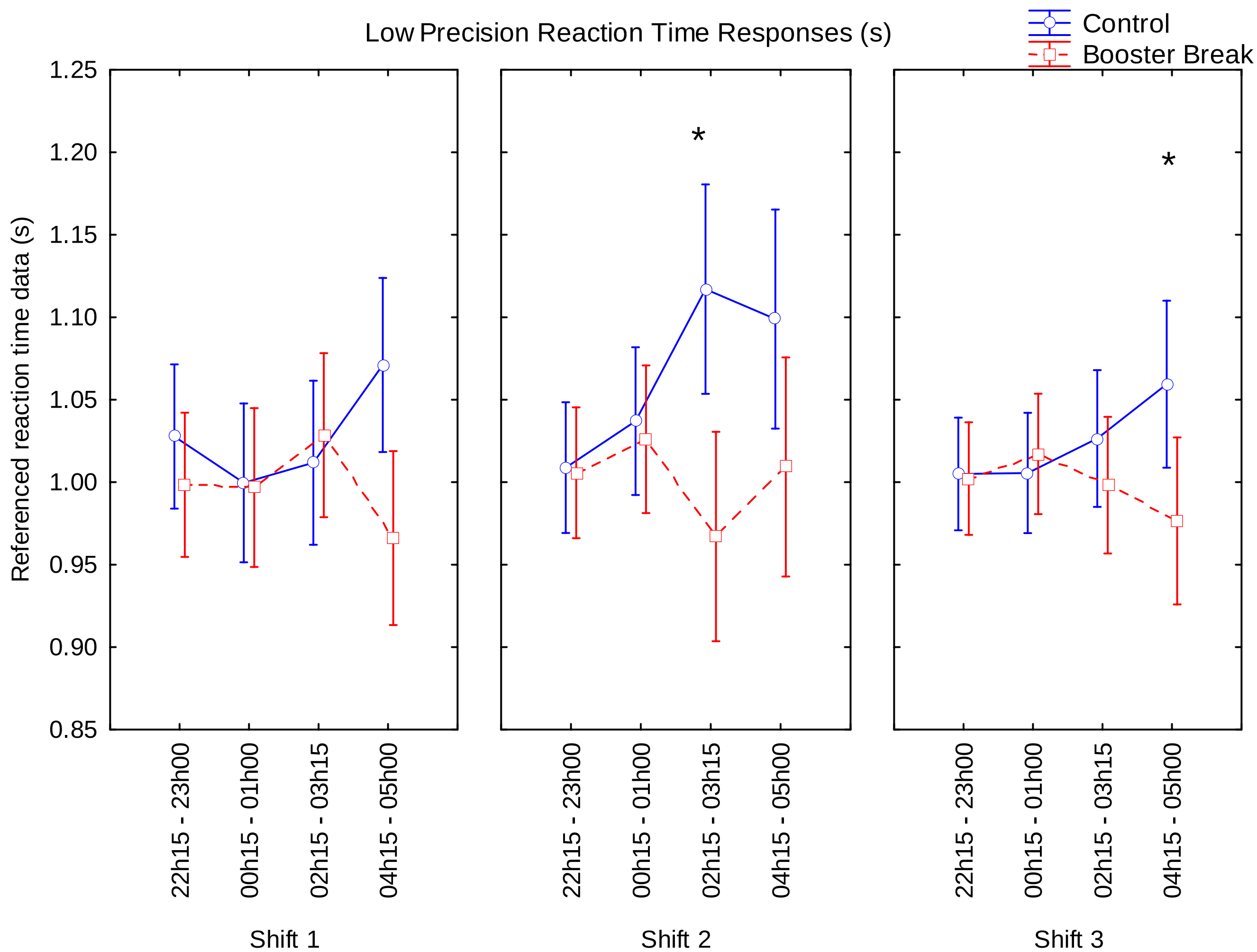

Figure 15: Low precision reaction time performance for the controlled and booster break group. Note: figure 15 corresponds to appendix table C1

(* denotes a significant difference, $p < .05$)

A significant ($p < .05$) difference between conditions at the end of each night shift (table VIII) indicating that the intervention strategy aided in improving end of shift performance, where as the control conditions followed the more natural deterioration of performance nearing to, and entering into the circadian nadir. This natural tendency of deterioration of performance evident within the control group is typically indicative of a circadian influence with performance peaking and waning with the circadian oscillations. The significant ($p < .05$) interactional effect between circadian effect and conditions indicated within table VIII explains the differences occurring between the control and booster break groups. The interpretation of this interaction is that the circadian influence between the two conditions is significantly different; this reiterates the previous statement with the control group following the circadian decline over the 8 hour night shift and the booster break group, on average improving near the period of the circadian nadir.

The low precision reaction time test provided a strong indication of the positive influential effects of the intervention near the end of shift, enabling the booster break group of subjects to work against the natural circadian down regulation and significantly improve response times compared to the control condition. Analysis of the day shift data indicated that the booster break group and day shift subjects followed a similar trend with no significant differences reported between the two conditions. The interactional effect discussed points to the fact that this parameter is influenced by the natural rhythm and that deterioration in performance can be expected over a night shift, should no intervention of this nature be implemented. It should however be borne in mind that this measure incorporated the component of precision and thus any conclusion here must be taken tentatively and consider the speed/accuracy trade off.

Summary of the three reaction time response measures

While an overall significant conditional difference was only calculated for the low precision reaction time test, one-way ANOVA analyses did indicate significant differences between conditions for individual test batteries during the high precision reaction time test during the end of shift performance (figure 14). While no significant differences between the conditions with regards to reaction time speed are evident within the three parameters, it is hypothesised that the intervention aided in improved performance typically during the end of the shifts. Therefore is would appear that the intervention positively influenced end of shift performance and thus hold merit during tasks requiring reaction responses.

High and low precision target deviation responses

The target deviation values provides an indication on the speed/accuracy trade off which might have occurred during both the high and low precision reaction time response tests. The 3-way ANOVA statistical analyses of high precision target deviation (table IX) revealed no significant effects for the general statistical analyses, signifying the fact that subjects responded the same during this measure over the course of the three night habituation phase and that high precision target deviation response were not affected by circadian fluctuation during the night shift. Further analysis incorporating the controlled day shift data produced no significant effects of conditions, with day time responses following the same trend as during the night shifts.

In order to assess the differences between conditions for the greatest target deviation values a 3-way ANOVA analysis was performed on the highest mean values for each condition for the three nights. The analysis indicated a significant difference between conditions (table 16 appendix) with the highest deviation values for the control group being significantly greater than those of the booster break group. As this is an average of each night, the general tendency among the data does not suggest that one condition performed better, as indicated by the lack of statistical data above, but simply that consideration of overall performance difference between conditions should be considered, should a task involve high levels of precision and speed together.

The 3-way ANOVA analyses of the low precision reaction time responses (table IX) indicated significant differences between conditions as well as interactional effects between circadian influences and conditions. Figure 16 indicates a reverse trend to that of the data represented in figure 15 in that the booster break groups enhanced reaction time speeds are evidently the result of decreased awareness of the degree of target deviation. In viewing the overall data from the low precision tests it would appear that the booster break groups sacrificed accuracy for speed and the control group speed for accuracy.

Table IX: Overview High Precision target deviation (HPTD) and Low Precision target deviation (LPTD) reaction time responses significant effects within data

Note: X = A significant effect at a level of 0.05

Measures	**Condition**				**Circadian effect**				**Habituation**				**Circadian effect*Condition**			
	All T; D 3	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**
HPTD																
LPTD	X			X									X		X	X

Key: **All T; D 3** = all tests over the three days (Final day effect), **T 4; All D** = Final test for each day (End of shift effect), **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days(Overall effect)

In assessing the speed accuracy/trade off, it appears that while the booster break groups on average, performed better during the second half of the night shift (figure 15) there was an average increase in target deviation (figure 16) corresponding with that enhance performance. It should thus be noted that potentially, while performance speed improved for the booster break group, there was a decline in precision for the booster break groups – particularly for the second and third night shifts.

The interactional effects within table IX are symptomatic of the speed/accuracy trade off, particularly within the booster break group and hence should speed be a requirement without accuracy then the intervention is positive, however should accuracy also be of importance, then in light of the overall reaction time test neither condition performed significantly better.

A covariate analysis with chronotype indicated no significant interaction between condition and chronotype. This is similar to what was found for all the above reaction time performances and would therefore suggest, in light of this study, that chronotype had no significant impact on response time or deviations in accuracy. Within certain measures, the intervention or lack therefore played a strong role with the overall strongest influencing fact of the Fitts tests data being that of the circadian rhythm occurring over the 8 hour shift.

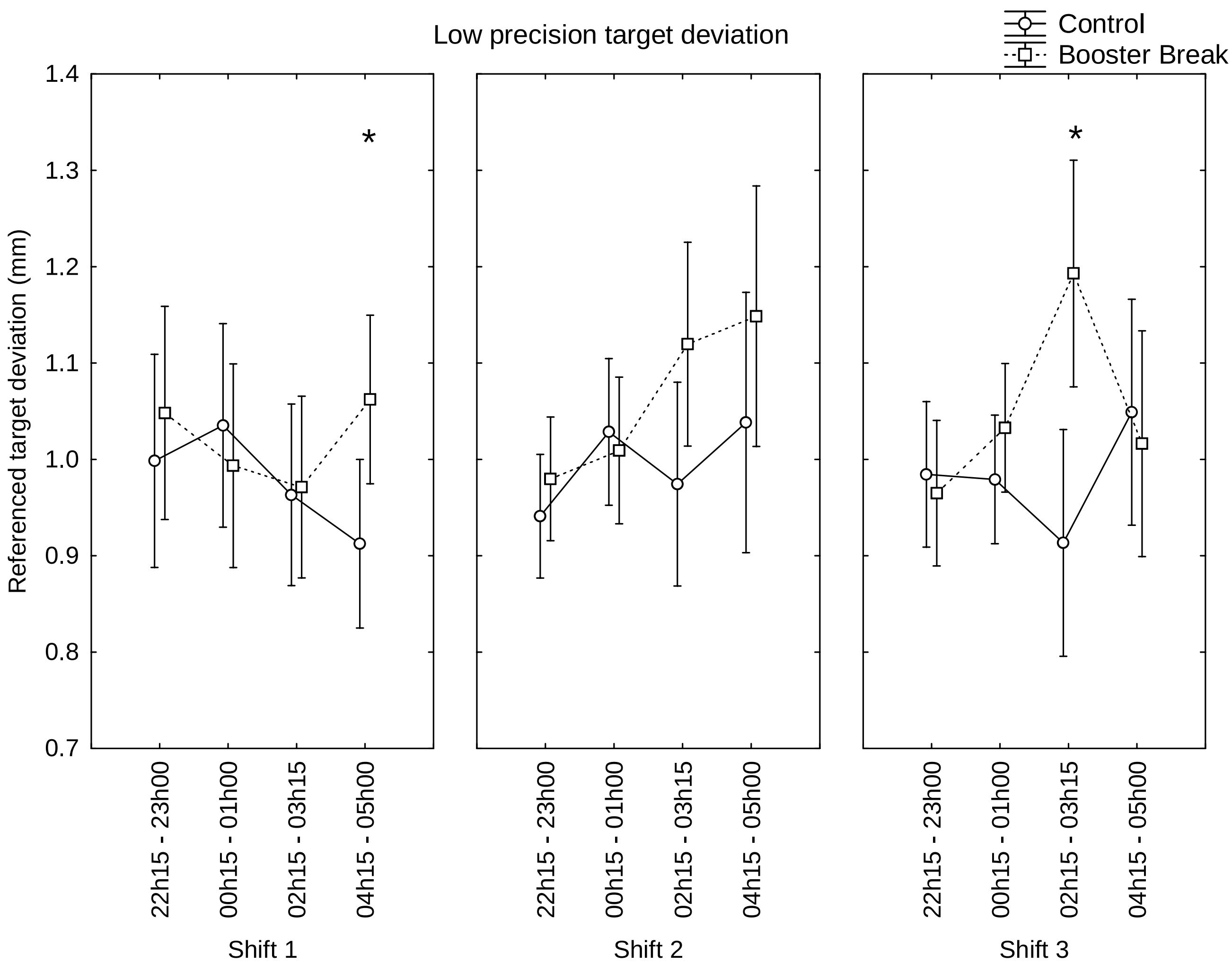

Figure 16: Low precision target deviation for the controlled and booster break group.
Note: figure 16 corresponds to appendix table C1
(* denotes a significant difference, p < .05)

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PROBED MEMORY RECALL

Data represented indicates the mean number of correctly recalled words from the 12 unrelated words memorised during the 30 second learning period. Subjects recalled as many words as possible, with all correct responses indicating one value. The data for each test are the mean of two tests performed during each battery of tests.

The statistical 3-way ANOVA analysis (see appendix C1) indicates no significant conditional effects, circadian effects or habituation effect over the three night shifts. Figure 17 depicts the number of correctly recalled words for each shift. Memory recall over the first night shift remained constant while recall ability varied slightly during the second and third night shift. The second and third shift indicate a deterioration in memory ability later into the shift, however the decline is not significant and does not indicate a strong circadian rhythmic effect.

The lack of significance within the data for the night shift conditions and lack of a clear indication of a circadian effect leads to the conclusion that the probed memory recall test is a weak indicator of memory performance under these circumstances. Analysis of the day shift data indicated similar trends in memory performance, reiterating the point that the probed memory recall test used was not sensitive enough to elicit a significant performance difference between conditions or over the course of an 8 hour day or night shift.

Additional chronotype differences proved to have no significant impact of memory performance with the number of correctly recalled words being the same for each of the three chronotype groups.

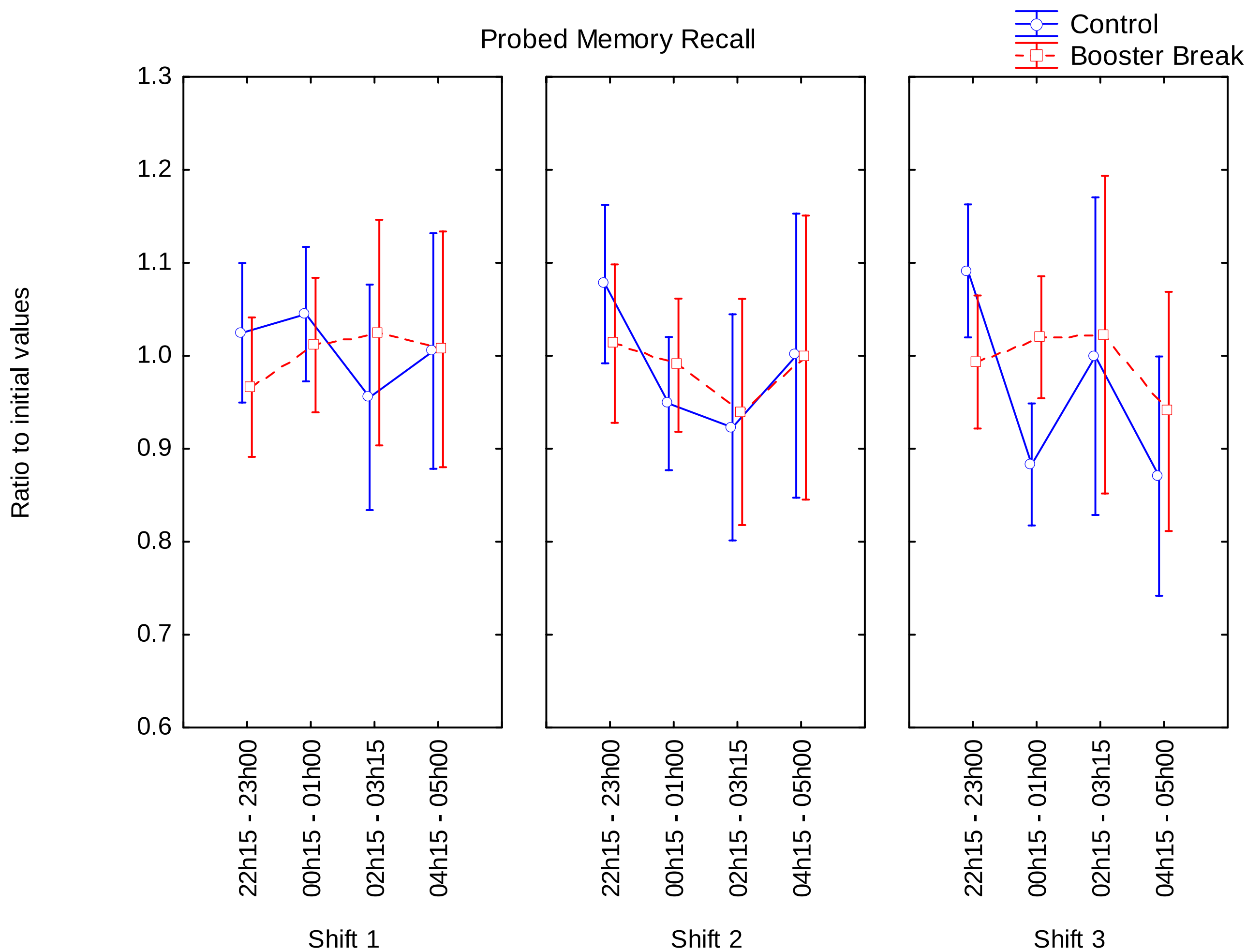

Figure 17: Probed memory recall test means scores for the controlled and booster break group. Note: figure 17 corresponds to appendix table C1

SACCADE LATENCY

The saccade latency responses were recorded during the high and low precision reaction time tests, with the data representing the time of stimulus presentation (dot appearing on the screen) to the movement of the eye. Scores represent the mean saccade latency time for each trial of the HP and LP reaction time tests.

