THE EFFECTS OF NIGHT WORK AND TASK DIVERSIFICATION ON EFFICIENCY OF PERFORMANCE

BY

LYNNE KERRY MUNTON

THESIS

Submitted in fulfilment of the requirements for the Degree

Master of Arts

Department of Human Movement Studies

Rhodes University, 1998

Grahamstown, South Africa

ABSTRACT

This study investigated the effects of night work on performance efficiency. Night work is generally acknowledged to impair performance, yet much research has contradicted this assertion. The feasibility of including brief periods of physical activity to stimulate arousal within mentally demanding workshifts was also evaluated.

Thirty six postgraduate volunteers were assigned to either the cognitive tasks (CT) or cognitive and motor tasks (CMT) group. All subjects performed three psycho-motor tests, using the Vienna Test System, at midday and midnight. The CMT group performed a short cycling activity before each test. Heart rate responses served as physiological measures, the Perceived Strain Scale was used to quantify individual perceptions of strain and performance efficiency was assessed in terms of speed and accuracy.

Although several trends were apparent, no significant differences ($p < 0.05$) were revealed with respect to the three performance variables between the midday and midnight test sessions, or between the CT and CMT subjects, other than the higher heart rates recorded in the CMT group. In summary, neither time of day nor physical activity were found to affect performance within the controlled environment of this study.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to the following people:

My supervisor, Professor Pat Scott, for the guidance and support she has given me over the last three years (including burning the midnight oil with me on numerous occasions!).

My parents, for their continual support and encouragement throughout my academic career.

Graham Smith, for his invaluable help with data input and production of graphs, and for his tremendous patience and encouragement over the final stretch.

Lynda-Fé Croeser, who assisted in the laborious task of inputting data into the computer.

My subjects, who so willingly and enthusiastically gave of their valuable sleep and work time to participate in this study.

The financial assistance of the Centre for Science Development, (HSRC, South Africa) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the Centre for Science Development.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

STATEMENT OF THE PROBLEM

INTRODUCTION

While 24-hour operations have long been a part of emergency occupations, the need for "around the clock" workers has increased dramatically in industry during recent years. This augmented 24-hour demand has led to an escalation in research directed towards the impact of aberrant work hours on the human operator. The majority of these studies have focused on the general area of shiftwork with particular reference to the influence of shiftwork on psycho-social phenomena. Less research appears to have been conducted which specifically examines the effects of night work on efficiency of performance. During this period of extended work hours there has also been a marked rise in the use of visual display units and control panels within modern industrial workplaces as a direct consequence of increased automation of production lines. It should be borne in mind that the successful operation of these control panels is reliant on the timely and accurate responses of the worker to external stimuli. These psycho-motor responses could well be impaired in a drowsy worker as a result of loss of attentiveness and concentration experienced during night work.

According to Folkard, "humankind has evolved as a diurnal species that is habitually active during the daylight hours and sleeps at night" (Folkard, 1987: p30). Recognition of this inherently diurnal nature would appear to be corroborated by the findings of Menna-Barreto *et al.* (1993) who describe how shift systems which entail night work tend to result in the disruption of the worker's circadian rhythm in a large number of physiological and psychophysiological parameters. The obvious conflict between working at night as opposed to the "natural" daytime hours, has led to night work being referred to as an "unnatural" mode of work which can result in numerous problems for both the individuals concerned, and the organisations employing them (Walker, 1978; Monk and Folkard, 1983; Folkard, 1987).

Rosa (1990) describes how peak activity with regards to physiological, psychological and social processes, tends to coincide with daylight and evening hours. A reduced worker alertness has indeed been found to occur during the night shift and has been associated with an increased risk of injury and accidents, and a subsequent decrease in productivity due to operational errors. Both Rosa (1990) and Bonnet and Arand (1994) attribute this reduced alertness and declining performance to the additive effects of a night-time circadian low-point in physiological arousal, combined with inadequate sleep during daylight hours on returning from the night shift.

Vast discrepancies with regards to time of day and occurrence of accidents have been noted within the literature. Several studies (Wyatt and Marriott, 1953; de Vries-Griever and Meijman, 1987) found the highest incidence of accidents to be linked to the night shift. In contrast, Adams *et al.* (1981) recorded a higher frequency during the morning shift. Pokorny *et al.* (1987) ascribe these apparent inconsistencies to the nature of the task being performed, the task load, differing personal characteristics of the workers involved, as well as the starting hour of the work period.

While Monk and Folkard (1983) acknowledge the widespread agreement in the literature that an overall decrement in performance occurs during the night shift, they also recognise the discrepancies which exist in terms of performance efficiency across a wide selection of psycho-motor tasks. They noted that although night work tends to yield inferior performances on simple processing and monitoring tasks as compared to daytime results, high memory loaded tasks appear to be best performed at night, such as was found by Monk and Embrey (1981). These results tend to be unrelated to differences in workload between day and night shifts. The present study incorporated a variety of psycho-motor tasks as it was recognised that both simple and complex tasks are required within most working environments.

Walker (1978) and de Vries-Griever and Meijman (1987) challenge the validity of comparing *in situ* day and night shifts as they maintain that the work environment is dissimilar during these two periods. Walker for example, argues that the activity level in industry tends to be greater during the day which may facilitate a greater occurrence of daytime accidents in comparison to the night shift. De Vries-Griever and Meijman, on the other hand, report that supervision and control are generally less stringent at night and as such might lead to a higher accident rate. It is nonetheless critical to ensure that optimal levels of performance and safety are maintained throughout the working period, irrespective of the time within the 24-hour cycle, in view of the potential high cost of an error to both the worker and society (Folkard and Monk, 1979). The demands of a particular task should be assessed in detail and the shift must then be designed in such a manner as to facilitate optimal performance. The present study attempted to avoid the possibility of dissimilar work conditions between day and night shifts by testing in a laboratory setting wherein physical and social environmental factors could be rigorously controlled and standardised. This permitted a valid comparison of results in performance efficiency between the day and night data collection periods.

According to Rosenfeld *et al.* (1989) the introduction of computer and automation-based technologies into modern industrial settings has substantially altered the lifestyle of their employees through the decrease in predominantly manual labour. Much industrial work now requires a significant cognitive component with minimal physical effort, yet simultaneously precipitates an increase in emotional and mental stress. The combined influences of a night-time low-point in physiological arousal (Bonnet and Arand, 1994) and increased mental stress, effectively lower an individual's ability to perform optimally at night. This has led to the investigation of possible means to stimulate the attentional processes of the human operator and thereby enhance performance proficiency.

The present study examined performance efficiency during cognitive tasks conducted at different times within a 24-hour cycle. These cognitive tasks were administered by means of a recently devised computerised system, the Vienna Test System (VTS). The VTS has been used in both psychological and medical fields, as well as by management in the selection of employees in the mines and industry, and in the evaluation of driving capabilities (Maree, 1994). This system comprises numerous psycho-motor tests which assess various aspects of an individual's cognitive and motor ability, including concentration ability, decision-making time and reaction time. One is able to evaluate these psycho-motor capabilities under both "calm" and "pressured" conditions in a laboratory situation. Although the results of laboratory work may not always accurately depict occurrences in a true working environment (Wisner, 1989), they do suggest critical implications with respect to both the worker and industry, in terms of safety and productivity. Walker (1978) recognised the need to develop tests to assess individual susceptibility to night work. This study therefore incorporated a battery of tests presented in a controlled laboratory environment. This in turn aimed to provide essential benchmark data with regard to the application of the Vienna Test System in the assessment of industrial work performance during night hours.

Although several studies have investigated the influence of "prophylactic naps" and stimulants such as caffeine, on performance (Bonnet and Arand, 1994; Linde, 1995), minimal research appears to have examined the effects of including short periods of physical activity within the work schedule. The present study thus included the repetitive gross motor activity of cycling to contrast the mentally demanding psycho-motor tasks performed on the VTS. Although a cycle ergometer was used in this laboratory simulation of a work environment, the principle involved may be transferred to an industrial situation where the cycling activity can be substituted by another form of physical work as a means of task diversification. The subject pool was thus divided into two groups, namely a cognitive tasks (CT) group who performed mental tasks only, and a cognitive and motor tasks (CMT) group who participated in both mental and physical tasks.

Rosa (1990) acknowledges that although night work is known to have both physiological and psychological costs for the worker and the family, the need for 24-hour staffing will probably continue to increase. This study thus employed an interdisciplinary approach of a simulated work environment in an attempt to identify and quantify potential problem areas associated with night work. The results obtained may 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 work performance at night.

STATEMENT OF THE PROBLEM

Homo sapiens is recognised as being a diurnal species with inherent circadian rhythms. Although it has long been recognised that efficiency of performance varies throughout the day, there is a lack of consensus in the literature with regards to the exact nature and magnitude of these changes in performance across a range of tasks. This ambivalence identified the need for further investigation concerning the influence of time of day on an individual's level of performance in specified psycho-motor tasks. The present research project thus examined differences with respect to midday and midnight performance proficiency in three selected psycho-motor tests. Minimal research appears to have evaluated the potential benefits of incorporating short periods of physical activity within the work schedule as a means of stimulating the worker's arousal system. This study therefore compared the performance of a cognitive and motor tasks group, who performed both cognitive and physical tasks with that of a cognitive tasks group, who participated solely in cognitive activities.

RESEARCH HYPOTHESIS

The general hypothesis of this project was that both time of day and task diversification would affect efficiency of performance in the three selected psycho-motor tests.

STATISTICAL HYPOTHESES

HYPOTHESIS 1: There is no difference in efficiency of performance between midday and midnight data collection periods in the three psycho-motor tests.

Ho: $\mu_D = \mu_N$

Ha: $\mu_D \neq \mu_N$

HYPOTHESIS 2: No difference exists in efficiency of performance between the cognitive tasks group and the cognitive and motor tasks group in the three psycho-motor tests.

Ho: $\mu_{CT} = \mu_{CMT}$

Ha: $\mu_{CT} \neq \mu_{CMT}$

Where:

	D	=	the mean response at midday
	N	=	the mean response at midnight
	CT	=	the mean response for the cognitive tasks group
	CMT	=	the mean response for the cognitive and motor tasks group

DELIMITATIONS

The research sample was confined to postgraduate students between the ages of 22 and 30 years. This subject pool comprised 36 volunteers, each of whom was randomly assigned to either the cognitive tasks (CT) or cognitive and motor tasks (CMT) group. Each group contained equal numbers of males and females. The subjects acted as their own controls.

Data collection consisted of three separate phases. The initial phase involved the collection of basic demographic data, a verbal explanation of the test procedures, as well as the administration of written consent forms. At the same session a demonstration of the three psycho-motor tests to be performed during the ensuing data collection sessions was given. This was followed by the opportunity for the subjects to become familiar with the requirements of these three psycho-motor tasks.

The two test phases were conducted at standardised times, namely between 11:15 and 12:45am (midday) and between 11:15 and 12:45pm (midnight). In an attempt to minimise the effects of learning on subsequent performance, these two data collection sessions were held two weeks apart and the order of participation in these sessions was randomly determined. During these two phases the subjects performed the three psycho-motor tests, randomly presented. The CMT group performed a two minute bout on a cycle at a moderate power output prior to each of the tests, while subjects in the CT group were required to perform the test battery without participation in the diverse task of cycling.

Heart rate activity provided a measure of the physiological responses of the subjects throughout the testing period. Those subjects in the CMT group were further required to maintain their heart rate within a preset threshold of between 115 and 125 beats per minute whilst cycling. This was equivalent to approximately 60% of age predicted maximal heart rate. Subjects were also required to rate their perceptions of the demands of the various tasks, together with their perceived ability to cope with these demands, via the use of Scott's (1994) Perceived Strain Scale (PSS). Efficiency of performance, in terms of speed and accuracy, was determined from the results of the three psycho-motor tests administered on the Vienna Test System (VTS).

In order to simulate shiftwork conditions, as well as to limit the effects of cumulative fatigue, subjects were requested to adjust their sleep/wake cycles for two days prior to each data collection session (The Subject Instruction Sheet is included in Appendix B). Subjects were further asked to refrain from consumption of food, caffeine, or any form of stimulant, for 4-5 hours prior to testing.

The test environment was rigorously controlled. Only the experimenter and the subject were present with minimum interaction occurring between the two in an attempt to standardise data collection and to eliminate extraneous distractions. No immediate feedback on performance was provided in order to avoid competition between subjects. Individual feedback was however available once each subject had completed their two data collection sessions.

LIMITATIONS

A relatively small sample pool consisting of 36 postgraduate students was used in this research project as a result of temporal and logistical restrictions.

Postgraduate students, who tend to work at night, were used in this study. Testing occurred outside of external academic pressures such as examinations or thesis deadlines so as to minimise and standardise possible mental stresses.

Subjects may not have rigorously adhered to the request to adjust their sleep/wake cycle, or to refrain from using stimulants prior to data collection. This may in turn have affected their test responses.

The subjects' psychological state at the time of testing may have influenced their test performances.

CHAPTER II

REVIEW OF RELATED LITERATURE

INTRODUCTION

According to Parkes (1994) continuous production processes together with other commercial activities which operate on a 24-hour schedule, have become increasingly commonplace in recent years. Shiftwork and in particular night work, has however, long been known to disturb the natural tendency of man to sleep at night and be active during the day. Monk and Folkard (1992) argue that from both a biological and social standpoint humans are "meant" to be day workers. Although shiftwork represents an "unnatural" type of work, it may not necessarily prove harmful, but it does provide a potential source of stress for the worker.

It is this unnatural ambience which lead Colquhoun (1970) to rate shiftwork among those factors which may result in sub-optimal performance of the human operator in a given work system. Shiftwork, and specifically night work, presents a multifaceted problem which Monk (1988) challenged as being in need of a multifaceted solution, wherein the needs of society must be balanced against those of the individual.

The proposed research project lies in the domain of *Ergonomics* which constitutes a rapidly developing field of research in South Africa. Ergonomics refers to the study of the relationship between the worker and his occupation, equipment and environment. Ergonomic assessments apply a collective body of knowledge drawn from various cognate disciplines, specifically biomechanics, physiology and psychology. It therefore involves the multidisciplinary analysis of a particular work environment with the aim of harmonising task demands and worker capacities through the design or adjustment of factors in the workplace (Oborne, 1987). Ergonomics seeks to solve job-related problems through the use of appropriate intervention strategies which allow one to "fit the task to the person" rather than adopting the Procrustean method of "fitting the person to the task" (Grandjean, 1986). This human-centred approach is designed to optimise worker well-being and should in turn give rise to optimal performance which subsequently enhances productivity.

Rutenfranz *et al.* (1976) recommend that ergonomic studies be undertaken to ensure that the reasons given for the introduction of shiftwork can adequately justify the phenomenal stress that is imposed on the human operator by night and shiftwork. The present project employed an holistic analysis of a simulated working environment in an attempt to identify possible factors responsible for determining performance efficiency of the human operator when exposed to night work. The incorporation of short periods of task diversity was also assessed as a potential intervention strategy designed to facilitate optimal human performance during sub-optimal working conditions.

SHIFTWORK

Many researchers regard the advent of artificial lighting to have paved the way for the development of shiftwork. While this invention has undoubtedly assisted in the spread of shiftwork, this mode of work has in fact been a part of man's existence for centuries. Monk and Folkard (1992) report that the prominent change from the pre-industrial era lies in the number of people affected by shiftwork. The prevalence of shiftwork has indeed increased dramatically over the last 50 years in both industrialised and developing countries (Colquhoun and Rutenfranz, 1980a; Kogi, 1985; Ong, 1992). A description of what "shiftwork" entails, is required prior to discussing the numerous reasons which necessitate its inclusion within modern society.

"Shiftwork" is a term which means different things to different people. Walker (1978) regards all working members of the community as being on shifts, yet acknowledges that most individuals work a "normal spell" during day hours and are referred to as "day workers". Those individuals who are employed outside of this "normal spell" are labelled as "shiftworkers". Walker subsequently describes shiftwork as work performed at unusual hours outside those which are considered as normal in the morning and afternoon. This is reiterated in the later research of Tepas (1982) who defined shiftwork as any permanent work outside of a daylight core time period, or the rotation of the work schedule in such a manner which results in most work being outside of this basic core.

Åkerstedt and associates define shiftwork as being a vague term which usually refers to "a workhour system in which a relay of employees extends the period of production beyond the conventional daytime third of the 24-h cycle" (Åkerstedt *et al.*, 1984: p409). On the other hand, shiftwork has been described by Monk and Folkard (1992) as any employment conducted outside the "day working window" on a regular basis. This "day working window" parameter is defined as the hours between 07:00am and 18:00pm. Work undertaken outside of these hours is generally considered to be "abnormal" or "unnatural". Monk and Folkard proceed to report the general consensus that true shiftwork is that which entails working at night.

People have long been involved in work at these "unnatural" hours, particularly within the medical and protection sectors, yet this practice was unusual on a more general basis until the advent of Industrialisation. It would appear that modern society is becoming increasingly reliant on the shiftwork system. This reliance may be attributed to three main sources, namely technological, economic and social advancements.

According to Monk and Folkard (1992) it would be both economically unfeasible and practically impossible for many modern industries to interrupt their manufacturing processes. The major technological developments which have occurred within industry, together with the high cost of new machinery, have resulted in the need for continuous operations in order to yield a maximum return on expenditure. "Round-the-clock" operations are also necessary to meet the rising demands for social services in particular health care, transport facilities, security arrangements and grocery outlets.

It could thus be summarised that the incidence of shiftwork will be dependent on several factors including the attributes of the process, the level of public demand for the product and the production targets required by management. Kogi (1985) suggests that night work in particular has been "exported" from industrialised countries primarily for economic reasons. It would appear that in developing nations the lack of stringent restrictive legislature and the availability of a large, cheap labour force encourages the development of shiftwork. Ong (1992) further notes that shiftwork in industrially developing countries is seen as a means to better utilise resources and to create employment. This is of particular interest in a country like South Africa where a pronounced dual economy occurs. Shiftwork is considered to be a means of benefitting the community via the creation of employment, yet Walker (1978) queries the personal costs involved in adopting this mode of work.

It is important to note that while the majority of shiftworkers are blue-collar employees involved in some form of manual labour, there are a growing number of white-collar workers engaged in shiftwork due to the increasing use of computer operations (Colquhoun and Rutenfranz, 1980b; Folkard 1987). One can thus recognise a change in the nature of shiftwork from predominantly manual work to that which demands substantial cognitive input. This marked shift in task requirements prompted the present study to assess performance in selected cognitive tasks via the use of a computer aided testing system, namely the Vienna Test System. In this manner the results obtained under laboratory conditions could be related to actual work environments such as to optimise worker efficiency, particularly during the operation of computerised apparatus.

NIGHT WORK

While "shiftwork" and "night work" are often used interchangeably within the literature, the focus of the present study was specifically on the effects of night work on efficiency of performance.

Man has long been known to work during the night hours, yet this mode of work was traditionally associated with a limited number of occupations, particularly in the medical domain where around-the-clock availability of services is a necessity (Bosch and de Lange,1987; Monk and Folkard, 1992). Night work has however become a significant component of the expanding shiftwork system which is permeating almost all sectors of the work environment. According to Åkerstedt *et al.* (1984) and Adams *et al.* (1986), it is the night shift which instigates the many problems associated with shiftwork. It would appear that the underlying factor against night work is man's inherent nature as a diurnal rather than a nocturnal creature (Monk and Folkard, 1983). It is for this reason that Walker (1978) characterises night work as an "unnatural" mode of work.

The night shift generally commences at 10:00pm (Dirken, 1966) and is defined by Kogi and Thurman (1993) as being a period of at least seven consecutive hours which includes the interval from midnight to 05:00am. The exact parameters of the night shift do however, appear to be determined by individual organizations and nations, and as such vary on a worldwide scale in terms of duration, as well as starting and finishing times. For example, the night shift switchboard operators investigated by Browne (1949) worked a nine-hour period from 23:00pm to 08:00am, while the night shift employees in a modern graphics plant studied by Costa *et al.* (1989) worked a shorter period from 21:00pm to 04:30am.

Performance and Safety Consequences of Night Work

Folkard describes how "the night shift is associated with impaired productivity and safety" (Folkard, 1987: p47). This corresponds with the general acknowledgement in the literature of the reduction in speed and accuracy, as well as the increased frequency of potential accidents which are associated with night work (Browne, 1949; Bjerner *et al.*, 1955; Bonnet and Webb, 1978; Folkard, 1987; Rosa, 1990; Moore-Ede, 1993; Monk *et al.*, 1996).

Several researchers (Colquhoun, 1971; Rutenfranz and Colquhoun, 1979; Walsh, 1990) attribute the decrements in performance efficiency of night workers to the fact that these individuals are required to maintain an equivalent state of alertness as their daytime counterparts, yet at a time when their natural tendency would be to sleep. Conversely, night workers must attempt to sleep during the "alert" phase of the circadian sleep tendency rhythm. This tends to result in fragmented and shorter sleep which may exacerbate sleepiness on the night shift and subsequently impair performance.

Performance and efficiency have been found to vary over the day (Blake, 1967; Folkard and Monk, 1979; Craig and Condon, 1984) with a "low ebb" occurring at night. While this trough is generally regarded as the cause for poor night shift performance, de Vries-Griever and Meijman (1987) argue that this overlooks other influential factors which may outweigh strictly circadian ones. In fact it appears that a host of factors may individually or collectively affect performance at night. Besides the obvious biological influences of circadian rhythm disruptions and sleep loss, there are numerous social and personal (health and motivational effects) factors that may lead to performance decrements and possible accidents.

While many studies have demonstrated impairments in performance during night work, Folkard (1996) recognises that performance in some tasks may be relatively good at night, although this may be dependent on variables such as the number of successive night shifts and hence on the degree of circadian rhythm adaptation. For example, a study by Monk and Embrey (1981) found few errors in a task involving short-term memory in a rapid rotation shift system as temperature rhythms were unadjusted.

Discrepancies with regards to differences in accident frequency between day and night have also been noted. Williamson and Feyer (1995) maintain that although there is substantial evidence that the early morning hours of the night shift are associated with the poorest performance, the degree to which this is translated into accidents is not well understood. Pokorny *et al.* (1987) and de Vries-Griever and Meijman (1987) contend that several additional factors must be considered when examining the relationship between accidents and time of day. These include time on task, work load and personal characteristics of the task operators. There are also significant situational, task and worker-related differences across shifts which must be borne in mind (Folkard, 1996).

Although there is considerable evidence that performance efficiency and safety may be compromised when working at night, there appears little doubt that the forces which have stimulated the growth of shiftwork and night work in the past will continue to operate in the future. This emphasises the need to examine those factors, both personal and environmental, which effect the performance of these workers. An attempt can then be made to control and minimise any negative influences.

FACTORS WHICH AFFECT PERFORMANCE

Analysis of human performance in any situation, be it daily living, working or sporting activities, requires the consideration of a multitude of variables. These include the dynamic interaction between personal and environmental factors. Here Levi describes how "reactions are elicited from the interactions between, or misfit of, environmental opportunities and demands, and individual needs, abilities and expectations" (Levi, 1994: p80).

Two classes of factors which affect operational safety on the shift system have been identified by Smith and Folkard (1993), namely "internal" and "external" factors. Internal factors include features of the circadian system, as well as personality, while external factors are comprised of shift schedules, job type, social and family variables. Monk and Folkard (1983) agree that performance at night is highly dependent on both the nature of the task and the nature of the individual performing this task. Any mismatch between the worker and his work environment could lead to serious problems such as mental fatigue and a lowered ability to concentrate and make decisions. It is thus necessary to examine factors which may influence performance in the general work environment. Particular emphasis will be placed on evaluating the extent to which these factors may affect performance efficiency during night work.

Personal Factors

Circadian Rhythms

According to Monk and Folkard (1992), *Homo sapiens*, like numerous other species on this planet, is essentially a "rhythmic species". Many functions of the human body have long been recognised to exhibit periodic variations, such as the menstrual cycle. Of concern in the present study however, are those fluctuations which occur on a daily basis, the so-called circadian rhythms.

Among those body functions which show diurnal variations are sleep, readiness to work and many autonomic processes including heart rate, blood pressure and body temperature (Grandjean, 1986). Diurnal variations have also been observed in performance and efficiency, for example Craig and Condon (1984) convey the general impression in the literature that efficiency "waxes and wanes" with time of day.

These functions have been found to fluctuate even when normal time cues are removed, such as when subjects are placed in isolation units. In this environment subjects continue to wake and sleep on a regular basis over the day. This has lead many researchers, including Folkard (1987), to believe that circadian rhythms are at least partially determined by an endogenous body clock. However, the different adjustment rates of these rhythms when people work at unusual times of the day gives rise to the possibility that the various circadian rhythms are controlled by several separately operating biological clocks (Folkard and Monk, 1985; Åstrand and Rodahl, 1986; Folkard, 1987).

It is of interest to note that circadian rhythms measured in free-running conditions such as those which occur in isolation studies, usually run over approximately 25 hours. This explains the derivation of the term "circadian" from the Latin *circa*, "about", and *dies*, "a day". Reilly *et al.* (1997a) describe how the body clock is adjusted, or, "entrained" to a 24-hour cycle by external time cues called *zeitgebers*. These temporal synchronisers include lightness/darkness, meal and work times, social influences and knowledge of clock time.

Circadian rhythms gear an individual for performance in the daytime, while the night is occupied with recuperation, relaxation and sleep (Grandjean, 1986; Reilly *et al.*, 1997a). Involvement in shiftwork, in particular night work, thus results in a disruption of these inherent rhythms. Ong (1992) adds that the circadian rhythm phase shifts induced by shiftwork can have significant effects on the worker in terms of performance efficiency, motivation, sleep patterns, family and social life and health. These phase shifts occur slowly over a considerable period and are a means of re-entraining the rhythms.

A decrease in sleep duration and quality is common amongst night workers (Rutenfranz *et al.*, 1976; Tepas and Mahan, 1989; Folkard, 1996; Bach de Oliveira *et al.*, 1997) and stems primarily from disruptions in circadian rhythmicity (Spelten *et al.*, 1995). The ensuing sleep debt can in turn impair performance and may therefore compromise safety. Further problems originating from the desynchronisation of the time-keeping mechanisms are chronic fatigue, depression and gastro-intestinal disorders, all of which may have an adverse effect on an individual's well-being and ultimately on performance. However, it should be borne in mind that there are marked individual differences in circadian rhythm adjustment, thus some people will be able to tolerate the stresses of shift- and night work with minimal deleterious effects.

Age

Several physiological functions start to deteriorate or decrease with advancing age. These include the visual and auditory processes as well as maximum heart rate and maximal oxygen consumption. It is these reduced and failing capacities which Oborne (1987) believes are responsible for the problems generally experienced by older workers. Hence age forms an important criterion in terms of worker selection for certain jobs, for example heavy manual labour.

Åkerstedt and Torsvall (1981) noted that advancing age induces changes in sleep patterns and circadian rhythms. Here, the "critical age" when adverse effects first arise is approximately 40-50 years. There is also a general agreement within the literature (Åkerstedt and Torsvall, 1981; Folkard, 1987; Spelten *et al.*, 1995; Reilly *et al.*, 1997b) that increasing age is associated with "morningness": the tendency to be more aroused in the morning than at night. This early phased circadian rhythm results in earlier bedtimes and waketimes.

Adjustment to shiftwork, and night work in particular, has been found to become more difficult with age, and is accompanied by a decrease in resistance to the stresses imposed by these modes of work (Grandjean, 1986; Parkes, 1994). The combined effects of ageing and aberrant work hours could thus place older shiftworkers at a greater risk than younger individuals and may lead to a substantial lowering of performance efficiency.

Davies and Parasuraman (1982) examined the effects of age on performance of vigilance tasks. They observed that older individuals tended to perform poorly under specific circumstances, such as when signal frequency increased or when an increased memory load in reporting and discriminating signals was involved. These results suggest that older workers are likely to perform poorly in highly cognitive and sustained attention tasks. This decrease in performance may be accentuated should such tasks be performed at night.

Although it would seem preferential to minimise the use of older workers in shift- and night work, the rapid growth of 24-hour operations together with the gross unemployment problems evident in many countries today, leads to the inclusion of older individuals in these types of work. To this end, Härmä (1996) recommends that for people over the age of 40 years continuous night work should be voluntary, regular health checks should be arranged, and the opportunity to transfer from night to day work should be available.

