INVESTIGATION OF THE EFFECT OF SHORT DURATION BREAKS IN DELAYING THE ONSET OF PERFORMANCE RELATED FATIGUE DURING LONG DISTANCE MONOTONOUS DRIVING AT DIFFERENT TIMES OF THE DAY

BY

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ABSTRACT

Road traffic accidents are a serious burden to the health systems of many countries especially in South Africa. Research aimed at reducing traffic related accidents is of importance as traffic crashes are rated as the second leading cause of fatalities in South Africa and ninth in the world. Despite the extensive efforts into research and development of new technology, driver fatigue still remains a cause of vehicle accidents worldwide. Fatigue plays a role in up to 20% of vehicle accidents with many being serious or fatal. Numerous coping behaviours are employed by drivers to counteract the negative effects of fatigue. The most common coping behaviours include taking short naps, talking to passengers, listening to the radio, opening windows and drinking stimulants.

Driving breaks have long been identified as an effective countermeasure against fatigue. Most research done in driving breaks has investigated the duration of the breaks, activity undertaken during the break and the frequency of the breaks taken outside the vehicle. However limited literature is available on the effectiveness of breaks in counteracting the effects of fatigue. The objective of the current study was aimed at assessing whether short duration breaks are an effective countermeasure against fatigue. Physiological, neurophysiological, subjective and performance measures were used as indicators for fatigue. Additional focus of the research was determining whether breaks were more or less effective at counteracting the effects of fatigue at different times of day.

Twelve participants were recruited for the study, six males and six females. The participants were required to perform a driving task on a simulator for 90 minutes. The study consisted of four independent conditions, namely driving during the day with breaks, driving during the day without breaks, driving during the night with breaks and driving during the night without breaks. The without breaks conditions were similar except that they occurred at different times of the day, one session at night and the other session during day time, as was the case for the conditions with breaks. The driving task used in the current study was a low fidelity simulator tracking task. The participants were required to follow a centre line displayed on a tracking path as accurately as possible.

The measurements that were recorded in this study included physiological, performance, subjective and neurophysiological. Physiological measures included heart rate and heart rate variability (frequency domain) and core body temperature. The ascending threshold of the critical flicker fusion frequency was the only neurophysiological measurement included in the current investigation. Performance was quantified by mean deviation from a centre line participants were meant to track. Two rating scales were used: Karolinska sleepiness scale and the Wits sleepiness scale were used for the measurement of subjective sleepiness. Heart rate, heart rate variability and mean deviation were measured continuously throughout the 90 minute driving task. Critical flicker fusion frequency, temperature and the subjective scales were measured before and after the 90 minute driving task.

The results indicated that the short duration breaks during day time had a positive effect on driving performance; however the breaks at night had a negative effect on driving performance. Heart rate was higher during the day compared to night time and the heart rate variability high frequency spectrum values were lower during the day condition, to show the activation of the sympathetic nervous system which is characteristic of day time. The night conditions had lower heart rate values and higher heart rate variability high frequency values, which show the activation of the parasympathetic nervous system which is dominant during periods of fatigue and night time. Subjective sleepiness levels were also higher at night compared to day time.

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TABLE OF CONTENTS

Figure **List of figures** **Page**

List of tables

CHAPTER 1
INTRODUCTION

1.1 Background of the study

Road traffic accidents are a serious burden to the health systems of many countries especially in South Africa. Research aimed at reducing traffic related accidents is of importance, as traffic crashes are rated as the second leading cause of fatalities in South Africa and ninth in the world (World Health Organisation, 2005). Declines in performance during a vigilance task have been reported in many vigilance tasks, such as train driving, radar watching and driving. According to Lee (2007) the performance breakdowns during driving are as a result of driver attention. Four factors have been identified as major contributors to attention impairments: alcohol, fatigue, aging and distraction.

Despite the extensive efforts into research and development of new technology, driver fatigue still remains the major cause of vehicle accidents worldwide (Baulk *et al.,* 2008). Fatigue plays a role in up to 20% of vehicle accidents with many being serious or fatal (Horne and Reyner, 2001). According to the Road Traffic Management Corporation, 2009), 9% of all fatal accidents in South Africa are as a result of driver fatigue. Fatigue is often mentioned in accidents involving young drivers and truck drivers because these drivers tend to adopt risky strategies to drive at night and/or in a state of fatigue (Liang and Lee, 2010). Fatigue impairs the driver's information processing capability thus increasing the likelihood of various perceptual and attentional errors. Vigilance lapses caused by fatigue or monotony can pose a very serious injury risk, especially during driving. However one can never determine with certainty whether sleep related accidents are as a result of fatigue or hypovigilance. Grandjean (1979) highlighted the difficulty associated with determining with certainty whether the performance break down experienced during a vigilance task such as driving is due to hypovigilance was as a result of the monotonous nature of the task or the vigilance demands of the task are fatiguing. The management of fatigue on the road is made difficult by the fact that no on site tools are available for measuring fatigue on the road. Unlike other road issues such as speed and alcohol which can be easily measured with effective and accurate technologies, there are currently no effective on road measures for driver fatigue.