Saccade latency during the high precision test

Three-way ANOVA analysis revealed a significant overall circadian effect and final day effect (table X). The expected circadian implications would be a slowing in saccade response over the course of the 8 hour shift and hence an increase in response times. Figure 18 indicates the saccade latency response times, which contradictorily on average remain constant or slightly improve over the shift.

The significant circadian effect calculated and presented in table X must be cautiously assessed as the improvement in saccade speeds is unexpected and potentially misleading. It is believed that subjects became accustomed to the task and hence a degree of learning occurring which is responsible for the contradictory results.

Table X: Overview of Saccade latency response times for the High Precision (SLFP) and Low Precision (SLLP) reaction time responses significant effects within data

Note: X = A significant effect at a level of 0.05

Measures	**Condition**				**Circadian effect**				**Habituation**				**Circadian effect*Condition**			
	All T; D 3	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**
SLFP					X			X								
SLLP							X									X

Key: **All T; D 3** = all tests over the three days (Final day effect), **T 4; All D** = Final test for each day (End of shift effect), **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days(Overall effect)

The covariate analyses of chronotype indicated no significant effects of chronotype or interactional effect between condition and chronotype for the HP saccade latency data. Indications being that due to the potential of the learning effect it appears that each of the three different chronotypes progressed at the same level and hence had matched performances over the shifts.

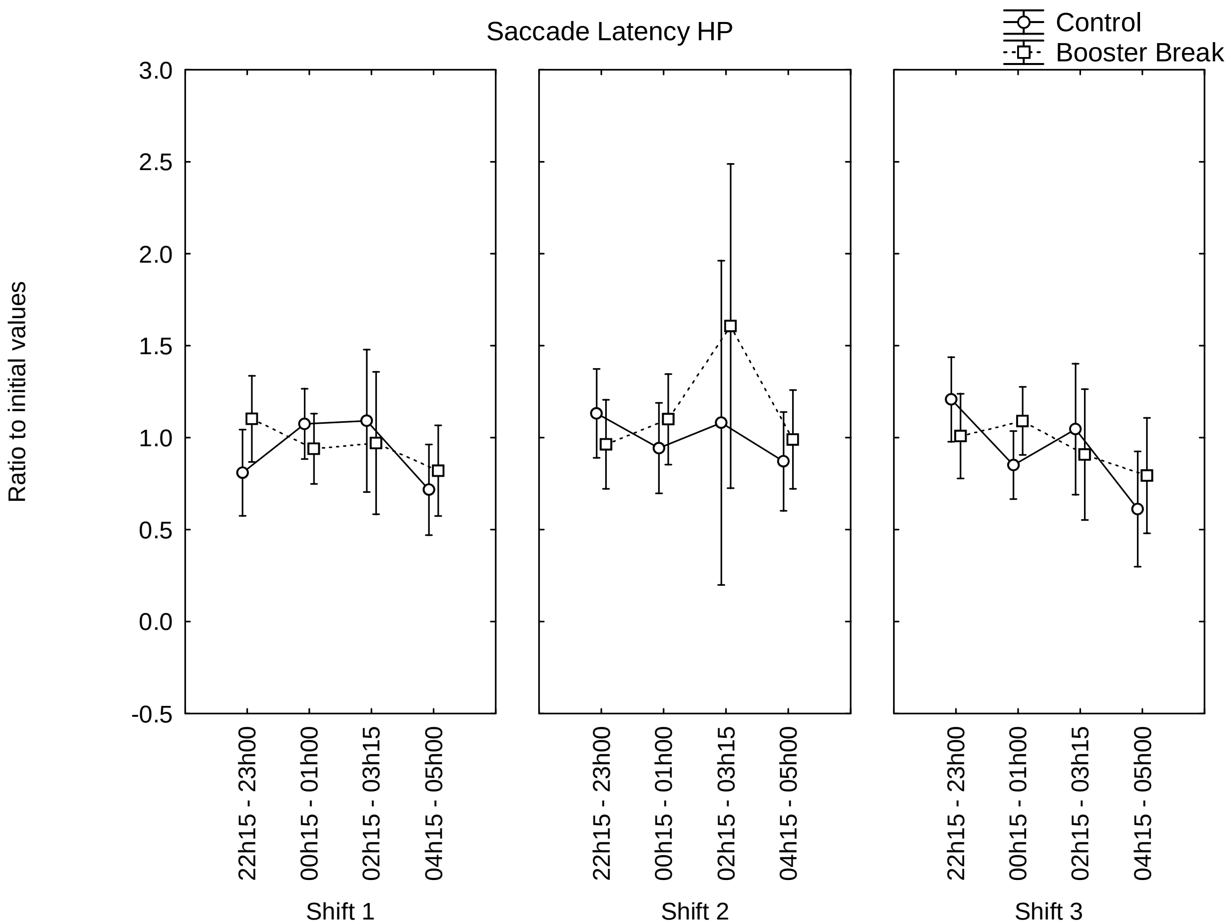

Figure 18 Saccade latency times taken during the high precision reaction time test for the control and booster break groups. Note: figure 18 corresponds to appendix table C1

Saccade latency during the low precision test

The saccade latency responses during the low precision reaction time test, on average followed a similar trend to that of the responses during the high precision test. The 3-way ANOVA statistical analysis indicated an overall significant ($p < .05$) interactional effect between circadian rhythm and conditions (table X). This is suggesting that the potential circadian rhythmic effects or potential learning effects differ between conditions. Evident within figure 19 is that fact that the responses between conditions over the three night shifts is in fact unpredictable, with no evident trend emerging. During the second shift, the control and booster break group's response times are opposite to those during the first night, and then within the third night switch again. This indicates a lack of consistency with the response and the lack of trends within the data over each night shift and for the entire shift schedule. Therefore it is tentatively suggested that between the learning effects and potential circadian influences one cannot conclude conditional differences for these measures.

A covariate analysis incorporating chronotype was performed to assess if possible differences might be evident due to the differences in chronotype. The statistical analysis revealed no such significant differences and thus it remains inconclusive surrounding the accurate interpretation of this data.

From the information presented in table X and the graphical representation below it must be noted that what appears to be a circadian effect is most likely a learning effect. The significant circadian effect occurring during the final tests on the third night is evidence more of a learning effect than a circadian rhythmic change. Typically a decline in performance near the circadian nadir is expected, however there is a marked increase in saccade response time and hence the speculation of a learning effect occurring is confirmed.

The data for both saccade latency tests defy the expected trends of down regulation due to circadian rhythmic fluctuations. The data strongly point to a learning effect occurring for both test criteria, with no significant conditional effects. Therefore under these conditions, the saccade test proved to be weak in indicating conditional or circadian influences.

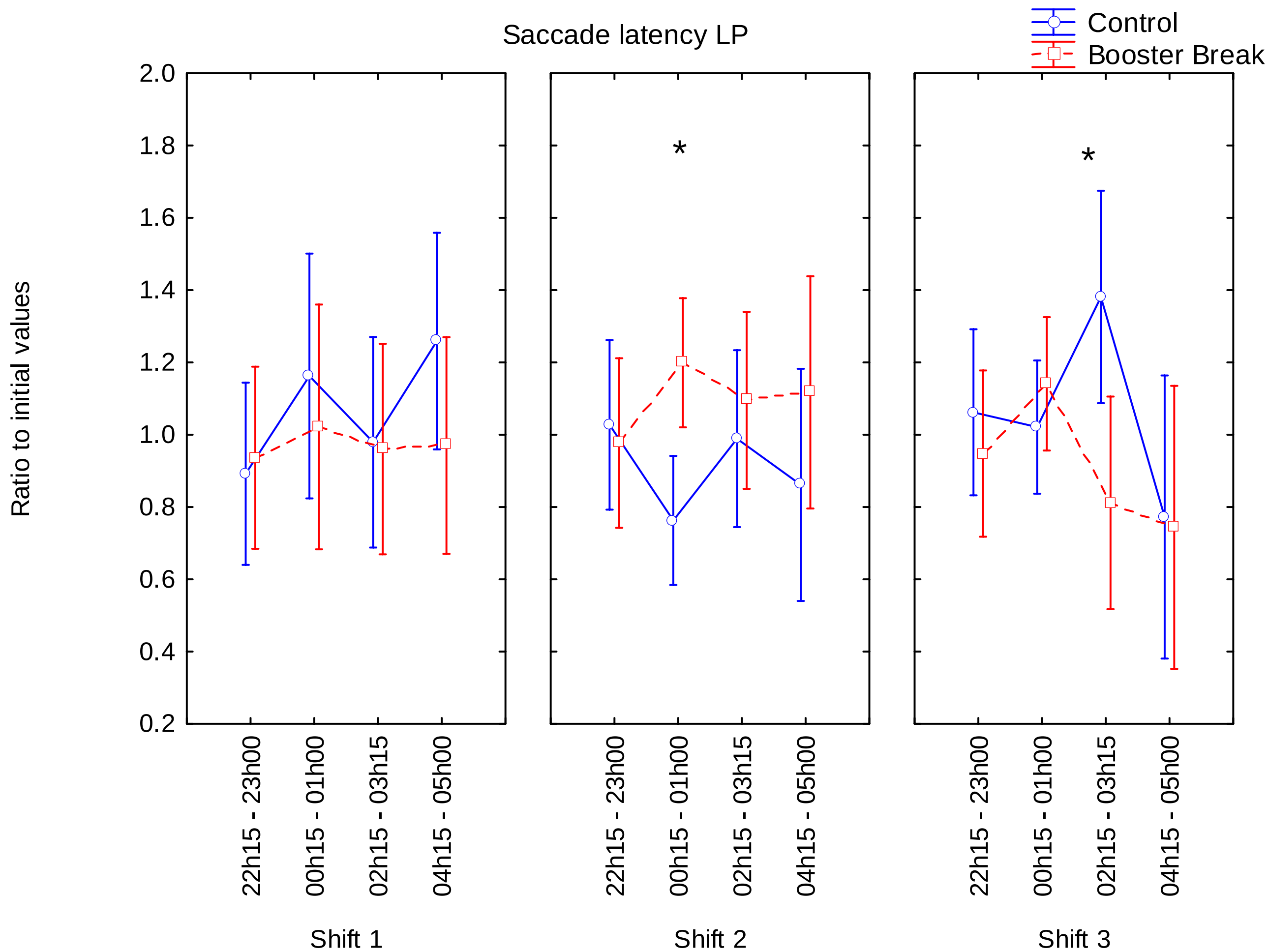

Figure 19 Saccade latency times taken during the low precision reaction time test for the control and booster break groups. Note: figure 19 corresponds to appendix table C1 (* denotes a significant difference, $p < .05$)

CRITICAL FLICKER FUSION FREQUENCY

Critical flicker fusion frequency values represent the results of a one trial ascending test, with the hertz value starting off at the lowest, with a slow flickering of the LED and increasing to a point at which subjects perceived the flickering light to be indistinguishable from a steady, non-flickering light.

The 3-way ANOVA statistical analysis revealed no significant habituation, circadian or conditional effect for the CFFF data recorded during the night shift schedules. Figure 20 indicates that during the first two shifts, subjects from both groups responded similarly.

Over the course of the third night, responses from the two groups deviated with the control groups reporting lower Hz values during the later stages of the shift. A more detailed statistical analysis, comparing the last three tests with a one-way ANOVA during the third shift produced a significant conditional effect. Thus from this analysis it can be said that during the final stages of the third night shift the control groups experienced a high level of mental fatigue and the deterioration of the arousal and consciousness levels of the brain (Baschera and Grandjean, 1979 and Weber **et al**., 1980), indicated by the decline in Hz values.

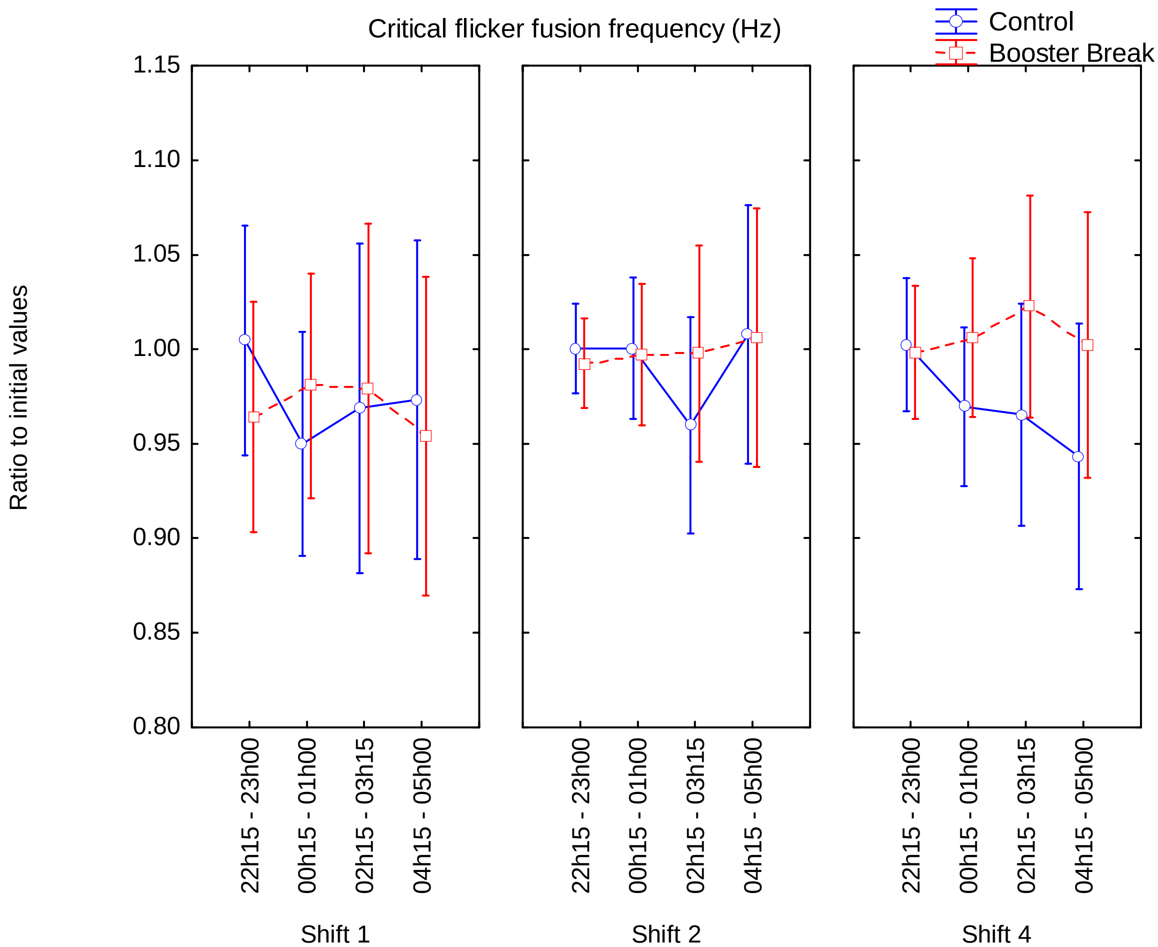

Figure 20: Critical flicker fusion frequency responses for the controlled and booster break groups. figure 20 corresponds to appendix table C1

Covariate analysis indicating the influence of chronotype on CFFF responses over the night shift indicated a p value of 0.079 for the interaction between condition and chronotype (table 9.2 appendix). While this is not significant at a level of .05, it does provide information that had the sample size been greater, there is potential for CFFF results to be influenced by chronotypes between the two night shift conditions. Figure 21 indicates that the intermediate and moderate morning types responded the same under each condition, maintaining similar scores over the night shift. Unexpectedly, the moderate evening type, argued to prefer night time work, experienced a less uniform response. It would appear that the booster break groups experiences a higher ($p = 0.79$) level of mental fatigue overall compared to the moderate evening type under the control conditions. A very speculative conclusion would thus entail that the intervention was more positive for those individuals not suited to night work and is less suited to those individual who are habitually awake later into the night.