Sex

Several physiological differences have been recognised to exist between males and females. Males possess a relatively larger muscle mass, less body fat and a greater concentration of haemoglobin than do females (McArdle *et al.*, 1991). These differences are in turn manifested in numerous performance variables including strength, maximal aerobic power and maximal oxygen consumption where males demonstrate significantly higher values than females. The predominant selection of males is therefore favoured in work environments where heavy manual labour is required. With reference to general involvement in shiftwork however, Härmä (1993) has identified that no systematic studies appear to have examined sex differences in terms of circadian adjustment.

According to Carpentier and Cazemian (1977) women adapt to shiftwork in a different way to men as a result of their physiological differences. Women exhibit a specific "temporal structure" which is a function of the menstrual cycle. Carpentier and Cazemian describe how this monthly cycle includes a "time of diminished resistance" during which a stronger deactivation occurs at night along with frequent reports of fatigue. This tiredness may also be related to the traditional roles of house-keeping and child-rearing which may induce physical and emotional fatigue as well as sleep disturbances. These negative variables may be further exacerbated by working at night and it has been found that menstrual problems are more common in shiftworkers.

As a result of these periodic hormonal changes, reproductive functioning and family roles, woman have in the past tended to be excluded from participation in shiftwork. Bosch and de Lange (1987) reported that women were only tolerated in select operations, such as health care. However, it appears that in recent years the female segment of the shiftworker population has been growing. It is thus critical to determine the effects, if any, of shift- and night work on the performance of female workers.

In 1960 Dalton recorded significant increases in the incidence of accidents during the pre-menstruum and menstruation phases. Performance decrements on certain tasks have also been found to occur at these periods. Redgrove (1971) attributes this decrease in efficiency partially to the emotional changes associated with the cycle, for example pre-menstrual tension.

There is a general impression in the literature, with little empirical evidence, that women demonstrate a tendency to perform better in the morning (Baker *et al.*, 1984; Folkard, 1987). While consistent sex differences in the performance trend over the day are yet to be established, Davies and Parasuraman (1982) expressed the opinion that any such differences tend to be very small and of no practical importance.

Physical Conditioning

The benefits of regular involvement in 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 (LBP) via an increase in flexibility and muscular strength. Physically conditioned individuals should thus be well equipped to cope with demands, both qualitative and quantitative, imposed on them by the work environment.

The escalation in automated processes and computerisation of modern workplaces has significantly changed the lifestyle of workers who now tend to be less subject to physical effort, yet often experience additional stress. This may be a result of the general shift, brought on by advancements in technology, from predominantly perceptual motor tasks to those requiring a greater cognitive component.

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 worker's social and recreational lifestyle due to the continuous alternation 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.

In a study conducted by Härmä *et al.* (1988), moderate physical training was found to improve the general fitness of a group of shiftworkers, whilst further decreasing work-dependent fatigue and musculoskeletal problems. These effects were observed to be most pronounced during the night shift where worker alertness was lowest. Several studies have indeed shown an increase in tolerance to shiftwork in physically conditioned workers. Reinberg *et al.* (1980) concluded from their research that individuals with high amplitudes in their circadian rhythms were better able to cope with the frequent rhythm disturbances caused by shiftwork. These high amplitudes, which are believed to result in an increased stability of the circadian rhythms, are reported to occur in physically fit individuals (Atkinson *et al.*, 1993).

Physical fitness is also generally recognised to promote sleep and enhance the quality of this sleep, thus minimising drowsiness at other times of the day (Härmä *et al.*, 1988; Härmä, 1993). This being true, the incorporation of well conditioned individuals in shiftwork would be valuable in terms of optimising performance efficiency and circadian adjustment to work at abnormal hours.

Regular physical activity may also act as a *zeitgeber*, or "temporal synchroniser" (Colquhoun and Rutenfranz, 1980a). In this instance, Atkinson *et al.* (1993) suggest that physical activity serves to bring all components of a particular rhythm into phase, thereby further minimising disruptions to the circadian cycle.

Physical conditioning may therefore be seen to play a critical role in terms of increasing worker wakefulness and alertness, and subsequently helps to improve tolerance to shiftwork by aiding in the adjustment of the circadian rhythms of an individual.

Personality-Related Differences

The psychological make-up of man has long been recognised as being a significant contributor to both intra- and inter-individual differences with regards to nature of performance in various situations. Personality has been described by Lazarus and Monat (1979) as being a relatively stable set of psychological structures and processes which organise human experience and determine an individual's actions and reactions to the environment. Barrow and Brown (1988) add that personality is partially a product of biological heredity, yet is further nurtured by an individual's cultural heritage. This corroborates the tendency in the literature to distinguish between two dimensions of personality, namely introversion-extroversion and morningness-eveningness, both of which appear to be determined by a combination of genetic and cultural input. The latter dimension has formed the main focus in research on individual differences in adjustment to shiftwork.

Monk and Folkard (1992) include the above-mentioned dimensions 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-type individuals tend to have early bedtimes and waketimes and are more alert during the morning (Kerkhof, 1985). E-types on the other hand, are more aroused later at night and experience difficulty in waking up early. Self-assessment questionnaires, such as that devised by Horne and Ostberg (1976), are commonly used for identifying morningness and eveningness characteristics.

M-types are generally found to be less tolerant to shiftwork, in particular, the night shift (Östberg, 1973; Monk and Folkard, 1992; Reilly *et al.*, 1997a). Monk and Folkard (1992) propose three reasons for this apparent difficulty in adaption. Firstly, M-types find it extremely hard to stay awake at night, or to sleep late in the morning, which is exactly the behaviour required of night workers. Secondly, M-types appear to be more susceptible to environmental *zeitgebers* (time cues). A third reason relates to the postulation 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.

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 bedtime. It would therefore seem that E-types would better cope with the demands of working at aberrant hours, such as was indicated by the 1980 study of Horne and associates where extreme M-types demonstrated a general decrease in performance efficiency over the day, whereas extreme E-types improved their performance later in the day.

It has been queried whether morningness-eveningness is a stable, genetically determined trait, or simply a reflection of a recently developed habit (Folkard, 1987). The present study, for example, incorporated young adults drawn from a student population. In such an environment it is commonplace to develop a nocturnal lifestyle as a result of work demands imposed on the student. An M-type individual could thus temporarily acquire E-type characteristics, yet may revert back to their morningness tendency at a later stage.

The second circadian type reviewed by Monk and Folkard (1992) entails the quantification of individual differences along the dimension of introversion-extroversion. These characteristics may be identified by using Eysenck's (1958) shortened questionnaire for the measurement of two dimensions of personality. Introverts generally tend to be quiet, thoughtful, non-impulsive individuals and are often loners. Extroverts, on the other hand, are usually carefree, compulsive and highly sociable with an almost constant need for stimulation and challenge.

There is a general agreement in the literature that arousal rate in both introverts and extroverts increases over the day, with this rate being greater in the latter personality group (Blake, 1971). Blake reports that introverts generally have a greater level of arousal in the morning, while extroverts have a higher level later in the day. These circadian variations in arousal level appear to be responsible for increased alertness and vigilance capacities of extroverts during evening and night shifts.

Several authors have attempted to draw parallels between the dimensions of morningness-eveningness and introversion-extroversion. Horne and Ostberg (1977) for example, suggest that one may be able to predict that introverts are more capable of sustaining attention during the day, while extroverts are more vigilant in the evening and at night. This would seem to indicate that introverts tend to be M-types and extroverts tend to be E-types (Horne and Ostberg, 1977; Walker, 1978; Folkard *et al.*, 1979). The findings of Kerkhof (1985) and Vidacek *et al.* (1988) however, demonstrate that the dimension of morningness-eveningness is more important than that of introversion-extroversion in determining individual differences in circadian rhythm adjustment to work at varying times of the 24-hour cycle.

The final circadian type described by Monk and Folkard (1992) is identified by the Circadian Type Questionnaire (CTQ) designed by Folkard *et al.* (1979). The CTQ was developed in order to evaluate three circadian variables, namely morningness, sleep pattern rigidity and vigour. Individuals with low scores in rigidity tend to exhibit variable bedtimes and waketimes. Such individuals combined with low values of morningness and high scores in vigour are generally found to suffer less from circadian disruptions imposed by shiftwork, in particular night work.

The studies discussed above would appear to favour extrovert "evening types" with high scores in vigour as being most suited to work during the evening and night hours. Personality characteristics may thus prove highly useful in the selection of shiftworkers as they may help to identify those individuals who would better tolerate and adjust to work at aberrant hours. However, both temporal and logistic limitations would be present should one for example, attempt to assess the personality characteristics of all workers in a large factory. Although personality variables were not directly included within the scope of the present study, the general "morningness-eveningness" tendencies and preferred work times of the subjects were recorded.

In summary, it can be seen that numerous personal factors may determine the manner in which an individual will perform in any given situation. It was therefore necessary to standardise as many of these factors as possible during the present study such that the influence of the two primary variables under investigation, namely time of day and task diversification, could be maximised.

Environmental Factors

Shift Systems

A review of the available literature on shift scheduling indicates that while some shift designs are preferential to others, no ideal shift system is agreed upon. Folkard (1992) in fact suggests that there is no "best" shift system as any design is a tradeoff between accommodating the worker's social needs and health and safety aspects.

There are three widely used shift systems: rapidly rotating, weekly rotating and permanent night shifts. Each of these systems has its advantages and drawbacks.

Rapidly rotating systems are found to cause the least disturbance to the endogenous body clock (Folkard, 1987; Knauth, 1996). Wedderburn (1992) favours these systems as they provide for both the physical and social needs of the worker. Monk *et al.* (1996) describes how *weekly rotating shifts* are generally regarded as being the worst system as disruptions to the circadian rhythms lead to a cumulative sleep debt. It would appear however, that these systems tend to be the most commonly used.

Permanent night shifts are recommended by Wilkinson (1992) who maintains that an acceptable level of circadian rhythm adjustment can normally be achieved. This nocturnal orientation may in turn improve sleep and performance. Folkard (1992) further adds that permanent night shifts are preferential when safety is crucial. However, Folkard (1992) and Knauth (1993) argue that these shifts are not desirable to most people as they hinder social contacts. On the other hand, Colquhoun and Rutenfranz (1980b) noted that women appear to prefer permanent night work as it facilitates the organisation of domestic responsibilities.

Where rotation of shifts occurs, a forward direction (morning-afternoon/evening-night) is favoured (Folkard, 1987; Knauth, 1996; Bach de Oliveira *et al.*, 1997) as this causes minimum disturbance of diurnal rhythms. One further variable to consider in terms of the design of shift systems is that of the length of the shift. Here, Rutenfranz *et al.* (1976) believe that a shift should not exceed eight hours, except where the work is low in physical and mental demands, while Knauth (1996) recommends that extended work periods of nine to twelve hours should be avoided.

Due to the lack of one "ideal" shift system, it would appear that regardless of which system is followed, another design may be seen to be more acceptable (Scott, 1997).

Physical Environment

The physical environment, including noise, lighting, temperature, work space and vibration, can both enhance or impair performance. Bailey (1982) reports how humans are particularly vulnerable to extreme conditions in the physical environment, while Singer (1980) lists 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.

Noise, for example, is an inherent part of many monitoring situations (Stroh, 1971) and is especially evident in automated working environments. The term "noise" refers to an unwanted sound and thus tends to be associated with impairments in performance, particularly when complex tasks are involved (Hancock, 1984). Constant noise may also decrease an individual's ability to sustain attention. Graeber *et al.* (1991) describes how the cockpit environment with its constant background noise together with dim lighting and automated systems can contribute to a decrease in vigilance and difficulty in staying awake during long-distance flights. This may in turn jeopardise safety. However, moderate noise may have an arousing effect on some individuals, and the absence thereof may in fact impair performance (Bailey, 1982). It is also important to acknowledge individual differences with regards to perception and tolerance of the various environmental conditions.

In order to minimise possible effects of the physical environment on performance, the present study was conducted in a laboratory where lighting and noise levels, as well as work space could be standardised.

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. Bailey (1982) acknowledges the general consensus that audience effects such as social pressure and competition, tend to enhance performance of well-learned skills, yet negatively influence performance during the early stages of skill acquisition. The present study attempted to reduce any possible effects of social facilitation and to standardise data collection by testing subjects in the presence of the experimenter only, and by minimising interaction between subject and experimenter.

Apart from the social environment, domestic commitments may further affect work performance. The nature of shiftwork, especially that which involves working at night, clashes with normal family routines. These "unsocial" working hours (Colquhoun and Rutenfranz, 1980a) tend to result in reduced family and social contacts (Bosch and de Lange, 1987; Ong, 1992). Spelten *et al.* (1995) note that women appear to experience greater strain because of their domestic responsibilities. This strain arises when home conditions are not conducive to undisturbed rest, thus leading to sleep deprivation and increased fatigue. It is these factors, along with the general dissatisfaction expressed by shiftworkers due to tiredness and a disordered life (Léonard, 1981), which may subsequently impair job performance.

Environmental factors of both a physical and social nature can thus be seen to play a major role in determining human performance. Although it appears to be relatively easy to standardise the physical environment, it is also necessary to consider the influence of social and family factors on the worker. However, these latter social factors are far more difficult to control, particularly when dealing with workers *in situ*. Laboratory studies may be successful in isolating individuals from social and domestic stressors, yet the applicability of such studies to real-life situations must be established.

LABORATORY VERSUS FIELD TESTING

There appears to be a considerable amount of controversy in the literature in terms of the validity of laboratory and field studies of shiftwork. It is thus necessary to examine the advantages and disadvantages of these two modes of study in order to determine their utility in identifying problem areas in the workplace.

According to Monk and Folkard (1992) field studies tend to be rare occurrences in view of their high costs and the associated political difficulties. These difficulties arise when scientists attempt to gain access to the work environment as one needs to convince both management and the unions of the potential benefit of the proposed investigation in order to ensure co-operation from both parties. *In situ* investigations cannot be as rigorously controlled with respect to social and environmental factors such as occurs in laboratory environments. There is also the possibility of contamination of results due to external distractions which are part of all working environments, yet are specific to each situation. Oborne (1987) however, argues that these field studies have a greater validity in terms of relating back directly to the work situation.

Another potentially limiting variable to contend with during these field assessments is that of the Hawthorne effect. This refers to instances where individuals appear to behave in a particular manner simply because they are in an experimental situation (Oborne, 1987). The attitudes of the workers, management and the unions towards the study will also play an important role in determining worker performance. Oborne describes how a negative Hawthorne effect commonly occurs in industry as workers perceive the results of the investigation to affect future productivity and payment norms. A decrease in productivity may therefore take place throughout the course of the investigation, hence achieving lower norms. "Normal" production thereafter will appear to demonstrate an increase in productivity. Oborne (1987) thus suggests that it may often be necessary not to explain all aims of an investigation to the workforce in an attempt to minimise these possible detrimental effects.

A common problem experienced in field studies of shiftwork is that of trying to standardise day and night work conditions such that valid comparisons may be made. There is a general recognition in the literature of the substantial differences between the various shifts (Walker, 1978; Glenville and Wilkinson, 1979; Monk and Embrey, 1981; Monk and Folkard, 1985b). These differences occur with respect to the number of workers involved, type of work, lighting and supervision levels, group morale and distractions. It may thus be extremely difficult to determine intershift differences in "real task" performance (Monk and Folkard, 1992) as these varying work conditions may be responsible for differences in output and accident frequency (Walker, 1978).

The alternative to *in situ* testing is laboratory simulations of shiftwork, but this too tends to be overshadowed by a multitude of problems. Although several studies have incorporated actual shiftworkers, the artificial nature and shorter duration of the laboratory tasks may present significantly different results than would occur under natural work conditions (Monk and Folkard, 1985b). Walker (1978) identifies that factory workers tend to work below their maximum ability such that they maintain a "spare capacity" should situational demands increase. When exposed to laboratory simulations however, the worker may perform maximally as a consequence of motivational or competitive factors, thereby misconstruing performance measures. Monk and Folkard (1985b) add that simulated work may bias performance in a negative manner as the worker may perceive the required tasks as being trivial and irrelevant.

Monk and Folkard (1985b) also report how laboratory studies generally comprise a relatively small subject pool and therefore do not facilitate adequate inter-individual comparisons. Another factor to consider is that these studies tend to utilise student volunteers; however, students may have very different circadian and sleep patterns to actual shiftworkers and also tend to be younger. It is therefore recommended that these factors be accounted for when analysing performance.

While laboratory studies allow for standardisation of local physical conditions, as well as providing stringent control over stimuli presented to the subjects, this extremely "sterile" environment has been found to unsatisfactorily account for social influences and work realities (Monk and Folkard, 1985b; Rohmert, 1987). On the other hand, Rutenfranz and Colquhoun (1979) expressed the opinion that laboratory research is better able to control for complex motivational and situational factors that are known to obscure field assessments. As such Grandjean (1986) believes that laboratory studies have an advantage in that they usually make it possible to distinguish between "cause and effect".

An additional class of shiftwork study is identified by Monk and Folkard (1992), namely the use of surveys. These constitute an easier means of obtaining "field" data with regards to the effects of shiftwork than do *in situ* evaluations. Surveys are conducted in the form of interviews and/or questionnaires which are employed both prior to, and following the implementation of a particular intervention strategy, such as to quantify its impact. The main problem associated with the conduction of surveys relates to possible contamination of data by the Hawthorne effect, plus the possibility of "false" responses to these "self-report" questionnaires.

It is important to bear in mind that ergonomics is an *applied science*. As such there is a need to conduct both rigorous laboratory experiments, as well as field testing which together acknowledge the network causality of factors underlying a worker's response to varying external demands. It is necessary to use valid tests in a laboratory setting in order to isolate and determine the extent to which specific factors may influence performance efficiency, and thereafter to apply the results in a "real-life" context while taking cognizance of the total work environment. The present study chose to collect data under strictly controlled laboratory conditions, thereby attempting to standardise motivational and situational variables. The psycho-motor tasks performed by the subjects were specifically selected due to their applicability to actual work environments. The results of these tests could therefore be related to many modern worksites where efficient performance is dependent on the timely and accurate responses of the human operator to external stimuli.

ASSESSMENT OF PERFORMANCE

The extreme complexity of human behaviour provides evidence of the vast number of interacting variables which determine individual performance in a given situation. It was thus deemed essential to assess the effects of night work on performance efficiency in terms of the three inter-related "effort continua" proposed by Borg (1973).

Borg (1973) reported that a physically stressful situation to which an individual tries to adapt, may be examined in terms of physiological, perceptual and performance responses. He refers to these three measures as "stress indicators" or "effort continua". Later, in 1976, Borg stressed the need to adopt an interdisciplinary approach when examining the three effort continua. He maintained that each continuum should initially be studied separately and thereafter the data should be integrated as the continua in essence complement one another.

It is important to recognise that although these effort variables are essentially related to physical work, the concept also bears application to mental work. Similar means of measuring the three effort variables can be used in both physical and mental work.

Physiological Measures

Several physiological indicators are commonly used to quantify an individual's response when performing work of a physically and/or mentally stressful nature. These include cardiovascular measurements such as heart rate and blood pressure, percent of maximal oxygen uptake, electromyographic (EMG) activity, electroencephalographic (EEG) activity, core and skin body temperature, neural and endocrinal changes. One of the most simple and frequently used physiological measures of responses to varying demands is that of heart rate.

Heart Rate

Heart rate is regulated by both intrinsic and extrinsic mechanisms. The inherent rhythmicity of the heart is determined by the firing rate of the natural cardiac pacemaker, namely the sinoatrial node which results in the heart beating approximately 70 times per minute at rest (Ganong, 1991). Extrinsic regulators, in the form of sympathetic and vagal control, are responsible for the tremendous fluctuations which occur in heart rate (Rompelman *et al.*, 1980; McArdle *et al.*, 1991). These variations are not exclusively a function of internal physiological events, but are also influenced by a network of psychological and performance-related factors. Ganong (1991) and McArdle and associates (1991) identified some of the factors which can accelerate (tachycardia) or slow down (bradycardia) heart rate: ambient temperature, food intake, body position, phases of respiration, sleep, physical activity, and emotion. Diurnal variations are also recognised to affect heart rate levels (Walker, 1978; Shephard, 1984; Monk and Folkard, 1992). These variations appear to stem from the sleep-activity cycle (Monk and Folkard, 1992) where heart rate values are lowest at night and increase during the day with a peak in the afternoon (Åstrand and Rodahl, 1986).

The occurrence of both inter-individual and intra-individual variability in heart rate patterns, which exist even under controlled environmental conditions, often tend to be ascribed to psychological, or emotional influences. McArdle *et al.* (1991), for example, maintain that variations in an individual's emotional state can significantly affect cardiovascular responses, even during complete rest. This underlies the difficulty experienced in recording a "true" resting heart rate (Rompelman *et al.*,1980; McArdle *et al.*, 1991). It is interesting to note that the individual's anticipation of an impending event may alone lead to an increase in heart rate (McArdle *et al.*, 1991).

Much research recently has focused on examining the relationship between mental load and cardiovascular responses, including that of heart rate (Carroll *et al.*, 1987; Goldstein and Shapiro, 1988; Johnston *et al.*, 1990; Linden, 1991). Most of these studies have opted to use a mental arithmetic task which demands continued concentration, yet requires minimal effort physically. Johnston *et al.* (1990) describe these mental arithmetic tasks as "active coping tasks" which entail that the subject responds to a difficult, but not impossible, demand in order to achieve a specified goal. These authors acknowledge that active coping tasks have been shown to elevate cardiovascular responses. This is illustrated in a study by Carroll and associates (1987) who demonstrated that heart rates of subjects performing a mental arithmetic task were associated with "additional heart rates". In other words, their recorded heart rates were excessive relative to predicted heart rates based on concurrent levels of energy expenditure. These "additional heart rates" are regarded by Strφmme *et al.* (1978) as a useful indication of psychological activation and hence may be attributed to the psychologically challenging nature of the mental arithmetic task.

One can thus observe the close relationship between physiological and psychological events. In any analysis of human performance, it is critical to draw attention to the *human element* as there will inevitably be a significant cognitive and affective appraisal of the situation on hand which will bear an influence on physiological processes and ultimate psycho-motor output. This may in turn have a positive or negative effect on an individual's efficiency of performance. It was therefore decided to include the assessment of heart rate responses during the performance of the cognitively demanding psycho-motor tasks used in the current research project.

Fluctuations in heart rate can be easily observed in a laboratory setting and *in situ* through the use of a portable non-intrusive monitoring device. The present study thus employed a short-range radio telemetry system (Polar Sport Tester Heart Rate Monitor) to observe and store heart rate responses.

Perceptual Measures

Borg (1970) suggested that "man reacts to the world as he perceives it and not as it really is". As such, any given stimulus received by two people may be interpreted in entirely different manners. Perception may be described as the intervening variable between stimulus and response which facilitates the processing and meaningful interpretation of raw sensory information. Perception therefore serves as a guide to subsequent psycho-motor behaviour and hence is critical for efficient performance (Barrow and Brown, 1988).

Perceptual assessments of the perceived difficulty of a specific task may be obtained through the use of psycho-physical ratio scaling methods, for example Borg's (1970) Rating of Perceived Exertion Scale (RPE). These scales attempt to correlate corresponding physiological and psychological activities, as well as offering a means of quantifying subjective responses. Borg (1976) cautions against the sole use of verbal expressions as a means of assessing an individual's perception of a task as he maintains that the interpretation and precision of these expressions tends to be difficult to quantify and significant inter-individual differences occur.

The present study made use of Scott's (1994) Perceived Strain Scale (PSS), a rating scale which allows for direct intra- and inter-individual comparisons by providing a tangible numerical representation of the perceptions of an individual.

Perceived Strain Scale

The Perceived Strain Scale (PSS) offers an objective measure of the amount of strain being experienced by a person under varying stressful conditions. Scott (1994) realised the need to take cognizance of both the demands of the task, and the individual's unique perception of their ability to cope with those demands, in order to evaluate the stress imposed and strain experienced in a specific situation. To this end, the PSS requires individuals to rate their perceptions of the task demands (*td*), together with their perceived ability to cope (*pac*) with the imminent task.

The PSS comprises four 10-point rating scales with verbal anchors (A copy of this scale is included in Appendix B). Subjects are required to firstly rate the task demands in terms of difficulty (*simple-difficult*) and complexity (*basic-complex*), and secondly to rate how taxing (*effortless-taxing*) and demanding (*undemanding-demanding*) they perceive the task will be. These ratings are then applied to two simple equations to calculate an Evaluation of Task Demands (ETD) and an Evaluation of Perceived Strain (EPS).

ETD scores are indicative of an individual's overall appraisal of a particular task, while EPS scores express the individual's perception of the level of strain they will experience while performing that task. Scott (1994) emphasises the need to maintain an appropriate balance between the stressful task demands and the person's capability to deal adequately with these demands such that strain may be avoided. This should subsequently facilitate an improvement in efficiency of performance.

Performance Measures

According to Borg (1973), performance measurements are often preferred to physiological measurements in terms of their predictive capacity. Performance results, for example reaction time, are considered by Borg to be extremely sensitive to both physical and emotional stress. As such, the extent to which an individual is influenced by these stressors whilst performing a particular task, will be reflected by the nature of the results.

Most performance types are measured in terms of speed and accuracy. These two measures are described by Borg (1978) as being "ordinary ergonomic criteria" and as such should be considered during any ergonomics investigation.

Speed refers to the time taken to execute a particular task, namely response time. Response time can be broken down into reaction time and movement time. "Reaction time" represents the latency period between the stimulus presentation and the initiation of a response (Kerr, 1982), while "movement time" indicates the time taken to carry out the required response.

Reaction time has long been known to vary according to the type of stimulus presented. Bailey (1982), for example, maintains that a person can hear a signal and respond to it in approximately 150 milliseconds, while a visual signal will be seen and responded to in a slightly longer time of about 200 milliseconds when in close proximity. Several factors may shorten these reaction limits, such as practice, or an increase in the intensity of the stimulus. On the other hand, this reaction time may be lengthened by factors including fatigue and increasing task complexity (Bailey, 1982).

Accuracy is determined by means of recording the number of errors made whilst performing a task. Blake (1971) identifies two types of errors, namely omissive and commissive. The former type refers to the failure to execute the required response, while the latter occurs when a response is made when it is not required. Certain activities, once learned, can be performed with minimal errors; however, Bailey (1982) points out that experience gained, particularly on automatic activities, will increase speed of performance more than accuracy of performance.

The primary goal of any business is to increase productivity. Attainment of this goal often lends to a stressful work environment where workers are required to perform tasks at a fast pace and may also experience an information overload. Kerr (1982) identified several ways in which an individual responds to an overload of information. For example, one can increase working speed at the expense of accuracy. This reduction in accuracy may however be an unacceptable means of coping should the task require precision. A second response may be to process data in a serial fashion; however, this may lead to a slowing down or delay in performance which might be equivalent to an error. In the instance of partially automated or continuous production lines, there is little or no opportunity to decrease response time. Here it is critical that system designers consider human limitations together with the task requirements (Bailey, 1982).

The relationship between speed and accuracy is commonly referred to as the "speed-accuracy tradeoff". This relationship has long been studied, yet remains inconclusive. In 1930, Weiskotten and Ferguson found that speed of mental performance suffered as a result of fatigue induced by sleep loss, while accuracy actually increased. A study conducted by Pew (1969) displayed a negative correlation between speed and accuracy in most choice-reaction tasks. However, he emphasised that this performance limitation was due to individual differences and was not a task specific effect. Later, Copes and Rosentswieg (1972) examined performance efficiency on a series of psycho-motor tests in order to determine the effects of sleep loss. They observed that accuracy in a target throw task was least affected by lack of sleep, while reaction time and movement time were significantly affected.

Craig and Condon (1984) recorded an efficiency deficit in several mental operations tasks at specific times of day. They attributed much of this deficit to the tradeoff between speed and accuracy where performance became faster, at the expense of accuracy, as the day progressed. The authors however, suggested that the increase in speed towards the end of the workshift may be due to accumulating fatigue rather than the influence of time of day.

The present study examined performance efficiency in terms of speed and accuracy of responses to selected psycho-motor tasks presented on a computerised apparatus called the Vienna Test System.