Drivers have extensive knowledge with regards to fatigue and the factors affecting fatigue while driving and most of them are aware of the effectiveness that different methods have in counteracting the effects of fatigue (Nordbakke and Sagberg, 2006). Despite this knowledge and in order to comply with time constraints, drivers often tend to continue driving while fatigued and take various strategies that are only partially effective in coping with fatigue (Oron-gilad and Shinar, 2001). The most common coping behaviours include taking short naps, talking to passengers, listening to radio, opening windows and drinking stimulants (Gershon *et al.*, 2009). According to Horne and Reyner (2001) only naps and caffeine provide temporary relief. All the other countermeasures have no scientific basis to support their effectiveness. It seems as if coping behaviours are influenced by the age and experience of the driver (Nordbakke and Sagberg, 2006). Older drivers tend to use more valid methods such as stopping for a nap whereas younger drivers tend to adopt coping methods that are easy to manage and do not require stopping the car.

A distinction exists also between coping behaviour used by professional and non-professional drivers. The methods used mostly by nonprofessional drivers include talking on a cellular phone or talking to passengers (Gershon *et al.*, 2004). These coping strategies are usually aimed at helping them pass the time, reduce their feelings of boredom and do not require advance preparation. The coping behaviours chosen by most professional drivers include stopping for a short nap, drinking coffee, shelling and eating sunflower seeds, smoking, stopping to exercise and washing the face. All these behaviours require advance planning and stopping (Oron-Gillard and Shinar, 2000).

Although professional and non-professional drivers use different coping behaviours, listening to the radio and opening the window were perceived by both groups as being effective and used frequently (Reyner and Horne, 2002). This indicates that drivers prefer to use countermeasures that are easily accessible and do not require pre-planning. It has been suggested that in-vehicle technological countermeasures are easily accessible because they are inside the vehicle and do not require pre-planning. Fatigue countermeasures in vehicles refer specifically to technological devices that provide in vehicle countermeasures to prevent fatigue.

The countermeasures that have been investigated include the Carmate® (Verwey and Zaidel 1999) and the interactive cognitive task (ICT) (Gershon *et al*., 2009). Both these authors reported that these countermeasures were effective at counteracting the effects of fatigue. However further research must be done to determine the effectiveness of in vehicle countermeasures and the time of day when these countermeasures are most effective.

The objective of the current investigation was to assess whether short duration breaks can be used to delay the onset of fatigue or/and prevent hypovigilance due to monotony. The investigation was based on the projections of some futurists (Asimov, 1990) that in the future, with the aid of Intelligent Vehicle Highway Systems the driving task could be completely automatic. Hancock and Parasuraman (1992) have projected that steering will be carried out by automated systems and that only high-level goals, such as the desired destination will be left to the driver. Substantial progress has been made toward achieving this goal. Some motor vehicles are now installed with anti-collision systems, cruise control, lane tracking. All these systems assist with the control of the vehicle (Regan, 2004). Based on the available technology, the envisaged completely automated vehicle could be realized in the near future.

Assistance systems that take over control have been introduced in other industries such as aviation. The automated systems in shipping and aviation have proven to be efficient and have increased performance (Parasuraman ,1998). Therefore the implementation of these systems to motor vehicles can be beneficial in many ways such as decreasing inter vehicle distance and traffic on the roads (Wright, 1990). One particular manner in which these systems could be used to benefit the driver was explored in this research. The introduction of automated systems in vehicles could provide the drivers with an opportunity to take microbreaks while these systems take over the driving task thus allowing the drivers to take a break while inside the vehicle. Taking breaks while driving could be beneficial in many ways. This could mean that drivers will not have to stop to take a break, this can be done while they are in the vehicle, and therefore they will not lose any time off their journey. Loss of time is one of the key reasons forcing drivers to continue with their journey although they might be fatigued (Brown, 1997). The study was designed to provide insight to whether micro-breaks taken while inside the vehicle would be an effective countermeasure.