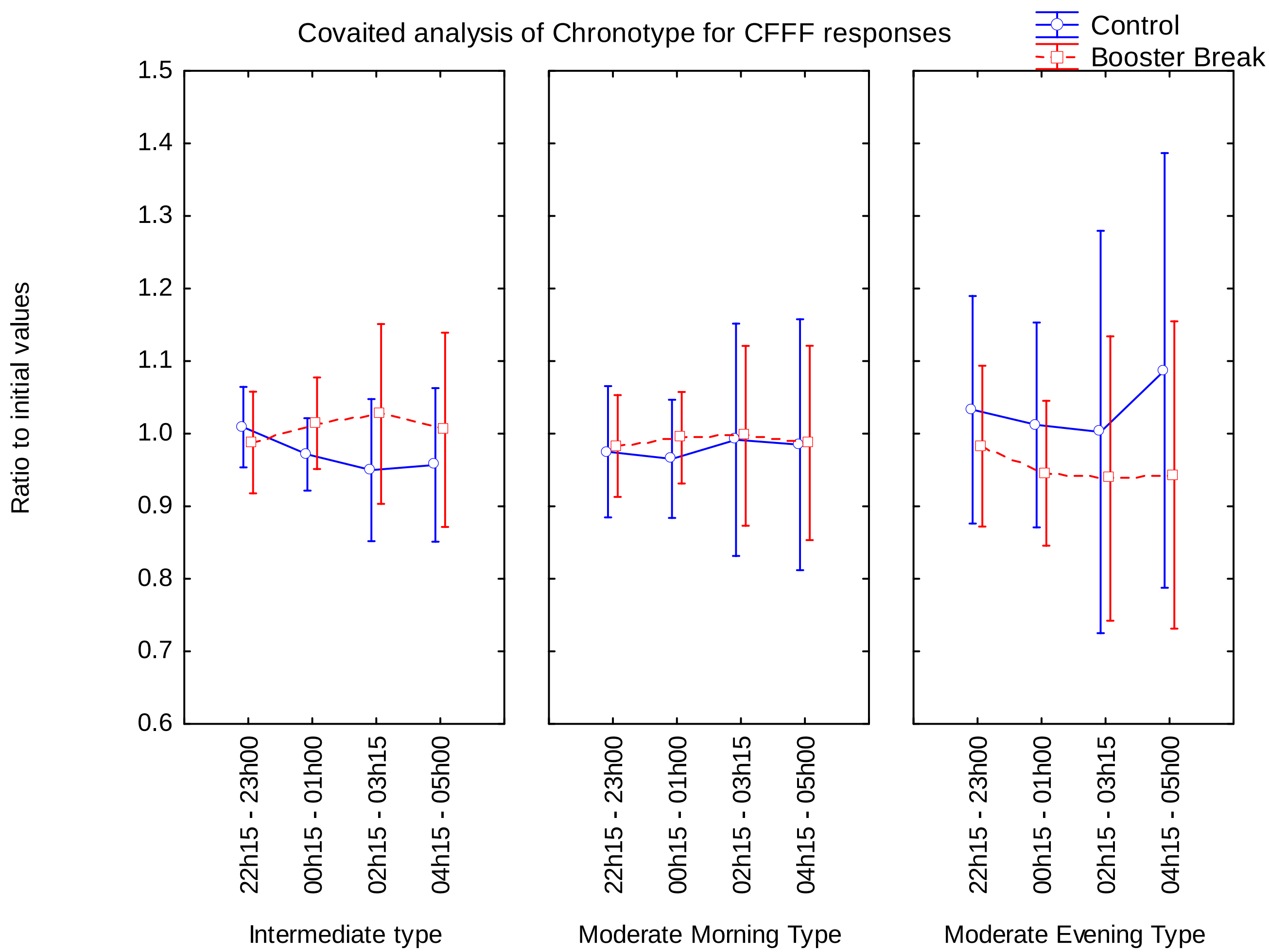

Figure 21: Covariate analysis of chronotype and conditional effects for critical flicker fusion frequency responses between the control and booster break groups. Note: figure 21 corresponds to appendix table C1

SUBJECTIVE SLEEPINESS PROFILE

The subjective sleepiness profile comprising the Wits and Karolinska sleepiness scales provide an indication of the subjects' perceived level of sleepiness based on a five point cartoon face design and a 9 point scale respectively, with higher values signifying a high level of fatigue and sleepiness as perceived by the subject at the time of administration.

Wits sleepiness scale (WSS)

The 3-way ANOVA statistical analysis indicated in table XI and depicted in figure 22 indicates the significant ($p < .05$) circadian effect over the course of each night shift. As can be seen, the subjects perception of sleepiness increasing in an almost linear fashion over the course of the night reaching it maximum at the end of the shift. Additionally, a significant interactional effect between circadian effect and conditions was calculated overall and for the third night shift.

This interaction is representative of the fact that while both conditions are influenced by the natural down regulation of the circadian rhythm, the extent of the influence differs between conditions. This is particular evident for the second and third night shift, where there is a deviation in trends typically occurring after the second test battery (00h15 – 0h10). The deviation, evident in figure 22 indicates that the control group's sleepiness perception increases above that of the booster break groups.

Table XI: Overview subjective sleepiness profiles indicating significant effects within data

Note: X = A significant effect at a level of 0.05

Measures	**Condition**				**Circadian effect**				**Habituation**				**Circadian effect*Condition**			
	All T; D 3	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**
WSS					X		X	X					X			X
KSS		X	X	X	X		X	X				X				

Key: **All T; D 3** = all tests over the three days (Final day effect), **T 4; All D** = Final test for each day (End of shift effect), **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days(Overall effect)

As indicated within table XI, there is an overall circadian effect, with the down regulation of the circadian system over the course of the night shift resulting in an increase in perceived fatigue level. Additionally, the interactional effect between circadian effect and condition suggests that the effect due to the natural biological rhythms is different between conditions and that in fact one of the conditions enabled subjects to work against the strong down regulation and report less perceived fatigue (table XI). This interactional effect is particularly evident during the third shift with there being a significant overall difference ($p < .05$) between conditions, when related to the influence of the circadian rhythm. Over the course of the third shift, the control group reported higher levels of fatigue with this group reporting significantly ($p < 05$) higher levels during the final period of the shift – this period previously suggested to mark the nadir in temperature (figure 11), where temperature minimums coincide with heightened levels of perceived sleepiness and marked decrements in performance measures as a consequence of the circadian nadir.

No significant effect of chronotype was calculated for the WSS, indicating that the degree of morningness or eveningness of the subjects within this sample did not influence the level of perceived sleepiness, as measures of the 5 point scale of the wits sleepiness scale.

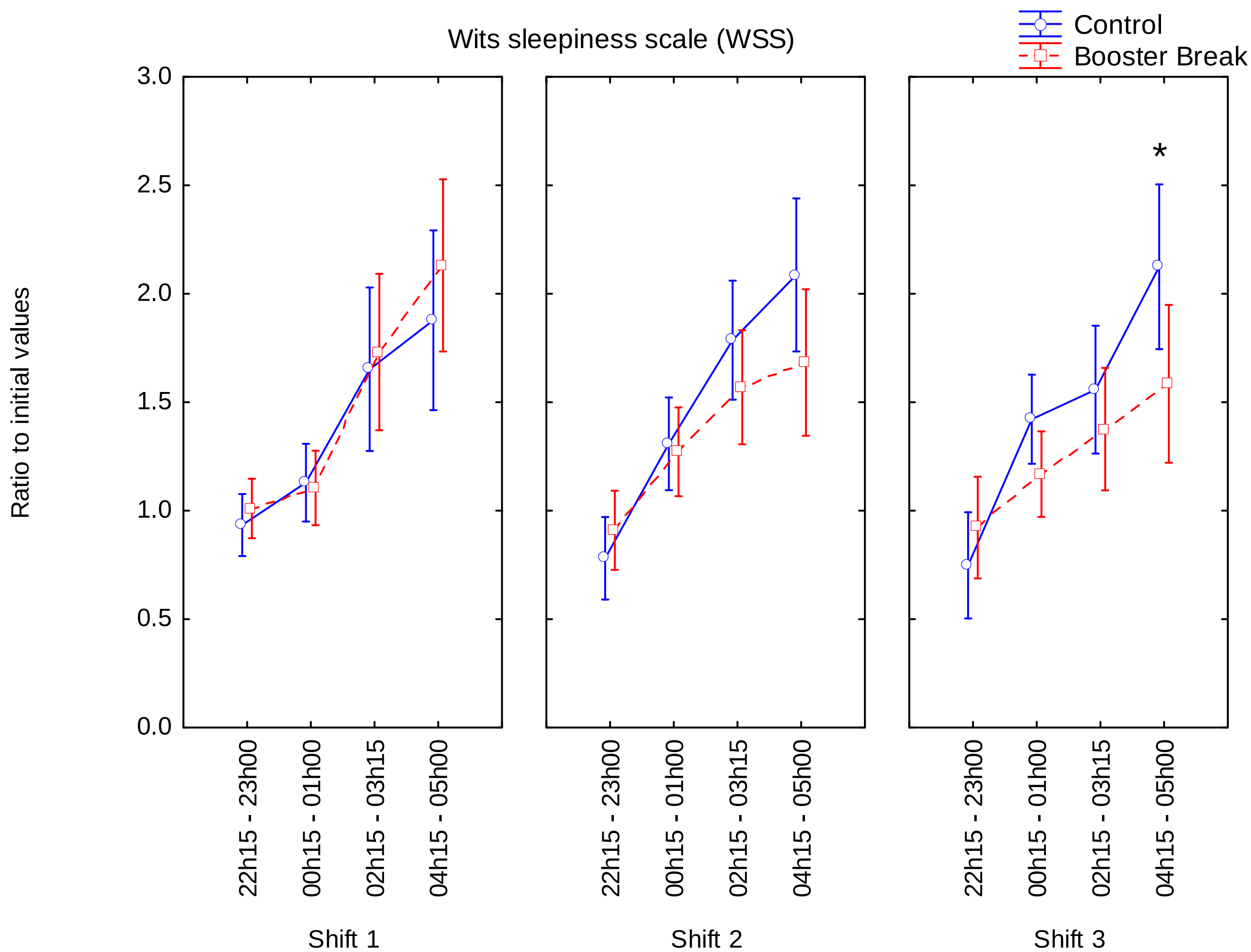

Figure 22: Wits sleepiness scale profiles for the controlled and booster break groups. Note: figure 22 corresponds to appendix table C1

(* denotes a significant difference, $p < .05$)

Karolinska sleepiness scale (KSS)

The KSS which is a 9 point scale allows for greater variations in selection of sleepiness stages and thus potentially provides a more subjective rating than the shorter WSS. Similar to the WSS data, an overall significant ($p <.05$) circadian effect is evident (table XI and figure 4.12.1) with the subjects' perceived level of sleepiness increasing over the course of the night shift and reaching a maximum at the end of the shift.

The KSS was more strongly influenced by the two different conditions, this potentially due to the larger range of levels of sleepiness from which subjects were able to select.

From table XI it is apparent that there is an over significant difference ($p < .05$) between conditions with the control groups on average reporting higher levels of fatigue. Additionally, the end of shift level of fatigue is important, as previously stated this is the period of time when endogenous temperature reaches its nadir. A 3-way ANOVA indicated that over the three shifts, the booster break groups had significantly ($p < .05$) lower levels of perceived fatigue for the final test occurring between 04h15 and 05h00 (table XI).

It was further calculated that in fact, the control group reported significantly ($p < .05$) lower fatigue level between the period of 02h15 and 05h00 during the second and third nights (table XI and figure 23.). Overall the KSS data revealed that the intervention resulted in lower overall level of perceived fatigue and a lower end of shift level of perceived fatigue.

This point is further emphasised by the analysis of the mean highest points of ratings of sleepiness in that a significant difference ($p > .05$) between conditions was calculated (table 16 appendix). Thus indicating that the control subjects' perception of fatigue overall was significantly higher, with a one-way ANOVA indicating that this was more prevalent during the first and second night shifts (figures 14.2 and 14.3 appenix). Similar to WSS data, the covariate analysis of chronotype indicated no significant influences of chronotype for ratings of perceived fatigue.

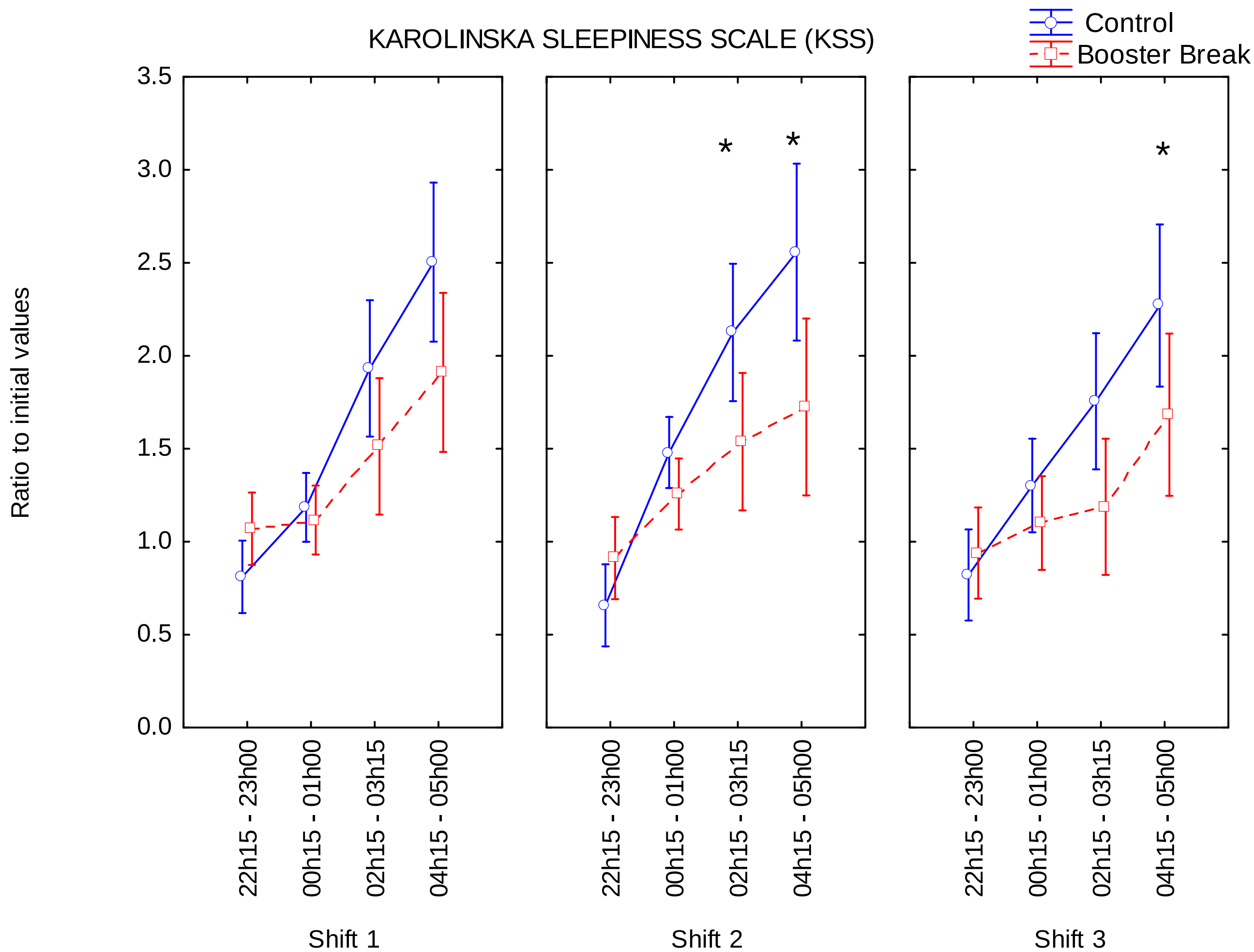

Figure 23: Karolinska sleepiness scale profiles for the controlled and booster break groups. Note: figure 23 corresponds to appendix table C1

(* denotes a significant difference, $p < .05$)

INTER-BREAK PERFORMANCE INDICATOR

Beading performance

Between test batteries subjects were required to perform a simple beading task, producing a range of patterned necklaces. The data represented here indicates the total weight of total beading performance between each test battery. In order to obtain a rate of production, the weight of the beads was subtracted from the previous weight and divided by the total time (minutes) between the two test batteries. This providing an indication of total work performed between each test battery over the 8 hour shift.

Beading performance measurements indicate a decrement in performance rate occurring during the later stages of the night shift for both conditions. As is evident from figure 24, performance rate decreases start between 03h15 (post test 3) and 04h15 (preceding test 4) for the first night shift. During the second and third night shift, the decrease in performance rate occurs earlier in the shift between 01h00 (post test 2) and 02h15 (preceding test 3). Overall, a significant ($p < .05$) circadian effect (table XII) was calculated which indicates that performance rate was influenced by the natural circadian down regulation which is evident by the dip in performance rate indicated in figure 24.

The circadian effect is further evidenced in the final effect with performance rates reaching a minimum for each shift during the final inter test period. Additionally, a significant interactional effect (table XII) is evident between circadian effect and condition for the final two measures on the third night. This indicating that the decrease in performance rate during this time period was significantly ($p < .05$) influenced by condition. In assessing figure 24 it became evident that during this period, the decrement in performance rate for the control groups was significantly more than that of the booster break group and hence during the final stages of the third night it would appear that the intervention has a more positive effect on the end shift performance rate.

The overall rate of beading, over the course of the night shift was the same for each condition with subjects following a similar pattern of performance during the three night shifts. The circadian down regulation occurring in the later stages of the shift proved to be most influential on the beading rate with the effect of condition having no influence of performance.