Vienna Test System

The Vienna Test System (VTS) is a computer aided testing device which is comprised of a personal computer, VGA monitor and keyboard together with a peripheral interface which supports the operation of several peripheral units. The VTS enables the presentation of a large variety of psychodiagnostic tests, as well as data storage and rapid evaluation of results. Such a computer system is designed to provide maximum objectivity, accuracy and reliability during psychological and psycho-motor assessments. The VTS software is relatively user-friendly and every test offers an instruction and practice phase; no special computer skills are required to operate the system (Schuhfried, 1994).

One can select a single test or administer a test battery using the tests available. Many of these tests in turn offer several test versions which differ in duration and difficulty. It is thus possible to compile a test battery using the various tests and test versions such that specific research requirements may be met.

The present study made use of a test battery comprising three psycho-motor tests. These included the tests of Concentration Under Monotonous Conditions (Q11), Reactive Stress Tolerance (RST3), and Work Performance Series (WPS). Brown *et al.* (1988) identified the most commonly used psychologically stressing tasks examined under laboratory conditions to be those which entail mathematical, conceptual, or perceptual problems which are presented at a pace that makes accurate solution difficult. Such tasks tend to be selected as a result of their applicability to the varying stressful demands occurring in real-life working situations. The three tasks chosen for this particular study required the use of control-type panels such as may be found *in situ*. Efficient performance of these tasks was dependent on the speed and accuracy of psycho-motor responses to the given stimuli.

Prior to reviewing the three psycho-motor tasks, it is necessary to include a brief description of *psycho-motor performance*.

Kerr (1982) distinguishes between the three components of psycho-motor performance: "psycho" refers to the operations which control motor activity, namely perceptual, decisional and nervous system commands; "motor" relates to any muscular activity which is directed to a specific objective; while "performance" is the observable end product or behaviour. One can therefore identify the critical interaction between perceptual and motor processes in determining the quality of psycho-motor performance. Colquhoun (1982) reiterates this in his definition of performance as:

> "scores of efficiency at various tasks which require the use of cerebral processes in responding to specified sensory information by appropriate motor actions"
> (Colquhoun, 1982: p59)

Test of Concentration Under Monotonous Conditions (Q11):

Vigilance, or, sustained attention tasks are common in many work settings and generally involve the prolonged monitoring of a monotonous stimulus in a physically inactive situation. Such tasks often induce drowsiness and feelings of boredom (Parasuraman, 1984; Wedderburn, 1987), yet it should be borne in mind that some individuals may consider vigilance tasks to be interesting and challenging.

Warm (1984) cautions that in an automation-oriented society it is important that vigilance tasks be performed efficiently as failure to detect critical signals could have disastrous consequences. Omissions of this nature may be more pronounced during night work which the majority of workers associate with increased tiredness and impaired alertness (Browne, 1949; Wyatt and Marriott, 1953; Walsh, 1990).

Johnson (1982) and Fröberg (1985) identify sleep loss as being a further confounding variable that may have negative effects on the performance of long, monotonous tasks which require little involvement and arousal. This may be exacerbated in night workers who have accrued a sleep debt due to disturbed and insufficient day sleep (Wyatt and Marriott, 1953; Rutenfranz and Colquhoun, 1979; Folkard, 1987; Walsh, 1990; Bach de Oliveira *et al.*, 1997).

The Concentration Under Monotonous Conditions (Q11) test was included within this study as it is a measure of attentiveness under monotonous conditions. The Q11 test is an action test with freely selectable speed, however, the subject is encouraged to work as quickly and accurately as possible. The monotonous nature of the material presented is designed to produce an habituation effect which usually gives rise to a decrease in concentration. The results of this test may therefore be used to determine individual differences in attentiveness (Q1, 1989).

Work Performance Series Test (WPS):

The Work Performance Series (WPS) test is an example of what Folkard and Monk (1985) refer to as a "working memory" task; namely it involves both the short-term storage, and the processing of, information. These authors acknowledge the difficulty experienced by researchers in attempting to establish normal diurnal trends in working memory. The best time to perform such tasks appears to depend on the precise demands of the task as well as the abilities of the individual performing it.

Short-term memory can be described as a temporary memory store where information is held temporarily, usually for a few seconds (Bailey, 1982). While this type of remembering is used in thousands of tasks performed each day, Folkard (1987) believes that a task which requires immediate retention is best done early in the morning as immediate recall decreases thereafter. It is therefore possible that the performance of tasks involving short-term memory during the night shift may result in more errors than during the day.

The WPS test assesses sustained concentration on numerical tasks performed under time pressure and includes the use of short-term memory (Schuhfried, 1994). This test allows one to determine an individual's ability to sustain concentration during performance of a prolonged mentally taxing task, whilst resisting fatigue and distraction.

Test of Reactive Stress Tolerance (RST3):

In many human-machine systems, continuous perception of information, and its efficient and quick processing are of prime importance. Here, an individual may be confronted with a large number of stimuli to which reactions must be made within a limited time period. A person's ability to cope with these task demands is referred to by Schuhfried (1994) as *reactive stress tolerance*.

The test for Reactive Stress Tolerance (RST3) is performed using the peripheral Vienna Determination Unit (VDU). This is a complex multiple stimulus reaction unit which measures reaction speed, accuracy and reaction behaviour under stressful conditions (Schuhfried, 1994). The test entails reacting to a range of visual and acoustic stimuli by pressing a corresponding button or foot pedal. The RST3 test consists of three phases; each phase presents equal numbers of stimuli at a different rate and thus creates varying levels of psycho-physical stress.

This test places substantial demands on an individual's perceptual, information-processing and motor abilities. The results subsequently yield a great deal of information about the person's ability to cope with stressful situations (Maree, 1994). This information may be particularly significant when considering the additional stresses already placed upon night workers: an overload to the information-processing capacities could well be detrimental to efficiency of performance.

The inter-related triad of physiological, perceptual and performance factors which collectively determine overall human behaviour is best examined using an holistic, ergonomic approach. The multidisciplinary nature of such an investigation would appear to have tremendous potential with regards to assessing the intricate, multifaceted problems faced by shift- and night workers. This could in turn aid in the development of effective intervention strategies designed to improve worker well-being and tolerance of work at aberrant hours and subsequently enhance performance.

COPING STRATEGIES

It is essential to develop and implement viable coping strategies to minimise the numerous deleterious effects of shift- and night work and to improve individual tolerance to work at these unnatural hours. Kogi and Thurman (1993), together with Monk and associates (1996) stress that any coping strategies employed must be participatory in nature as this worker-oriented approach is more likely to enhance worker safety and well-being. This should in turn optimise the worker's effectiveness and productivity. It is also important to realise that "shift work is too broad and multifaceted a problem to be solvable exclusively by worktime interventions" (Monk and Folkard, 1992: p62), thus coping measures must extend outside of the work environment.

According to Monk and Folkard (1992), there is no single solution that will immediately alleviate problems associated with shiftwork. They emphasise that an individual's ability to cope is determined by three primary and inter-related factors, namely the circadian system, sleep, as well as social and domestic circumstances. One must aim to acquire a balance between these factors without critically impairing any one area.

Circadian, sleep and domestic strategies tend to take place away from the workplace. Techniques to minimise disruption to the circadian rhythms include ensuring regularity of mealtimes, social interaction and timing of sleep, as well as avoiding the strong daylight *zeitgeber* by wearing sunglasses on the way home from work. Sufficient and undisturbed sleep is imperative to maintain alertness on the night shift. The home environment needs to be conducive to such conditions thus changes may need to be made to the normal domestic and social routines to accommodate for aberrant work schedules. Shift systems also need to be designed either to maximise or minimise circadian rhythm adjustment, decrease sleep loss, and should consider the social and family needs of the worker.

These strategies alone may be insufficient to deal with the stresses imposed by shift- and night work and need to be further supplemented with work-site interventions.

Work performed at night, particularly over a prolonged period, is often accompanied by drowsy moments (Wedderburn, 1978), and subsequent lapses in attention which Shephard (1984) attributes to "micro sleeps", namely naps of a few seconds duration. These dramatic decreases in arousal may have catastrophic effects for both the worker and society should critical signals be missed. Shephard suggests a number of stimulating mechanisms, for example noise, competition and physical activity. Wedderburn (1987) provides a number of standard remedies to combat drowsiness specifically while driving long distances, yet which may be applied to other work environments. These include stopping for a physical break or light refreshment, listening to a tape or singing, and direct body stimulation such as stretching or scratching. It can thus be seen that a variety of *in situ* coping strategies is available; selection of a specific strategy should take cognizance of the specific environmental conditions and task requirements, together with individual preferences.

Much of the modern work environment has become automated and thus involves a substantial amount of time spent operating visual display terminals (VDT's) and control panels. Bullock (1990) and Lee *et al.* (1992) emphasise the need to counteract the stresses of static work via the inclusion of brief periods of physical activity in the work schedule. Monk and Folkard

(1992) also encourage people to keep active on the night shift, while Takeuchi *et al.* (1985) report that exercise normally has an arousing effect.

A further intervention strategy designed to maintain worker motivation and concentration is that of job rotation (Walker, 1978; Singer, 1980; Bullock, 1990). This acts as a means of task diversification and may be particularly useful in preventing fatigue induced from under-arousing monotonous tasks, or over-arousing complex tasks by alternating these assignments. Should task diversification be possible within a shift, Monk and Folkard (1992) recommend that boring, monotonous tasks be performed initially, while interesting or challenging tasks should be included in the latter part of the shift.

This research project investigated the possibility of incorporating short periods of task diversification in the work schedule. Stroh (1971) recommended the inclusion of a "mild physical" task as a means of improving vigilance. A moderate cycle bout was therefore included in between performance of the predominantly cognitive psycho-motor tests. This served as a means of stimulating the subject's arousal system with the aim to increase individual alertness, particularly during the night test session.

There are a number of other commonly proposed strategies including the use of naps, central nervous system stimulants, such as caffeine, as well as short rest breaks and social contacts.

Several researchers, including Bonnet and Arand (1994) have found the use of "naps" to be effective in terms of sustaining nocturnal alertness and performance. However, Monk and Folkard (1992) advise that naps should only be used as a "topping up" process before the night shift, and may in fact compromise safety as these short periods of sleep can result in sleep inertia, or grogginess (Gillberg, 1985; Monk and Folkard, 1992)."

Central nervous system stimulants, for example caffeine and amphetamines, tend to offer short-term help in improving alertness (Monk and Folkard, 1992), yet Monk (1988) advises against using these stimulants for five hours prior to sleep as they may disrupt subsequent sleep.

Another coping measure which is recommended is that of brief rest periods (Colquhoun, 1959; Walker, 1978; Singer, 1980; Grandjean, 1986), which are particularly important in a repetitive task requiring constant concentration. These short breaks further provide the opportunity for social contact with other workers (Stroh, 1971; Grandjean, 1986).

Pre-Employment Screening

Efficient performance in many occupations relies on the integration of the biological characteristics of the worker and the design of equipment and the workplace. Similarly, an attempt needs to be made to match the biological and social needs of an individual with the requirements of shift- and night work in order to reduce conflict. This requires the use of pre-employment screening.

According to Monk *et al.* (1996), one must be careful of arbitrarily ruling out certain individuals and denying them the opportunity to do shiftwork as knowledge is not sufficiently developed to conclusively identify suitable and unsuitable people. While it is recognised that individuals differ in their tolerance of aberrant work hours, it may be advisable to counsel those people who are identified as being more susceptible to shiftwork problems against engaging in this mode of work (Monk and Folkard, 1985a; Monk *et al.*, 1996).

Walker (1978) and Moog (1987) deem it necessary to develop valid predictive tests of an individual's adaptability to shiftwork, and night work in particular. Such tests may include questionnaires for example the Morningness-Eveningness Questionnaire devised by Horne and Ostberg (1976) and the Circadian Type Questionnaire (CTQ) formulated by Folkard and associates (1979).

When using pre-employment screening, it is important that the goals of these selection techniques be explained to the workers and worker unions as these methods tend to be regarded as discriminatory with the consequence that many countries prohibit screening.

CONCLUSION

In summary, the problems encountered by shiftworkers, and especially those involved in night work, range from disturbances of the circadian rhythms and inadequate sleep, to social and family disruptions (Kogi, 1985). Folkard (1996) maintains that the magnitude of strain experienced by the worker is highly dependent on both personal differences, such as age, sex and personality, and situational differences, including the work environment and domestic circumstances. The combined effect of these factors may in turn affect performance capabilities, and may subsequently compromise efficiency and safety. It is thus imperative to develop suitable coping measures to enable individuals to deal with the additional stresses of these unnatural work hours.

CHAPTER III

METHODOLOGY

INTRODUCTION

Night work has been recognised as being a multifaceted problem in need of a multifaceted solution. The present study thus employed an holistic approach to the analysis of a simulated working environment in order to acknowledge the network of factors which collectively affect performance capabilities when working at night. Performance efficiency was examined according to Borg's (1973) three "effort continua" thereby providing tangible assessments of the physiological, perceptual and performance-related responses made during the midday and midnight testing conditions.

SUBJECT CHARACTERISTICS

The research sample was confined to postgraduate students between the ages of 22 and 30 years. This subject pool comprised 36 volunteers and included equal numbers of males and females. The subjects were randomly divided into two groups, namely the cognitive tasks (CT) group and the cognitive and motor tasks (CMT) group. Subjects in the CT group performed the psycho-motor tests only, while the CMT subjects completed a two minute bout of cycling prior to each psycho-motor test.

SUBJECT SELECTION

A letter containing general information with regards to the proposed study, and requesting volunteers, was distributed to various academic departments at Rhodes University (A copy of this letter is included in Appendix A). All interested individuals were requested to fill in their name and contact details in the table provided.

These potential subjects were then individually contacted and invited to attend a demonstration of the Vienna Test System (VTS) prior to formally consenting to participate in this research project.

INFORMED CONSENT

All volunteers were provided with an informed consent information sheet which detailed the aims of the study and what would be required of them as subjects (A copy of this letter is included in Appendix A). Prior to participation in the two test periods, each subject was presented with a detailed verbal explanation of the procedures and instrumentation to be utilised during data collection. A demonstration of the requirements of the three selected psycho-motor tasks using the VTS was also included, together with the opportunity to practise these tasks. Thereafter the subjects were required to complete a written consent form, thereby acknowledging their willingness to participate in the study (See Appendix A).

PILOT TESTING

Two male and two female student volunteers were involved in the pilot test. This test was conducted in order to determine the validity and utility of the instrumentation and psycho-motor test battery to be employed during data collection. It further facilitated the standardisation of experimental procedures and allowed the researcher to become familiar with the test protocol and to establish comprehensible verbal instructions for each test. Potential problem areas were identified, such as the need to request subjects to refrain from pressing any buttons on the VTS until asked to do so; failure to do this could result in an unnecessary interruption of the test battery and thus interfere with the standardised test protocol. The desired amount of artificial (fluorescent) lighting was also determined during the pilot study. No natural lighting was used in order to standardise environmental conditions.

PHYSIOLOGICAL PARAMETER

Heart Rate

Heart rate is a frequently used physiological measure of an individual's response to varying stressful demands. Although the heart is known to beat approximately 70 times per minute during complete rest, this inherent rhythm is influenced dramatically by extrinsic stressors, including environmental, performance-related and psychological factors (Ganong, 1991; McArdle *et al.*, 1991). Heart rate measurements were thus included in the present study to determine whether time of day or intergroup differences occurred during performance of the psycho-motor tasks.

The Polar Sport Tester Heart Rate Monitor was used to record heart rate during the two test sessions. This comprises a wrist monitor which receives and stores signals sent telemetrically from a transmitter which is in turn attached to the subject's chest by means of an elastic belt. These heart rate data can later be accessed for analysis and subsequent correlation with perceptual and performance measurements.

The Transmitter and Elastic Belt

The Polar transmitter should be centred on the individual's chest below the inferior border of the pectoralis major muscle group. This transmitter is in turn attached to an elastic belt which may be adjusted such that it fits comfortably around the chest region. One must ensure that good contact is made between the transmitter and the skin; the conductive electrode strips may be moistened with water or an electro-conducting gel to improve contact.

The Wrist Monitor

The Polar heart rate monitor consists of an LED display screen together with a **SET/START-STOP** button, a **STORE/RECALL** button, a **SELECT▲** button and a **SIGNAL▼** button. The monitor may be worn on the wrist or held within 90-110 cm of the subject so as to remain within the range of the transmitter. During the present study however, the monitor was positioned on a chair next to, or behind, the subject such that it could not be seen by the subject when operating the control panels of the Vienna Test System (VTS). Subjects would in turn not be influenced in any way by feedback on their cardiovascular responses. The heart rate monitor was further placed away from the VTS in an effort to eliminate possible disturbance by electrical activity emanating from the computerised apparatus.

Programming the Polar Sport Tester Heart Rate Monitor

Prior to commencing data collection, the heart rate monitor had to be programmed with regards to setting the heart rate limits which were required during the two minute cycling bouts, as well as selecting the time interval at which heart rate would be recorded.

With time of day appearing on the display screen, the **SELECT▲** button was pressed once. The **SET/START-STOP** button was then pressed twice to select the upper heart rate limit function. At this stage, the desired highest heart rate of 125 b/min was set by using the **SIGNAL▼** button which lowered the default value in decrements of five. This limit was stored by pressing the **STORE/RECALL** button. Thereafter the lower heart rate limit of 115 b/min was set by using **SELECT▲** which raised the default value in increments of five. This heart rate value was also stored via pressing **STORE/RECALL**.

After setting the required limits, the **SELECT▲** button was pressed, followed by the **SET/START-STOP** button in order to access the recording interval function. Here, intervals of 5, 15 or 60 seconds are available: the 15 second interval was utilised during this study and was selected by using **SELECT▲**. The **STORE/RECALL** button was again pressed to store the chosen value.

Once the limits and recording interval had been set, the stopwatch function appeared on the display screen. Data collection was initiated by pressing **SET/START-STOP** once. The **STORE/RECALL** button was used during the collection period to record the beginning and end of each psycho-motor test. Data collection was eventually terminated by pressing the **SET/START-STOP** button.

It should also be noted that during the cycling bouts performed by the cognitive and motor tasks (CMT) subjects, a heart rate "beep" was used to indicate whenever the subject's heart rate rose above or fell below the preset limits of 125 and 115 b/min, respectively. This served to assist the individual to maintain the required moderate power output. The heart rate "beep" was turned on at the start of the two minute period by pressing the **SIGNAL▾** button. This button was pressed again at the end of the cycling period in order to switch off the "beep".

Data Retrieval

Once data collection was completed, the data stored within the wrist monitor were retrieved by downloading into a computer. The Polar Heart Rate Analysis Software was selected from the main menu and memory transfer was engaged once the monitor was correctly plugged into the Polar interface unit. Thereafter the data were displayed by means of a heart rate curve, a copy of which was subsequently printed out (An example of these printouts is included in Appendix C). The average heart rates during each psycho-motor test were also calculated using the Polar Heart Rate Analysis Software.

PERCEPTUAL PARAMETER

Perceived Strain Scale

Scott's (1994) Perceived Strain Scale (PSS) was used to obtain perceptual ratings of the stress imposed and strain experienced by the subject whilst performing the various psycho-motor tests.

The PSS consists of four 10-point rating scales anchored with descriptive verbal expressions (See Appendix B). The use and objectives of this scale were explained to each subject prior to participation in the two test periods. Subjects were requested to be as honest and spontaneous in their ratings as possible.

Instructions for Use

Subjects were required to objectively rate the present task demands (*td*) with respect to difficulty (*simple-difficult*) and complexity (*basic-complex*). Following this, the subjects were requested to give personal ratings of how taxing (*effortless-taxing*) and demanding (*undemanding-demanding*) they perceived the task would be. The appropriate scores were then recorded by the experimenter and were later substituted into two simple equations to calculate an Evaluation of Perceived Strain (EPS) and an Evaluation of Task Demands (ETD):

$$\text{EPS} = \left[\frac{(td_1 + td_2)}{2}\right] \div \left[\frac{(pac_1 + pac_2)}{2}\right]$$

where:	EPS	=	Evaluation of Perceived Strain (the ratio being expressed as a numerical representation from 0.1 through 1 and to 10)
	td_1	=	1st rating of task demands
	td_2	=	2nd rating of task demands
	pac_1	=	1st rating of perceived ability to cope
	pac_2	=	2nd rating of perceived ability to cope.

$$\text{ETD} = \frac{[\,\overline{td} + \Sigma pac\,]}{3}$$

where:	ETD	=	Evaluation of Task Demands (represented numerically 1.0-10.0)
	$\overline{td}$	=	the mean of *td* ratings ie. $\frac{1}{2}(td_1 + td_2)$
	Σpac	=	the sum of *pac* ratings ie. $(pac_1 + pac_2)$

(Scott, 1994)

PSS ratings were taken following the instruction and practice phases of each psycho-motor test, immediately prior to starting the test phase. Subjects were also reminded of the length of each test as it was recognised during the pilot study that test duration had a strong influence in determining the rating scores.

PERFORMANCE PARAMETER

Vienna Test System

The Vienna Test System (VTS) is a universal psychodiagnostic testing device which can be used to administer a variety of standardised psycho-motor tests. The VTS offers an objective measurement of an individual's performance with an emphasis placed on the speed and accuracy with which the tests are completed. Results are automatically scored and may be saved to a database from which they can be retrieved for further processing and manipulation.

The particular Test System used in this study was the Vienna Test System PC/S. This system consists of a standard personal computer complete with a keyboard and a VGA screen for the visual presentation of the test programmes, as well as the Peripheral Interface PC/S which supports the operation of several peripheral units. These include the testee's panel which was used during the test of Concentration Under Monotonous Conditions and the Work Performance Series test, together with the Vienna Determination Unit which was used during the test of Reactive Stress Tolerance.

Instructions For Use

Six test batteries were compiled using three specific psycho-motor tests selected for the present project. The single tests making up each test battery were presented consecutively and thus facilitated a smooth-running and standardised test protocol. These test batteries were randomly assigned to the subjects during the test sessions. Once a test battery was selected from the main menu, the testee data were entered and the first test programme was started.

The test programmes offer defined instruction and practice phases which are designed to ensure testee understanding of the task requirements. Detailed instructions for each of the three psycho-motor tests are included in Appendix B. The next stage is the test phase which continues automatically until the end of the test after which the results are immediately saved to a diskette. These results may then be accessed via the data management function and a printout can be obtained.

Test of Concentration Under Monotonous Conditions (Q11)

The Q11 test examines an individual's ability to maintain attentiveness under monotonous conditions over a seven minute period. This study made use of the Standard 1 (S1) test version. Here, four model figures, which are simple-structured and very similar, are displayed throughout the test on the upper row display of the screen. Another single figure is presented in the lower row display. This configuration is illustrated in Figure 1. The testee is required to indicate whether this lower figure is the same as, or different to, the four constant figures. This is achieved by pressing either the red ("same as") or the green ("different to") key on the testee panel. The lower figure changes in a pseudo-random sequence as soon as the testee has indicated his/her choice. The Q11 test is thus self-paced, however the subject is requested to work as quickly and as accurately as possible (Maree, 1994).

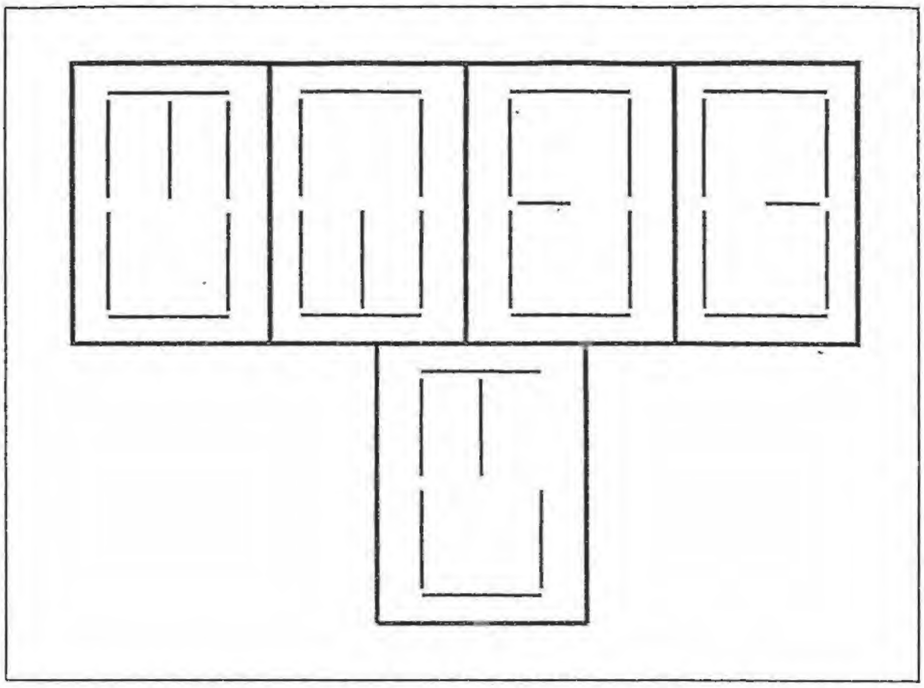


Figure 1: The Q11 test screen with four model figures on the upper row display and a single figure on the lower row display.

Work Performance Series Test (WPS)

The Work Performance Test (WPS) may be described as a "mental agility" task where the subject is required to perform continuous addition tasks, as well as memorise information in between calculations. This test assesses an individual's ability to sustain concentration whilst completing as many calculations as accurately as possible within ten minutes (Schuhfried, 1994).

The Standard 2 (S2) test version was used in this study. In this version the subject is required to add two single-digit numbers, displayed one on top of the other, and then to type in their sum using the keypad of the testee's panel. Prior to entering the solution however, the subject must memorise the bottom number on the screen. The following screen will contain a new number at the bottom while the top number of the calculation will be blank. The subject must work out the solution by adding the recently memorised number to the new bottom number. This new bottom number must be now be memorised before entering the solution; this process is repeated for the duration of the test. (Figure 2 shows the apparatus used during this test, together with an example of the test screen).

The technique suggested during the instruction phase of this test is summarised as follows:

(1) Memorise the bottom number.

(2) Enter the solution of the two numbers.

(3) A new number will appear at the bottom.

(4) Work out the new solution.

(5) Memorise the bottom number before entering the new solution.

There is one further aspect of the test to be remembered by the subjects: should the solution be greater than 9, only the units number should be entered on the keypad.

For example: 3 + 4 = 7 ... Enter: 7

5 + 8 = 13 ... Enter: 3

The WPS test is also a self-paced test, however the subjects were again requested to work as fast and as accurately as possible.

Test of Reactive Stress Tolerance (RST3)

The RST3 test is administered on the peripheral Vienna Determination Unit (VDU). This is a multiple stimulus reaction unit which measures response time and accuracy under varying levels of stress (Schuhfried, 1994).

The VDU is a work panel which is inclined towards the testee. The upper part of the panel is fitted with two parallel rows of five lamps which are coloured white, yellow, red, green and blue. Five buttons corresponding to these colours are found in the lower part of the panel. Two white lamps in the middle of the unit correspond to a left and right foot pedal. There are also two square keys arranged to the left and right of the central white lamps. These correspond to a high and low pitched signal, respectively. The VDU work panel and foot pedals are displayed in Figure 3.

The Standard 1 (S1) test version was selected for this research project and takes approximately 12 minutes to complete. The subject is required to respond to a range of visual and acoustic stimuli by pressing a corresponding button or foot pedal. These stimuli are presented in a pseudo-random sequence during three phases each consisting of 180 signals. The first phase is a slow, low stress training period where 38 signals are presented per minute. This is followed by a fast, high stress phase where 63 signals per minute are presented. The third phase occurs at a medium speed of 56 signals per minute and constitutes a recovery period (RST3, 1992).

Figure 2: The apparatus used during the WPS test: the monitor (with example test screen displayed), and testee panel.

Figure 3: The apparatus used in the RST3 test: the Vienna Determination Unit work panel and foot pedals.

Unlike the Q11 and WPS tests, the RST3 test is machine-paced as the stimuli are presented for a fixed time regardless of whether the subject reacts to them or not. There are short intervals between the three test phases which allow for brief instructions to be given to the subject referring to the requirements of the next phase (RST3, 1992).