The proposed intervention could shed light on to what actually happens during long distance monotonous driving, whether the performance decline seen over time is attributed to hypovigilance cause by monotony or actual fatigue. Performance decrements caused by hypovigilance can be alleviated by a change in stimulation, whereas fatigue requires rest in order to replenish the depleted resource. Therefore in cases of hypovigilance, the breaks are expected have a positive effect on driving performance as they will provide a change in stimulation allowing the drivers a break from the driving task. In the case of fatigue, whether the breaks will be effective will actually depend on whether the duration of the breaks was sufficient to replenish the resources. However, this is not a clear cut situation as fatigue can be affected by monotony, thus a change in stimulation could actually lead to an improvement in fatigue symptoms.

Time of day is also crucial in the development of fatigue, as individuals tend to experience the symptoms of fatigue at certain periods during the day, which coincide with natural circadian rhythm down regulation periods. Therefore in the study different periods which correspond to the body’s natural down regulation and up regulation were chosen. This was done to determine whether the onset of fatigue and or hypovigilance during long distance monotonous driving will develop and progress in the same manner during different times of the day. Moreover the aim was to also establish at what time of the day the micro-breaks would be mostly suitable for use as a countermeasure.

1.2 Statement of the problem

Driver fatigue has been a serious problem globally and is responsible for many traffic related incidences (Horne and Reyner, 2002). The management of both fatigue and hypovigilance is considered to be crucial, particularly for the maintenance of alertness and performance and the reduction in erroneous behaviour during driving (Åkerstedt *et al*., 2001, Van Dongen *et al*., 2003). In vehicle fatigue, countermeasures have the potential to delay the onset of drive fatigue and as a consequence prevent some of the fatigue related incidences. The aim of this study was to investigate the effectiveness of short breaks in delaying the onset of fatigue during long distance monotonous driving at different times of the day.

CHAPTER II:
REVIEW OF LITERATURE

2.1 Overview

The literature review of the current study has been divided into three sections. The first section addresses the prevalence of traffic incidents in developing countries, focusing on South Africa. Detailed information was obtained pertaining current trends in traffic incidents. The second section discusses the causes of traffic incidences in developing countries. The causes of the traffic incidences were grouped into three categories, human, vehicle and environmental factors. The main focus was on driver fatigue as a cause of traffic incidences, different types of fatigue and the common countermeasures used by drivers against fatigue. The last section is a review of the most common methods used for the analysis of driver fatigue, as there is no way to directly measure the extent of fatigue itself (i.e. no absolute measure of fatigue). All research concerning fatigue merely measures certain manifestations or indicators of fatigue (Grandjean, 1979).

2.2 Prevalence of road traffic incidences

Worldwide, road traffic injuries are a major cause of death and disability, with a disproportionate number occurring in developing countries (Amarentunga *et al.*, 2006). According to the Global Burden of Disease Study 2000, road traffic injuries ranked as the ninth leading cause of death and eighth cause of disability adjusted life years (DALYs) lost globally (Murray *et al.*,2001). Road injuries are projected to become the third leading cause of DALYs lost by 2020 if the current trends continue (Krug *et al.*, 2000).The overall traffic injury fatality rate for developing countries according to the World Health Organisation (WHO) database is estimated to be 20.7 deaths per 100,000 population, which exceeds the average of 15.6 deaths per 100,000 population for high income countries (Nantulya and Reich, 2002). Developing countries account for a much higher number of road global fatalities and injuries in proportion to the number of motor vehicles owned. In 1998 developing countries owned 32% of the global vehicles, however these countries accounted for more than 85% of the global fatalities and 90% of DALYs lost due to road traffic injuries (GRSP, 2001).

2.2.1 Prevalence of road traffic incidences in South Africa

South Africa which is a developing country has one of the highest injury rates in the world. In South Africa, traffic injuries are ranked second to interpersonal violence (Matzopoulus, 2004). The road traffic fatality rate is 39.7 per 100 000 inhabitants, which is almost double the global rate (Murray *et al.*, 2001). The proportion of deaths from traffic injuries in South Africa has been identified as one of a quadruple burden in combination with pre-transitional causes related to poverty and development, the emerging chronic disease burden and the HIV/AIDS epidemic (Bradshwaw *et al.,* 2002). The extremely high traffic injury mortality rate appears to be fuelled by several external factors, such as economic growth, migration, and active vehicle fleet.