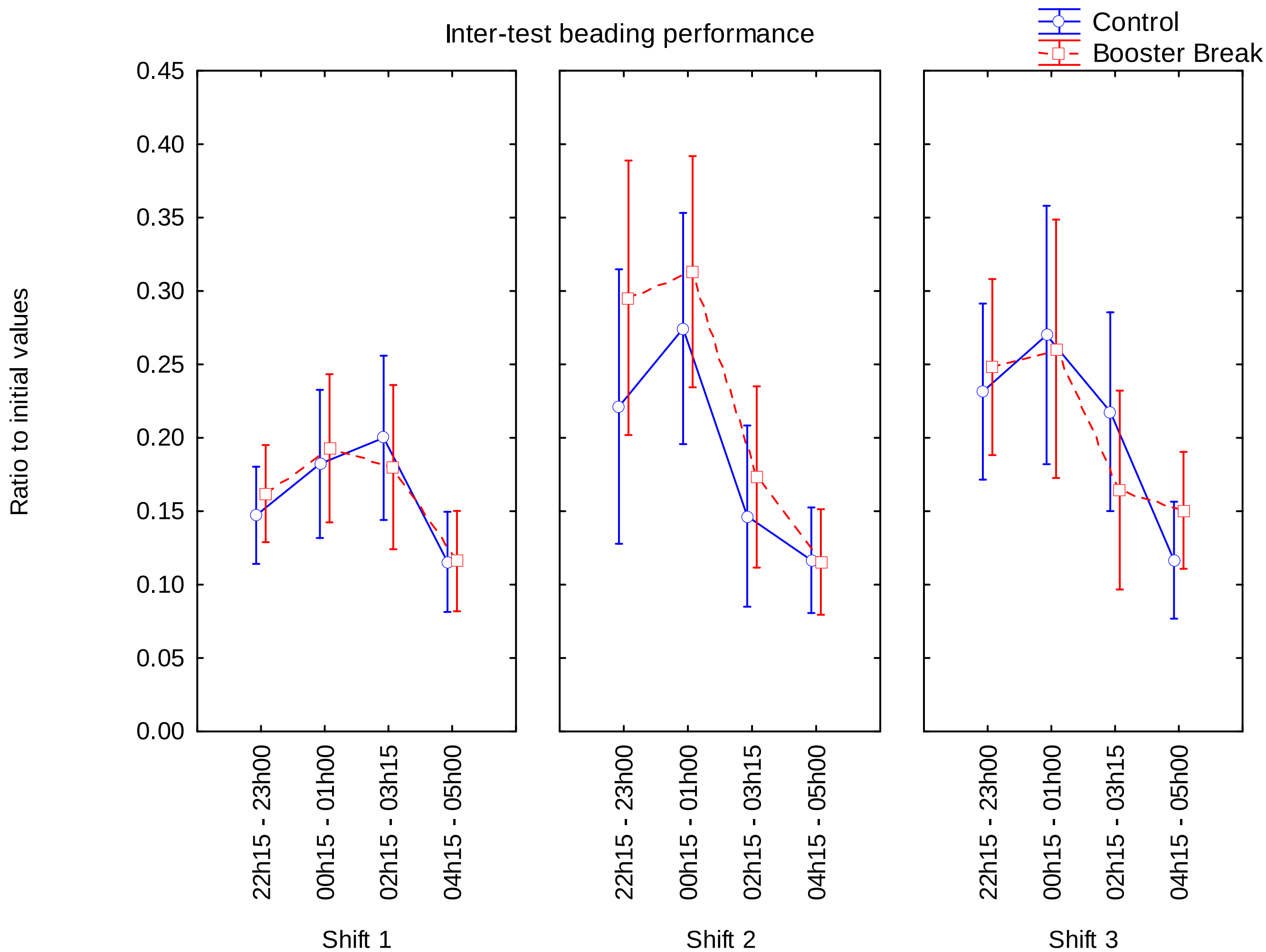

Figure 24: Inter-test beading performance for the control and booster break groups during the three night shifts. Note: figure 24 corresponds to appendix table C1

Table XII: Overview of Inter-test beading performance for significant effects within data

Note: X = A significant effect at a level of 0.05

Measures	**Condition**				**Circadian effect**				**Habituation**				**Circadian effect*Condition**			
	All T; D 3	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**
Beading rate					X	X	X		X						X	

Key: **All T; D 3** = all tests over the three days (Final day effect), **T 4; All D** = Final test for each day (End of shift effect), **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days(Overall effect).

THE DAY SHIFT CONTROL GROUP

The day shift group functioned as a standard control group in order to assess the trends in performance of all parameters under more typical day time performance measures. Three-way ANOVA analyses were performed comparing firstly the control night and control day shift groups to assess for significant overall conditional differences between the two condition as a result of the difference between the day shift and night shift. Second, a similar comparison was made between the booster break group and the standard night shift, particularly for those variables which indicated a positive significant against the control night shift group.

The analyses of the relevant statistics are evident in table XIII, with only variables indicating significance being represented. The physiological measurements of temperature were excluded from the analyses based on the significant difference in ambient temperature measurements between the day and night shifts.

Table XIII: Night shift group comparisons to day shift groups for overall significant differences between conditions

	Control day and control nigh groups	**Control day and booster break groups**
HRF*	X (negative)	X (positive)
SRT	X	
HP	X	
LP*	X	
WSS	X	
KSS*	X	

Note:HFR = heart rate frequency, SRT = simple reaction time, HP = high precision reaction time, LP = low precision reaction time, WSS = Wits sleepiness scale, KSS = Karolinska sleepiness scale. * denotes those variables that indicated a significant ($p < .05$) difference between the two night shift conditions

Table XIII indicates that a significant difference between the control day and night shift groups does not predict a significant difference between the day shift group and the booster breakers. The information presented shows that for these six variables the control day shift had significantly better outcomes compared to the control night shift group, which was expected due to the night shift condition. However, the lack of significant overall differences between the control day shift group and the booster break group indicates that the booster break resulted in subjects performing similarly to the standard day shift subjects, for the above indicated variables.

The heart rate frequency data indicated a significant differences against both night shift conditions, however the trends in the data showing that the control night shift group had significantly lower average heart rates over the shift compared to the control day group while the booster breakers sustained heart rates were significantly higher than those of the control day shift. Hence, the booster breaks results in sustainably higher activity levels – greater than those reported by both control conditions.

In conclusion the data indicated that for the above mentioned six variables, the booster break intervention produced performance levels and subjective rating similar to those report during a typical day shift schedule where as the control night group experiences significant declines in comparison.

CHAPTER V

DISCUSSION

INTRODUCTION

There is increasing evidence that rotating shift work over 24 hours is associated with an excessive rate of accidents and errors in both physical and mental tasks during night work (Furlan **et al**., 2000). While the exact pathophysiology underlying these phenomena is still poorly understood it is hypothesised that in most cases of shift work, the job task is being performed in the presence of less favourable biophysical conditions compared with those achieved during habitual diurnal work. The greater inclusion of shift work into a range of industries and the predominating move towards the increased levels of sedentary cognitive based tasks, means that reanalysis of techniques geared at enhancing performance, subjective well-being and optimised safety have become paramount.

An additional element which requires consideration is the measured parameters which display a marked circadian rhythm. Knowledge of these parameters of the task providing insight into potential performance deteriorations and resulting areas of concern, which might provide information about which elements of the task are be suited for a particular period of time during a night shirt and or day shift.

The primary analyses of the data collected during this study assessed the overall effect occurring over the 8 hour shift and the end of shift performance in an attempt to isolate the potential circadian nadir and associated implication on physiological, psycho-physiological and performance measures. While the primary focus is that of the differences between the two night shift conditions, the implication of the circadian effect is additionally vital. A habituation effect was finally assessed in order to gain insight into the effect of fatigue as it accumulated over the three night shift phase and also to assess which measurement parameters indicated an adaptation from one night shift to the next.

The intervention strategy which provided an alternative rest break schedule, incorporating physical activity into the shorter more frequent rest breaks, aimed to optimise all components of the task, subjective feelings, and positively adjust the endogenous circadian rhythms enhancing entrainment rates to a short three night habituation shift cycle. The primary concern centred on the overall parameters and therefore the differences between the two conditions over the entire shift cycle. An additional element identified focused on the postulated circadian nadir which is argued to occur typically between 04h00 and 06h00. The circadian nadir is typically associated with the time of poorest performance, highest sleepiness and the greatest down regulation of the physiological endogenous components, and thus a secondary focus became that of the end of shift performance.

The secondary analyses to that of the differences between conditions was the assessment of the circadian effect in order to identify which components followed the natural biological circadian rhythm occurring over the night shift. The interactional effects between circadian rhythm and condition then provided insight into how the condition to which the subjects were exposed influenced the degree of change due to the influences of the circadian rhythm. Similarly the interaction with habituation indicating which parameters entrained quicker and under which condition.

Table XIV provides an overview of the primary statistical analyses which were performed and indicates all significant ($p < .05$) effects. The parameters are grouped to make for more simplistic analyses, however will be discussed individually in order to make inferences across parameters as poor performance within one area often implicated decrements within another.

Table XIV: Summary of significant effects found for all parameters measured

Measures	**Condition**				**Circadian effect**				**Habituation**				**Circadian effect*condition**				**Habituation*condition**			
	All T; D 3	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**	**All T; D 3**	**T4; All D**	**T3&4; D3**	**ALL T; ALL D**
Tymp T (°C)					X		X	X												
Skin T (°C)					X		X	X		X		X								
HRF	X			X	X			X					X			X				X
LF/HF RATIO								X												
HF BAND					X			X												
LF BAND					X			X												
HP RT					X		X	X		X		X						X		X
LP RT		X		X												X				
HP TD																				
LP TD	X			X									X		X	X				
SRT					X			X												
PMR																				
BEAD RATE					X	X	X		X										X	
SL HP					X			X												
SL LP							X													X
CFFF																				
KSS		X	X	X	X		X	X					X			X				
WSS					X		X	X					X							

Key: **All T; D 3** = all tests over the three days, **T 4; All D** = Final test for each day, **T3&T4; D 3** = final two tests during the third day, **All T; All D** = overall effect with all tests over the three days. **Tymp T** = tympanic temperature, **Skin T** = sink temperature, **HRF** = heart rate frequency (bt.min^{-1}), **LF/HF ratio** = low frequency/high frequency ratio, **HF band** = high frequency band, **LF band** = low frequency band, **HR RT** = high precision reaction time, **LP RT** = low precision reaction time, **HP TD** = high precision target deviation, **LP TD**= low precision target deviation, **SRT** = simple reaction time, **PRM** = probed memory recall, **Bead rate** = inter-break beading rate ,**SL HP** = saccade latency high precision test, **SL LP** = saccade latency low precision, **CFFF** = critical flicker fusion frequency, **KSS** = karolinska sleepiness scale, **WSS** = wits sleepiness scale.

EFFECTS OF BOOSTER BREAKS

Heart rate frequency, low precision reaction time, low precision target deviation and Karolinska sleepiness scale data indicated a conditional difference between the controlled night and experimental night shift groups for the overall assessment. The short conclusion being that the significant conditional differences favoured the experimental group indicating the positive consequences of the intervention implemented during the night shift schedule.

The booster break intervention resulting in the maintenance of physiological responses as reflected by the heart rate response over the course of the shift while under controlled conditions, heart rate frequency declined. The low precision data responses indicating the positive effects of the intervention on response time to the stimulus, however affected perception and thus the degree of accuracy. This is reflected by the significantly lower response times within the low precision test and the significantly higher target deviation values resulting from the booster break.

In essence a trade off between speed and accuracy occurred, as the booster break intervention resulted in faster response times on the low precision test there is a significant increase in target deviation scores. Therefore the booster break supported the motor program generation enabling faster responses but not perception and hence the feedback control during the low precision test resulting in the significantly higher target deviation values.

Positive effects for the KSS as a result of the booster break are most evident during the final periods of the night shift as indicated by the significantly lowers ratings of perceived sleepiness by the control group. Exposure to the booster break resulted in subjects within the experimental group reporting lower sleepiness values during the period of the temperature nadir which is associated with periods of greatest sleepiness. This is reflected by the fact that while both the control and experimental group's sleepiness rating are greatest during the temperature nadir, the booster break subjects rating are significantly lower.

CIRCADIAN INFLUENCES

The natural circadian rhythm proved to be the most influential component affecting a significant number of variables. Table XIV shows these effects indicating the dominance of the circadian rhythm for the overall effect and final shift effect. No significant circadian effects were calculated for the end of shift performance, which can be interpreted as an indication of lack of habituation effect during the final stages of the shifts.

Heart rate data and heart rate variability

The heart rate frequency data which gave an indication of the subject's heart rates during the six test batteries gives an indication of the effects of fatigue on physiological functioning as well as the down regulation occurring over the shift cycle. While the LF/HF ratio, HF bands, and LF bands are better indicators of the autonomic shifts between the sympathetic and parasympathetic nervous system (Mitani **et al**., 2006), the heart rate data provides a simple analyses of activity levels and the impact on physiological responses over the course of the shift schedule. The data presented within this study indicates a significant ($p < .05$) interactional effect between circadian effect and condition (Table XIV) for the heart rate frequency data. Therefore, under controlled conditions heart rate followed the natural circadian rhythm declining over the course of the shift schedule, while exposure to the booster break enabled for the maintenance of this physiological response (figure 4.1). Van Amelsvoort **et al** (2001) reported similar finding for nurses working under normal night shift conditions with the apparent lack of any intervention resulting in a steady decline in average heart rate over the course of the night shift.

Literature suggested that heart rate values would increase during periods of work time and decrease during sleep time regardless of the different working hours (Ito **et al**., 2001). Therefore within the current study, it was hypothesised that as subjects from both conditions were exposed to the same working condition, that heart rates would remain similar. This is in fact not the case as evident from figure 4.1, and since the booster breaks were not performed during testing time it may be concluded that the booster break intervention causes sustainably higher activity levels as reflected by the smaller down regulation and thus higher heart rates.

Further interpretation one needs to incorporate the spectral analyses of the heart rate data in order to indentify the effects of shift work on the circadian fluctuations of the autonomic nervous system and more specifically the sympathetic activity (Ito **et al**., 2001) which typically predominates during the day and hence periods of higher arousal. Figures 4.2, 4.3, and 4.4 indicate the spectral analyses of the HRV data with no significant conditional differences evident (Table XIV) between the night shift conditions. Comparative analyses of the day shift data indicate similar trends with an increase in sympathetic activity during the first three test batteries corresponding with a decline in parasympathetic activation. This is then followed by an equal cycling between the two branches of the autonomic systems over the rest of the shift.

Findings from the current research for the spectral analyses data indicate similar results to those reported by Ito **et al** (2001) in that HRV variables exhibit similar patterns of circadian rhythms regardless of the type of shift (day or night). Furthermore Ito **et al** (2001) reported that HRV variables are dependent on activity levels; inter-test levels of performance as measured by the beading task indicate no overall significant conditional differences showing similar levels of performance and mental activity between test batteries. The only activity differences between test batteries is the scheduled booster break, which resulted in similar declines for the physiological variables of temperature and HRV, as well as beading rate. However the booster break did positively influence the sustainability of activity levels as indicated with the heart rate frequency data. Therefore, coming back to the findings of Ito **et al** (2001), the booster break activity produced contradictory finds indicating no significant differences reflecting differences in activity levels as reflected by the HRV variables.

Mitani **et al** (2006) alternatively found that when working a straight 24 hour shift the natural circadian rhythm of the cardiac autonomic nervous system caused a nocturnal decrease in the total power of HFV and the LF band, and an increase in the HF component. This is more typical of HRV during normal periods of activity during the day time hours and nocturnal rest (Malik **et al**., 1996). The circadian effects presented within Table XIV for the three spectral analyses of HRV are not typical of what Mitani **et al** (2006) found in that an increase in sympathetic activity corresponds with an increase in parasympathetic activity, thus indicating working an 8 hour shift caused a change in the typical rhythmic effects of HRV over a 24 hour period as reported by Mitani **et al** (2006) and Van Amelsvoort **et al** (2001). The trends found are closer to the findings of Ito **et al** (2001) with a cycling between autonomic branches during the working periods, irrespective of the type of shift worked. A plausible explanation for the current research finding similar trends to that of Ito **et al** (2001) is that fact that both Mitani **et al** (2006) and Van Amelsvoort **et al** (2001) sample groups consisted of individuals performing a variety of jobs, while within the current research and that of Ito **et al** (2001) the sample of subjects all performed similar tasks.

Van Amelsvoort **et al** (2001) reported that working nights causes a shift of the autonomic balance towards sympathetic dominance. The findings from the LF/HF ratio data indicates a similar shift with sympathetic activation increasing over the night shift with only one reported dip occurring during the middle of the shift between 02h15 – 03h15. Literature stipulates that increases in sympathetic dominance might lead to the expected increased cardiac burden due to increase catecholamine secretion during an anticipated period of rest and recuperations (Ludovic **et al**., 2001 and Van Amelsvoort **et al**., 2001).

However, while this has a potential negative aspect, Furlan **et al** (2000) argued that reduction in sympathetic tone during night work to be associated with decreased alertness and deterioration of working performance, promoting an excess of accidents and errors in the performance of job tasks. Therefore there appears to be a negative and positive aspect to the increase sympathetic tone as one factor increases the risk of cardiac problems, the other functions to maintain a level of performance.

The increase sympathetic tone results in an increase in catecholamine secretion as this branch of the autonomic system is responsible for functioning of the body under stressed states (Freitas **et al**., 1997 and Pumprla **et al**., 2002), typically associated with day time functioning. Thus in conjunction with the significant differences between heart rate data (figure 4.1), it may lead to the conclusion that the intervention enabled the sympathetic branch to be more productive as represented by the sustainably higher activity levels that are reflected by the smaller down regulation and thus higher heart rates. Alternatively, within the control group the down regulating circadian influence dominated over the sympathetic tone.

Therefore in conclusion it is thought that this mismatch might be the cause for concern when it comes to increase cardiac burden, and that the exercises might alleviate this burden to some extent by maintaining a higher overall heart rate.