TEST PROTOCOL

Data collection was divided into three phases. During the first phase, the test protocol was described to the subjects. This included a demonstration of the three psycho-motor tasks, the opportunity to practice each of these tasks, as well as an explanation of the aims and use of the Perceived Strain Scale (PSS) and Polar heart rate monitor. Thereafter all subjects were required to sign a written consent form, yet were reminded that they could withdraw from the study at any time. Basic demographic data were also obtained, including date of birth, morningness-eveningness tendencies, work time preferences and present level of physical involvement.

The two test phases were conducted in a random order, at approximately two week intervals in an effort to minimise learning. These test sessions took place at standardised times, namely between 11:15 and 12:45am (midday) and between 11:15 and 12:45pm (midnight). Each session lasted approximately 45 minutes, although this was slightly shorter in the cognitive tasks only subjects as they were not required to participate in the diverse task of cycling. The test environment was standardised with respect to lighting and noise: the same amount of artificial lighting was used during the midday and midnight sessions while curtains were utilised to exclude natural lighting. Only the subject and experimenter were present in the laboratory during data collection. It was considered necessary to standardise these environmental conditions as several researchers, including Glenville and Wilkinson (1979) and Monk and Folkard (1985b), believe there to be great differences in the work environment between day and night shifts thus creating problems in trying to determine intershift differences in performance.

Subjects were also required to adjust their sleep/wake cycles for two days prior to participation in the two test periods in an attempt to simulate shiftwork conditions (A copy of these instructions is included in Appendix B). A further request was to abstain from consumption of food, caffeine, alcohol and other stimulants for 4-5 hours before each test session.

Before the subject arrived for testing, the computer was prepared for data collection so as to minimise distractions. A test battery was randomly selected from the main menu. Testee data together with test details were then entered. At this point the instruction phase of the first psycho-motor test was presented on the screen. The **ESC** key was pressed to pause the programme.

Once the subject arrived, the Polar electrode belt with attached transmitter was adjusted to fit comfortably around his/her chest region. The wrist monitor was held within one metre of the subject by the experimenter who then checked whether the monitor was registering the subject's heart rate. Should the heart rate not have appeared on the screen, a small amount of electro-conducting gel or water was placed behind the electrodes to enhance contact with the skin. Prior to commencement of testing, the subject's heart rate was monitored and a "reference" value was recorded.

It was critical to standardise the instructions given to each subject as these could possibly have influenced perceptual ratings and effort. A detailed summary of the verbal instructions given is included in Appendix B. The subject was reminded that they would be performing three tests on the Vienna Test System. Each subject was also given a brief outline of the sequence of the data collection period. Subjects in the cognitive tasks (CT) group entered immediately into the instruction phase of the first test, followed by a short practice phase, then completion of the PSS scale before starting the actual test. However, the cognitive and motor tasks (CMT) subjects participated in a two minute bout of cycling before the instruction phase of each test.

A cycle ergometer was placed directly next to the test area. Once the height of the ergometer had been adjusted, the subject was asked to start pedalling. At this time the **SET/START-STOP** button on the heart rate monitor was pressed to begin storage of heart rate data at 15 second intervals. The CMT subjects were required to maintain their heart rate within the preset limits of 115 and 125 beats per minute, thus producing a moderate power output so as not to physically fatigue the subject. The heart rate "beep" function was turned on at the onset of cycling by pressing the **SIGNAL▾** button. This sound would occur whenever the heart rate did not fall within the limits. The resistance dial on the cycle ergometer was adjusted in order to effect an increase or decrease in the subject's heart rate so as to reach the specified threshold. At the end of the two minute cycling period the **SIGNAL▾** button was pressed again to switch off the "beep" which would otherwise have distracted the subject.

During the *instruction phase* verbal instructions were given by the experimenter. The subject was requested not to perform any action until asked to do so. The *practice phase* presented the subject with the opportunity to become familiarised with the requirements of the task. Any mistakes made during the practice period were immediately indicated to the subject, although it was noted that no feedback would be provided during the actual test.

Following the practice phase, the PSS scale was administered. Here the subject was asked to rate their perceptions of the present task demands, as well as their perceptions of their ability to cope with these demands. Subjects were asked to be as honest in their ratings on the PSS as possible. Once these values were recorded, the *test phase* was started. Subjects were reminded that they were to work as quickly and as accurately as possible during the tests. As soon as the first test began, the **SET/START-STOP** button was pressed in the case of the CT subjects, while **STORE/RECALL** was pressed for the CMT subjects. The experimenter sat behind the testee during each psycho-motor test. Heart rate was monitored and any comments made by the subject were recorded on the data sheet (A copy of the data sheet is included in Appendix B).

At the start and end of each test the **STORE/RECALL** button was pressed, while **SET/START-STOP** was used to terminate data collection following the completion of the third psycho-motor test. The subject's results were automatically saved to a diskette after each test.

At the end of the test session the electrode belt and transmitter were removed from the subject. The subject was then thanked and asked whether they could offer any general or specific comments. They were also reminded that detailed feedback would be given on the completion of the entire data collection period (A copy of this form is provided in Appendix C).

STATISTICAL ANALYSES

The three response variables under investigation are initially presented in isolation; thereafter the data are integrated in recognition of their inter-related nature. Statistical analyses were performed using the statistical software packages of Statgraphics (Version 6.0) and Excel (Version 5.0). Due to uncertainty in the literature with regards to possible diurnal sex differences, it was decided to first perform Two-Sample analyses using the Mann-Whitney U-test to determine whether any significant differences existed between the male and female results. Analyses were undertaken using data derived from the mental arithmetic (WPS) test and corresponding physiological and perceptual data as the majority of the subjects identified this task to be the most difficult. A subsequent lack of significant differences enabled the pooling of male and female data.

Thereafter, various descriptive measures, including means, standard deviations and co-efficients of variation, were calculated. These measures were used to compare midday and midnight results for the entire sample (N=36), as well as between the cognitive tasks (CT) group (N=18) and the cognitive and motor tasks (CMT) group (N=18). These results were later converted into an appropriate graphical form.

It should be noted that several heart rate values were lost during data collection following interference in signal transmission by the computerised Vienna Test System. These missing data points were completed by inserting the mean yield of the values that were present (Snedecor and Cochran, 1980). The completed data set was then used during statistical analyses.

One-way Analyses of Variance were performed to establish whether significant differences ($p < 0.05$) occurred between the midday and midnight results and the CT and CMT groups. Non-parametric (Kruskal-Wallis) statistical tests were used as the assumptions of homogeneity and normality could not be met, as well as to accommodate the small sample sizes.

CHAPTER IV

RESULTS AND DISCUSSION

INTRODUCTION

Since the advent of artificial lighting, night work has become an increasingly common form of employment. Unfortunately, there appear to be numerous problems accompanying this mode of work. These problems stem primarily from biological, sleep and social disruptions. Much research has focused on the extent to which these factors may affect the worker's efficiency of performance. However, there remains a general lack of consensus with regards to the effects of night work on performance variables such as the speed and accuracy of responses. There is also an uncertainty surrounding the nature of inter-individual differences in tolerance to work at these aberrant hours.

The present study adopted an holistic approach to this multifaceted problem. Selected physiological, perceptual and performance-related factors were collected during day and night testing conditions. Physiological responses were measured in the form of heart rate, and personal ratings of the perceived strain experienced were also recorded. The Vienna Test System was used to administer three psycho-motor tests to the subjects. Efficiency of performance was determined by evaluating the speed and accuracy with which these tasks were completed.

The results obtained will initially be presented and discussed separately. A general discussion will then attempt to integrate the variables under investigation and so doing facilitate a better understanding of how individual behaviour may be affected by time of day.

The following key will be used throughout the Results and Discussion:

Subject Groups:

ALL	: all subjects (N=36)
CT	: cognitive tasks subject group (N=18)
CMT	: cognitive and motor tasks subject group (N=18)
AM-ALL	: midday results for all subjects (N=36)
PM-ALL	: midnight results for all subjects (N=36)
AM-CT	: midday results for cognitive tasks group (N=18)
AM-CMT	: midday results for cognitive and motor tasks group (N=18)
PM-CT	: midnight results for cognitive tasks group (N=18)
PM-CMT	: midnight results for cognitive and motor tasks group (N=18)

Response Variables:

REFHR	: reference heart rate
HR-	: average heart rate
MAX-	: maximum heart rate
ETD-	: estimated task demand rating
EPS-	: estimated perceived strain rating
TN-	: total number of responses
C-	: number of correct responses
IT-	: number of timely responses
D-	: number of delayed responses
O-	: number of omitted responses

Test Variables:

-Q	: Q11 test
-W	: WPS test
-R	: RST3 test
-S	: slow phase of RST3 test
-M	: medium phase of RST3 test
-F	: fast phase of RST3 test

Note: With reference to the bar graphs, midday results are indicated with striped bars, while midnight results are represented by means of solid bars.

SUBJECT CHARACTERISTICS

The research sample consisted of 36 postgraduate students. These volunteers were randomly allocated to the two subject groups, namely the cognitive tasks (CT) group, and the cognitive and motor tasks (CMT) group. Each subject group comprised equal numbers of males and females. It is necessary to note that the male and female results were combined only after no significant differences were indicated by non-parametric statistical analyses.

The mean age of the subjects was 22 years, while the average involvement in some form of moderate-to-vigorous physical activity was three times per week.

During the introductory session, all subjects were requested to complete a short information sheet (A copy of this sheet is included in Appendix B). These responses are summarised in Table I. The first question enquired whether the subjects considered themselves to be a "morning" person, or an "evening" person. Seventeen individuals indicated that they were morning-types, while 19 subjects considered themselves to be evening-types. As earlier mentioned, it is common for students to develop a nocturnal lifestyle as a result of the work demands placed on them. Thus, a morning-type individual could temporarily acquire evening-type characteristics, yet may later revert back to their morningness tendency. It would therefore seem possible that several of those individuals who regarded themselves as evening-types may previously have displayed morningness characteristics.

TABLE I: Summary of responses given on the Subject Information Sheet.

VARIABLE		ALL	CT	CMT
MORNING-TYPES		17	9	8
EVENING-TYPES		19	9	10
PREFERRED WORK TIME:	MORNING	18	10	8
	AFTERNOON	6	2	4
	NIGHT	12	6	6
ACTUAL WORK TIME:	MORNING	14	9	5
	AFTERNOON	8	2	6
	NIGHT	14	7	7

The subjects were also asked to indicate their preferred and actual work times. With respect to preferred work time, the morning proved to be the most popular work time, while the afternoon was the least preferred work period. In terms of actual work times, however, similar numbers of subjects worked predominantly during the morning and night. These preferred and actual work times were largely determined by morning lecture schedules, afternoon sporting involvement and social or work-related activities at night.

Finally, the subjects were requested to describe any measures they employed in order to remain alert while working. A summary of these coping strategies is illustrated in Figure 4. The majority of subjects indicated that they simply "took a break" from the task they were doing. This break involved engaging in something completely different such as watching television or listening to music. These activities may be considered as forms of "task diversification". Physical activity was as popular a means of maintaining, or regaining alertness as was the consumption of caffeinated beverages, including coffee and tea. Short naps were also used by a few of the subjects.

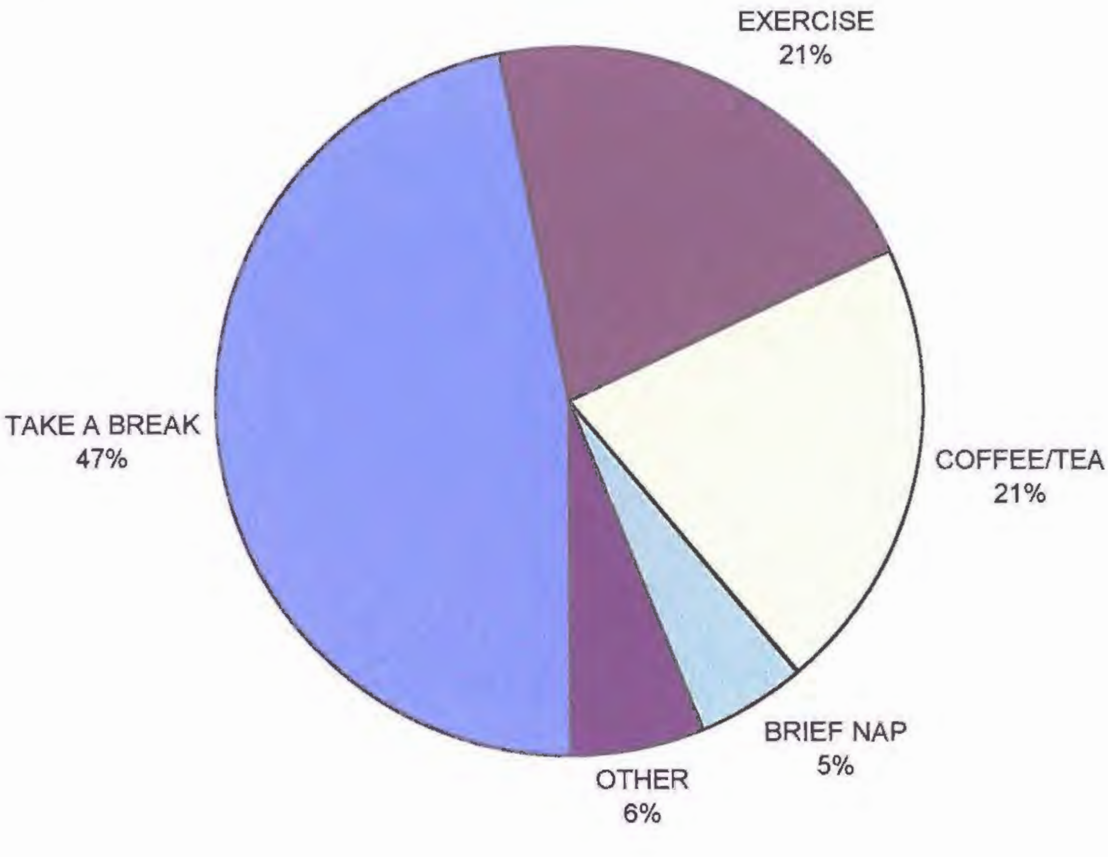


Figure 4: Summary of the various coping strategies generally used by the subjects to remain alert while working.

PHYSIOLOGICAL RESPONSES

Heart Rate

A Polar Sport Tester Heart Rate Monitor was employed to record heart rate at 15 second intervals throughout the test sessions. These data were used to identify possible differences in heart rate between the two subject groups and to determine whether heart rate fluctuated as a function of time of day.

A "reference" or resting heart rate was recorded prior to data collection. This served as a baseline value from which subsequent changes in heart rate could be recognised. A mean resting heart rate of 62 ($\pm$10) b/min was calculated for the group as a whole. This value falls below the "normal" average resting heart rate of 70 b/min (Ganong, 1991). However, this would be expected of the healthy young adults who participated in this study as the majority engaged regularly in some form of strenuous physical activity, thus resulting in a lowering of resting heart rate. This is referred to as "training bradycardia" (Åstrand and Rodahl, 1986).

The "mean" and "maximum" heart rate values recorded during performance of the three psycho-motor tests at midday and midnight are displayed in Tables II-IV. Maximum values are indicative of the highest heart rates elicited by the subjects during a particular test. One-Way Analyses of Variance using non-parametric statistical tests were performed to establish whether significant differences occurred across the midday and midnight results, and across the CT and CMT groups. A significance level of $\alpha < 0.05$ was selected.

TABLE II: Average and maximum heart rates recorded during the Q11 test.
(Standard deviation is given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
HRQ: $\bar{X}$ (b/min)	74.5 [13.5]	72.4 [10.4]	66.9 [11.4]	82.1 [11.3]	67.4 [8.7]	77.3 [9.8]
CV (%)	18.2	14.4	17	13.7	12.9	12.7
MAXQ: $\bar{X}$ (b/min)	83.6 [14.9]	80.5 [11.6]	76.1 [13]	91 [13]	74.9 [9.2]	86.1 [11.3]
CV (%)	17.8	14.5	17.1	14.3	12.3	13.2

Note: bar denotes a statistically significant difference ($p<0.05$)

Table II presents the heart rate data from the test of Concentration Under Monotonous Conditions (Q11). Although both the average midnight Q11 heart rate of 72.4 b/min and the maximum value of 80.5 b/min fell nominally below the midday recorded values of 74.5 and 83.6 b/min respectively, a lack of significant differences in "working" heart rate was found with respect to time of day. On the other hand, significant differences were evident across the CT and CMT groups during both the midday and midnight Q11 tests. The only exception was with respect to the maximum heart rates between the midday CT group and the midnight CMT group where there was no significant difference. Substantially higher heart rates were recorded in the CMT subjects with the highest overall mean (82.1 b/min) and maximum (91 b/min) heart rates found during the midday tests.

TABLE III: Average and maximum heart rates recorded during the WPS test. (Standard deviation is given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
HRW: $\bar{X}$	77.8	75.6	71.4	84.1	70.8	80.4
(b/min)	[13]	[10.8]	[11.2]	[11.7]	[9.9]	[9.7]
CV (%)	16.7	14.3	15.6	13.9	14	12.1
MAXW: $\bar{X}$	87.1	85.1	80	94.2	79.3	90.78
(b/min)	[14.8]	[13]	[12.5]	[13.6]	[10.3]	[13.25]
CV (%)	17	15.3	15.7	14.5	12.9	14.6

Note: bar denotes a significant difference ($p<0.05$)

The heart rates elicited during the Work Performance Series (WPS) test are displayed in Table III. Once again nominally lower average (75.6 b/min) and maximum (85.1 b/min) heart rates were recorded during the midnight tests when compared to the mean midday heart rate of 77.8 b/min, and the maximum value of 87.1 b/min. Statistical analysis of these data indicated no significant difference. However, differences between the CT and CMT subject groups were found to be significant across the two test sessions, with the exception of that between the midday heart rates of the CT group and the midnight data of the CMT group. The highest overall average and mean heart rates obtained during the WPS test also occurred within the midday test session of the CMT group. These values were 84.1 b/min and 94.2 b/min respectively.

Table IV is divided into three separate components corresponding to the three phases[1] of the Reactive Stress Tolerance (RST3) test. Heart rate responses recorded during the slow phase of this test are displayed in Table IV(A). No apparent time of day differences are observed when comparing the average and highest heart rates during the midday and midnight test periods. Here, the group mean at midday was 78.6 b/min, while the mean at midnight was 78.9 b/min. The highest heart rate recorded at both times of day was 85 b/min.

Significant differences were found to exist between the two subject groups across the midday and midnight test sessions. Again it should be noted that the highest average (86.2 b/min) and maximum (93.1 b/min) heart rates were elicited by the CMT subjects at midday.

---

1 The order of the RST3 test phases is slow, fast and then medium speeds. However, the results will be presented with the slow phase first, the medium phase second and lastly the fast phase.

TABLE IV: Average and maximum heart rates recorded during the slow (A), medium (B) and fast (C) phases of the RST3 test.
(Standard deviations are given in square brackets)

A

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
HRS: $\bar{X}$ (b/min)	78.6 [12.6]	78.9 [12.9]	71.1 [10.3]	86.2 [10]	73.3 [10.4]	84.4 [13.1]
CV (%)	16	16.4	14.4	11.6	14.2	15.5
MAXS: $\bar{X}$ (b/min)	85 [13.5]	85 [14.3]	76.9 [10.3]	93.1 [11.4]	78.8 [10.7]	91.1 [15]
CV (%)	15.9	16.8	13.4	12.2	13.6	16.5

B

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
HRM: $\bar{X}$ (b/min)	80.4 [12]	79.4 [11.1]	73.9 [9.9]	86.9 [10.4]	75.3 [10.3]	83.4 [10.6]
CV (%)	14.9	13.9	13.4	12	13.7	12.6
MAXM: $\bar{X}$ (b/min)	87.1 [12.1]	85.9 [10.9]	81.2 [9.8]	93.1 [11.5]	81.5 [9.8]	90.3 [10.4]
CV (%)	13.9	12.7	12.1	12.3	12	11.5

C

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
HRF: $\bar{X}$ (b/min)	83.1 [12.8]	82.6 [11.8]	75.3 [9.3]	90.9 [11.1]	77.5 [9.2]	87.6 [12.2]
CV (%)	15.4	14.3	12.3	12.2	11.8	13.9
MAXF: $\bar{X}$ (b/min)	90.4 [13.8]	88.9 [12.6]	82.4 [10.5]	98.3 [12.3]	83.4 [8.3]	94.3 [13.9]
CV (%)	15.3	14.1	12.7	12.5	10	14.7

Note: bar denotes a significant difference ($p < 0.05$)

Table IV(B) shows the heart rates measured during the medium speed phase of the RST3 test. The mean heart rate for all subjects at midday was 80.4 b/min, while the average at midnight was below this value at 79.4 b/min. The maximum midnight heart rate of 85.9 b/min was also lower than that recorded during the midday tests, namely 87.1 b/min. Although these variations were not significantly different, those differences between the CT and CMT subjects were again found to be significant, except for the differences in the mean and maximum heart rate responses between the CT and CMT subjects at midnight. The highest heart rates recorded during this medium speed phase were those of the CMT subjects at midday. The average heart rate value of these individuals was 86.9 b/min, and the maximum value was 93.1 b/min.

Finally, Table IV(C) contains the heart rate data recorded during the fast phase of the Reactive Stress Tolerance test. While both the average (83.1 b/min) and maximum (90.4 b/min) values for the subjects during the midday test session were nominally above those obtained at midnight (82.6 b/min and 88.9 b/min respectively), these time of day differences were not significant. Once again, significant differences were apparent between the CT and CMT subjects during both test times, and the most elevated mean (90.9 b/min) and maximum (98.3 b/min) heart rate responses were observed in the CMT group at midday.

Although non-parametric analyses of the heart rate data indicated a lack of significant differences with respect to time of day, a general trend was evident in the three psycho-motor tests, where mean and maximum values were nominally lower during the night testing sessions. These lower heart rates may be related to the "damping" or "shutting down" of many body functions at night (Grandjean, 1986; Monk *et al.*, 1996) which corresponds with a circadian trough in physiological activation (Åkerstedt *et al.*, 1984) and the relaxed, sleepy portion of the circadian sleep tendency cycle (Walsh, 1990; Reilly *et al.*, 1997a).

An overall examination of differences in heart rate responses between the CT and CMT groups revealed a tendency for the cognitive and motor tasks subjects to elicit higher values. These elevations would seem to be a direct result of participation in the cycling activity. Although the instruction and practice phases offered a "relaxed" environment in terms of physical exertion required, they did not appear to be long enough to allow the subject's heart rate to return to "resting" levels.

Figure 5 graphically depicts the general trend in heart rate data throughout the various psycho-motor tests. Here, one can observe a similar pattern in all subject groups. The lowest values were recorded during the monotonous Q11 test, where little cognitive or motor involvement was required, while heart rate increased in the mentally demanding WPS test. It should be noted that the Work Performance Series test is an example of an "active coping task" which tends to be associated with increased heart rate responses due to the high levels of attentiveness required for efficient performance (Carroll *et al.*, 1987; Johnston *et al.*, 1990). Further elevations in heart rate are apparent within each of the three phases of the physically and mentally demanding RST3 test: the slow phase is associated with lower heart rate values than the medium speed phase which in turn elicited lower values than the fast, high stress phase.

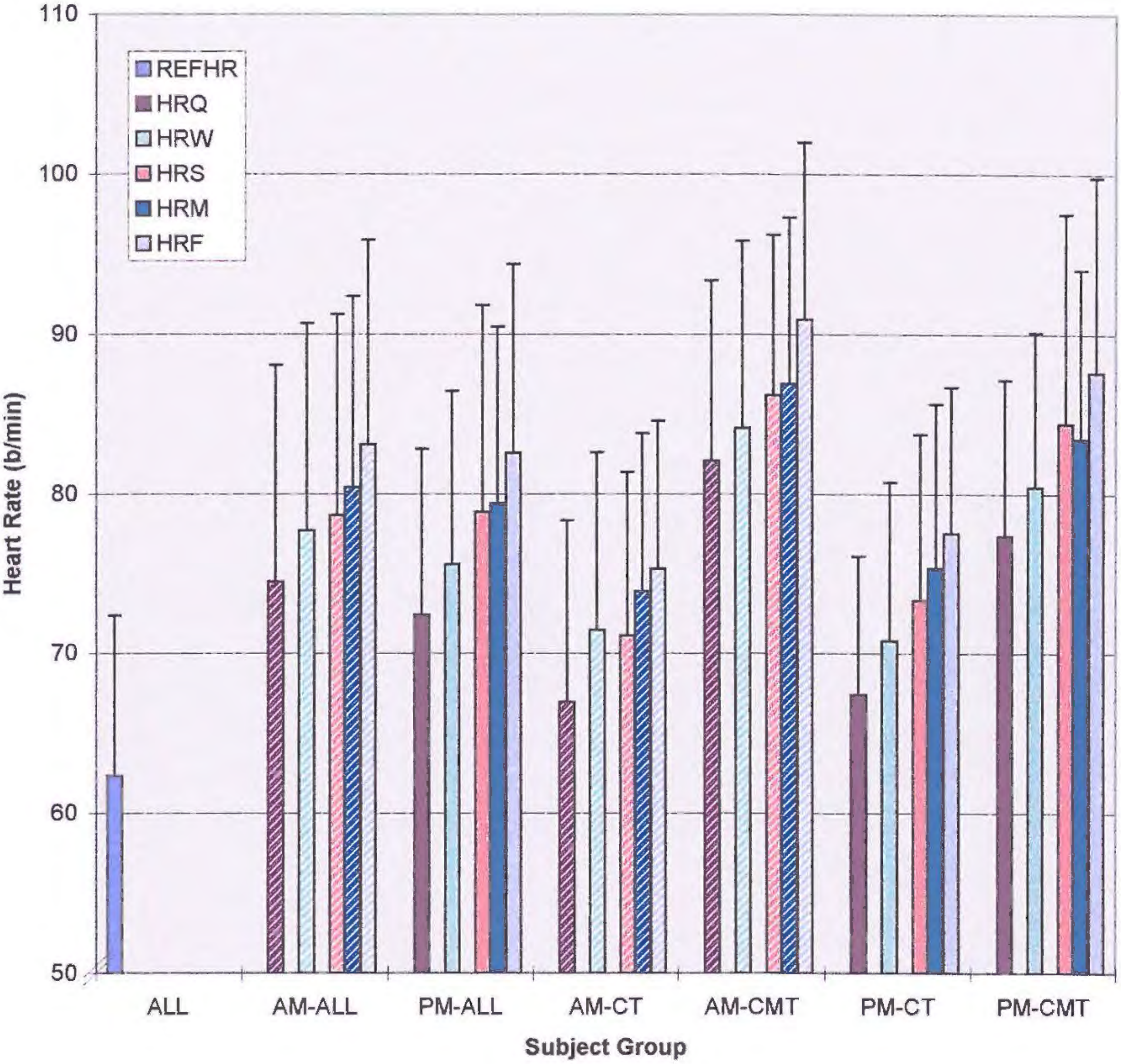


Figure 5: Average heart rates recorded during the Q11 and WPS tests, and the slow, medium and fast phases of the RST3 test.

All measures of heart rate, regardless of time of day, were found to be substantially elevated above the initial group "reference" value. These elevations, together with differences in heart rate between the psycho-motor tests, are in part indicative of the "additional heart rates" proposed by Strømme *et al.* (1978) and may also be attributed to the varying levels of cognitive and motor involvement required during the psycho-motor tests. However, anxiety induced by the test environment may also have played a role in elevating the subject's heart rates. According to McArdle *et al.* (1991) an individual's mere anticipation of an approaching event may elicit higher heart rates.

The large standard deviations and co-efficients of variation (as much as 18%) are evidence of the considerable individual differences in working heart rate responses, plus the varying degrees of test-related anxiety experienced. It is possible that a larger sample size may have smoothed out the inter-subject variability and thereby given rise to more substantial midday/midnight differences.

(An example of individual heart rate data is presented in Appendix C).