The Arrive Alive safety campaign which was launched in South Africa in 1997 has revealed that there has been a steady rise in the number of road traffic related fatalities (RTMC, 2008). The numbers peaked in 2006, with over 16000 crashes occurring on the roads (Road Traffic Report, 2008). This rise in car crashes can be attributed to the economic growth in South Africa, which influences car sales and subsequently the active vehicle fleet. From the first quarter of 1993 to the second quarter of 2008 South Africa has experienced uninterrupted economic growth (Statistics South Africa, 2008). As the number of car crashes peaked in 2006, a similar trend could be observed in car sales, as 55122 new cars were sold in December 2006 in comparison to 49806 and 45110 in December 2005 and December 2007 respectively.

However as the economic crisis hit South Africa the, Gross Domestic Product (GDP) contracted in the third and fourth quarter of 2008, officially plunging the economy into recession (Statistics South Africa, 2008). The effects of the recession were reflected in the car sales and vehicle crashes. In December 2009 there were only 30470 new vehicles sold and the corresponding number of fatal crashes also went down to 10,857 (RTMC, 2009). No single external factor could account for the growing safety issue in South Africa, but active vehicle fleet seems to play a significant role.

2.2.1.1 Road traffic incidences based on the user group

According to the information received from the road traffic report (RTR) of 2009, for the period between 2008 and 2009, driver fatalities were 29%, passenger fatalities were 34% and pedestrian fatalities were 36% of all the fatal crashes. The data shows that compared to other road users' pedestrians bear the high burden of injuries and fatalities from road traffic crashes (Mabunda *et al*., 2007).

2.2.1.2 Road traffic incidences based on age group and gender

A study done by Mabunda *et al*. (2007) of the 7390 deaths recorded, 76% were male and 24% were female. Overall, there were 3.3 male deaths for every female pedestrian death (Mabunda *et al*., 2007).

Out of all of the fatalities 8975 recorded in 2009, 92% were males and 8% females. In 2009 the highest fatalities for male drivers was recorded for the 30 to 34 age group, with 16% of all fatalities occurring in this group, followed by the 25 to 29 age group with 13% of all traffic related fatalities occurring in this group. For the female drivers the highest fatalities were recorded in the 30 to 35 followed by the 35 to 39 age group, with 1.5% and 1% respectively, of all fatalities recorded (RTMC, 2009).

When considering all road users, more males are involved in traffic related fatal crashes in comparison to females. Alcohol misuse by male drivers has been identified as the single factor that contributes significantly to this situation. Information provided by the Medical Research Council shows that 61% of pedestrians and 59% of all drivers killed in road crashes were intoxicated. The pedestrian deaths between 2001 and 2004 showed that 62 %of males had blood alcohol concentration (BAC) of 0.22 g/100 ml in comparison to 42 % of the females were found to have a BAC of 0.21g/100 ml (Mabunda *et al.*, 2007). Alcohol misuse is a serious problem in South Africa, which has one of the highest alcohol consumptions in the world per head for all individuals who drink alcohol (Rehm *et al.*, 2003). Two thirds of all trauma patients, who were treated for injuries in trauma units in Cape Town, Port Elizabeth and Durban between 1999 and 2001, had a blood alcohol concentration greater than 0.05 g/100 ml.

The high exposure of males to traffic accidents has also been attributed to their greater exposure to traffic. Although most motor vehicles drivers are males, a high proportion of males involved in traffic related accidents are pedestrians, passengers or cyclists suggesting the co-existence of other social and behavioural factors contributing to their vulnerability (Zwi *et al.*, 1993). Masculinity also plays a role in placing male drivers at a higher risk of traffic related accidents. The dominant ideals of masculinity across all racial groups are predicated on a striking gender hierarchy with demonstration of toughness, bravery and defence of honour, readily translated to risk-taking behaviour (Hearn, 2007). Some of the road deaths particularly those caused by speeding and drunk driving can also result from enactment of toughness and risk taking (Ratele, 2008).

2.2.1.3 Road traffic incidences based on day of the week and time of the day

Almost one quarter of all fatal weekly crashes during the period between January 2009 and December 2009 in South Africa occurred on Saturday and 60% of all 8975 fatal crashes in 2009 took place over weekends from Friday to Sunday (RTMC, 2009). The greater incidence of traffic accidents occurring over weekends was also reported by other researchers (Odero *et al.*, 1997). They reported that 52% off all traffic incidences occurred over weekends. Pedestrian deaths also peaked on Saturday, with 24% of all the recorded 7364 deaths, followed by 17.2 % on Sunday (17.2%) and 15.5 % on Friday (Mabunda *et al.,* 2007).