From a practical point, the heart rate data indicated that working at night results in a shift of the autonomic system with a continual cycling between the autonomic branches with a conclude increase of overall sympathetic tone based on the LF/HF ratio data. The practical implication stemming from the lack of significant differences between condition for autonomic control and the significant heart rate frequency responses is that the intervention enabled the sympathetic tone to dominate over the circadian down regulation, while under standard shift conditions subjects are more strongly influenced by the natural down regulation.

While only a tentative speculation, it is hypothesised that the increase or maintenance of heart rate frequency due to the exercise breaks, reduces the strain placed on the cardiovascular system as a result of increase sympathetic tone during a period of expected relaxation and recuperation. Increased activity levels result in increased heart rates, aiding the sympathetic activation and potentially initiating a response where the cardiovascular system is not as taxed as a result of the autonomic system attempting to increase heart rate while in a relaxed sedentary state.

The circadian temperature (tympanic) pattern evident within figure 4.5 follows the described literature from Hanneman (2001), Reilly and Waterhouse (2009) and Wright **et al**., (2002) with a gradual decline over the shift, reaching the lowest point or nadir around 04h00. The skin temperature rhythms, which in accordance with Reilly and Waterhouse (2009) are lower than the core temperature rhythms fluctuated more under the influence of the ambient temperature changes than due to the internal clock (figure 4.6).

The lack of significant conditional differences between the temperature rhythms was expected due to the short duration and low intensity nature of the exercise routine.

Reilly and Waterhouse (2009) confirm this indicating that temperature increases during light/moderate exercise typically start to occur around seven minutes into the exercise. Furthermore as the environmental condition remained constant for both groups, as reflected by the matched skin temperature rhythm, it is apparent that ambient influences played a minimal role in influencing core temperature changes. The key information coming from the lack of significant conditional differences and the equal rate of down regulation is that changes or improvements in measured parameters can be confirmed to be contributed to the influence of the effects of the intervention and not due to the thermo-regulator mechanisms associated with physical activity.

The declining temperature rhythms and nadir have been associated with increased sleepiness (Matsumoto **et al**., 2002), decreased subjective alertness, simple cognitive performance (Johnson **et al**., 1992) and slowing of reaction time responses (Wright **et al**., 2002). The majority of the variables studied are argued to be under the influence of the same pacemaker as the temperature rhythm with lowest temperature typically associated with the greatest down regulation of functioning (Dijk **et al**., 1992 and Reilly **et al**., 2007).

High precision (figure 4.8) and simple reaction time test data from the current research (figure 4.7) confirmed the finds by Monk **et al** (1996), Wlodarczyk **et al** (2006), Wright **et al** (2002) and Wyatt **et al** (1999) with reaction time performance following a time-course with the tympanic temperature rhythms. The circadian effects, most evident during the second and third nights showed an average increase in response times typically reaching a maximum within the temperature nadir. With no significant differences evident between the two conditions for temperature rhythms and significant conditional differences evident within the above mentioned reaction time tests, it can be tentatively suggested that the intervention strategy enable subjects to work against the internal clock, which under standard conditions is implicating performance to elicit a circadian rhythm similar to that of temperature as indicated by Dijk **et al**., 1992 and Reilly **et al**., 2007.

The low precision test had an interaction effect between circadian effect and condition (Table XIV) which indicates that the control group, and hence a lack of intervention, allowed for strong influences of the circadian rhythm while the exercise breaks prevented the significant decline in performance during the nadir of temperature for this parameter.

Matsumoto **et al** (2002) in studying the effects of temperature rhythms on subjective sleepiness ratings found that these two components mirrored each other and hence additionally pointed to the fact that they are controlled by the same pacemaker which is similar to what Johnson **et al** (1992) found with simple cognitive performance and alertness. The results from the subjective sleepiness profiles follow what has previously been reported with steady increases in sleepiness ratings mirroring the decline in temperature rhythms (Matsumoto **et al**., 2002 and Scott **et al**., 2006). Of significant importance here is the fact that during the time of the temperature nadir stipulated by Reilly and Waterhouse (2009), the experimental group had significantly ($p < .05$) lower ratings of sleepiness during the final night (figure 4.15) and last two nights (4.16.1). It can therefore be stated that during the final stages of the shift the intervention strategy had positive effects on subjective ratings of fatigue, enabling those subjects to feel more alert.

The subjective sleepiness profiles (figure 4.15 and 4.16.1) data indicates that the extent of the conditional differences between ratings of perceived fatigue becomes greater during the second and third night shift. From this it is hypothesised that the intervention becomes more effective later into the shift schedule and hence it is postulated that with longer shift cycles the intervention strategy might significantly improve subjective feelings of perceived fatigue to a greater extent, as the potential cumulative fatigue increases.

Memory performance indicated by the probed memory recall test indicated no significant effects at all (Table XIV) and additionally produced contradictory finds to those of Blatter and Cajochen (2007) and Johnson **et al** (1992) in that memory performance, as measured here did not mirror the endogenous circadian rhythms of temperature. The lack of significant data and the contradictions to the literature point to the fact that this measure was a weak indicator of memory performance under these circumstances.

While the memory performance test produced no significant effects, the inter-test beading performance data followed a distinctive circadian rhythm during the second half of the night shift. Figure 4.17 indicates that there is a cumulative fatigue effect occurring with the beading rate declining from the first to the third shift. A clear circadian nadir can be seen, indicating that performance here followed with the temperature decline and corresponding increase in subjective sleepiness and decreased reaction performance.

Similar CFFF values were found over the three shifts with no significant differences indicating no circadian variations in CFFF. This is supported by the findings of Kraemer **et al** (2000) who reported no significant circadian variations in CFFF over the course of a two day and two night shift schedules. Alternatively in looking at various shift schedules Kogi and Saitio (1971) and Luczak and Sobolewski (2005) found a clear circadian CFFF rhythm indicating extremely low CFFF values during the temperature nadir and hence a correlation between low CFFF values, the declining temperature, and mental performance.

The contradicting literature makes drawing conclusion based on the lack of significant responses difficult. However it can be tentatively suggested that within the realm of this study the CFFF test (within the current setup) was a weak indicator and predictor of fatigue based on previously discussed findings strongly pointing to the evidence of fatigue and down regulation. At this stage it should be noted that motivation and attention within the test, play a significant role as the potential for subjects to terminate the test prematurely due to eye strain is a plausible explanation of the inconsistency within the results. Additionally, Iwasaki **et al** (1989) indicated a strong influence of light intensity and viewing angle stipulating that these factors have shown to produce large variances within results.

The saccade latency responses indicated within figures 4.12 and 4.13 produced contradictory finds to that of the reviewed literature. Schleicher **et al** (2008) found saccades to be a reliable indicator of fatigue showing a decline in response time with increase fatigue and Van Beers (2007) included a review on the importance and validation of saccade response based on the lack of voluntary control, suggesting that subjects are unable to control the main sequence of saccades, and that under fatigued states the saccades speed should decline.

The lack of a significant decline in saccade response time for both the high and low precision tests potentially indicates a learning effect occurring over the repeat measures. It is however not clear why a significant fatigue effect was not apparent within the data, however analyses of the day shift response produced similar findings.

SUMMARY OF CIRCADIAN EFFECTS

The endogenous temperature rhythms have been argued to be one of the strongest indicators of circadian oscillations occurring under standard conditions (Matsumoto **et al**., 2002). A steady decline of tympanic temperature rhythms was evident, with a nadir in temperature being reached during the final test battery during the night shifts. Reaction time, simple cognitive processes, subjective alertness, and mental and physical performance have all been indicated within the literature to follow a time-course with the rhythm of core temperature (Dijk **et al**., 1992, Reilly **et al**, 2007 and Wright **et al**., 2002).

Therefore from the general conditional effects indicated and circadian effect from Table XIV the general implication is a positive end of shift outcome for the experimental group compared to those individuals exposed to the typical shift schedule. The neurobehavioral measurements of CFFF, and saccade latency and memory performance (probed memory recall) did not follow the circadian trends with that of temperature rhythms.

From a practical point of view it becomes evident that the measurement of tympanic temperature can be used to extrapolate subjects' performance outcomes and perceived sleepiness ratings with both these measures following the literature reviewed. The complication comes in attempting to use one such measure incorporated with an intervention such as the one tested within this study to predict performance, mood, and fatigue based on the temperature rhythm. This is so due to the data indicating that within the majority of the cases, the time-course of temperature and certain parameters followed as expected under the standard condition, while the intervention tended to result in improvements particularly during the nadir. From a theoretical point of view, the temperature rhythms can be utilised to extrapolate a worst case scenario where under either standard conditions or with exposure to such an intervention certain parameters will follow the down regulation. This potentially provides insight into periods of time, based on knowledge of workers temperature rhythm, when they should perform better or subsequently worse. Therefore, utilising temperature as a worst case scenario enables such an intervention to produce potentially higher than expected outcomes.

The practical significance, from the overall analyses of the conditional and circadian data is that neurobiological responses (CFFF and saccade latency) and memory (probed memory recall) are not easily traced based on the circadian temperature rhythms. However, subjective sleepiness, reaction time responses and general performance (based on beading data) follow the trends of temperature fluctuations, and hence from the data presented within the study it is feasible to utilise temperature as a guideline for expected outcomes with these variables.

HABITUATION EFFECTS

The evidence of an habituation effect within a measured parameter involves a gradual improvement from the first shift to the third shift, therefore a change is overall response from day to day typically moving towards a more positive third day response. Table XIV indicates a significant habituation effect evident for the skin temperature measures and high precision reaction time responses.

The interpretation of the skin temperature data and the knowledge of the impact of ambient temperature changes on this measure lead to a conclusion that what appears as a habituation effect over the three nights is in fact due to changes in ambient temperature.

The high precision reaction time test data suggesting an habituation effect is more representative of a the difference in response times during the final test battery, particularly on night 2 (figure 4.8). The booster break intervention appears to produce a positive habituation effect during the final test battery on the second night, however during the third shift both conditions indicate a deterioration in reaction time response,. therefore no positive habituation is evident.

In review of all the parameters and variables measured, it would appear that due to the short nature of the shift cycle no habituation occurred. A stronger influencing factor appears to be that of cumulative fatigue and the natural oscillating circadian rhythm.

SUMMARY OF BOOSTER BREAK EFFECTS

The booster break effect proved to have no significant influence on temperature measurements over the course of the three shifts; however it did positively influence certain measures which under controlled conditions followed the time-course of temperature down regulation.

From the research the booster breaks proved to have a positive influence of heart rate frequency response resulting in sustainably higher activity levels which is inferred for the smaller down regulation of this variable over the shift cycle. Low precision response time data indicated the positive influence of the booster breaks on motor program generation in producing faster response times particularly during the temperature nadir. A negative aspect of the booster break within this parameter is however the negative impacts on perception and hence feedback control which is indicated by the significantly lager target deviation values recorded during the low precision test.

Subjective sleepiness and hence ratings of perceived fatigue particularly during the period of highest circadian down regulations are positively influenced by the booster break indicated by significantly lower sleepiness ratings during the temperature nadir.

The booster breaks therefore affect elements of reaction time response and subjective ratings of fatigue during a period (the temperature nadir) which is associated, under standard conditions, to implicate the slowest responses and highest values on fatigue and sleepiness rating scales. Additionally, the sustainability of higher activity levels indicated by the heart rate frequency data is thought to function as a mechanism aiding sympathetic activations and thus safe guarding the cardiovascular system by initiating higher average heart rates during a period expected to be associated with rest and rejuvenation.

The booster break intervention alternatively had no significant overall end of shift effects, thus indicating that all positive significant influences of the intervention typically occurred during the second and third shifts. Alternatively, the time-course of variables following the temperature declines is evident across all three shifts. Therefore the impacts of circadian down regulation as a result of temperature declines is believed to be the strongest influencing factor, with circadian rhythms influencing the majority of the variables.

Overall the booster break had a positive influence, with its strongest affects occurring during the second and third shifts within the period of the circadian nadir. This effect is most beneficial as reports within the literature indicate the nadir to be the period of time associated with greatest risk of injury and worst performance.

Within the realm of the current research it was also indicated that probed memory recall and critical flicker fusion frequency are weak indicators of the impacts of shift work. All other measured variables however, indicated response to the shift work schedule and hence the circadian rhythms with the booster break providing a positive mechanism aiding in performance and subjective feelings during the night shift schedule.

Finally, the spectral analyses of the heart rate data indicated a general shift towards sympathetic domination which was expected as subjects remained in a state of higher arousal than is typical of sleep. The cycling between the two branches of the autonomic system appears to function to maintain a state of equilibrium, such that neither branch of the autonomic system totally dominated with increased parasympathetic activity (increase in down regulation) being matched with an increase in sympathetic tone (increased arousal) in an attempt to maintain what the author hypothesises is balance between the two states.

COMPARISONS AGAINST THE DAY SHIFT CONTROL

The day shift data indicated the expected trends in performance which would occur under standard conditions to indicate the validity of the variables. In comparison with the night shift data an expected outcome was found with the control day shift having significantly better performance ratings than the subject working under the control condition at night (table XIII). Additionally, the implementation of the booster break into the night shift brought performance levels on the reaction time test level with those found during the night. Similar ratings of perceived fatigue were also found between the booster break group and the control day shift subjects, this further emphasising the positive influences of booster break activity during a night shift.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

Establishing the effect of scheduled booster breaks during a night shift cycle on sedentary cognitive based tasks, provides insight into the potential positive effect on overall performance and perceptual measures. The intervention tested in this study aimed to check the improvement potential considering the circumstances under which most shift workers find themselves as a result of the desynchronisation from rotating shift schedules where night work is incorporated. The current research undertook a holistic approach by assessing a wide range of variables in order to identify which follow a circadian rhythm and ultimately which variables are positively affected by the booster break.

SUMMARY OF PROCEDURES

The research design set out to ascertain the impact of a frequently performed exercise and stretching routine on physiological, psycho-motor, psychophysiological and perceptual measures during a three night habitation shift. A three way independent sample comprising twelve subjects each made up the three test conditions. Two night shift groups ran concurrently comprising the controlled night shift groups who were exposed to a ‘typical’ eight hour shift design with one long 30 minute mid-shift break and two 15 minute shorter breaks on either side. Alternatively, the experiment group was exposed to hourly 7.5 minute booster breaks in which subjects performed a light stretching warm up followed by a 3 minute moderate exercise intensity aerobic stepping sessions finished off with a light stretching session before returning to work. The day shift portion of the study comprised a three day control shift schedule were one group of twelve subjects who were exposed to a ‘typical’ eight hour shift similar to the night shift design.

All shift schedules were performed within the Biopharmaceutical research institute (BRI) laboratory, with subjects required to report to the lab at 21H00 for the night shift and 07h00 for the day shift. Following a pre-shift meal, the first of 6 test batteries began with subjects performing the batteries in groups of 4. The groups rotated until all subjects had been tested after which the shift schedules began at 22h00 and 08h00 for the night and day shift respectively. During the periods between test batteries and breaks, subjects performed two tasks. The first of which was a continuous beading task producing a range of beaded designs which formed part of the inter-test performance measures. Additionally every hour subjects were required to fold and pack 5 application packets. Tasks performed between test batteries and breaks were design to keep subjects busy but at the same time not elicit any undue arousal or fatigue from mental or physical strain.

At 4 predetermined times during the 8 hour shift schedules, subjects in the same groups of 4 performed the battery of tests. Subjects completed 4 stations during testing, always starting and ending at the same test station. During the shift schedule breaks, the control groups retired from the working area and had a light meal in the recreational room under the supervision of a researcher. During the same time period, the experimental group received a similar meal however had to continue working while eating. The booster breaks performed hourly were instructed by the author with subjects participating in groups of four. In an effort to control intensity, the stepping rate was controlled via a metronome at 125 – 135 $bt.min^{-1}$. Throughout the 8 hour shifts, all groups received a total of 1 hour break time, either comprising the two 15 minute and one 30 minute breaks (control group) or six 7.5 minute booster breaks and one 15 minute break (experimental group).

Following the 8 hour shift, the subjects performed one more post shift test before returning home. Subjects were instructed to remain in bed for a minimum of 5 hours and attempt to sleep for the duration they would typically receive over an average night. Subjects were instructed not to consume alcohol or alertness enhancing substance either 24 hours before a shift or following a shift.

During the 8 hour shifts, continuous measures of heart rate were recorded. Additionally, during the 6 test batteries, physiological responses in the form of tympanic and skin temperature were recorded, while performance measures of beading rate, saccade latency and a variety of reaction time tests were recorded. Subjects also completed two subjective sleepiness profiles, a short term memory rest and a neurobiological test comprising critical flicker fusion frequency. The sequence of test remained the same throughout the study.

SUMMARY OF RESULTS

The most relevant results within the current research are those of the overall effect incorporating the three shift cycles and the differences between conditions over the cycle and the impact of the natural circadian rhythm. Additionally the end of shift measurements taken during the circadian nadir are important in assessing if the booster break positively influenced the variables during the period of the circadian nadir.

The physiological responses indicated a significant conditional difference for the heart rate frequency responses indicating sustainably higher activity levels within the subjects exposed to the booster break as reflected by the smaller down regulation over the shift cycle. The additional heart rate data indicated a shift towards sympathetic activation during the night shift schedule with no conditional differences evident. The physiological measures of temperature, particularly that of tympanic temperature indicated a strong circadian down regulation reaching a nadir between 04h15 – 05h00.