PERCEPTUAL RESPONSES

Perceived Strain Scale

Scott's (1994) Perceived Strain Scale (PSS) was included in this study in order to assess intra- and inter-individual differences with regards to the amount of strain experienced during performance of the various psycho-motor tests. The first part of the scale requires the individual to objectively rate the demands of the forthcoming task. Thereafter the individual is asked to rate their perceived ability to cope with these demands. Using these ratings, an overall Evaluation of the Task Demands (ETD) can be determined together with an Evaluation of the individual's Perceived level of Strain (EPS) while performing that task. ETD scores are represented numerically from 1.0 to 10.0; scores closer to 10.0 indicate that the task demands are perceived as being high. EPS scores are represented numerically from 0.1 through 1.0 and to 10.0. An EPS score less than 1.0 is an indication that strain is being experienced by the individual, the lower the score the greater the perceived strain. EPS scores above 1.0 are indicative of the individual perceiving his/her ability to cope with the task demands (Scott, 1994).

Tables V-VII present the average PSS ratings calculated for each of the three psycho-motor tests during the midday and midnight test conditions.

Table V displays similar ETD scores across the subject groups at both times of day for the Q11 test. All subjects thus considered the requirements of this test to be relatively simple and undemanding. These scores ranged between 3.35 and 3.51; both values were calculated for the CMT group, the former refers to the midday test session, while the latter score is indicative of the task demands being perceived to be higher during the night tests. Similar midday and midnight ratings (3.5 and 3.46 respectively) were made by the CT group.

TABLE V: Average Perceived Strain Scale ratings calculated for the Q11 test. (Standard deviations are given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
ETDQ: $\bar{X}$	3.43 [1.18]	3.48 [1.35]	3.5 [1.04]	3.35 [1.32]	3.46 [1.18]	3.51 [1.54]
CV (%)	34.32	38.81	29.81	39.42	34.23	43.8
EPSQ: $\bar{X}$	0.88 [0.28]	0.95 [0.49]	0.82 [0.23]	0.93 [0.31]	1.06 [0.6]	0.85 [0.35]
CV (%)	31.54	51.81	27.85	33.68	56.86	40.6

All EPS scores for the Q11 test, with the exception of the CT group at night, fell nominally below 1.0, thus suggesting that strain was experienced by the subjects. Subjective comments made by the subjects attributed this strain to the length of the test rather than the actual task requirements. The greatest difference in EPS scores occurred between the scores of the CT subjects at midday (0.82) and at midnight (1.06). Variability was also found to be highest in the CT group at midnight. This variability may have occurred due to the differing approaches taken to prolonged monitoring tasks as some individuals consider these tasks to be boring, whilst others regard them as being interesting and challenging. These differing perceptions may respectively lead to high or low levels of perceived strain.

A combined analysis of the low perceived task demands together with EPS scores close to 1.0 would appear to indicate that the majority of subjects felt fairly confident of coping with the Q11 test without experiencing undue strain.

TABLE VI: Average Perceived Strain Scale ratings calculated for the WPS test. (Standard deviations are given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
ETDW: $\bar{X}$	6.89 [1.57]	7.15 [1.49]	6.77 [1.47]	7.01 [1.7]	7.08 [1.22]	7.21 [1.75]
CV (%)	22.83	20.78	21.76	24.27	17.16	24.24
EPSW: $\bar{X}$	0.97 [0.19]	0.88 [0.2]	0.98 [0.19]	0.95 [0.2]	0.88 [0.24]	0.88 [0.16]
CV (%)	19.94	22.72	18.86	21.44	26.97	18.32

The Perceived Strain Scale ratings calculated for the WPS test are shown in Table VI. Here, the ETD scores range between 6.77 (CT group at midday) and 7.21 (CMT group at midnight). These high values are evidence of the difficulty and complexity of the task demands perceived by all subjects with regards to this test. All EPS scores fell below 1.0 and therefore indicated that a certain degree of strain was felt by the subjects. It is interesting to note that both subject groups perceived this test as being more taxing and demanding during the midnight test condition: an average EPS rating of 0.97 was recorded at midday, while a lower score of 0.88 was calculated for the midnight test period. The combination of high perceived task demands (ETD) and low perceived ability to cope (EPS) with these demands reveals that the majority of the subjects experienced strain during the WPS test.

TABLE VII: Average Perceived Strain Scale ratings calculated for the RST3 test. (Standard deviations are given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
ETDR: $\bar{X}$	5.12 [1.61]	5.5 [1.67]	5.64 [1.54]	4.61 [1.56]	5.61 [1.64]	5.38 [1.75]
CV (%)	31.52	30.45	27.22	33.96	29.19	32.49
EPSR: $\bar{X}$	0.96 [0.3]	0.93 [0.26]	0.94 [0.24]	0.98 [0.36]	0.91 [0.25]	0.95 [0.27]
CV (%)	31.59	28.06	25.87	36.63	27.7	28.94

Table VII displays the average PSS ratings calculated for the test of Reactive Stress Tolerance. The ETD scores indicate that the subjects perceived the task requirements to be moderately difficult. The lowest rating (4.61) of these task demands was given by the CMT group at midday, while the CT group recorded the highest ETD score (5.64) at the same time of day. Similar EPS scores were calculated for each subject group across both test conditions. These values ranged from 0.91 (CT subjects at midnight) to 0.98 (CMT subjects at midday).

These results thus demonstrate that while some subjects may have experienced strain, the group as a whole felt they could cope with the moderate demands of the RST3 test.

The ETD and EPS ratings for each of the three psycho-motor tests are graphically presented in Figures 6 and 7 respectively. In Figure 6, a common trend can be observed where the ETD ratings are lowest for the Q11 test and highest for the WPS test. Substantial differences in perceived task demands occur between these two tests, while there is a smaller difference between the scores calculated for the RST3 and WPS tests. It can thus be summarised that the task requirements for the Q11 test were considered to be basic while the RST3 test was found to be more complex. The high cognitive demands of the WPS test led to this being perceived as the most difficult and mentally taxing of the three psycho-motor tests. This corresponds with the general agreement amongst the subjects that the latter test was the "hardest" and most "exhausting".

No general trends emerge when examining the EPS ratings for the various psycho-motor tests as illustrated in Figure 7. With the exception of the Q11 results for the CT group, one can however, observe an overall increase in strain experienced during the midnight tests. A likely contributing factor in this respect was that a feeling of tiredness and sleepiness was expressed by many of the subjects during this night session.

It is also necessary to acknowledge the large standard deviations which are evident particularly in the Q11 test at midnight. These indicate how the same situational demands may be interpreted very differently by different people and may in turn have led to the varying levels of strain being experienced by the subjects in this study.

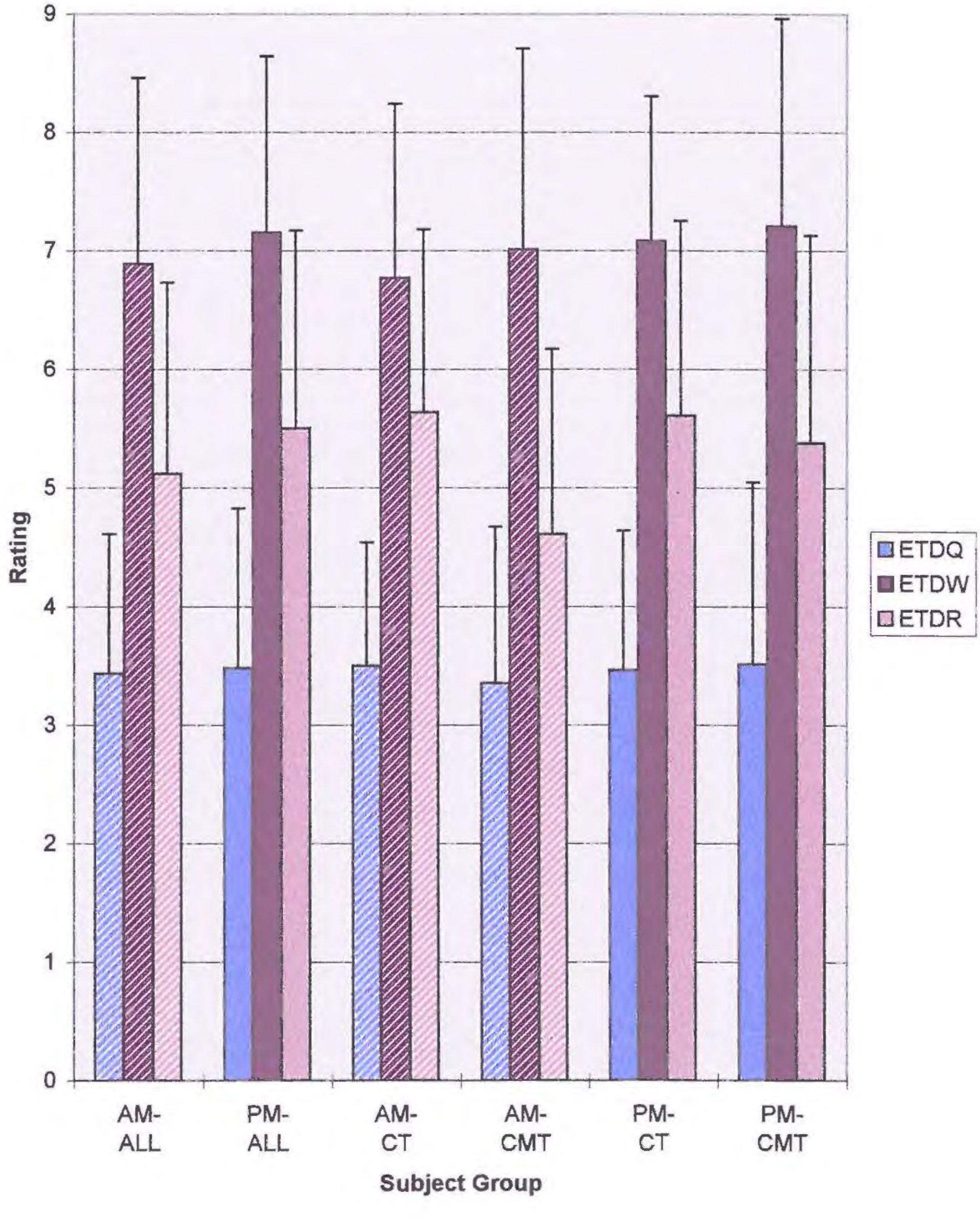


Figure 6: Average ETD scores calculated for the Q11, WPS and RST3 tests.

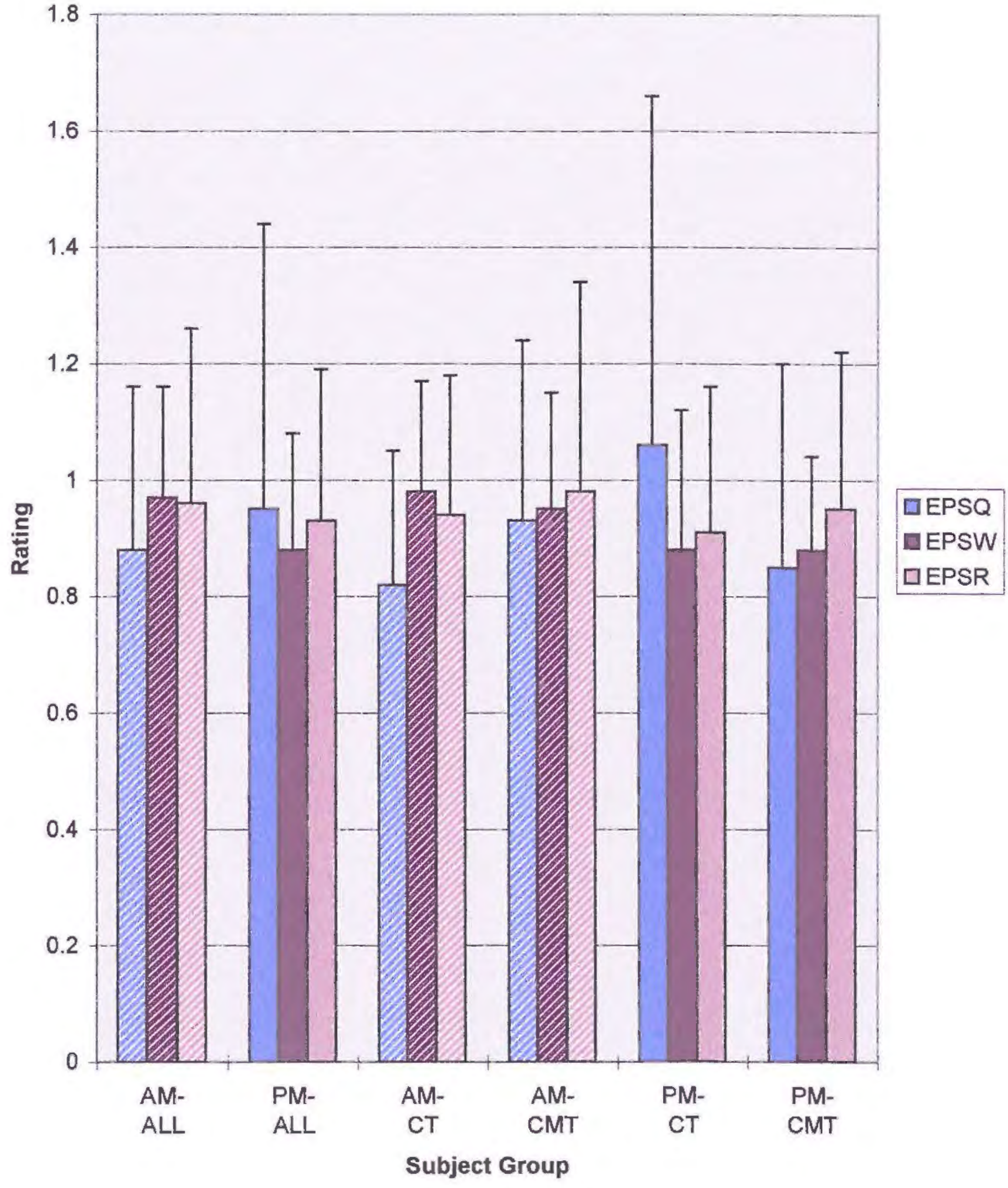


Figure 7: Average EPS scores calculated for the Q11, WPS and RST3 tests.

In summary, statistical analysis of these perceptual data revealed no significant differences between the two test conditions, or between the CT and CMT groups. However, there does appear to be a general trend in the ETD scores where midnight ratings tend to be marginally higher than those made during the midday session, while the EPS ratings demonstrate a tendency for greater strain to be experienced during the midnight tests. Thus the night tests were perceived as being more difficult and stressful for the subjects.

PERFORMANCE RESPONSES

Vienna Test System

Performance efficiency was evaluated in terms of the speed and accuracy of responses made whilst completing three psycho-motor tests. The tests were administered on a computerised apparatus known as the Vienna Test System (VTS). This system allowed for the random-order presentation of the three tests which included a test of Concentration Under Monotonous Conditions, Reactive Stress Tolerance and a Work Performance Series test. The results of each psycho-motor test are displayed in tabular and graphical form below.

Test of Concentration Under Monotonous Conditions (Q11)

The Q11 test provides a measure of an individual's attentiveness under monotonous conditions. The total number of responses made during the seven minute test, both correct and incorrect, is indicative of overall work speed, while the quality of work performance is determined by the number of correct responses.

TABLE VIII: Average total number of responses (TNQ) and correct responses (CQ) recorded during the Q11 test.
(Standard deviations are given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
TNQ: $\bar{X}$	565.1 [89]	570.2 [87.7]	567.4 [93.5]	562.8 [87]	584.1 [90.9]	556.3 [84.6]
CV (%)	15.8	15.4	16.5	15.5	15.6	15.2
CQ: $\bar{X}$	552.1 [83]	558.7 [82.3]	555 [89.1]	549.3 [79]	572.8 [87]	544.6 [77.1]
CV (%)	15.1	14.7	16.1	14.4	15.2	14.2

No significant differences were found across time of day, or between the two subject groups. Table VIII shows that the average total number of responses made by all subjects at midday, regardless of participation in exercise, was 565.1. This was marginally lower than that recorded at midnight (570.2). The corresponding number of correct responses made during the day (552.1) was also marginally lower than those made at night (558.7). These responses are graphically portrayed in Figure 8.

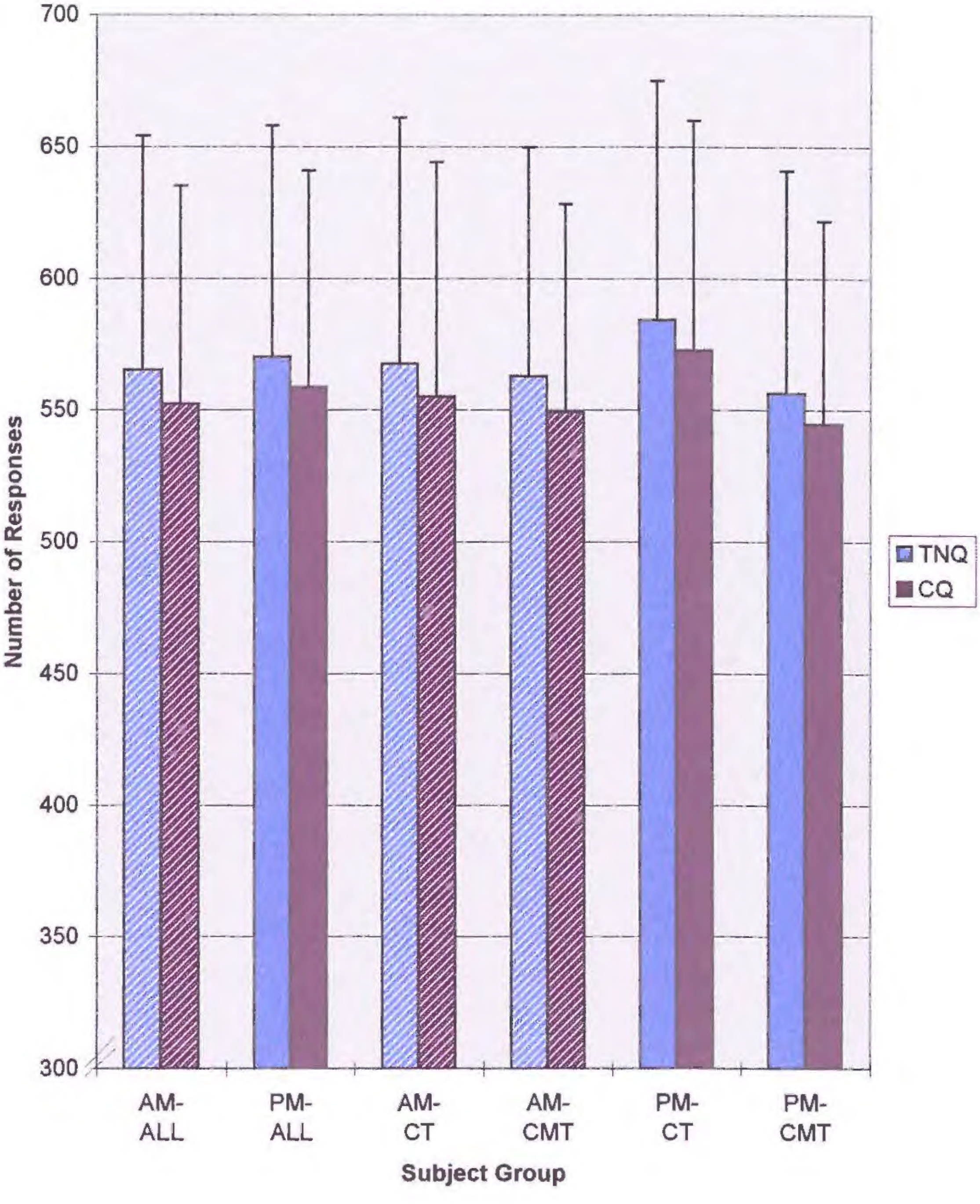


Figure 8: Average total number of responses (TNQ) and correct responses (CQ) recorded during the Q11 test.

It would thus appear that these results do not correlate with those of Bonnet and Webb (1978) who recorded a decrement in performance on a vigilance task at night, as well as those of Monk and Folkard (1983) who reported that night work tends to elicit inferior performances on simple processing and monitoring tasks.

It is of interest to note that the CMT subjects demonstrated a slower work speed and lower accuracy rate at night. The overall group responses were thus largely determined by the results of the CT group. The high standard deviations illustrate considerable inter-subject variability with respect to ability to concentrate over a sustained period.

It should also be noted that a general trend was observed where most errors were made in the latter half of the test. This may have been the result of a decrease in concentration, as well as boredom associated with the monotonous nature of the task. It would therefore seem advisable to follow the suggestion made by Monk and Folkard (1992) to perform monotonous tasks early in the work schedule and keep interesting tasks for the end of the shift when the worker is most likely to be mentally fatigued and thus more prone to making mistakes. (An example of the printout from the Q11 test is included in Appendix C).

Work Performance Series Test (WPS)

The WPS test examines an individual's ability to remain alert whilst performing a continuous series of addition tasks, as well as memorising selected information between these calculations. Working speed and work accuracy are determined by the total number of items done and the total number of correct responses respectively.

TABLE IX: Average total number of responses (TNW) and correct responses (CW) recorded during the WPS test.
(Standard deviations are given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
TNW: $\overline{X}$	227.3 [63.2]	236.2 [56.8]	232.4 [63.9]	222.2 [64]	236.1 [52]	236.2 [62.8]
CV (%)	27.8	24.1	27.5	28.8	22	26.6
CW: $\overline{X}$	211.6 [65.7]	223.5 [58.6]	216.2 [69.2]	206.9 [63.7]	222 [53]	225 [65.2]
CV (%)	31.1	26.2	32	30.8	23.9	29

Although no significant differences were found with respect to the two test conditions and subject groups, a similar trend to that observed in the Q11 data can be noted in Table IX and in Figure 9 where nominally higher numbers of total responses and correct responses were recorded for the entire sample at midnight. The average total calculations completed at night was 236.2 and the average number of correct responses was 223.5, while the corresponding number of responses recorded during the midday WPS tests were 227.3 and 211.6 respectively. It is possible that the task characteristics of the Work Performance Series test lead to more efficient performance at midnight. The WPS test involves the use of "working memory", namely the short-term memory, and processing of, certain information (Folkard

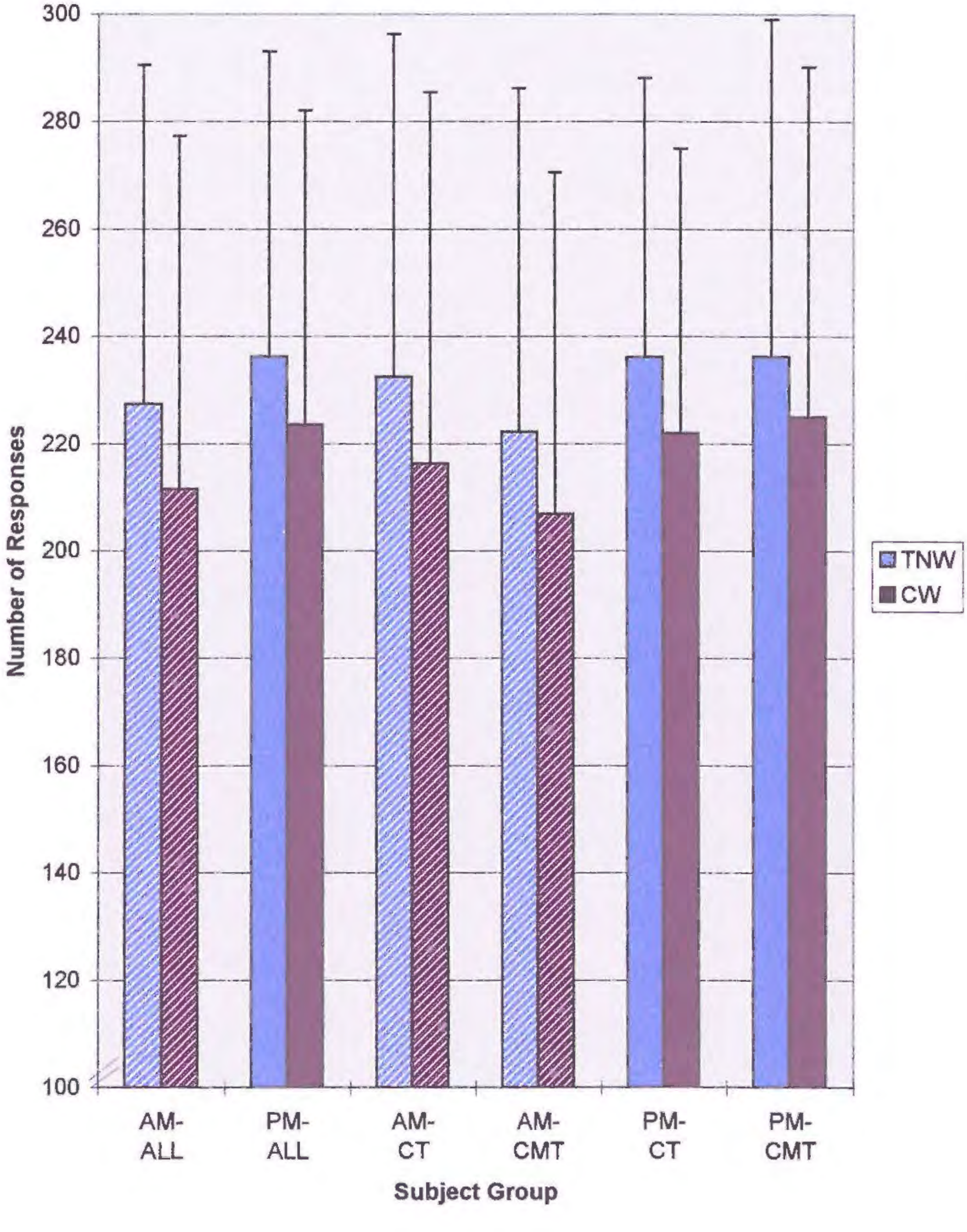


Figure 9: Average total number of responses (TNW) and correct responses (CW) recorded during the WPS test.

and Monk, 1985). de Vries-Griever and Meijman (1987) submitted that working memory may function better at night, such as was evident in the earlier study of Monk and Embrey (1981) who found fewer errors on the night shift in a task requiring short-term memory. Knauth and associates (1995) also noted fewer faults during a high memory load test conducted at night.

The large standard deviations apparent in the results of this test reveal marked inter-subject differences in ability to sustain attentiveness during the performance of a mentally demanding task over a prolonged period. Many subjects also battled with the technique required to successfully complete the test. This lead to frustration, loss of concentration and subsequent decreases in work speed. On the other hand, those individuals who were able to establish a rhythm achieved higher levels of accuracy with faster times. (See Appendix C for an example of the printout for the WPS test).

Test of Reactive Stress Tolerance (RST3)

The test of Reactive Stress Tolerance examines an individual's reaction time and accuracy whilst reacting to a range of visual and acoustic stimuli under varying levels of stress. The test is divided into three parts each comprising 180 signals. These signals are presented at different rates, namely a slow speed, followed by a fast speed, and finally a medium speed. Several variables are recorded for each phase. These include the number of correct responses, the number of timely and delayed responses, as well as the number of omitted responses.

TABLE X: Average number of correct (CS), in time (ITS), delayed (DS) and omitted (OS) responses recorded during the slow phase of the RST3 test.
(Standard deviations are given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
CS: $\bar{X}$	178.8 [1.6]	178.9 [1.5]	178.5 [1.9]	179.1 [1.2]	178.9 [1.8]	178.8 [1.2]
CV (%)	0.9	0.8	1	0.7	1	0.6
ITS: $\bar{X}$	177.9 [2.7]	177.8 [2.5]	177.4 [3.5]	178.5 [1.5]	178.1 [1.7]	177.4 [3.1]
CV (%)	1.5	1.4	2	0.8	0.9	1.8
DS: $\bar{X}$	0.9 [1.6]	1.1 [1.8]	1.1 [2.2]	0.6 [0.7]	0.8 [1.1]	1.4 [2.2]
CV (%)	186.5	157.8	195	114.2	131.8	160.3
OS: $\bar{X}$	0.7 [1.1]	0.7 [1.3]	0.8 [1.3]	0.6 [0.9]	0.8 [1.7]	0.6 [0.9]
CV (%)	160.8	183.1	168.3	150	202.7	139.1

Table X reveals the same average numbers of correct responses made by all subjects during the slow phase of the RST3 test at both midday (178.8) and midnight (178.9). The majority of these responses were made within the time during which the stimuli were presented. The number of timely and delayed reactions were also similar during the day (177.9 and 0.9 respectively) and night (177.8 and 1.1 respectively). Similar values in terms of signals omitted were recorded for both test conditions. No obvious trends or differences can be seen across the CT and CMT groups.