The circadian rhythmic influence had the strongest influence on the measured parameters. All measured test variables excluding high precision target deviation responses, probed memory recall responses and critical flicker fusion frequency data followed a time-course with circadian temperature measures. The simple reaction time, high and low precision reaction time, target deviation low precision, beading performance, and subjective sleepiness profiles indicated a circadian decline with responses reaching the worst during the indicated temperature nadir.

From the above mentioned variables, significant conditional differences were indicated overall for the low precision reaction time test and Karolinska sleepiness scale favouring the booster break and target deviation responses during the low precision favouring the control condition.

The results thus indicating that the booster break aided subjects in working against the natural circadian nadir for elements of reaction time response, subjective sleepiness and heart rate frequency. The intervention resulting in a significant end of shift improvement in ratings of perceived fatigue and response times on the low precision reaction time test improving motor unit generation compared to that of the control condition. Overall, the booster break resulted in sustainably higher activity levels aiding the sympathetic autonomic system by maintaining an average higher heart rate over the shift schedule. Additionally, the booster breaks resulted in significantly higher overall response times and lower overall perceived sleepiness ratings.

RESPONSES TO HYPOTHESES

The hypotheses address the variables in groups of physiological responses, psychomotor performance, psychophysiological measures, subjective sleepiness profiles, and cognitive performance. When considering the hypothesis these will be indicated independently as to address each measured variable against the proposed hypotheses.

Hypotheses 1:

The hypothesis tested was that over the three night shifts habituation there would be a difference in measured variables between the two conditions for the overall effect.

$$H_a: \mu GTV_{Control} \neq \mu GTV_{Experimental}$$

Therefore, as there are overall conditional differences for heart rate frequency, low precision reaction time test, low precision target deviation responses, and Karolinska sleepiness profiles; the null hypothesis was tentatively rejected.

Alternatively, due to the lack of significant overall conditional differences for the other measures variables, the null hypothesis is tentatively accepted for these variables.

Hypotheses 2:

The hypothesis tested was that during the third night shift, there would be a difference in measured variables between the two conditions.

$$H_a: \mu GTV_{Control} \neq \mu GTV_{Experimental}$$

The null hypothesis is rejected for heart rate frequency and low precision target deviation responses. Alternatively, the null hypothesis is tentatively accepted for all other measured variables.

Hypotheses 3:

The hypothesis tested was that there would be significant conditional difference between the measured variables for the final early morning test (04h15 – 05h00) over the three nights.

$$H_a: \mu GTV_{Control} \text{ (T4 All days)} \neq \mu GTV_{Experimental} \text{ (T4 All days)}$$

Therefore, since there is a significant conditional difference for the low precision reaction time responses and Karolinska sleepiness profiles the null hypothesis is rejected for these variables.

Alternatively, the null hypothesis is accepted for all other measured variables.

CONCLUSIONS

From the present study it has been presented that the positive effects of alternative rest break schedules in the form of a booster break can have a positive effect on the sustainability of activity levels reflected by increase heart rate frequency, influences of perceptions of fatigue indicated by the Karolinska sleepiness profiles and enhanced motor performance generation indicated from the reaction time tests. One negative aspect appears to be that of feedback control with a decrease in precision evident within the low precision reaction time test.

The importance of performance over the entire shift schedule is paramount; however more specifically the results indicated the positive influence of the booster break during the period of greatest down regulation at the time of the temperature and circadian nadirs. As a natural decline in responses and performance and increase in sleepiness is expected to occur over the course of an 8 hour shift, the positive end of shift effects resulting from the booster break are instrumental in the prevention of potential accidents and lowering of performance during a period associated with lowest arousal and performance measures (Monk **et al**., 1996; Scott **et al**., 2006; Van Dongen **et al**., 2003). Furthermore, while the booster break group were exposed to higher activity levels, the lack of significant differences favouring the control group indicates that the intervention did not exhaust these subjects. Therefore while reporting positive effects, the booster breaks intensity was sufficient to aid the subjects while not exhausting them over the course of the 8 hour shift.

The current study indicated the importance of parameters which are able to indicated the progression of the natural down regulation of the circadian system as it oscillates over a night shift. The tympanic temperature measurements proved to be a valuable non-invasive technique of tracking the circadian oscillations during a shift cycle. While the temperature measurements proved to be strong indicates of the circadian rhythms, measure of probed memory recall, saccade latency and critical flicker fusion frequency proved to be weak indicators, with theses parameters following no distinctive pattern.

The current research indicated the importance of taking an holistic approach in studying the effects of night work and the implications of the oscillating circadian nadir. The assessment of all measured variables individually and in conjunction with each other, provided valuable insight into individual effects as well as how the various components interacted and corresponded. The results indicating how the assessment of one variable such as the endogenous temperature rhythm can provide insight into the expected effects on performance and subjective ratings.

While no documented study of this nature were found within the literature, prior research into the implication of shift work supported a significant number of findings indicating the validity of the results found and additionally the positive influences resulting from the booster break intervention.

RECOMMENDATIONS

Future investigations looking at the effects of rescheduled rest breaks incorporating an element of physical activity into a night shift schedule on physiological, cognitive, psycho-physiological and subjective parameters should consider the following recommendations:

1. Future investigation within the scope of the current research should consider a shift schedule of a longer duration in an attempt to clearly identify habituation effects. Additionally, using a single sample group who are exposed to all three conditions over a period of time might lessen the variance present within the data due to intra subject differences. Finally an increased sample size would increase the data pool and allow for greater statistical analyses.

2. The confinement of the subjects for the total duration of the shift schedule to the laboratory would ensure day time activity (for night shift) and night time activity (for day shift) can be continuously monitored to ensure subject adhere to the guidelines provided. This would also allow for 24 hour analyses of heart rate to indicate the full extent of shift work and the intervention on the autonomic shifts.

3. Different designs of the booster break should be considered, possibly altering the intensity of the exercise or duration of the break in an attempt to find the best possible design under these circumstances.

4. The stage of the female subject's menstruation cycle should be considered and matched for.

5. Utilising subjects who have prior experience with shift work would allow for a more accurate depiction of the effects of the booster break and circadian effects in individuals more accustomed to the rotating shift schedule.

6. The test battery should be designed to obtain measures on a more frequent basis to indicate a closer replication of the circadian oscillations.

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Note: Asterisked citations * are secondary sources. These were not directly consulted and are referenced as fully primary sources, indicated in brackets, permit.

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Appendix A: General information

1 Advertisement to Subjects

2 Break Down of Habituation Information

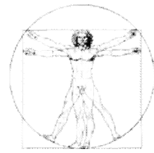
3 Morningness-Evening Questionnaire

4 Letter to the Subject

5 Subject Consent Form

6 Ethical Considerations

ADVERTISEMENT TO SUBJECTS



ATTENTION ALL RHODES STUDENTS STAYING FOR APRIL VACATION

Do you sleep 7 - 8 hours each and every night?
Are you a non smoker?
Are keen to see what it is like to work over a night shift?
Do you want to earn some easy money?
Then we have just the study to keep you busy this vacation.

The Department of Human Kinetics and Ergonomics is running two Masters Projects relating to ***SLEEP DEPRIVATION AND SHIFT WORK*** over the April vacation and the study requires between 36 and 48 student volunteers.

Dates: Between **6th April and the 17th of April 2009**

Where: Biopharmaceutics Research Institute Laboratory (above House Keeping services)

Who: the following criteria are required for participation:

- **Males and females, aged between 18 and 26 years**
- **Non smokers**
- **No prior shift work experience**
- **No sleep related disorders (sleep apnea, obstructive sleep disorder, insomnia)**
- **No consumption of alertness enhancing medication**
- **Good physical health**
- **Regular sleeping pattern (at least 7 to 8 hours of sleep a night)**

How long: 3 consecutive night shifts, 8 hour shifts per night

What will you get from it: You will get to see what it is like to work a night shift. We will feed you throughout your shifts too.

You will also receive between **R180 and R220** for your three days work.

What will you have to do: You will be aiding the University in preparing/packing the application forms and prospectuses that need to go out to all potential 2010 students.

<u>What will we test</u>: the benefits of night time napping on your performance to various types of reaction time tasks, as well as your Heart rate, perceptions of sleepiness and eye blink frequency, which is indicative of sleepiness

<u>Where would you stay</u>: you would have to either be in Vacation residences or in your own digs.

IF YOUR INTERESTED IN PARTICIPATING OR WOULD LIKE TO FIND OUT MORE, PLEASE CALL OR EMAIL WES (0823341929 / wesleyrosslombard@gmail.com) OR JONO (0722260430 / j.davy@ru.ac.za).

BREAK DOWN OF HABITUATION INFORMATION

SESSION 1

1. **Welcome and Introduction**
2. **Handout subject letter**
3. **Explanation of project**: Introduction about shift work and role of napping and booster breaks in alleviating and improving night time performance
4. **Experimental set up**; 3 days of work, most = night shifts, quarter = day shift
5. **Mon – Wed**: group 1: 6 men, 6 women, 6 morning types, 6 evening types,.

   12 subjects = divided into 3 groups

   1 subgroup of 4 = nappers

   1 subgroup of 4 = work normal shift

   1 subgroup of 4 = booster breaks

6. **Thur – Sat** = as above, Sun – Tues = as above
7. Shift start at 21h00 = come and get fed and re briefed. Pre shift testing and then you work from 22h00 – 06h00.
8. Work periods = 45 mins to 70 mins. Perform a packing task and a bead threading task. When you are not working you will either be performing a 15 min test battery, or resting and being fed.
9. In the case of the **nap condition** = no official breaks. After 01h00 to 05h00 = you can nap any time for a max of 1 hour. You will be exposed to a pre and post nap test
10. Or you will be exposed to a **booster break**, each hour for 7.5 minutes = do basic exercises and stretches to invigorate you.
11. **Standard night shift** = work normal shift schedule = 2 x 15 min breaks and 1 x 30 min break. You will just sit quietly and read magazines and eat during your break.
12. **Equipment and testing**: we will perform tests on you throughout the night = monitor progress
    a. HR: using this belt that fits around your chest, we will measure your heart rate throughout the shift.
    b. Tympanic temperature:
    c. Simple reaction time
    d. Subjective sleepiness: Wits sleep scale, Karolinska Sleepiness scale,
    e. Eye tracker and precision task performance
    f. Critical flicker fusion frequency
    g. Memory test: digit symbol substitution task
    h. Sleep diaries: 3 days before, during testing, 3 days after testing
13. **Questions**:
14. **Don'ts**: No alcohol or drugs 48 hours before testing
    a. No caffeine 24 hours before testing and no caffeine during testing – no energy drinks like red bull or coffee
    b. No alertness enhancing drugs – bioplus, energy tablets etc
    c. No smoking
    d. No napping on the day or afternoon before you report for the night shift
15. **Dos**: sleep a minimum of 5.5 hours after your night shift
    a. Ask questions
    b. Feel free to leave the study if you are any stage not comfortable with the study
    c. Please report any injuries, illnesses or medicines being taken to the researchers
    d. Women that are pregnant, are encourage to inform the researchers as shift work will have a negative impact on developing baby
16. **Questions**
17. **Informed consent**

18. **Morningness eveningness questionnaire**: explanation: answer as honestly as you can
19. **Take anthropometrics**
20. Indicate when next session can happen: Thursday or Friday: further 30 mins, from 08h30 – 12h30 and 14h00 – 17h00 both days

SESSION 2

1. **Subjects arrive at the BRI lab:** welcome and tour of the lab.

2. **Information RE which shifts each subject is to work, dates, times and conditions:** each subject is informed as to which group they have been assigned too. They are informed of the dates that they are required to work as well as the times:
    a. **Night workers:** dates range from the 6th to the 14th of April. Subjects are informed that they must report to the lab at 21h00 (for pre shift meal) for each of their three shifts. They are reminded of the following:
        i. **No caffeine consumption of any form**
        ii. **No alcohol or drug consumption**
        iii. **No vigorous exercise**
        iv. **No napping prior to first shift**
        v. **Minimum of 5.5 hours slept post shift (in one block preferably)**
    b. **Each subject is then informed of the particular condition in which they will be required to work:**
        i. Nap condition: each subject is instructed that they will be required to work from 22h00 to 01h00 at which point they will have the choice to have a 1 hour nap any time between 01h00 and 05h00 am. They will be permitted to lie down in a darkened room for 1 hour, after which the researcher will wake them by gently calling their names. Prior to the nap, each subject will undergo a test battery. A post test will also be administered.
        ii. The Booster break condition: each subject will perform a short battery of light exercises (stretches and basic stepping) for a period of 7.5 mins (each hour).
        iii. Standard night shift: each subject will perform a standard 8 hour shift. Subjects will be privy to 2 x 15 minute breaks and 1 x 30 minute mid shift break, during which subjects will be fed and be permitted to sit quietly in a separate room and read magazines and interact in a very sedate manner.
    c. **Each subject will then be exposed to the beading task and the application packing**
    d. **Each subject will then be exposed to the battery of tests:**
        i. **Eye tracker and precision task performance**

ii. **Memory task**
iii. **Simple reaction time, Wits sleep scale, Karolinska scale, PANAS**
iv. **CFFF, Tympanic temperature and Infra red temperature taken of the forehead**
v. **Heart rate**

3. **Subjects will then be reminded of when they will be working and presented with a shift reminder slip. The sleep diary will then be presented and explained to each subjects. Subjects were also instructed when to fill out the diary and sent on their way.**

MORNINGNESS-EVENING QUESTIONNAIRE

MORNINGNESS-EVENING QUESTIONNAIRE

(Self Assessment Version)

Adapted from Horne and Ostberg, 1976

For each question, please select the answer that best describes you by circling the point that best indicates how you have felt in recent weeks.

1. *Approximately* what time would you get up if you were entirely free to plan your day?

   5. 5:00 AM – 6:30 AM
   4. 6:30 AM – 7:45 AM
   3. 7:45 AM – 9:45 AM
   2. 9:45 AM – 11:00 AM
   1. 11:00 AM – 12 noon

2. *Approximately* what time you go to bed if you were entirely free to plan your evening?

   5. 8:00 PM – 9:00 PM
   4. 9:00 PM – 10:15 PM
   3. 10:15 PM – 12:30 AM
   2. 12:30 AM – 1:45 AM
   1. 1:45 AM – 3:00 AM

3. If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?

   4. Not all at
   3. Slightly
   2. Somewhat
   1. Very much

4. How easy do you find it to get up in the morning (when you are not awakened unexpectedly)?

   1. Very difficult
   2. Somewhat difficult
   3. Fairly easy
   4. Very easy

5. How alert do you feel during the first half hour after you wake up in the morning?

   1. Not at all alert
   2. Slightly alert
   3. Fairly alert
   4. Very alert

6. How hungry do you feel during the first half hour after you wake?

1. Not at all hungry
2. Slight hungry
3. Fairly hungry
4. Very hungry

7. During the first half hour after you wake up in the morning, how do you feel?

1. Very tired
2. Fairly tired
3. Fairly refreshed
4. Very refreshed

8. If you had no commitments the next day, what time would you go to bed compared to your usual bedtime?

1. Seldom or never later
2. Less than 1 hour later
3. 1-2 hours later
4. More than 2 hours later

9. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week, and the best time for him is between 7-8 AM. Bearing in mind nothing but your own internal 'clock', how do you think you would perform?

4. Would be in good form
3. Would be in reasonable form
2. Would find it difficult
1. Would find it very difficult

10. At *approximately* what time in the evening do you feel tired, and, as a result, in need of sleep?

5. 8:00 PM -9:00 PM
4. 9:00PM – 10:15 PM
3. 10:15 PM – 12:45 PM
2. 12:45 PM – 2:00AM
1. 2:00 AM – 3:00 AM

11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last two hours. You are entirety free to plan your day. Considering only your 'internal clock', which one of the four testing times would you choose?

6. 8 AM – 10 AM
4. 11 AM -1 PM
2. 3 PM – 5 PM
0. 7 PM – 9 PM

12. If you got into bed at 11 PM, how tired would you be?

0. Not at all tired
1. A little tired
3. Fairly tired
5. Very tired

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following are you most likely to do?

4. Will wake up at usual time, but will not fall back asleep
3. Will wake up at usual time and will doze thereafter
2. Will wake up at usual time, but will fall asleep again
1. Will not wake up until later than usual

14. One night you have to remain awake between 4-6 AM in order to carry out a night watch. You have no time commitments the next day. Which one of the alternatives would suit you best?

1. Would not go to bed until the watch is over
2. Would take a nap before and sleep after
3. Would take a good sleep before and nap after
4. Would sleep only before the watch

15. You have two hours of hard physical work. You are entirely free to plan your day. Considering only your internal 'clock', which of the following times would you choose?

4. 8 AM – 10AM
3. 11 AM - 1 PM
2. 3 PM – 5 PM
1. 7 PM – 9 PM

16. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week. The best time for her is between 10 -11 PM. Bearing in mind only your internal 'clock', how well do you think you would perform?

1. Would be in good form
2. Would be in reasonable form
3. Would find it difficult
4. Would find it very difficult

17. Suppose you can choose your own work hours. Assume that you work a five-hour day (including breaks), your job is interesting, and you are paid based on your performance. At *approximately* what time would you choose to begin?

5. 5 hours starting between 4-8AM
4. 5 hours starting between 8-9 AM
3. 5 hours starting between 9AM – 2 PM
2. 5 hours starting between 2 – 5 PM

1. 5 hours starting between 5 PM – 4 AM

18. At *approximately* what time of the day do you usually feel your best?

5. 5 – 8 AM
4. 8 – 10 AM
3. 10 AM – 5 PM
2. 5 – 10 PM
1. 10 PM – 5 AM

19. One hears about “morning types” and “evening types”. Which one of these types do you consider yourself to be?

6. Definitely a morning type
4. Rather more a morning type than an evening type
2. Rather more an evening type that a morning type
1. Definitely an evening type

LETTER TO THE SUBJECT

LETTER TO SUBJECT

Dear ………………………………….

Thank you for participating in this project entitled:

"The effects of Booster Breaks during a sedentary night shift on physiological, psychomotor, psycho-physiological, and cognitive performance over a 3 night shift habituation phase"

The Department of Human Kinetics and Ergonomics at Rhodes University is interested in researching the effects of two different intervention strategies on certain physiological, mood and perceptual responses as well as reaction time performance during simulated night shift conditions, compared to a standard night shift condition with standard breaks. An additional comparison will be made between these conditions and a simulated standard day shift.

Intervention 1: The focus of the first intervention will be the effects of napping on the ensuing fatigue from the de-synchronisation of normal circadian rhythms through the introduction of night shift work, and whether or not napping will increase arousal levels and thus yield an improvement in reaction time performance as well as subjective level of sleepiness and mood states.

Intervention 2: The focus of the second intervention are the effects of 'Booster Breaks' on the physiological, perceptual and reaction time performance during a simulated 3 night shift schedule. Due to the circadian disruptions associated with night shift work, increased levels of fatigue often occur. The intervention proposes to decrease the ensuing fatigue during a night shift through the implementation of Booster Breaks thus attempting to improve vigilance, subjective measure of sleepiness and fatigue and performance bases measures.

Procedure

You will be required to partake in two pre test habituation session during which the various procedures and the experimental set ups shall be explained to you in detail. You shall also be made aware of the risks and benefits associated with the research to be done. The entire testing period will be carried out in the Biopharmaceutics Research Institute laboratory. You will be required to take part in three consecutive night (or day) shifts during which you will perform a standard packing task and beading threading task for a duration of 8 hours (standard work shift). At regular, staggered intervals (roughly every 45 minutes), you will stop working. During this time you will either perform a battery of tests or alternatively, you will be permitted to rest, and be provided with a selection of standard sandwiches and a sugar free, caffeine free soft drink or fruit juice. You will also have unlimited access to water and ablution facilities throughout the shift. The shift will start at 22h00 and finish at 06h00.

The test battery to be administered consists of five different stations. Measures include a simple reaction time task, subjective sleepiness and mood state questionnaires, critical flicker fusion frequency, saccade latency and precision task performance as well as a memory test. Throughout the shift, Heart rate variability will be recorded through the use of a Suunto® T6 heart rate memory belt, and regular periodic tympanic temperatures will be recorded.

Once the shift has ended, and once you have completed the post shift test battery, you will be free to return to your place of residence and sleep for the remainder of the day. You are required and encouraged to attempt to sleep a minimum of 5.5 hours during the course of the day, and report for work promptly at 21h00, at which point you will be fed a standard pre-shift meal.

Requirements

Prior to testing, we ask that you refrain from the following:

- Consumption of alcohol and drugs 48 hours prior
- Caffeine ingestion 24 hours prior
- Vigorous physical activity 24 hours prior
- Napping during the morning or afternoon of the first day

Prior to testing, we ask that you:

- Report any illnesses or medication intake of any sort
- Maintain a normal (regular) sleeping pattern up to the start of testing
- Complete a daily sleep diary 3 days prior to, during testing and 3 days after
- Ask any questions you may have at any time
- Bring your bank details to the 2nd session

At the habituation session, the following measurements and information will be taken:

Stature; Mass; Age; Home language

You will also be required to fill out a Morningness – Eveningness Questionnaire (Horne and Östberg, 1976). The results of this assessment will be used as the criteria to classify and evenly distribute subjects across the different conditions, according to chronotype. A Sleep disorders questionnaire will also be administered to identify subjects that may potentially affect the overall results negatively. You will also be required to fill out a sleep diary for three days prior to the start of your condition. You will also be required to keep a similar diary during the testing period.

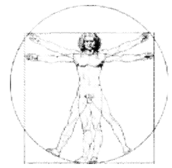
If, at any period of time during the testing procedure, you feel the need to withdraw from the study **for whatever reason**, you are free to inform the researchers that you do not wish to continue to take part in the research any more. You are under no obligation to stay against your will, or complete testing should you feel the need to discontinue from the study. All information obtained will be **stored confidentially** and all data will be coded so ensure your **anonymity**. We thank you for your interest in our research projects, please feel free to ask us any questions you may have about the process at any time.

Yours sincerely,

Jonathan Davy
MSc student
Department of Human Kinetics and Ergonomics
Rhodes University

Wesley Ross Lombard
MSc student
Department of Human Kinetics and Ergonomics
Rhodes University

SUBJECT CONSENT FORM



SUBJECT CONSENT FORM

I,……………………………………..having been fully informed of the research projects entitled:

“The effects of Booster Breaks during a sedentary night shift on physiological, psychomotor, psycho-physiological, and cognitive performance over a 3 night shift habituation phase”

Do hereby give my consent to act as a subject in the above named research.

I am fully aware of the procedures involved as well as the potential risks and benefits associated with my participation as explained to me verbally and in writing. In agreeing to participate in this research I waive any legal recourse against the researchers of Rhodes University, from any and all claims resulting from personal injuries sustained whilst partaking in the investigation. This waiver shall be binding upon my heirs and personal representatives. I realise that it is necessary for me to promptly report to the researchers any signs or symptoms indicating any abnormality or distress. I am aware that I may withdraw my consent and may withdraw from participation in the research at any time. I am aware that my anonymity will be protected at all times, and agree that all the information collected may be used and published for statistical or scientific purposes or for teaching purposes.

I have read the information sheet accompanying this form and understand it. Any questions which may have occurred to me have been answered to my satisfaction.

SUBJECT (OR LEGAL REPRESENTATIVE):

………………………. …………………….. …………………

(Print name) (Signed) (Date)

PERSON ADMINISTERING INFORMED CONSENT:

……………………… …………………….... …………………..

(Print name) (Signed) (Date)

WITNESS:

……………………… ……………………… …………………..

(Print name) (Signed) (Date)

ETHICAL CONSIDERATIONS

The proposed research aims to determine the physiological, perceptual and mood state effects of Boosters Break intervention during simulated night shifts, compared to a standard night and day shift. 48 Rhodes University students will be recruited to participate in the study. The sample group will be evenly distributed with half males and half females.

The study will take place in the Biopharmaceutics Research Institute (BRI) laboratory on Rhodes University campus. Subjects taking accommodation in vacations residences will be accommodated for, to ensure they are placed in a quiet section of the residence in order to facilitate subsequent day sleep.

Habituation

Prior to testing, subjects will attend a habituation session at the BRI laboratory, where the requirements, as well as the possible risks and benefits associated with the study will be explained. A letter of information (appendix B) will be handed to the subjects explaining procedures and requirements. Following this, subjects will receive a letter of informed consent (appendix C) which is to be signed by the subjects and witnessed as recognition that they fully understand all the potential risk, benefits and procedures associated with the study. By signing the letter of informed consent subjects will also be indicating their awareness and ability to withdraw from the study at any period of time, and that they are under no obligation to continue participation within said study, should they no longer wish to.

Subjects will be presented with a subject information form, on which details such as name, age, stature and mass will be recorded. Each subject will subsequently be assigned a research code number for **anonymity** purposes. Onwards, all subject data will be recorded under the research code number as will all archived data; all to ensure total anonymity of subject information.

Subjects will be required to complete the Horne and Östberg (1976) morningness-eveningness questionnaire; this is to ensure an even distribution of subjects throughout conditions based on chronotype. This will ensure that any differences between the conditions can be attributable to the potential effects the Booster Break, and not chronotype.

Subjects will also be required to complete a simple Sleep Disorders questionnaire: this will identify any Sleep-related disorders which might confound results. Those subjects suffering from insomnia or having highly irregular sleeping patterns or any other identifiable sleep disorder will not be permitted to continue any further with the study. These subjects identified to have sleep disorders would make statistical comparisons across conditions difficult and decrease the validity of the data obtained under the different conditions.

During habituation subjects will have the procedures, tasks and testing procedures explained to them in detail.

Subjects will receive **remuneration** at a rate of between R8.00 and R10.00 per hour amounting to a total of between R192.00 and R240.00 respectively, for the total of 3 consecutive nights or day shifts worked. Should a subject opt to with draw from the study at any point, they will be remunerated to the value of work completed.

1. **Procedures**

Subject's are only required to take part in one condition and thus will work either 3 consecutive nights or days, depending on the schedule they are signed to.

Night shift work

Subjects taking part in the night shift schedule will be required to work 3 consecutive night shifts, starting at 22h00 and ending at 06h00. The night shift schedule is divided into the control condition and the intervention Booster Break condition. Prior to the start of both condition's subjects will receive a pre shift meal at about 21h00. At pre defined intervals throughout the shift schedule, subjects will be provided with an assortment of sandwiches and juice. Subjects will be provided with water on request during the entire shift. Subjects will work in a cycle of approximately 45 minutes after which they will either be exposed to a formalised break period or a battery of tests. Under the intervention strategies subjects will be exposed to a 7.5 minute booster break approximately every hour.

Subjects will be permitted to utilise the toilet when they require doing so.

Day shift work

The day shift cycle follows the same structure as the controlled night condition. Subjects will be required to work from 08h00 – 16h00 and will receive all the same necessities afforded to the night shift schedules. No intervention strategy will be implemented during the day shift work.

2. **Task Requirements**

A prearranged task has been selected for the subjects during the 45 minute working time and will be explained in detail to them during the habituation. The task is simple and requires subjects to fold and pack the Rhodes University application forms and prospectuses for 2010 into an envelope. An additional card making process will be included.

Subjects will be seated at a desk while performing the packing task. This task will place no time stress on the subjects and will not require any explicit force production. No strain will be experienced by the subjects as the task will neither physically nor mentally tax the subjects. All tools and materials in the task present no risk to the subjects throughout the task and it requires minimal skill to complete. Subjects will receive a practice during the habituation session.

3. **Testing Procedures**

Pre shift

During habituation subjects will receive a sleep diary, the use of which will be explained verbally in detail. Three days prior to testing, subjects are required to complete the daily sleep logs within the sleep diary and bring it with them to the first testing session. This will enable researchers to assess the subject's daily sleep pattern leading up to the testing.

On-going measure

Throughout the duration of the 3 simulated shift schedules, subjects will be fitted with Polar Heart Rate Monitor Memory belts which will collect beat-to-beat heart rate information.

Test Battery

At predetermined intervals subjects will complete a battery of test conditions assessing subjective measures of sleepiness and mood, reaction time performance, saccade latency and vigilance.

5 stations have be proposed for the set up of the testing procedure

I. On an hourly basis the subjects will have their tympanic temperature measured using a tympanic membrane thermometer. This is a non-invasive measure that is quick to obtain and will provide little disruption to the subjects' work. The measuring unit has changeable plastic covers that can be changed after each subject for hygienic reasons.
II. Through the use of the eye tracker and a simple precision task utilising a touch screen, subjects' saccade latency will be measured. The subjects will be fitted with the eye tracker and perform no more than two precision tasks taking approximately 2 minutes to complete.
III. A reaction time task will also be performed using a touch screen: this test will require the subject to wear no additional equipment and will take 2 minutes to complete.
IV. Subject measures of fatigue and sleepiness will be recorded at pre defined intervals. These are simple paper and pencil tests. The Wits Sleep wake scale and the Karolinksa Sleepiness Scale are to be administered every 2 hours.
V. Finally, subjects will be required to complete a simple memory task, this again requiring no equipment and taking place every 2 hours.

During the test battery procedure all measures obtained will be of a passive nature requiring minimal effort on the part of the subjects. A variety of equipment will be used during the testing procedures, Polar heart rate monitors memory belts, eye tracker, tympanic thermometer and infra red thermo imagining camera are all of commercial standards which have not been modified in any way for the testing procedures. All equipment listed above utilises batteries, therefore should an error in the equipment occur, subjects are at no risk of receiving an electrical shock.

Intervention

The intervention consists of Booster Breaks of 7.5 minutes in duration. This will take the form of simple exercise and stretching activities maintained at a low-to-moderate exercise intensity, ensuring that heart rate never exceeds 65-70 % APMHR (age predicted maximum heart rate). Booster Break will consist of push-ups, sit-ups, stretching exercises of the neck, shoulders, back and legs, step-ups and cycling on a stationary bicycle.

Risk involved

During the night shift schedule subjects will be working against their circadian rhythms. Resulting in potential sleep deprivation effects due to the extended period of time spent awake, particularly during the first night shift. With this, there is a chance of a degree of sleepiness, and cognitive and physical fatigue being experienced by the subjects during the simulated night shift schedule. The effects of the sleep deprivation experienced by subjects will have no long term impacts, with recuperative day sleep following the night shifts and study, easily reversing the effects.

As previously discussed all equipment being used is of standard commercial use and has not been modified. All measures obtained are of a non-invasive nature. The task requirements placed on the subjects require minimal effort and place very little cognitive or physical strain on the subjects.

Benefits involved

The potential benefits associated with subjects performing a simulated night shift schedule and being exposed to Booster Breaks are that should the results from the intervention strategy prove to elicit positive influences on subject fatigue, performance and vigilance during the night shift, numerous workers working nights shifts might benefit from shift reformation and possible new and innovative methods to deal with fatigue associated with night shift work.

Minimal research into the effects of Booster Breaks on shift work have been performed; however the research to date has suggested that the presumed short term effect of booster breaks are restorative, refreshing, and energising changes during the shift cycle. Further research into the design and implementation of booster breaks might fuel greater research into the restorative impact of booster breaks for shift workers.

The conditions under which subjects will be working are not that dissimilar to those of normal shift workers. The subjects are provided with a safe controlled environment within the BRI laboratory, with clean toilet facilities and adequate nutritional replenishment. All possible measures have been taken to ensure those residing in residence's have the most comfortable environment available to ensure the most successful day time sleep.

Archived information

All information obtained will be captured either in a written form or electronically. All electronically captured data will be archived on the personal computer of the researcher involved, as well as the computer utilised during data collection. Written reposes will be archived initially in subject coded files, following this during data reduction; responses will be captured in spreadsheets for statistical analysis. At all times, archived data will be stored under the subjects' research code to ensure total anonymity of data, both during transfer and statistical analysis.

All data will remain in archives until the completion of the masters research project or until such time as feedback has been received from the examiners. Access to all data will only be granted to the researchers directly involved in the research project. Once statistical analysis is complete, should subjects wish, they will at this time be privy to feedback regarding their results. Feedback to subjects will be in written form and will contain information only from the subject who is requesting it.

Should any of the data be utilised other than for the current research project, it will be utilised within the Human Kinetics and Ergonomics department for projects of a similar nature or teaching purposes. This will be done so under the subject research codes to maintain the anonymity of the subject involved within the study.