TABLE XI: Average number of correct (CM), in time (ITM), delayed (DM) and omitted (OM) responses recorded during the medium phase of the RST3 test. (Standard deviations are given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
CM: $\overline{X}$	175 [4.5]	175.6 [4.2]	174.6 [4.7]	175.3 [4.3]	175.6 [3.4]	175.6 [4.9]
CV (%)	2.5	2.4	2.7	2.4	1.9	2.8
ITM: $\overline{X}$	161.3 [17.2]	164.9 [11.1]	162.3 [15.9]	160.3 [18.8]	165.8 [6.1]	164 [14.6]
CV (%)	10.6	6.7	9.8	11.7	3.7	8.9
DM: $\overline{X}$	13.7 [14.1]	10.7 [9]	12.3 [12.4]	15 [15.9]	9.8 [5.2]	11.6 [11.7]
CV (%)	103.1	83.8	100.5	105.7	53.3	100.5
OM: $\overline{X}$	3.3 [3.5]	2.8 [3.1]	3.7 [4]	3 [3]	2.8 [2.7]	2.7 [3.6]
CV (%)	105.2	111.9	109.5	99.7	94	131.4

The results recorded during the medium phase of this test are shown in Table XI. The same numbers of correct responses occurred for the entire sample during the day and night sessions of 175 and 175.6 respectively. However, the number of reactions made in time at midnight (164.9) was marginally higher than those made at midday (161.3). Consequently, the number of delayed reactions recorded during the night test condition (10.7) was nominally lower than those made in the day (13.7). The number of missed stimuli were similar at both times of day. No marked differences occurred between the two subject groups.

Table XII displays the response data for the fast phase of the RST3 test. The average total number of correct responses made by all subjects, at midday was 171.4, while a similar value of 172.9 was recorded at midnight. The number of timely reactions were once again marginally higher in the night test condition (150.8) than during the day (143.5). Nominal differences are also evident in the delayed responses where the average number of delayed reactions at midday was 27.9 as compared to the 22.1 recorded at midnight. Similar numbers of signals were omitted by the subjects during the two test sessions. No obvious patterns were noted between the results of the cognitive tasks and cognitive and motor tasks groups.

TABLE XII: Average number of correct (CF), in time (ITF), delayed (DF) and omitted (OF) responses recorded during the fast phase of the RST3 test. (Standard deviations are given in square brackets)

VARIABLE	AM-ALL	PM-ALL	AM-CT	AM-CMT	PM-CT	PM-CMT
CF: $\bar{X}$	171.4 [8.4]	172.9 [6.2]	169.5 [10.3]	173.3 [5.7]	172.2 [5.9]	173.6 [6.5]
CV (%)	4.9	3.6	6	3.3	3.5	3.7
ITF: $\bar{X}$	143.5 [28]	150.8 [18.4]	142.9 [28.8]	144.2 [28]	152.1 [16.8]	149.6 [20.3]
CV (%)	19.5	12.2	20.2	19.4	11.1	13.6
DF: $\bar{X}$	27.9 [22.4]	22.1 [14.9]	26.6 [20.5]	29.1 [24.7]	20.2 [12.4]	23.9 [17.3]
CV (%)	80.4	67.7	77	84.8	61.3	72.2
OF: $\bar{X}$	6.4 [7.5]	5.1 [5.1]	7.9 [9.2]	5 [5.3]	5.8 [5.3]	4.4 [4.9]
CV (%)	116.7	99.2	116.6	104.9	91	111.1

Although statistical analyses of the RST3 data showed a lack of significant differences between the midday and midnight test sessions, and between the CT and CMT groups, an overall examination of the test results reveals a general trend in the medium and fast phases.

Here, the number of correct and timely responses tends to increase marginally at night, with the number of delayed and omitted responses decreasing. No similar patterns were observed in the slow phase data.

Figure 10 illustrates the comparison between the total number of correct responses and timely responses made during all three phases of the RST3 test. The greatest number of correct and in time responses were made in the slow phase. Thereafter, the number of responses in both variables can be seen to decrease in the medium phase, with more substantial decreases in the fast phase. Such results would be anticipated due to the nature of the task demands where the increasing rate of stimulus presentation is associated with increases in the amount of stress placed on the individual. The standard deviations follow a similar pattern as an increase in inter-subject variability coincided with the progressively greater levels of stress. These measures of variability are indicative of individual differences in coping with stressful situations, as well as varying information-processing capabilities.

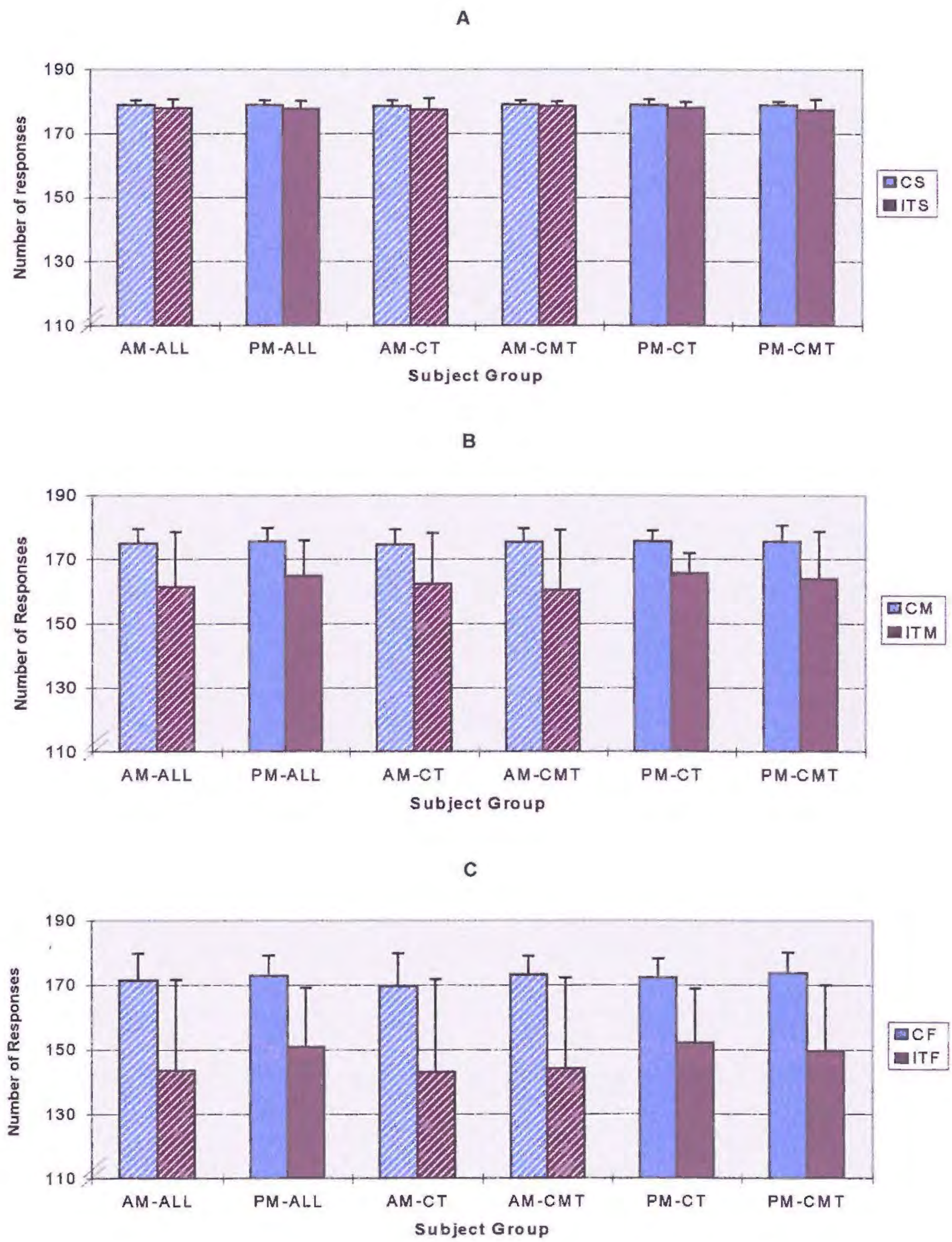


Figure 10: Average number of correct and timely responses recorded during the slow (A), medium (B) and fast (C) phases of the RST3 test.

On the other hand, Figure 11 displays the number of inadequate responses made, namely delayed and omitted responses. These responses were most pronounced in the fast, high stress phase of the test. The number of delayed and missed responses then decreased during the medium speed phase where more time was available to make adequate responses. Very few subjects made inadequate responses during the slow phase. These results are thus indicative of a negative correlation between speed and accuracy. Once again large standard deviations are apparent, particularly in the medium and fast phases. This reveals how different people cope with stressful situations.

A final note of interest is that the results printout for this test includes a "reaction matrix" which compares the reactions required to those actually performed. The majority of the subjects appeared to confuse the white colour light with the white lights corresponding to the foot pedals, as well as confusing the low and high tones. This led to the occurrence of incorrect and "multiple" reactions, in other words the number of inadequate responses made in addition to incorrect responses. (Appendix C contains an example of the printout of results for the RST3 test).

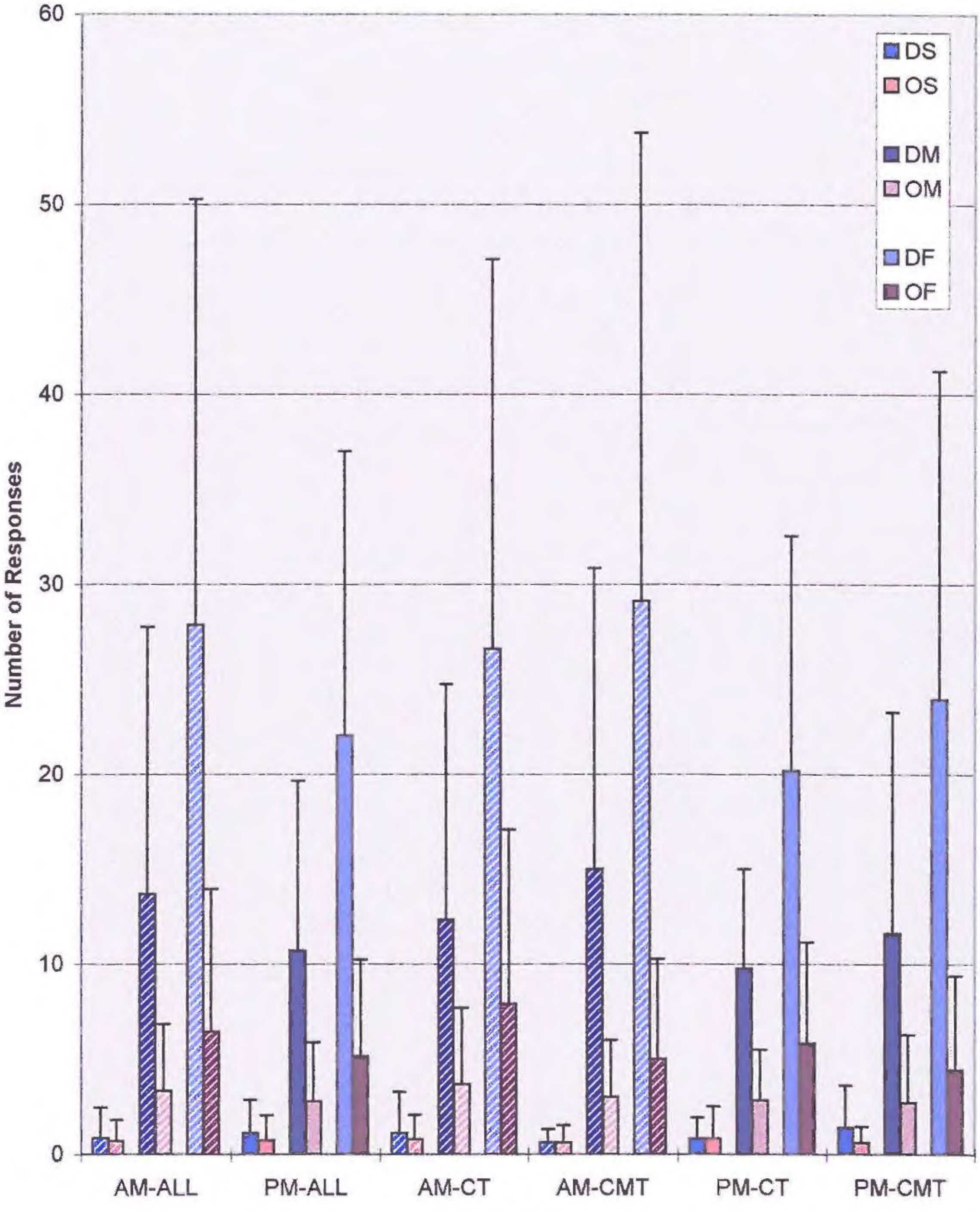


Figure 11: Average number of delayed and omitted responses recorded during the slow, medium and fast phases of the RST3 test.

GENERAL DISCUSSION

The effects of night work and task diversification on performance efficiency were assessed in terms of Borg's (1973) three inter-related "effort continua", namely physiological, perceptual and performance responses. An integration of these data is necessary in order to provide an holistic understanding of the various factors influencing individual performance during the midday and midnight test sessions.

The lower heart rate responses observed at night may have been a function of the circadian trough in physiological activation described by Åkerstedt *et al.* (1984). This may have led to the general feeling of tiredness and sleepiness that was expressed by many of the subjects during the night tests which may in turn have contributed to the increase in perceived strain experienced. However, no significant impairment of performance was apparent in the three psycho-motor tests; in fact, work speed and accuracy tended to increase at night.

Several factors may have been responsible for these performance results, including an increase in mental effort in order to combat tiredness. This corresponds with the findings of Wyatt and Marriott (1953) who noted that the majority of workers considered night work to require more effort than day work. The increased mental effort during the night test conditions may further be linked to the additional strain perceived by the subjects at night; this may have led to a greater amount of invested effort by the subjects so as to avoid impaired performance. It should be noted that the test situation produced a positive Hawthorne effect as most of the subjects appeared to be motivated to perform well, with some individuals clearly demonstrating competitive tendencies. These motivational factors may have sustained arousal levels and thereby prevented a decrease in concentration.

It has also been suggested (de Vries-Griever and Meijman, 1987) that alertness may arise during the execution of a difficult task. The Work Performance Series and Reactive Stress Tolerance tests were considered to be the most difficult of the psycho-motor tests and many of the subjects reported that they had to concentrate harder when performing these tasks during the night. The strain experienced, together with the increased cognitive and motor involvement required while completing the WPS and RST3 tests, is manifested in the higher heart rate responses as compared to those recorded in the Q11 test where the task demands were generally regarded as being basic.

The subjects were also aware that the test period was short in duration. They could thus make a concerted effort during the tests without becoming mentally fatigued. It would therefore appear that the test duration of approximately 45 minutes was too short to induce any noticeable fatigue such as commonly occurs in "real-job" shifts where workers are required to remain alert over 8-12 hours. A similar battery of tests to that used in this study, if performed at regular intervals throughout an eight hour shift, may have shown progressive decrements in work speed and accuracy due to accumulated mental fatigue. These decrements may have been exacerbated during the night shift when coupled with the damping of physiological processes such as was evidenced in the decreased heart rate responses. This combination may have induced a state of drowsiness and decreased alertness which are typically experienced when working on the night shift (Browne, 1949; Wyatt and Marriott, 1953; Wedderburn, 1978; Walsh, 1990).

It is necessary to note that the different task requirements of the three psycho-motor tests may also have reduced the build-up of fatigue by providing an additional means of task diversification in the form of task rotation. Performance of a single type of cognitive task may otherwise have been associated with increasing mental fatigue. Once again, this fatigue when added to the recognised circadian trough in physiological functions at night may have subsequently compromised performance efficiency and safety. Under such circumstances, it is possible that the arousing effect (in the form of elevated heart rates) of the brief physical activity performed by the cognitive and motor tasks (CMT) group may have minimised this fatigue build-up, thus causing the subjects to feel more alert and better able to cope with the demands of ensuing tasks.

The adjustment of the subjects' sleep/wake patterns for two days prior to each test session may be considered to mirror a rapid rotation shift system which is found to least disrupt the endogenous circadian rhythms (Folkard, 1987; Knauth, 1996). Although this attempt was made in order to simulate an actual shiftwork schedule, it should be borne in mind that the performance decrements on the night shift are not all directly related to circadian rhythms. A multitude of social, personal and other factors may influence night-time performance to a greater extent (de Vries-Griever and Meijman, 1987).

Monk and Folkard (1985b) maintain that the artificial nature of laboratory simulations may produce very different results than would occur under natural work conditions. This may be attributed to the absence of external distractions including those which stem from domestic and social situations, as well as the cumulative negative effects associated with the shiftwork experience. As this study attempted to standardise extraneous variables, the simplified and "sterile" nature of the laboratory environment may have eliminated many of the additional stresses which are usually faced by night workers and which collectively impair night performance.

In addition, this study used postgraduate students who Monk and Folkard (1985b) suggest may have very different personal characteristics, such as circadian and sleep patterns, to real-life shiftworkers. As students tend to work at night on a regular basis, this may further have led to the increase in performance efficiency during the midnight tests.

It should also be noted that night performances were assessed at approximately midnight during the present study. However, the time commonly associated with the greatest dip in performance and safety is around 3:00am (Folkard, 1996).

Finally, the effects of practice or learning on subsequent performance should be acknowledged. Although the two test sessions were held two weeks apart in an attempt to minimise such effects, the tests performed during the second test session tended to exhibit faster work speeds with fewer errors. This may have been a result of increased familiarisation with the task requirements together with the subjects feeling less anxious in the test environment. These learning effects may have masked any time of day influences over performance.

These above-mentioned factors may thus have led to the results not supporting the general consensus in the literature of performance impairments at night (Browne, 1949; Bjerner *et al.*, 1955; Bonnet and Webb, 1978; Folkard, 1987; Rosa, 1990; Monk *et al.*, 1996).

In conclusion, there does not appear to be a single cause-effect relationship which governs individual behaviour at varying times of the day. It is evident that performance efficiency across the day can be affected by numerous external factors combined with individual variability. The results of this study may thus indicate that time of day *per se* may not be the predominant factor influencing performance. The decrease in arousal at night demonstrated in this study by the lowered heart rate responses, may be adequately compensated by means of various strategies, including an increase in mental effort. Should this decrease in arousal however, be combined with negative social and personal effects, then performance impairments may well be exacerbated on the night shift.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

The inclusion of shift- and night work in modern workplaces has increased dramatically in order to meet technological, economic and social demands. The night shift has however, been associated with numerous problems for the workers involved as *Homo sapiens* is inherently diurnal in nature being active during the day and sleeping at night (Folkard, 1987; Bach de Oliveira *et al.*, 1997). Monk (1988) reports how night work tends to cause disruptions in an individual's natural biological rhythms, sleep patterns and social schedules. The magnitude of these disturbances will be modified by a multitude of personal and situational differences; the combination of which determines the objective stress and subjective strain experienced by the worker (Colquhoun and Rutenfranz, 1980a) and may ultimately impair work performance and compromise safety (Folkard, 1996).

This study thus investigated the effects of working at night on an individual's efficiency of performance. Although there is a general consensus in the literature (Browne, 1949; Bjerner *et al.*, 1955; Bonnet and Webb, 1978; Folkard, 1987; Rosa, 1990; Moore-Ede, 1993; Monk *et al.*, 1996) that night work is associated with decrements in performance efficiency, together with an increase in accidents, the results of many studies have not supported this assumption (Adams *et al.*, 1981; Monk and Embrey, 1981; Knauth *et al.*, 1995). It has been suggested that these differences in output and accident frequency may be partly attributed to inter-shift differences with respect to work conditions, job requirements and personal characteristics of the workers involved (Walker, 1978; Glenville and Wilkinson, 1979; Monk and Folkard, 1985b). Data collection was therefore conducted in a laboratory environment wherein many of these extraneous variables could be standardised. This enabled valid comparisons to be made between day and night work thereby maximising the influence of time of day on efficiency of performance.

Advancements in technology have led to the computerisation of many work environments (Colquhoun and Rutenfranz, 1980b; Rosenfeld *et al.*, 1989) and according to Folkard and Monk (1979), this has subsequently brought about a considerable shift from predominantly perceptual-motor tasks typical of earlier times to those requiring a significantly greater cognitive input. The subjects were thus required to complete a series of psycho-motor tests at both midday and midnight. The specific tests used in this study were selected due to their substantial cognitive component and emphasis on speed and accuracy, all of which are critical elements in the general work environment. These tests were administered using a computer aided testing device, the Vienna Test System. Here, the subjects had to respond to the various stimuli presented via the use of control panels which are also common features in many workplaces. The results in this study would thus appear to be applicable to real-job performance.

One of the main problems associated with the night shift is that of increased drowsiness and a decreased state of alertness (Browne, 1949; Wyatt and Marriott, 1953; Wedderburn, 1978; Walsh, 1990). These problems arise as the night shift coincides with the relaxed, sleepy phase of the circadian sleep tendency cycle (Walsh, 1990), as well as the night-time damping of many body functions, including heart rate (Grandjean, 1986; Monk *et al.*, 1996). Heart rate activity was thus recorded throughout the midday and midnight test sessions in order to determine whether this physiological function did fluctuate across the day.

It is essential that the worker be able to sustain concentration at an optimal level throughout the workshift: a brief lapse in attention could result in a fatal error, or the omission of a critical response. However, the increase in "static" work, such as monitoring of visual display terminals, is not conducive to maintenance of arousal. Several researchers (Stroh, 1971; Shephard, 1984; Wedderburn, 1987; Bullock, 1990; Lee *et al.*, 1992) have suggested the inclusion of brief periods of physical activity within the work schedule as exercise is recognised by Takeuchi *et al.* (1985) as having an arousing effect. This prompted the present study to assess the feasibility of including a short cycling activity within the mentally demanding test situation. This principle of task diversification may be used as an *in situ* intervention to combat drowsiness and in turn enhance performance efficiency.

It was further recognised that considerable individual differences may occur with respect to perception of strain in any given situation. This subjective strain may have a profound effect on subsequent performance and may also influence the extent to which a person can tolerate work at aberrant hours. Perceptual responses during the midday and midnight tests were thus obtained via the use of Scott's (1994) Perceived Strain Scale.

METHODOLOGY

Thirty six volunteer postgraduate students, all of whom were between 22 and 30 years of age, participated in this study. These subjects were randomly assigned to either the cognitive tasks

(CT) group or the cognitive and motor tasks (CMT) group. Each subject group comprised equal numbers of males and females.

Data collection consisted of three phases, the first of which incorporated a verbal explanation of the test protocol, a demonstration of the three psycho-motor tasks, as well as an opportunity to practice these tasks. Basic demographic data were also recorded and all subjects were required to complete a written consent form.

The two test phases were conducted at set times: between 11:15 and 12:45am (midday) and between 11:15 and 12:45pm (midnight). The order of these test sessions was randomly determined with a two week interval in between so as to minimise learning effects. The test environment was rigorously controlled in an attempt to validate comparisons between day and night work. As such, data collection took place in a laboratory where environmental conditions, including noise and lighting, were standardised. In order to resemble shiftwork conditions as closely as possible, subjects were asked to adjust their sleep/wake patterns for two days prior to each test session. The subjects were further requested to refrain from using any form of stimulant, such as caffeine, for 4-5 hours before data collection such that any effects of the cycling activity could be maximised.

During each data collection period, the subjects performed three psycho-motor tests, randomly presented. Subjects in the CMT group were additionally required to participate in a two minute moderate power output cycling task prior to each psycho-motor test. The CT subjects performed the battery of tests without this physical break. Standardised instructions were given to each subject with minimal interaction occurring between subject and experimenter.

Overall performance proficiency was assessed in terms of physiological, perceptual and performance-related variables. Heart rate was used to provide a measure of the subject's physiological responses whilst performing the psycho-motor tests. A heart rate monitor was also employed to assist the CMT subjects in maintaining their heart rates within the required limits of 115 and 125 beats per minute during the cycle period.

Immediately before starting each psycho-motor test, Scott's (1994) Perceived Strain Scale was administered. Here, the subjects were required to rate their perceptions of the demands of the forthcoming test, as well as their perceptions of their ability to cope with these demands. Performance efficiency was determined via the speed and accuracy with which the subjects completed each of the psycho-motor tests. These tests were presented using the Vienna Test System.

RESULTS

No significant differences were evident in heart rate responses between the midday and midnight test sessions. However, a general trend was noted where mean and maximum heart rate values were nominally lower at night.

Significant differences were found between the cognitive tasks (CT) and cognitive and motor tasks (CMT) subjects when examining heart rate responses at both times of day. The CMT group elicited higher average and maximum heart rates in both day and night tests than did the CT subjects.

Statistical analyses of the subjects' perceptual responses demonstrated a lack of significant differences with respect to time of day. The Evaluation of Task Demands (ETD) scores were however, found to be nominally higher at night, while the subjects' Evaluation of Perceived Strain (EPS) ratings tended to indicate that greater strain was experienced during the night test condition.

No significant differences were apparent with regards to perceptual responses between the CT and CMT groups.

A lack of significant differences occurred between midday and midnight when analysing the results of the three psycho-motor tests. A general trend was however evident in the results for the Test of Concentration Under Monotonous Conditions (Q11) and the Work Performance Series (WPS) test where work speed and accuracy were marginally greater at night. The medium and fast phases of the Reactive Stress Tolerance (RST3) test also showed a general pattern where fewer delayed and omitted responses were found during the midnight test results.

No significant differences were noted between the CT and CMT subjects with respect to performance results in the three psycho-motor tests.

HYPOTHESES

No significant differences were evident in efficiency of performance between midday and midnight data collection periods in the three psycho-motor tests, thus leading to the tentative acceptance of the null Hypothesis 1 for the physiological, perceptual and performance measures assessed in this study.

As no significant differences were found in the efficiency of performance between the cognitive tasks group and the cognitive and motor tasks group in the three psycho-motor tests, the null Hypothesis 2 is tentatively accepted for the three performance variables under investigation.

In summary, the findings of this study lead to the tentative acceptance of both null hypotheses and hence the rejection of the alternative hypotheses that performance is affected by time of day and physical stimulation.

CONCLUSIONS

The present study was conducted in a controlled laboratory environment. Under such conditions, various social, personal and work-related factors were standardised in an attempt to maximise the effects of time of day on performance efficiency. The nominal increase in work speed and accuracy observed during the midnight tests did not support the consensus in the literature that performance is generally impaired at night. It is thus suggested that time of day *per se* may not be the predominant factor responsible for night-time decrements in performance efficiency. Instead, the additive effects of the biological and social disruptions caused by night work, together with individual differences in tolerance to work at these unnatural hours, may play a greater role in determining performance on the night shift.

Lower heart rate responses were recorded during the midnight tests. These corresponded with the recognised night-time trough in physiological activation. Most subjects also expressed feelings of tiredness at night which may have lead to their increased ratings of perceived strain. It is possible that these inter-related physiological and perceptual factors may have resulted in a decrement in performance should the tests have been performed over a longer period. However, the relatively short duration of each data collection session, as well as the "test" environment which appeared to play a motivational role, effectively enabled the subjects to sustain attentiveness. Similar results may not have occurred should performance have been assessed over an eight hour workshift where cumulative fatigue is commonly experienced.

Although there were no noticeable differences in efficiency of performance between the two subject groups, the cognitive and motor tasks subjects did elicit significantly higher heart rates then the cognitive tasks group. This elevated physiological state may have important implications in terms of maintaining optimal arousal levels within a cognitively demanding eight hour work schedule. The incorporation of a short physical break may act as a means of task diversification and may thus help workers to remain alert and subsequently enhance performance, especially during the drowsy night shift.

RECOMMENDATIONS

The findings of this study reiterate the critical need for standardised testing to be conducted *in situ* in order to take cognizance of the entire work environment. It is thus suggested that the Vienna Test System be used in field studies where assessments of performance efficiency can be made at various times throughout an eight hour shift, as well as across successive night shifts. These studies should include experienced shift- and night workers and may utilise a similar battery of tests as was incorporated in this study. Field research must however, be supplemented with controlled laboratory research using identical tests and the same workers in order to distinguish between specific "causes and effects".

It is further recommended that such studies be conducted over a sufficient time period as is necessary to reduce associated practice and learning effects. This should in turn familiarise workers with the "test" situation and thereby minimise test-related anxiety which may further confound performance results. A larger sample size is also necessary to counteract inter-individual variability.

Twenty-four hour workplaces should be requested to keep meticulous records with respect to the number of errors and accidents occurring across various shifts, bearing in mind possible intershift differences. This type of survey may offer an additional means of obtaining field data and hence identifying problems associated with shiftwork.

Finally, the potential of using the Vienna Test System within pre-employment screening should also be assessed. The Reactive Stress Tolerance test, for example, may provide valuable insight with regards an individual's ability to cope under varying levels of stress, a factor which may have critical implications when working on the night shift where additional stresses are commonly experienced.

REFERENCES

NOTE: Asterisked citations are secondary sources and were not directly consulted. They are referenced as fully as the primary sources, indicated in brackets, permit.

Adams NL, Barlow A and Hiddlestone J (1981). Obtaining Ergonomics Information about Industrial Injuries: A Five Year Analysis. *Applied Ergonomics,* 12: 71-81.

Adams J, Folkard S and Young M (1986). Coping Strategies used by Nurses on Night Duty. *Ergonomics,* 29(2): 185-196.

Åkerstedt T and Torsvall L (1981). Shiftwork: Shift-Dependent Well-Being and Individual Differences. *Ergonomics,* 24(4): 265-273.

Åkerstedt T, Knutsson A, Alfredsson L and Theorell T (1984). Shift Work and Cardiovascular Disease. *Scandinavian Journal of Work, Environment and Health,* 10: 409-414.

Åstrand P-O and Rodahl K (1986). *Textbook of Work Physiology: Physiological Bases of Exercise.* Third Edition. New York: McGraw-Hill Book Company.

Atkinson G, Coldwells A, Reilly T and Waterhouse J (1993). A Comparison of Circadian Rhythms in Work Performance between Physically Active and Inactive Subjects. *Ergonomics,* 36(1-3): 273-281.

Bach de Oliveira CR, Moro FBP, Gomes G and Bins Ely VHM (1997). Night Work and Alternate Shift-Work. *Proceedings of the 13th Triennial Congress of the International Ergonomics Association, Tampere, Finland,* 1: 539-541.

Bailey RW (1982). *Human Performance Engineering: A Guide for System Designers.* New Jersey: Prentice Hall.

Baker MA, Holding DH and Loeb M (1984). Noise, Sex and Time of Day Effects in a Mathematics Task. *Ergonomics,* 27(1): 67-80.

Barrow HM and Brown JP (1988). *Man and Movement: Principles of Physical Education.* Fourth Edition. Philadelphia: Lea and Febiger.

Berch DB and Kanter DR (1984). Individual Differences. In JS Warm (ed): *Sustained Attention in Human Performance.* Chichester: John Wiley and Sons, pp. 143-178.

Bjerner B, Holm Å and Swensson Å (1955). Diurnal Variation in Mental Performance: A Study of Three-Shift Workers. *British Journal of Industrial Medicine,* 12: 103-110.

Blake MJF (1967). Time of Day Effects on Performance in a Range of Tasks. *Psychonomic Science,* 9: 349-350.

Blake MJF (1971). Temperament and Time of Day. In WP Colquhoun (ed): *Biological Rhythms and Human Performance.* London: Academic Press, pp. 109-148.

Bonnet MH and Arand DL (1994). The Use of Prophylactic Naps and Caffeine to Maintain Performance during a Continuous Operation. *Ergonomics,* 37(6): 1009-1020.

Bonnet MH and Webb WB (1978). The Effect of Repetition of Relevant and Irrelevant Tasks Over Day and Night Work Periods. *Ergonomics,* 21(12): 999-1005.

Borg G (1970). Perceived Exertion as an Indicator of Somatic Stress. *Scandinavian Journal of Rehabilitation and Medicine,* 2(3): 92-98.

Borg G (1973). Psychological and Physiological Studies of Physical Work. In WT Singleton, JG Fox and D Whitfield (eds): *Measurement of Man At Work: An Appraisal of Physiological and Psychological Criteria in Man-Machine Systems.* London: Taylor and Francis, pp. 121-128.

Borg G (1976). General Introduction: Psychophysiological Studies of the Three Effort Continua. In G Borg (ed): *Physical Work and Effort.* Oxford: Pergamon Press, pp. 1-10.

Borg G (1978). Subjective Aspects of Physical and Mental Load. *Ergonomics,* 21(3): 215-220.

Bosch LHM and de Lange WAM (1987). Shift Work in Health Care. *Ergonomics,* 30(5): 773-791.

Brown TG, Szabo A and Seraganian P (1988). Physical Versus Psychological Determinants of Heart Rate Reactivity to Mental Arithmetic. *Psychophysiology,* 25(5): 532-537.

Browne RC (1949). The Day and Night Performance of Teleprinter Switchboard Operators. *Occupational Psychology,* 23: 121-126.

Bullock MI (1990). Introduction: Ergonomics - A Broad Challenge for the Physiotherapist. In MI Bullock (ed): *The Physiotherapist in the Workplace.* New York: Churchill Livingstone, pp. 3-12.

* Carpentier J and Cazemian P (1977). *Night Work.* Geneva: International Labour Organization. (see Bosch and de Lange, 1987)

Carroll D, Turner JR and Rogers S (1987). Heart Rate and Oxygen Consumption during Mental Arithmetic, a Video Game, and Graded Static Exercise. *Psychophysiology,* 24(1): 112-118.

Colquhoun WP (1959). The Effect of a Short Rest-Pause on Inspection Efficiency. *Ergonomics*, 2: 367-372.

Colquhoun WP (1970). Circadian Rhythms, Mental Efficiency and Shift Work. In PR Davis (ed): *Performance Under Sub-optimal Conditions*. London: Taylor and Francis, pp. 28-30.

Colquhoun WP (1971). Circadian Variations in Mental Efficiency. In WP Colquhoun (ed): *Biological Rhythms and Human Performance*. London: Academic Press, pp. 39-107.

Colquhoun WP (1982). Biological Rhythms and Performance. In WB Webb (ed): *Biological Rhythms, Sleep, and Performance*. Chichester: John Wiley and Sons, pp. 59-86.

Colquhoun WP and Rutenfranz J (1980a). Introduction. In WP Colquhoun and J Rutenfranz (eds): *Studies of Shiftwork*. London: Taylor and Francis, pp. ix-xi.

Colquhoun WP and Rutenfranz J (1980b). Shiftworking: The General Picture. In WP Colquhoun and J Rutenfranz (eds): *Studies of Shiftwork*. London: Taylor and Francis, pp. 3-15.

Copes K and Rosentswieg J (1972). The Effects of Sleep Deprivation upon Motor Performance of Ninth-Grade Students. *Journal of Sports Medicine and Physical Fitness*, 12: 47-53.

Costa G, Lievore F, Casaletti G, Gaffuri E and Folkard S (1989). Circadian Characteristics Influencing Interindividual Differences in Tolerance and Adjustment to Shiftwork. *Ergonomics,* 32(4): 373-385.

Craig A and Condon R (1984). Operational Efficiency and Time of Day. *Human Factors,* 26(2): 197-205.

* Dalton K (1960). *British Medical Journal,* ii: 326-328. (see Redgrove, 1971)

* Davies DR and Parasuraman R (1982). *The Psychology of Vigilance.* London: Academic Press. (see Berch and Kanter, 1984)

Dirken JM (1966). Industrial Shift Work: Decrease in Well-being and Specific Effects. *Ergonomics,* 9(2): 115-124.

Eysenck HJ (1958). A Shortened Questionnaire for the Measurement of Two Dimensions of Personality. *Journal of Applied Psychology,* 42(1): 14-17.

Folkard S (1987). Circadian Rhythms and Hours of Work. In P Warr (ed): *Psychology At Work.* Third Edition. Great Britain: Penguin Books, pp. 30-52.

Folkard S (1992). Is there a "Best" Compromise Shift System? *Ergonomics,* 35(12): 1453-1463.

Folkard S (1996). Effects on Performance Efficiency. In WP Colquhoun, G Costa, S Folkard and P Knauth (eds): *Shiftwork: Problems and Solutions*. New York: Peter Lang, pp. 65-87.

Folkard S and Monk TH (1979). Shiftwork and Performance. *Human Factors*, 21(4): 483-492.

Folkard S and Monk TH (1985). Circadian Performance Rhythms. In S Folkard and TH Monk (eds): *Hours of Work: Temporal Factors in Work-Scheduling*. New York: John Wiley and Sons, pp. 37-52.

Folkard S, Monk TH and Lobban MC (1979). Towards a Predictive Test of Adjustment to Shift Work. *Ergonomics*, 22(1): 79-99.

Fröberg JE (1985). Sleep Deprivation and Prolonged Working Hours. In S Folkard and TH Monk (eds): *Hours of Work: Temporal Factors in Work-Scheduling*. New York: John Wiley and Sons, pp. 67-75.

Ganong WF (1991). *Review of Medical Physiology*. Fifteenth Edition. London: Prentice-Hall International Inc.

Gillberg M (1985). Effects of Naps on Performance. In S Folkard and TH Monk (eds): *Hours of Work: Temporal Factors in Work-Scheduling*. New York: John Wiley and Sons, pp. 77-86.

Glenville M and Wilkinson RT (1979). Portable Devices for Measuring Performance in the Field: The Effects of Sleep Deprivation and Night Shift on the Performance of Computer Operators. *Ergonomics,* 22(8): 927-933.

Goldstein IB and Shapiro D (1988). Cardiovascular Responses to Mental Arithmetic and Handgrip During Different Conditions of Postural Change. *Psychophysiology,* 25(2): 127-136.

Graeber RC, Rosekind MR, Connell LJ and Dinges DF (1991). Cockpit Napping. *World Airnews,* 27-31.

Grandjean E (1986). *Fitting the Task to the Man: An Ergonomic Approach.* London: Taylor and Francis.

Greenwood KM (1995). An Evaluation of the Circadian Type Questionnaire. *Ergonomics,* 38(2): 347-360.

Hancock PA (1984). Environmental Stressors. In JS Warm (ed): *Sustained Attention in Human Performance.* Chichester: John Wiley and Sons, pp. 103-142.

Härmä M (1993). Individual Differences in Tolerance to Shiftwork: A Review. *Ergonomics,* 36(1-3): 101-109.

Härmä M (1996). Ageing, Physical Fitness and Shiftwork Tolerance. *Applied Ergonomics,* 27(1): 25-29.

Härmä MI, Ilmarinen J, Knauth P, Rutenfranz J and Hänninen O (1988). Physical Training Intervention in Female Shift Workers: I. The Effects of Intervention on Fitness, Fatigue, Sleep, and Psychosomatic Symptoms. *Ergonomics,* 31(1): 39-50.

* Horne JA and Ostberg O (1976). A Self-Assessment Questionnaire to Determine Morningness-Eveningness in Human Circadian Rhythm. *International Journal of Chronobiology,* 4: 97-110. (see Greenwood, 1995)

* Horne JA and Ostberg O (1977). Individual Differences in Human Circadian Rhythms. *Biological Psychology,* 5: 179-190. (see Parasuraman, 1984)

Horne JA, Brass CG and Pettitt AN (1980). Circadian Performance Differences Between Morning and Evening "Types". *Ergonomics,* 23(1): 29-36.

Johnson LC (1982). Sleep Deprivation and Performance. In WB Webb (ed): *Biological Rhythms, Sleep, and Performance.* Chichester: John Wiley and Sons, pp. 111-141.

Johnston DW, Anastasiades P and Wood C (1990). The Relationship Between Cardiovascular Responses in the Laboratory and in the Field. *Psychophysiology,* 27(1): 34-44.

Kerkhof GA (1985). Inter-Individual Differences in the Human Circadian System: A Review. *Biological Psychology,* 20: 83-112.

Kerr R (1982). *Psychomotor Learning.* Philadelphia: CBS College Publishing.

Knauth P (1993). The Design of Shift Systems. *Ergonomics,* 36(1-3): 15-28.

Knauth P (1996). Designing Better Shift Systems. *Applied Ergonomics,* 27(1): 39-44.

Knauth P, Keller J, Schindele G and Totterdell P (1995). A 14-h Night-Shift in the Control Room of a Fire Brigade. *Work and Stress,* 9(2/3): 176-186.

Kogi K (1985). Introduction to the Problems of Shiftwork. In S Folkard and TH Monk (eds): *Hours of Work: Temporal Factors in Work-Scheduling.* New York: John Wiley and Sons, pp. 165-184.

Kogi K and Thurman JE (1993). Trends in Approaches to Night and Shiftwork and New International Standards. *Ergonomics,* 36(1-3): 3-13.

Lazarus RS and Monat A (1979). *Personality.* Third Edition. Englewood Cliffs: Prentice Hall.

Lee K, Swanson N, Sauter S, Wickstrom R, Waikar A and Mangum M (1992). A Review of Physical Exercises Recommended for VDT Operators. *Applied Ergonomics,* 23(6): 387-408.

Léonard R (1981). Night- and Shift-Work. In A Reinberg, N Vieux and P Andlauer (eds): *Night and Shiftwork: Biological and Social Aspects.* Oxford: Pergamon Press, pp. 323-329.

Levi L (1994). Work, Worker and Wellbeing: An Overview. *Work and Stress,* 8(2): 79-83.

Linde L (1995). Mental Effects of Caffeine in Fatigued and Non-Fatigued Female and Male Subjects. *Ergonomics,* 38(5): 864-885.

Linden W (1991). What Do Arithmetic Stress Tests Measure? Protocol Variations and Cardiovascular Responses. *Psychophysiology,* 28(1): 91-102.

Maree DJF (1994). *Psychomotor Performance: Provisional Report.* Pretoria: Human Sciences Research Council.

McArdle WD, Katch FI and Katch VL (1991). *Exercise Physiology: Energy, Nutrition, and Human Performance.* Third Edition. Philadelphia: Lea and Febiger.

Menna-Barreto L, Benedito-Silva AA, Moreno CRC, Fischer FM and Marques N (1993). Individual Differences in Night and Continuously-Rotating Shiftwork: Seeking Anticipatory rather than Compensatory Strategy. *Ergonomics,* 36(1-3): 135-140.

Monk TH (1988). Coping With the Stress of Shift Work. *Work and Stress,* 2(2): 169-172.

Monk TH and Embrey DE (1981). A Field Study of Circadian Rhythms in Actual and Interpolated Task Performance. In A Reinberg, N Vieux and P Andlauer (eds): *Night and Shiftwork: Biological and Social Aspects.* Oxford: Pergamon Press, pp. 473-480.

Monk TH and Folkard S (1983). Circadian Rhythms and Shiftwork. In R Hockey (ed): *Stress and Fatigue in Human Performance.* Chichester: John Wiley and Sons, pp. 97-121.

Monk TH and Folkard S (1985a). Individual Differences in Shiftwork Adjustment. In S Folkard and TH Monk (eds): *Hours of Work: Temporal Factors in Work Scheduling.* New York: John Wiley and Sons, pp. 227-237.

Monk TH and Folkard S (1985b). Shiftwork and Performance. In S Folkard and TH Monk (eds): *Hours of Work: Temporal Factors in Work Scheduling.* New York: John Wiley and Sons, pp. 239-252.

Monk TH and Folkard S (1992). *Making Shift Work Tolerable.* London: Taylor and Francis.

Monk TH, Folkard S and Wedderburn AI (1996). Maintaining Safety and High Performance on Shiftwork. *Applied Ergonomics,* 27(1): 17-23.

Moog R (1987). Optimization of Shift Work: Physiological Contributions. *Ergonomics,* 30(9): 1249-1259.

Moore-Ede MC (1993). *The Twenty Four Hour Society.* Reading: Addison-Wesley Publishing Company.

Oborne DJ (1987). *Ergonomics At Work.* Second Edition. Chichester: John Wiley and Sons.

Ong CN (1992). Working Time: Health and Ergonomics Considerations. *Ergonomics in Occupational Safety and Health,* 1-5: 487-495.

Östberg O (1973). Interindividual Differences in Circadian Fatigue Patterns of Shift Workers. *British Journal of Industrial Medicine,* 30: 341-351.

Parasuraman R (1984). The Psychology of Sustained Attention. In JS Warm (ed): *Sustained Attention in Human Performance.* Chichester: John Wiley and Sons, pp. 61-101.

Parkes KR (1994). Sleep Patterns, Shiftwork, and Individual Differences: A Comparison of Onshore and Offshore Control-Room operators. *Ergonomics,* 37(5): 827-844.

Pew RW (1969). The Speed-Accuracy Operating Characteristics. *Acta Psychologica,* 30: 16-26.

Pokorny MLI, Blom DHJ and Van Leeuwen P (1987). Shifts, Duration of Work and Accident Rate of Bus Drivers. *Ergonomics,* 30(1): 61-88.

Q1: Test to Examine Concentration Under Monotony. (1989). Mödling: Schuhfried.

Redgrove JA (1971). Menstrual Cycles. In WP Colquhoun (ed): *Biological Rhythms and Human Performance.* London: Academic Press, pp. 211-240.

Reilly T, Atkinson G and Waterhouse J (1997a). *Biological Rhythms and Exercise.* Oxford: Oxford University Press.

Reilly T, Waterhouse J and Atkinson G (1997b). Aging, Rhythms of Physical Performance, and Adjustment to Changes in the Sleep-Activity Cycle. *Occupational and Environmental Medicine,* 54: 812-816.

Reinberg A, Andlauer P, Guillet P, Nicolai A, Vieux N and Laporte A (1980). Oral Temperature, Circadian Rhythm Amplitude, Ageing, and Tolerance to Shiftwork. *Ergonomics,* 23(1): 55-64.

Rohmert W (1987). Physiological and Psychological Work Load Measurement and Analysis. In G Salvendy (ed): *Handbook of Human Factors.* New York: Wiley, pp. 402-428.

Rompelman O, Van Kampen WHA, Backer E and Offerhaus RE (1980). Heart Rate Variability in Relation to Psychological Factors. *Ergonomics,* 23(12): 1101-1115.

Rosa R (1990). Editorial: Factors for Promoting Adjustment to Night- and Shift Work. *Work and Stress,* 4(3): 201-202.

Rosenfeld O, Tenenbaum G, Ruskin H and Halfon S-T (1989). The Effect of Physical Training and Subjective Measures of Productivity and Efficiency in Industry. *Ergonomics,* 32(8): 1019-1028.

RST3: Test to Examine Reactive Stress Tolerance. (1992). Mödling: Schuhfried.

Rutenfranz J, Knauth P and Colquhoun WP (1976). Hours of Work and Shiftwork. *Ergonomics,* 19(3): 331-340.

Rutenfranz J and Colquhoun WP (1979). Circadian Rhythms in Human Performance. *Scandinavian Journal of Work, Environment and Health,* 5: 167-177.

Schuhfried G (1994). *Computer-Assisted Procedures for Ability and Personality Diagnostics: Catalogue 12/94.* Austria: Schuhfried.

Scott PA (1990). *The Development of a Psychophysical Scale for Evaluating Self-Perceived Strain.* Unpublished Phd Dissertation. Stellenbosch University, South Africa.

Scott PA (1994). The Perceived Strain Scale (PSS). Part I: Conceptual Model. *International Journal of Sport Psychology,* 22: 381-395.

Scott PA (1997). Theoretical Concepts on the Effect of Shiftwork on the Efficiency of Performance. *AIC Conference on Rostering and Shiftwork,* 8-9 September 1997, Johannesburg, South Africa.

Shephard RJ (1984). Sleep, Biorhythms and Human Performance. *Sports Medicine,* 1: 11-37.

Singer RN (1980). *Motor Learning and Human Performance.* Third Edition. New York: Macmillan Publishing Co.,Inc.

Smith L and Folkard S (1993). The Impact of Shiftwork on Personnel at a Nuclear Power Plant: An Exploratory Survey Study. *Work and Stress,* 7(4): 341-350.

Snedecor GW and Cochran WG (1980). *Statistical Methods.* Seventh Edition. Iowa: The Iowa State University Press.

Spelten E, Totterdell P, Barton J and Folkard S (1995). Effects of Age and Domestic Commitment on the Sleep and Alertness of Female Shiftworkers. *Work and Stress,* 9(2/3): 165-175.

Stroh CM (1971). *Vigilance: The Problem of Sustained Attention.* Oxford: Pergamon Press.

* Strφmme SB, Wikeby PC, Blix AS and Ursin H (1978). Additional Heart Rate. In H Ursin, E Baade and S Levine (eds): *Psychobiology of Stress: A Study of Coping Men.* New York: Academic Press. (see Scott, 1990)

Takeuchi L, Davis GM, Plyley M, Goode R and Shephard RJ (1985). Sleep Deprivation, Chronic Exercise and Muscular Performance. *Ergonomics,* 28(3): 591-601.

Tepas DI (1982). Work/Sleep Time Schedules and Performance. In WB Webb (ed): *Biological Rhythms, Sleep, and Performance.* Chichester: John Wiley and Sons, pp. 175-204.

Tepas DI and Mahan RP (1989). The Many Meanings of Sleep. *Work and Stress,* 3(1): 93-102.

Vidacek S, Kaliterna L, Radosevic-Vidacek B and Folkard S (1988). Personality Differences in the Phase of Circadian Rhythms: A Comparison of Morningness and Extraversion. *Ergonomics,* 31(6): 873-888.

de Vries-Griever AHG and Meijman TF (1987). The Impact of Abnormal Hours of Work on Various Modes of Information Processing: A Process Model on Human Costs of Performance. *Ergonomics,* 30(9): 1287-1299.

Walker J (1978). *The Human Aspects of Shiftwork.* London: The Pitman Press.

Walsh JK (1990). Using Pharmacological Aids to Improve Waking Function and Sleep While Working at Night. *Work and Stress,* 4(3): 237-243.

Warm JS (1984). An Introduction to Vigilance. In JS Warm (ed): *Sustained Attention in Human Performance.* Chichester: John Wiley and Sons, pp. 1-14.

Wedderburn AAI (1978). Some Suggestions for Increasing the usefulness of Psychological and Sociological Studies of Shiftwork. *Ergonomics,* 21(10): 827-833.

Wedderburn AAI (1987). Sleeping on the Job: The Use of Anecdotes for Recording Rare but Serious Events. *Ergonomics,* 30(9): 1229-1233.

Wedderburn AAI (1992). How Fast Should the Shift Rotate? A Rejoinder. *Ergonomics*, 35(12): 1447-1451.

Weiskotten TF and Ferguson JE (1930). A Further Study of the Effects of Loss of Sleep. *Journal of Experimental Psychology*, 13: 247-266.

Wilkinson RT (1992). Review Paper: How Fast Should the Night Shift Rotate? *Ergonomics*, 35(12): 1425-1446.

Williamson AM and Feyer A-M (1995). Causes of Accidents and the Time of Day. *Work and Stress*, 9(2/3): 158-164.

Wisner A (1989). Fatigue and Human Reliability Revisited in the Light of Ergonomics and Work Psychopathology. *Ergonomics*, 32(7): 891-898.

Wyatt S and Marriott R (1953). Night Work and Shift Changes. *British Journal of Industrial Medicine*, 10: 164-172.

APPENDICES

APPENDIX A: GENERAL INFORMATION

Letter to the Subject

Informed Consent Information Sheet

Subject Consent Form

HUMAN MOVEMENT STUDIES

To fellow postgraduate students

I am looking for volunteers (male/female, 22-30 yrs) to participate in my masters research project wherein I will be examining the *effects of working at night on efficiency of performance*. Due to the growing need for 24-hour operations, for example in industrial and medical environments, the incidence of night-shifts has increased dramatically. This has forced many individuals to change their natural diurnal lifestyle to that of a nocturnal nature, namely to sleep during the day and work at night. Unfortunately, these changes are accompanied by numerous problems for the workers concerned, including disruptions in biological rhythms, and a higher frequency of accidents and errors during the night hours as a result of a reduction in alertness. However, much controversy exists in the literature with regards the effects of night-work on performance efficiency in specific psychomotor tasks such as reaction time. I have therefore decided to examine various psychomotor components via the use of a computer-aided testing system: the Vienna Test System (VTS).

A second part to my study involves the incorporation of a 2 minute low/moderate intensity cycle (using an exercise bike) as a possible intervention strategy to stimulate the arousal level of the worker and thus enhance performance. Only half of the subjects will be required to participate in this exercise.

I will require approximately 2 hours of your time in total. This will be split into 3 separate data collection sessions at the Department of Human Movement Studies and will take place during the course of the third term. The first session (any time suitable to you) will incorporate the collection of general subject information, together with an introduction to the Vienna Test System. This will be followed by 2 testing periods, one at midday and the other at midnight (transport will be

Rhodes University
P O Box 94
6140 Grahamstown, South Africa

Telephone: (0461) 31 8468
Telegrams: 'RHODESCOL' Telex: 24 4211
Fax: (0461) 23803

available!). These testing sessions will be conducted 2 weeks apart. At the completion of the entire data collection period, I will inform you as to the overall results of the study, together with your individual scores.

If you are unsure and would like further information, please contact me at the HMS dept. (ph:318472) OR via e-mail: g91m1977@warthog.ru.ac.za. If you are interested in participating in this study, please complete the form provided.

Many thanks!

Lynne Munton

If you are interested in participating in this research project, please fill in your details below:

NAME	CONTACT ADDRESS	PHONE NO. (work & home)	E-MAIL ADDRESS

RHODES UNIVERSITY

DEPARTMENT OF HUMAN MOVEMENT STUDIES

INFORMED CONSENT SHEET

Project Title: THE EFFECTS OF NIGHT WORK AND TASK DIVERSIFICATION ON EFFICIENCY OF PERFORMANCE

General Aim of Project: This project will be examining the effects of working at night on performance efficiency in selected psychomotor activities.

Subject Pool: The research sample will be confined to postgraduate male and female students between the ages of 22 and 30 years. This subject pool will comprise approximately 50 volunteers, each of whom will be assigned randomly to either a cognitive tasks group or a cognitive/motor tasks group. Subjects in the cognitive tasks group will perform only 3 psychomotor tasks, while those in the cognitive/motor tasks group will participate in both the psychomotor tasks with cycling breaks.

Basic Procedure: Data collection will be split into 3 separate 45min sessions and will take place at the Department of Human Movement Studies. The first session will incorporate the collection of general subject information, administration of written consent forms, as well as an introduction to the Vienna Test System. Here subjects will have the opportunity to become familiar with the 3 psychomotor tasks to be performed during the 2 data collection sessions.

The 2 data collection sessions will be held at standardised times, namely between 11:15 and 12:45am (midday) and between 23:15 and 00:45pm (midnight), and will be conducted 2 weeks apart in order to minimise the learning factor. During these 2 sessions the subjects will perform the 3 psychomotor tasks, randomly presented. the cognitive/motor tasks group will perform a 2 minute bout on a cycle ergometer at a low-moderate power output prior to each of the tasks, while the cognitive tasks group will be required to perform the psychomotor tasks without participation in the diverse task of cycling.

Heart rate will be recorded throughout the 2 data collection sessions. Those subjects in the cognitive/motor tasks group will further be required to maintain their heart rate within a preset threshold of between 115 and 125 beats per minute whilst cycling. Subjects will also be required to rate their perceptions of the demands of the task, together with their perceived ability to cope with these demands, via the use of the Perceived Strain Scale.

Risks: Although there are no risks associated with this project, the collection of data at midnight necessitates the use of safety precautions, such as locking the door to the Department of Human Movement Studies throughout the collection period. To this end, Campus Security has been informed about the Department being utilized at night. Transport is also provided to and from the department for subjects who require it.

Benefits: There are no personal benefits as such to be gained via participation in this project. However, the results should provide a better understanding of differences in work efficiency during day and night hours and may prove valuable in terms of subsequent development of intervention strategies to minimise the conflict between aberrant work hours and the diurnal nature of man. On completion of the entire data collection period subjects will be provided with written feedback with regards their personal results and the overall findings of the study.

SUBJECT CONSENT FORM

I, --, having been fully informed of the research entitled:

THE EFFECTS OF NIGHT WORK AND TASK DIVERSIFICATION ON EFFICIENCY OF PERFORMANCE.

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 attendant to 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 or Rhodes University, from any and all claims resulting from personal injuries sustained. 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 the information collected may be used and published for statistical or scientific 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.