APPENDIX B: Schedules and Scale

1 Night shift schedule

2 Day shift schedule

3 Wits Sleepiness Scale

4 Karolinksa Sleepiness Scale

NIGHT SHIFT SCHEDULE

SUBJECTS	4	4	4
Hours	Control Night Shift	NAPS	BOOSTER BREAK
21H00			
21H15		PRE SHIFT TEST 2.0	
21H30			PRE SHIFT TEST 3.0
21H45	PRE SHIFT TEST 1.0		
22H00 - 22H15	SHIFT STARTS	SHIFT STARTS	SHIFT STARTS
22H15 - 22H30		TEST 2.1	
22H30 - 22H45			TEST 3.1
22H45 - 23H00	TEST 1.1		
23H00 -23H15			BOOSTER BREAK
23H15 - 23H30			
23H30 - 23H45			
23H45 - 00H00	TEA BREAK - FEED	FEED	FEED
00H00 - 00H15			BOOSTER BREAK
00H15 - 00H30		TEST 2.2	
00H30 - 00H45			TEST 3.2
00H45 - 01H00	TEST 1.2		
01H00 - 01H15			
01H15 - 01H30			BOOSTER BREAK
01H30 - 01H45			
01H45 - 02H00	LONG BREAK - FEED	FEEDING WITHOUT BREAK	BREAK WITH FEED
02H00 - 02H15	LONG BREAK - FEED		
02H15 - 02H30		TEST 2.3	
02H30 - 02H45			TEST 3.3
02H45 - 03H00			BOOSTER BREAK
03H00 - 03H15	TEST 1.3		
03H15 - 03H30			
03H30 -03H45			
03H45 - 04H00			FEED
04H00 - 04H15	TEA BREAK - FEED	FEED	BOOSTER BREAK
04H15 - 04H30		TEST 2.5	
04H30 - 04H45			TEST 3.4
04H45 - 05H00	TEST 1.4		
05H00 - 05H15			BOOSTER BREAK
05H15 -05H30			
05h30-05h45			
05H45 -06H00	SHIFT ENDS	TEST 2.6 shift ends	SHIFT ENDS
06H00-06H15			TEST 3.5
06H15 - 06H30	TEST 1.5		
06H30 - 06H45			

Day shift schedule

Subjects	4	4	4
Hours	Control	Control	Control
07H00-07H15			
07H15-07H30			PRE SHIFT TEST 1.0
07H30-07H45		PRE SHIFT TEST 1.0	
07H45-08H00	PRE SHIFT TEST 1.0		
08H00-08H15	SHIFT STARTS	SHIFT STARTS	SHIFT STARTS
08H15-08H30			
08H30-08H45			TEST 1.1
08H45-09H00		TEST 1.1	
09H00-09H15	TEST 1.1		
09H15-09H30			
09H30-09H45			
09H45-10H00	TEA BREAK - FEED	TEA BREAK - FEED	TEA BREAK - FEED
10H00-10H15			
10H15-10H30			
10H30-10H45			TEST 1.2
10H45-11H00		TEST 1.2	
11H00-11H15	TEST 1.2		
11H15-11H30			
11H30-11H45			
11H45-12H00	LONG BREAK - FEED	LONG BREAK - FEED	LONG BREAK - FEED
12H00-12H15	LONG BREAK - FEED	LONG BREAK - FEED	LONG BREAK - FEED
12H15-12H30			
12H30-12H45			TEST 1.3
12H45-13H00		TEST 1.3	
13H00-13H15	TEST 1.3		
13H15-13H30			
13H30-13H45			
13H45-14H00			
14H00-14H15	TEA BREAK - FEED	TEA BREAK - FEED	TEA BREAK - FEED
14H15-14H30			
14H30-14H45			TEST 1.4
14H45-15H00		TEST 1.4	
15H00-15H15	TEST 1.4		
15H15-15H30			
15H30-15H45			
15H45-16H00	SHIFT ENDS	SHIFT ENDS	TEST 1.5
16H00-16H15		TEST 1.5	
16H15-16H30	TEST 1.5		
16H30-16H45			

WITS SLEEPINESS SCALE

KAROLINKSA SLEEPINESS SCALE

Karolinska sleep scale

1 extremely alert

2 very alert

3 alert

4 rather alert

5 neither alert nor sleepy

6 some signs of sleepiness

7 sleepy, no effort to stay awake

8 sleepy, some effort to stay awake

9 very sleepy, great effort to stay awake fighting sleep

APPENDIX C: SUMMARY REPORTS

1 Three-way ANOVA tables –overall analyses between conditions

2 Covariate analyses tables

1 Three-WAY ANOVA TABLE

Heart rate frequency responses over the three night shifts for the control and booster break groups.

Repeated Measures Analysis of Variance (HRF) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.1180	1	0.1180	20.92	0.000148
HABITUATION	0.0003	**2.22**	**0.0002**	**0.05**	**0.949143**
HABITUATION*Condition	0.0218	**2**	**0.0109**	**3.51**	**0.038670**
CIRCADIAN EFFECT	0.1814	**5.55**	**0.0363**	**10.44**	**0.000000**
CIRCADIAN EFFECT*Condition	0.1795	**5**	**0.0359**	**10.34**	**0.000000**
HABITUATION*CIRCADIAN EFFECT	0.0484	**10.110**	**0.0048**	**2.53**	**0.006579**
HABITUATION*CIRCADIAN EFFECT*Condition	0.0557	**10**	**0.0056**	**2.92**	**0.001885**

High frequency heart rate data over the three shifts for the control and booster break groups

Repeated Measures Analysis of Variance (HF band) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.2878	1	0.2878	1.252	0.275273
HABITUATION	0.1175	2.22	0.0588	0.505	0.607224
HABITUATION*Condition	0.0772	2	0.0386	0.331	0.719807
CIRCADIAN EFFECT	3.0104	**5.44**	**0.6021**	**5.230**	**0.000240**
CIRCADIAN EFFECT*Condition	0.2628	5	0.0526	0.457	0.807727
HABITUATION*CIRCADIAN EFFECT	1.3761	10.110	0.1376	1.313	0.224599
HABITUATION*CIRCADIAN EFFECT*Condition	1.0228	10	0.1023	0.976	0.465275

Low frequency heart rate data over the three shifts for the control and booster break groups

Repeated Measures Analysis of Variance (LF band) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.5325	1	0.5325	2.188	0.153280
HABITUATION	0.7697	2,22	0.3849	2.500	0.093687
HABITUATION*Condition	0.4829	2	0.2415	1.568	0.219812
CIRCADIAN EFFECT	2.1748	5,44	0.4350	3.387	0.006954
CIRCADIAN EFFECT*Condition	0.8506	5	0.1701	1.325	0.259004
HABITUATION*CIRCADIAN EFFECT	2.0285	10110	0.2028	1.354	0.203179
HABITUATION*CIRCADIAN EFFECT*Condition	2.2597	10	0.2260	1.509	0.137412

Low frequency/high frequency heart rate data over the three shifts for the control and booster break groups

Repeated Measures Analysis of Variance (LF HF ratio) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0283	1	0.0283	0.116	0.736280
HABITUATION	0.1720	2.22	0.0860	0.885	0.419961
HABITUATION*Condition	0.2408	2	0.1204	1.239	0.299635
CIRCADIAN EFFECT	3.1819	**5.44**	**0.6364**	**4.445**	**0.001001**
CIRCADIAN EFFECT*Condition	0.6325	5	0.1265	0.884	0.494768
HABITUATION*CIRCADIAN EFFECT	0.5028	10.110	0.0503	0.382	0.953629
HABITUATION*CIRCADIAN EFFECT*Condition	0.8091	10	0.0809	0.615	0.800595

Tympanic temperature recordings over the three shifts for the control and booster break groups

Repeated Measures Analysis of Variance (Tympanic Temp) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0001	1	0.0001	1	0.449659
HABITUATION	0.0001	2.22	0.0000	1	0.328927
HABITUATION*Condition	0.0000	2	0.0000	1	0.608885
CIRCADIAN EFFECT	0.0041	**3.33**	**0.0014**	**32**	**0.000000**
CIRCADIAN EFFECT*Condition	0.0002	3	0.0001	2	0.194360
HABITUATION*CIRCADIAN EFFECT	0.0001	6.66	0.0000	0	0.882251
HABITUATION*CIRCADIAN EFFECT*Condition	0.0002	6	0.0000	1	0.339484

Skin temperature recordings over the three shifts for the control and booster break groups

Repeated Measures Analysis of Variance (Skin Temp) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0002	1	0.0002	0.4	0.557318
HABITUATION	0.0027	**2.22**	**0.0013**	**5.1**	**0.010477**
HABITUATION*Condition	0.0002	2	0.0001	0.4	0.692895
CIRCADIAN EFFECT	0.0100	**3.33**	**0.0033**	**14.2**	**0.000000**
CIRCADIAN EFFECT*Condition	0.0001	3	0.0000	0.1	0.962871
HABITUATION*CIRCADIAN EFFECT	0.0053	**6.66**	**0.0009**	**4.5**	**0.000364**
HABITUATION*CIRCADIAN EFFECT*Condition	0.0003	6	0.0000	0.2	0.965823

Simple reaction time responses for the controlled and booster break groups

Repeated Measures Analysis of Variance (Simple Reaction time) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0014	1	0.0014	0.05	0.8223
HABITUATION	0.0035	2.22	0.0018	0.09	0.9128
HABITUATION*Condition	0.0318	2	0.0159	0.82	0.4461
CIRCADIAN EFFECT	**0.2911**	**3.33**	**0.0970**	**5.04**	**0.0033**
CIRCADIAN EFFECT*Condition	0.1074	3	0.0358	1.86	0.1452
HABITUATION*CIRCADIAN EFFECT	0.1596	6,66	0.0266	1.34	0.2421
HABITUAITON*CIRCADIAN EFFECT*Condition	0.0556	6	0.0093	0.47	0.8306

High Precision reaction time response for the controlled and booster break groups

Repeated Measures Analysis of Variance (HP) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0196	1	0.0196	2.33	0.1409
HABITUATION	**0.0571**	**2.22**	**0.0285**	**5.89**	**0.0054**
HABITUATION*Condition	**0.0481**	**2**	**0.0240**	**4.96**	**0.0114**
CIRCADIAN EFFECT	**0.0789**	**3.44**	**0.0263**	**2.86**	**0.0435**
CIRCADIAN EFFECT*Condition	0.0288	3	0.0096	1.04	0.3794
HABITUATION*CIRCADIAN EFFECT	**0.0816**	**7.66**	**0.0136**	**2.47**	**0.0271**
HABITUATION*CIRCADIAN EFFECT*Condition	0.0687	6	0.0114	2.08	0.0603

Low Precision reaction time response for the controlled and booster break groups

Repeated Measures Analysis of Variance (LP) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.1136	1	0.1136	17.50	0.000386
HABITUATION	0.0306	2,22	0.0153	2.20	0.122512
HABITUATION*Condition	0.0205	2	0.0102	1.48	0.239718
CIRCADIAN EFFECT	0.0223	3,44	0.0074	1.06	0.373795
CIRCADIAN EFFECT*Condition	0.0952	**3**	**0.0317**	**4.51**	**0.006150**
HABITUATION*CIRCADIAN EFFECT	0.0160	6,66	0.0027	0.43	0.859764
HABITUATION*CIRCADIAN EFFECT*Condition	0.0746	6	0.0124	1.99	0.070772

High precision target deviation response over the three shifts for the control and booster break groups

Repeated Measures Analysis of Variance (Target Deviation HP) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0031	1	0.0031	0.036	0.851267
HABITUATION	0.0011	2,22	0.0006	0.007	0.993501
HABITUATION*Condition	0.2066	2	0.1033	1.183	0.315843
CIRCADIAN EFFECT	0.4124	3,44	0.1375	2.064	0.113419
CIRCADIAN EFFECT*Condition	0.0562	3	0.0187	0.281	0.838885
HABITUAITON*CIRCADIAN EFFECT	0.1540	6,66	0.0257	0.379	0.891277
HABITUATION*CIRCADIAN EFFECT*Condition	0.4138	6	0.0690	1.019	0.416086

Low precision target deviation response over the three shifts for the control and booster break groups

Repeated Measures Analysis of Variance (Target Deviation LP) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.2605	**1**	**0.2605**	**6.964**	**0.014991**
HABITUATION	0.0491	2,22	0.0246	1.061	0.354799
HABITUATION*Condition	0.0126	2	0.0063	0.273	0.762594
CIRCADIAN EFFECT	0.1017	3,33	0.0339	1.296	0.283193
CIRCADIAN EFFECT*Condition	0.2272	**3**	**0.0757**	**2.897**	**0.041601**
HABITUATION*CIRCADIAN EFFECT	0.2512	6,66	0.0419	1.529	0.173509
HABITAUTION*CIRCADIAN EFFECT*Condition	0.3654	**6**	**0.0609**	**2.224**	**0.044577**

Probed memory recall data for the controlled and booster break groups

Repeated Measures Analysis of Variance (Probed Memory recall) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0053	1	0.0053	0.108	0.7454
HABITUATION	0.0376	2.22	0.0188	0.517	0.5996
HABITUATION*Condition	0.0213	2	0.0107	0.293	0.7471
CIRCADIAN EFFECT	0.1451	3.44	0.0484	1.401	0.2503
CIRCADIAN EFFECT*Condition	0.1674	3	0.0558	1.617	0.1938
HABITUATION*CIRCADIAN EFFECT	0.3111	6.66	0.0518	1.676	0.1316
HABITUATION*CIRCADIAN EFFECT*Condition	0.1010	6	0.0168	0.544	0.7738

Saccade latency data recorded during the high precision reaction time test for the controlled and booster break groups

Repeated Measures Analysis of Variance (Saccade Latency HP) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.3682	1	0.3682	0.8038	0.3796
HABITUATION	1.3601	2.22	0.6800	2.4752	0.0957
HABITUATION*Condition	0.2732	2	0.1366	0.4972	0.6116
CIRCADIAN EFFECT	**3.9132**	**3.44**	**1.3044**	**3.2379**	**0.0276**
CIRCADIAN EFFECT*Condition	0.2498	3	0.0833	0.2067	0.8914
HABITUATION*CIRCADIAN EFFECT	1.4968	6.66	0.2495	0.6816	0.6647
HABITUATION*CIRCADIAN EFFECT*Condition	2.8422	6	0.4737	1.2942	0.2642

Saccade latency data recorded during the low precision reaction time test for the controlled and booster break groups

Repeated Measures Analysis of Variance (Saccade Latency LP) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0311	1	0.0311	0.117	0.735684
HABITUATION	0.0677	2.22	0.0339	0.156	0.855618
HABITUATION*Condition	1.5803	**2**	**0.7902**	**3.653**	**0.034075**
CIRCADIAN EFFECT	0.4816	3.44	0.1605	0.899	0.446403
CIRCADIAN EEFECT*Condition	0.8156	3	0.2719	1.523	0.216759
HABITUATION*CIRCADIAN EFFECT	2.0040	6.66	0.3340	1.473	0.192109
HABITUATION*CIRCADIAN EFFECT*Condition	1.9400	6	0.3233	1.426	0.209178

Critical flicker fusion frequency data for the controlled and booster break groups

Repeated Measures Analysis of Variance (CFFF) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.0120	1	0.0120	0.70	0.413005
HABITUATION	0.0280	2.22	0.0140	0.94	0.396443
HABITUATION*Condition	0.0226	2	0.0113	0.76	0.472746
CIRCADIAN EFFECT	0.0072	3.44	0.0024	0.25	0.859461
CIRCADIAN EFFECT*Condition	0.0269	3	0.0090	0.94	0.427849
HABITUATION*CIRCADIAN EFFECT	0.0197	6.66	0.0033	0.44	0.853627
HABITUATION*CIRCADIAN EFFECT*Condition	0.0146	6	0.0024	0.32	0.923493

Subjective sleepiness profile for the Wits sleepiness scale overall data of the control and booster break groups

Repeated Measures Analysis of Variance (WSS) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	0.4274	1	0.4274	0.902	0.3529
HABITUATION	0.3426	2.22	0.1713	0.608	0.5492
HABITUATION*Condition	1.1049	2	0.5524	1.960	0.1535
CIRCADIAN EFFECT	41.547	**3.42**	**13.849**	**95.88**	**0.0000**
CIRCADIAN EFFECT*Condition	1.1462	3	0.3821	2.645	0.0567
HABITUATION*CIRCADAIN EFFECT	1.4097	6.63	0.2350	1.375	0.2298
HABITUATION*CIRCADAIN EFFECT*Condition	1.4756	6	0.2459	1.439	0.2049

Subjective sleepiness profile for the Karolinska sleepiness scale overall data of the control and booster break groups

Repeated Measures Analysis of Variance (KSS) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Condition	5.9504	**1**	**5.9504**	**7.0027**	**0.0147**
HABITUATION	1.2195	2.22	0.6097	1.5234	0.2292
HABITUATION*Condition	0.2593	2	0.1296	0.3239	0.7250
CIRCADIAN EFFECT	62.2294	**3.44**	**20.7431**	**97.315**	**0.0000**
CIRCADIAN EFFECT*Condition	8.3922	**3**	**2.7974**	**13.124**	**0.0000**
HABITUATION*CIRCADIAN EFFECT	2.0137	7.66	0.3356	1.5530	0.1659
HABITUATION*CIRCADAIN EFFECT*Condition	0.2395	6	0.0399	0.1847	0.9806

Inter-test beading rate, overall data analysis for the control and booster break groups

Repeated Measures Analysis of Variance (beading performance without ref but per minute) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
CONDITION	0.0284	2	0.0142	0.4337	0.6517
HABITUATION	0.1880	**2,33**	**0.0940**	**12.8190**	**0.0000**
HABITUATION*CONDITION	0.0231	4	0.0057	0.7874	0.5374
CIRCADIAN EFFECT	0.684	**3,66**	**0.2281**	**25.7466**	**0.0000**
CIRCADIAN EFFECT*CONDITION	0.1495	**6**	**0.0249**	**2.8136**	**0.0143**
HABITUATION*CIRCADIAN EFFECT	0.1703	**6,99**	**0.0283**	**4.7269**	**0.0001**
HABITUATION*CIRCADIAN EFFECT*CONDITION	0.0692	12	0.005	0.9613	0.4872

2 COVARIATE ANALYSES TABLES

CFFF covariate analysis results for controlled and experimental groups

Repeated Measures Analysis of Variance (CFFF.sta) Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
{1}Condition	0.0056	1	0.0056	0.35	0.559944
{2}Chronotype	0.0023	2	0.0012	0.07	0.929904
Condition*Chronotype	**0.0920**	**2**	**0.0460**	**2.92**	**0.079931**
{3}DAYS	0.0360	2,18	0.0180	1.25	0.299404
DAYS*Condition	0.0611	2	0.0306	2.12	0.135021
DAYS*Chronotype	0.0472	4	0.0118	0.82	0.522857
DAYS*Condition*Chronotype	0.0776	4	0.0194	1.34	0.272468
{4}MEASURES	0.0051	3,36	0.0017	0.16	0.923281
MEASURES*Condition	0.0111	3	0.0037	0.35	0.791530
MEASURES*Chronotype	0.0189	6	0.0032	0.30	0.936401
MEASURES*Condition*Chronotype	0.0361	6	0.0060	0.56	0.757239
DAYS*MEASURES	0.0194	6,54	0.0032	0.41	0.867861
DAYS*MEASURES*Condition	0.0119	6	0.0020	0.26	0.956133
DAYS*MEASURES*Chronotype	0.1057	12	0.0088	1.13	0.342359