....	....	....
(PRINT NAME)	*(SIGNED)*	*(DATE)*

Subject (or legal representative):

....	....	....
(PRINT NAME)	*(SIGNED)*	*(DATE)*

Person administering Informed Consent:

....	....	....
(PRINT NAME)	*(SIGNED)*	*(DATE)*

Witness:

APPENDIX B: DATA COLLECTION

Data Collection: Equipment Check-List

Test Protocol

Subject Information Sheet

Subject Instruction Sheet

Data Recording Sheet

Perceived Strain Scale

Data Collection: Equipment Check-List

1. Data recording sheet and pencil
2. Heartwatches (2)

   Electrodes and Straps

   Redux Creme/Water

   Tissues
3. Computer

   Monitor

   Keyboard

   Vienna Test System Interface

   Peripheral Devices: Vienna Determination Unit and testee's panel
4. Chair
5. Cycle Ergometer
6. Perceived Strain Scale (PSS)

Test Protocol

Place the electrode belt with attached transmitter around the subject's chest region. Check that the heart rate monitor is registering the subject's heart rate. Record the subject's reference heart rate. Press the **SET/START-STOP** button at the start of the first test in the case of the CT (cognitive tasks only) subjects, or at the start of the first two minute bout of cycling in the case of the CMT (cognitive and motor tasks) subjects. The **STORE/RECALL** button should thereafter be pressed at the start and finish of each psycho-motor test, while the **SET/START-STOP** is used to terminate data collection.

Pre-Test Instructions:

1) Remind the subject that they will be required to complete three tests. Point out which tests are performed on the various VTS peripherals: responding to visual and auditory stimuli on the VDU; pressing the red and green keys in matching the bottom figure to the four top figures; and the addition and memory test using the numbered keys on the testee's panel.
2) Prior to starting the test battery, describe the order of the data collection period. For the CT subjects the order is as follows: the instruction phase, followed by a short practice phase, then completion of the PSS scale before starting the actual test. The CMT subjects must perform a two minute bout of cycling prior to the instruction phase of each test, thereafter the order remains the same.
3) Instruction phase: instructions will be read to the subject who is requested not to perform any action until the tester has completely finished reading the specific instruction.
4) Practice phase: the subject is requested to try and stay calm and relaxed during this phase as it merely constitutes a familiarisation period. Mistakes will be pointed out during this time, yet no feedback will be provided during the actual tests.
5) The subject is to complete the Perceived Strain Scale as quickly and honestly as possible immediately prior to each test.
6) The subject is reminded that they are to complete the test as quickly and as accurately as possible. Once a particular test has been completed, the CT subjects will proceed directly to the instruction phase of the following test, while the CMT subjects will perform a two minute bout of cycling at this stage.

Instructions: Q11

Ensure that the subject is seated comfortably.

1. For this test you will be using the red and green buttons on this keyboard. Please press down the green key once.
2. You will be presented with four patterns on top and one pattern below. Should the bottom pattern be the SAME as any of the top patterns, then press the RED button.

If the bottom pattern is DIFFERENT to all of the top patterns, then press the GREEN button.

3. You will now have the opportunity to practice this task. This is simply a practice phase, so please try to relax and familiarise yourself with the task requirements. Begin by pressing the green key.
   Good! Do you have any questions?

Before starting with the actual test, the subject is required to complete the PSS scale as quickly and as honestly as possible. Remind subject of the 7 minute test duration.

You will now be starting the test. Remember to work as quickly and accurately as possible. Please start by pressing the bottom black key.

Instructions: WPS

Ensure that the subject is seated comfortably.

1. Two numbers will appear on the screen. There will be a "plus" sign between them. You are required to add these two numbers together and then to enter the solution.
   eg: $5+4 = 9$... enter 9
2. If the solution is greater than 9, you are required to enter the *units* number only (the right-hand number).
   eg: $8+4 = 12$... enter 2
3. Press any key to continue.
4. After you have entered the solution, the bottom number will form the top number of the following equation, but it will not be visible. A new number will appear at the bottom.
5. You are required to add the new number to the number that has just disappeared BUT before entering this new solution, you must *memorise* the new bottom number!
   Try to use the following order:
   (i) memorise the bottom number
   (ii) enter the solution (at which time a new number appears at the bottom)
   (iii) work out the new solution
   (iv) memorise the bottom number
   (v) enter the solution, etc.
6. Press any key to continue.
7. There will now be a short practice phase wherein any mistakes you make will be pointed out to you. Try to work as quickly and as accurately as possible. Be careful not to press the wrong key even if you have the correct answer.
8. If you are unsure as to these instructions, you may review them by pressing the red key, or you may simply press any other key to continue.
   Good! Do you have any questions?
9. One final note is that you may correct an answer by using the "*" key (show this to the subject), but remember that this will cause you to lose time, so try not to use it too often.

Before starting with the actual test, the subject is required to complete the PSS scale as quickly and as honestly as possible. Remind subject of the 10 minute test duration.

You may now start the test by pressing any key. Remember to work as quickly and as accurately as possible.

Instructions: RST3

Move the subject to the Vienna Determination Unit (VDU). Ensure that the subject is seated comfortably. The subject should rest their wrists on the bottom ledge of the VDU). Adjust the position of the foot pedals such that the subject's knees are flexed $\approx 120°$. The balls of the feet should rest lightly on the ribbed section of the respective foot pedals.

1. Please press down on the ribbed part of the *foot pedals*, left foot first, then right foot, then left again, and right again. You may have noticed that as you pushed the pedals, the two lights on the black surface in front of you lit up.
2. These two lights correspond with the foot pedals: the left light corresponds with the left foot pedal and the right light corresponds with the right foot pedal.
3. Now "switch off" the lights by pressing the correct foot pedal.
   Good!
4. You will now see various *colours* light up on the top part of the VDU.
5. Press the corresponding coloured button at the bottom of the VDU to "switch off" the colours.
   Good!
6. Lastly, you will be presented with two *tones*. There is a high tone and a low tone.
7. Listen to them by pressing the "L" key for the low tone and the "H" key for the high tone (indicate these buttons to the subject). Please press these buttons fairly quickly: low tone, then high tone, then low tone and high tone again. Do not worry if the tone remains on after you have pressed the buttons.
8. Now "switch off" the tones by pressing the correct key.
   Good!

Now you have a chance to practice all of these responses together. There is no need to rush during this practice, so please relax. As soon as you are ready, you may start by pressing the red button.
Good!

There will now be another practice phase, but now you must try and react to the signals as quickly and as accurately as possible. Try to get into a rhythm; if you lose the rhythm, just relax and try to pick it up again! As soon as you are ready, you may start by pressing the red button.
Good! Do you have any questions?

Before starting with the actual test, the subject is required to complete the PSS scale as quickly and as honestly as possible. Remind subject of the 12 minute test duration and that the test is divided into 3 parts (slow speed - fast speed - medium speed) with quick breaks in between each phase.

Remind the subject to work as quickly and accurately as possible. The subject may then start the test by pressing the red button.

After first phase: Good! That was the first part of the test. The second phase will be somewhat faster than the first phase. Remember to respond as quickly and as accurately as possible. Start by pressing the red button.

After second phase: Good! That was the second part of the test. The third phase will be slightly slower. Remember to work as quickly and as accurately as possible. Start by pressing the red button.

General Comments:

No feedback will be given to the subject during the test sessions. Any comments made by the subjects during and after the tests are to be recorded.

SUBJECT INFORMATION SHEET Testee Code: _________

1. Name: ______________________________
2. Date of Birth: ____/____/_____
3. Sex (M/F): ______

Please indicate your answers to the following questions in the boxes provided:

4. Would you consider yourself to be a "morning" person (wake up early, go to bed early), or an "evening" person (wake up late, go to bed late)?
   Morning ☐ Evening ☐

5a. Do you **prefer** to work during the morning, afternoon, or at night? Please rate your response (1 = most preferred; 3 = least preferred).
   Morning ☐ Afternoon ☐ Night ☐

5b. At what time of the day do you work at present? Please rate your response (1 = maximal workload; 3 = minimal workload).
   Morning ☐ Afternoon ☐ Night ☐

6. What measures do you take, if any, in order to remain alert while working?
   Exercise ☐ Coffee ☐ Brief Nap ☐ Take a break ☐
   Other (please specify) ______________________________

7. How many times per week do you engage in some form of (moderate-to-vigorous) physical activity?
   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐

SUBJECT INSTRUCTION SHEET

Data Collection Sessions:

MIDDAY: date:_______ MIDNIGHT: date:_______

time:_______ time:_______

Please try to adhere to the following prior to participating in the data collection sessions:

Prior to Midday Data Collection

For 2 days before collection:	-go to bed at ≈10pm and wake up at ≈7/8am
On the collection day:	-do not eat, or drink alcohol or coffee (or any type of stimulant) for ≈4 hours prior to the test
	-you may drink cooldrinks or water
	-work as usual prior to the test

Prior to Midnight Data Collection

For 2 days before collection:	-go to bed after midnight and wake up at ≈10/11am
On the collection day:	-eat dinner at ≈6/7pm
	-do not drink alcohol or coffee
	-you may drink cooldrinks and water
	-no social outings!
	-work as usual prior to the test

Please do not hesitate to contact me should any problems arise. Many thanks for your willingness to participate in this study!

Lynne Munton
g91m1977@warthog -OR- HMS: 318472

DATA RECORDING SHEET Testee Code: ________

TEST VARIABLE	MIDDAY Date:				MIDNIGHT Date:			
Test Battery No.								
Reference HR (b.min^{-1})								
PSS Rating (RST3)								
PSS Rating (Q11)								
PSS Rating (WPS)								

Comments:

RST3: am: ____________________

pm: ____________________

Q11: am: ____________________

pm: ____________________

WPS: am: ____________________

pm: ____________________

GENERAL: ____________________

____

____

PERCEIVED STRAIN SCALE

TASK DEMANDS (td)

On a scale of 1 to 10, how would you objectively (almost as an outsider) rate the demands of the task presented?

SIMPLE 1 2 3 4 5 6 7 8 9 10 *DIFFICULT*

BASIC 1 2 3 4 5 6 7 8 9 10 *COMPLEX*

PERSONAL ABILITY TO COPE (pac)

On a scale of 1 to 10, how would you rate your personal ability to cope with demands of the present task?

EFFORTLESS 1 2 3 4 5 6 7 8 9 10 *TAXING*

UNDEMANDING 1 2 3 4 5 6 7 8 9 10 *DEMANDING*

APPENDIX C: RESULTS

Example of a Heart Rate Curve for a CMT subject

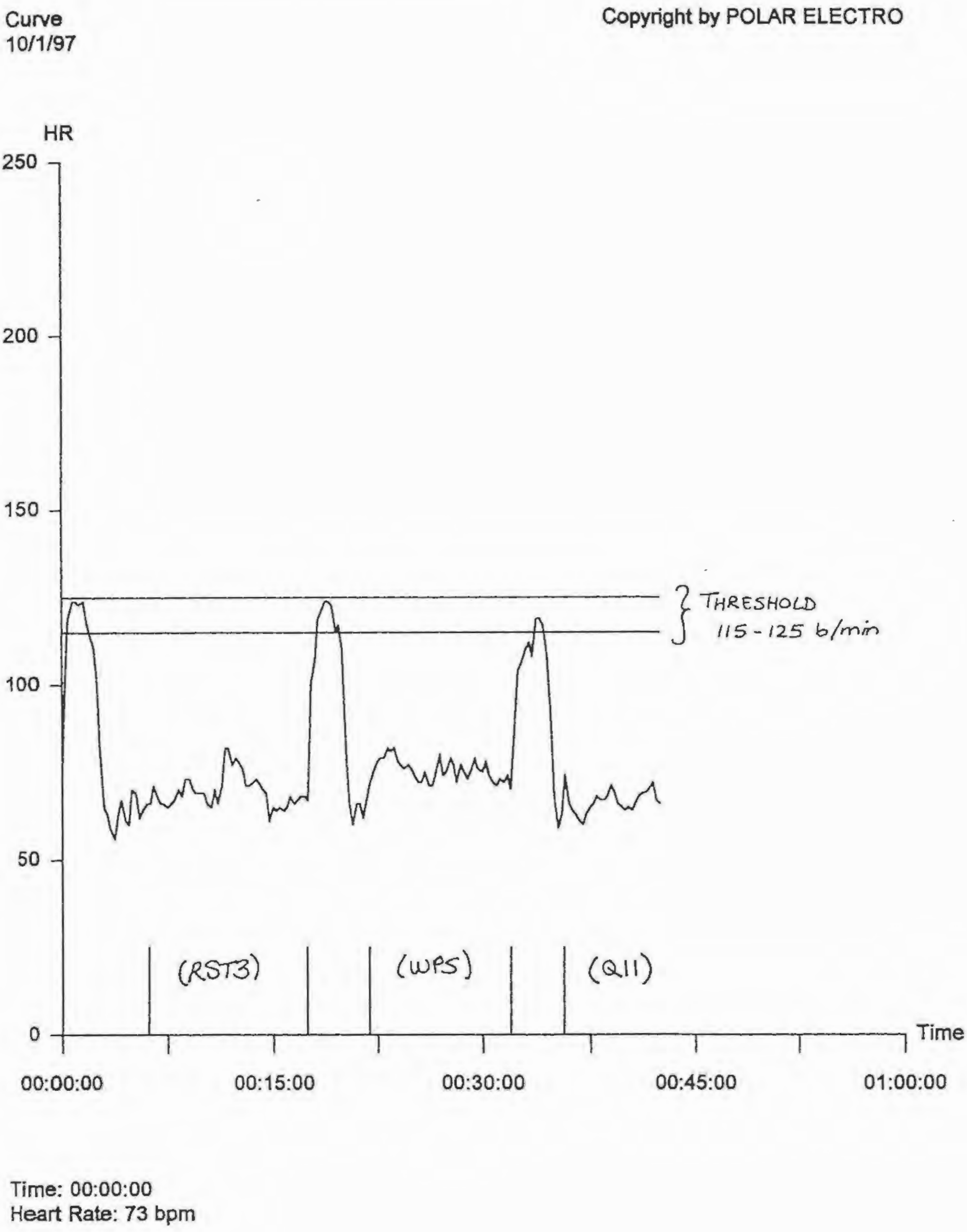
Example of Q11 Results Printout

Example of WPS Results Printout

Example of RST3 Results Printout

Subject Feedback Sheet

Example of a Heart Rate Curve for a CMT Subject



Q11

CONCENTRATION UNDER MONOTONY

Action test
No change in model figures
Test duration (min): 7

Testee code:
Date: 13-03-1997 - 06:08...06:21 (0:13)
Sex: female
Age: 22
Scoring code: erg.masters/pm 5

Parameter block: S 1
With practice phase

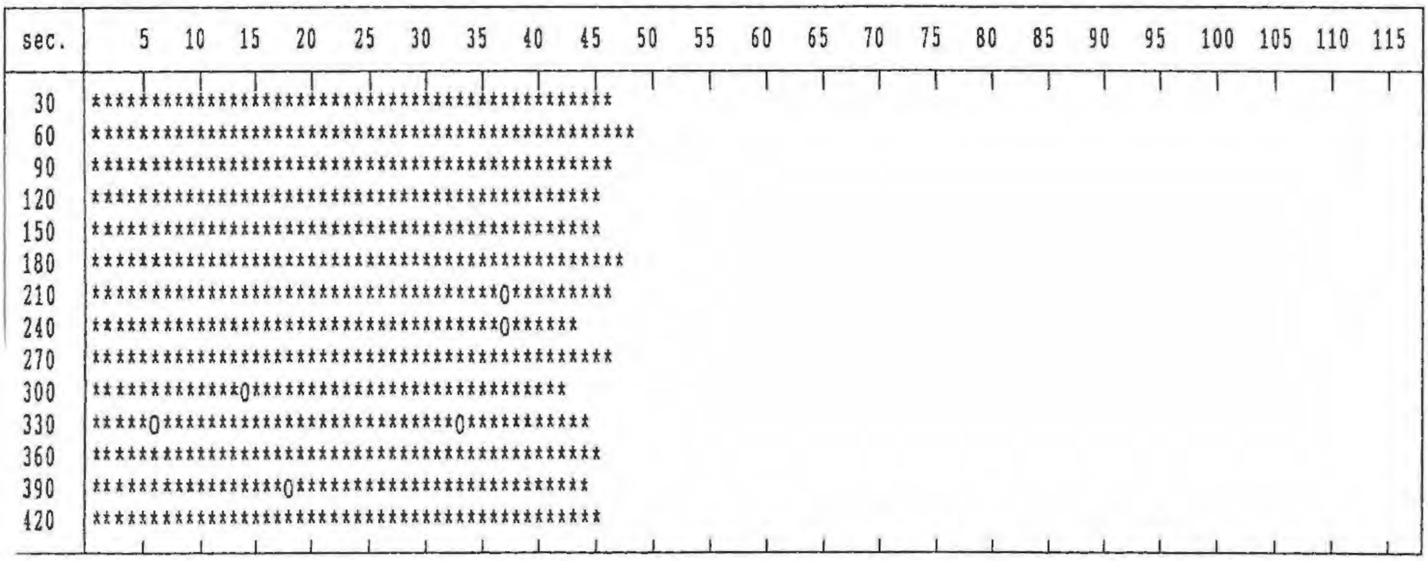
Items done : 632

Correct reactions : 626

Incorrect reactions: 6

% Incorrect : .95

Performance report: *...correct, o...incorrect



Work Performance Series

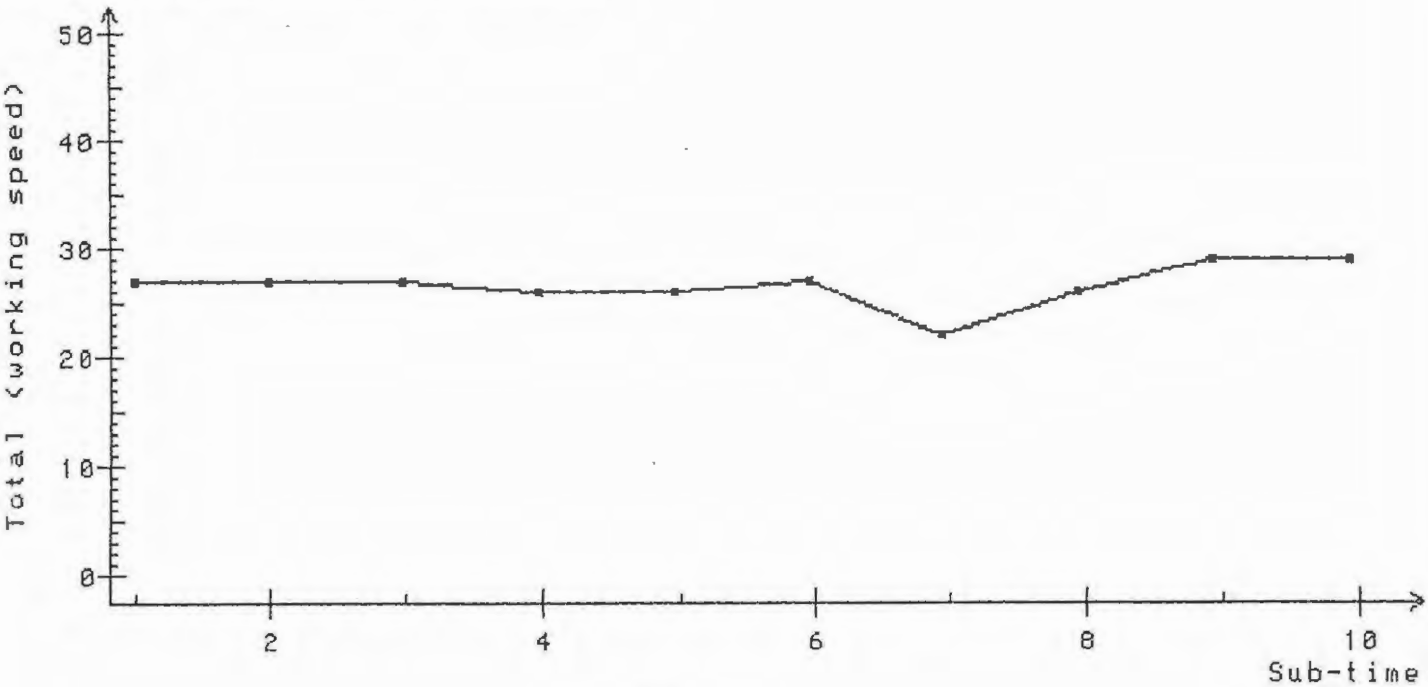
Assessing Work Performance and any Age-related or Sex-specific Variations - Occuring Therein	Testee code: Age: 22 Sex: female Education level: 5 Scoring code: erg.masters/pm Date: 13-03-1997 - 06:36...06:48 (0:12)

Parameter block: S 2 - R = Zo + Zu
No. of sub-times: 10
Number range of solutions: 1-17
Short-term memory part: Yes

Task: ALS-D (R = Nt + Nb)
Length of sub-time: 60 sec.
Practice phase: Yes

Table of results:

Test variable	Raw score
Total No. of responses	266
No. of correct responses	236
No. of incorrect responses	30
Percent Incorrect	11.28 %
Mean response time (sec.)	2.20
Std.dev. response time (sec.)	0.92
No. of corrections	0



R S T 3

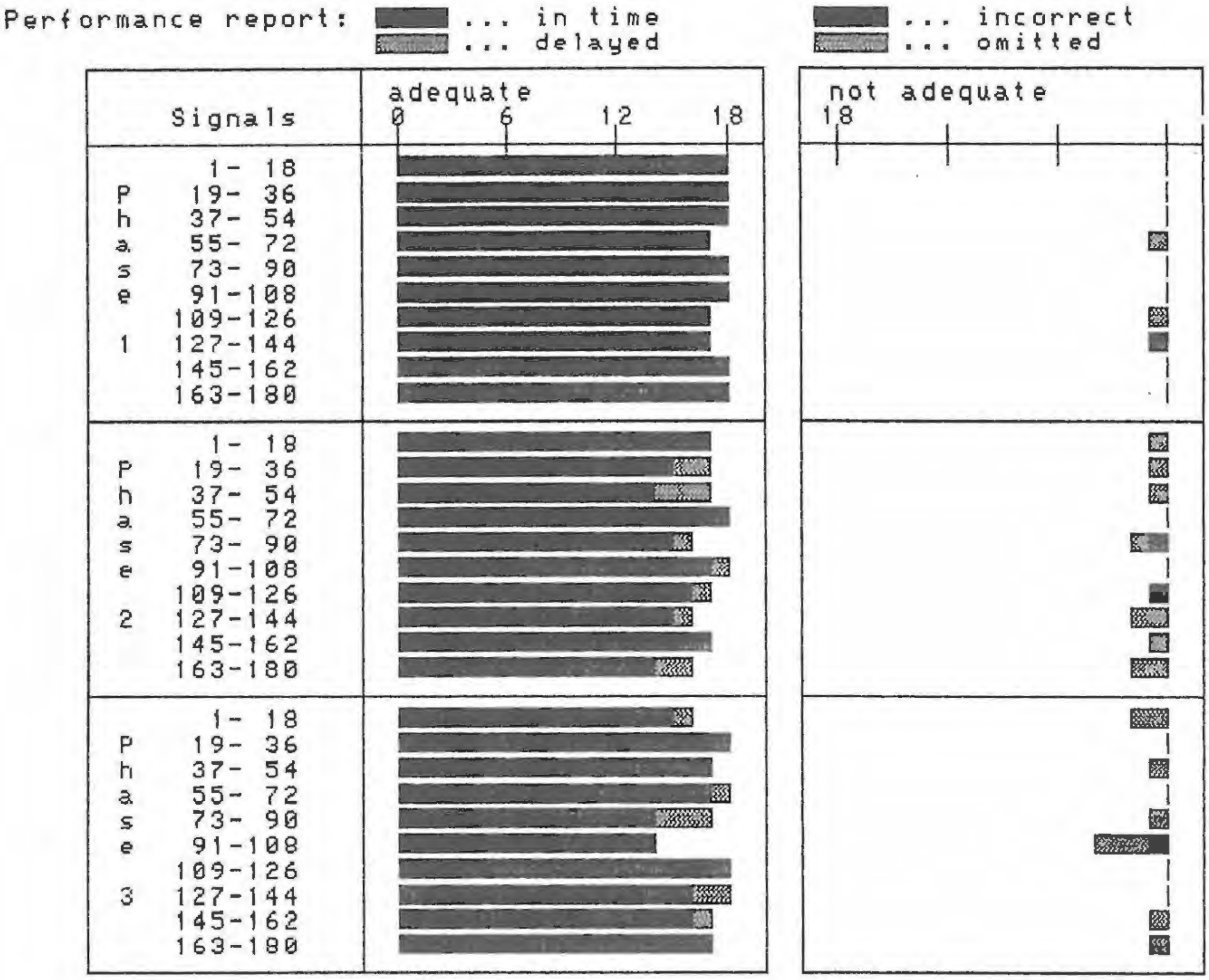
REACTIVE STRESS TOLERANCE
3 phases with 180 signals each
Phase 1: 38 signals/minute
Phase 2: 63 signals/minute
Phase 3: 56 signals/minute

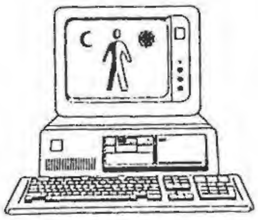
Testee code:
Date: 13-03-1997 - 06:21...06:36 (0:15)
Sex: female
Age: 22
Scoring code: erg.masters/pm 5

Parameter block: S 1 - RST3 - Standard 1
Alternative stimuli for: ---
With practice phase

Phase	correct	in time	delayed	omitted	incorr.	mult.rea.
1	177	177	0	2	1	0
2	169	158	11	9	2	2
3	170	162	8	9	1	4

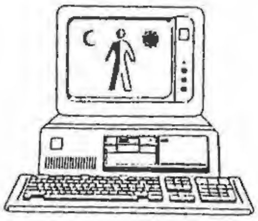
Reaction required		whi.	yel.	red	gre.	blue	r.f.	l.f.	h.t.	l.t.
		60	60	60	60	60	60	60	60	60
Reactions performed	white	58	.	.	.	.	.	.	.	.
	yellow	.	55	.	.	.	.	.	.	.
	red	.	.	55	.	1	.	.	.	.
	green	.	.	.	60	.	.	.	.	.
	blue	.	1	1	2	58	2	.	.	.
	r.foot	.	.	.	.	.	60	.	.	.
	l.foot	1	.	.	.	1	.	60	.	.
	h.tone	.	.	.	.	.	.	.	54	.
	l.tone	.	.	.	.	.	.	.	1	56


Performance report:
... in time
... delayed
... incorrect
... omitted
Signals
adequate
0 6 12 18
not adequate
18
Phase 1
Phase 2
Phase 3
1- 18
19- 36
37- 54
55- 72
73- 90
91-108
109-126
127-144
145-162
163-180



THE EFFECTS OF NIGHT WORK ON EFFICIENCY OF PERFORMANCE

SUBJECT FEEDBACK



CONCENTRATION UNDER MONOTONOUS CONDITIONS:

* *decide whether the bottom figure is the same as -press red key- or different to -press green key- the four figures on top*
* *measures attention performance under monotonous conditions*

TEST VARIABLE	MIDDAY	MIDNIGHT
No. items done		
Correct responses		
Incorrect responses		

Additional Comments: ______________________

WORK PERFORMANCE SERIES:

* *adding two numbers together, entering this solution and remembering the bottom number*
* *assessing concentration on numerical tasks done under time pressure*

TEST VARIABLE	MIDDAY	MIDNIGHT
Total no. responses		
No. correct		
No. incorrect		
Mean response time(sec)		
No. of corrections		

Additional Comments: ______________________

REACTIVE STRESS TOLERANCE:

* *reacting to audiovisual stimuli under low stress, high stress and medium stress conditions*

	Phase	Total correct reactions	No. in time	No. delayed	No. omitted	No. incorrect
MIDDAY	1					
	2					
	3					
MIDNIGHT	1					
	2					
	3					

Additional Comments: ______________________

____

____

____

Thank you once again for your willingness and enthusiasm to participate in this research project! If you have any queries, please do not hesitate to contact me.

Lynne Munton
Department of Human Movement Studies
E-mail: g91m1977@warthog.ru.ac.za