According to the road traffic report (2009) most fatal accidents occur between 18:00 and 21:00. Evidence from other studies shows a higher incidence occurring during the day (Odero *et al.*, 1997). This could be attributed to the high traffic volume during the day, resulting in greater risk of accident involvement as people travel to work, children go to school and commercial enterprises are open for business. The decline in traffic casualties at night may be explained by less night time activity and travel. There are some indications from both developing countries and industrialised countries that the case of fatality rate is higher for night time crashes than for those occurring during the day (Odero *et al.*, 1997).

Darkness and reduced visibility have been suggested as contributing factors at night but do not fully explain the high incidence of more severe injuries occurring between 18:00 and 24:00, which progressively decline as the night advances. The peak in accidents during this time has also been attributed to alcohol consumption (Nelson and Struber, 1991. The high fatality rates for night time crashes may also be explained by delays in reporting injuries and less efficient medical emergency services at night due to lower staffing levels within emergency units (Odero *et al.*, 1997).

2.3 Causes of road traffic incidences in developing countries

Several external factors have been identified as directly contributing to the escalating numbers of people killed on the roads in developing countries. This paragraph highlights the factors which have been reported to have a significant contribution to road traffic incidences.

2.3.1 Poor enforcement of traffic safety regulations

Stricter enforcement of driving laws and pedestrian regulation may assist in the reduction of traffic fatalities (Ameratunga *et al.,* 2004). If all current safety laws could be adhered to in the European countries serious injuries could be reduced by 50% (European Transport Safety Council, 1999), similar benefits could be seen in developing countries as well. Although most countries have set maximum speed limits, enforcing the limit is still a challenge in most developing countries, where most fatal crashes are attributed to exceeding the speed limit (Wu *et al.,* 2003; Sukhai and Seedat, 2008). Research conducted in other countries demonstrated that strict enforcement of speed regulation measures may be effective in preventing serious injury and fatalities from motor vehicle crashes (Engel and Thompson, 1992). In the United Kingdom the use of speed cameras has led to a

56% decrease in the number of pedestrians killed or injured (Organisation for Economic Co-operation and Development, 2003).

Stricter laws with regards to the regulation of alcohol sales could also be beneficial in reducing the number of traffic injuries and fatalities. Driver intoxication appears to play a huge role in most fatal accidents. In South Africa, legislation sets the driver maximum blood alcohol at concentration at 0.5 g/100 ml. However in 2001, 47% of all drivers killed in motor vehicle collision were above the legal limit (Matzopoulos, 2001). A study performed in the United States of America showed that the incidence of alcohol related mortality in motor vehicle crashes was lower during periods of zero tolerance and administrative license revocation laws were in effect (Villaveces *et al.,* 2003).

The use of seatbelts is one of the most simple and yet effective ways of reducing the severity of driver as well as occupant injuries (Wang *et al.,* 2003). Although the use of seatbelts has been made law and some vehicles are now installed with devices that force drivers and passengers to put on their seatbelts, utilisation of seatbelts in developing countries is still relatively low (Harris and Olukoga,2005;El-Sadig, 2004). When seatbelts are used they can reduce the risk of serious and fatal injuries by 40% and 60% respectively (Peden *et al.*, 2004).

2.3.2. Socioeconomic status

The relationship between socioeconomic status and road traffic injuries in developing countries has not been systematically investigated (Nantulya and Reich, 2002). However available evidence suggests that poor people bear the higher burden of morbidity and mortality from road traffic accident in developing countries. Populations with the greatest traffic injury burden are pedestrians, cyclists and passengers of buses, trucks and minibuses, and these road users typically belong to the low socioeconomic group (Nantulya and Reich, 2003). A study performed in Kenya found that 27% of commuters who had never been to school walked, 55% used public transport. On the other hand those with secondary level 81% travelled in private vehicles, 19% used public transport and none walked (Kapila *et al.,* 1982). The level of education affects income, which in turn influences the choice of transport and the associated road traffic risks. People with little formal education earn low incomes, therefore cannot afford expensive means of transport. The means of transport frequently used by poor people include walking, cycling, travelling by bus or truck. Individuals who walk or cycle are at a higher risk of traffic injury because they must compete with fast moving vehicles for space on multipurpose streets or roads making them vulnerable to traffic crash injuries (Nantulya and Reich, 2002). The disproportionate burden of morbidity and mortality in low and middle income countries, and among low socioeconomic groups in those countries illustrates problems of global inequities in health.

Socioeconomic status influences access to quality health care (Whitehead, 1992). In developing countries the public health infrastructure is usually not well equipped for providing emergency medical care for traffic injuries (Mock *et al.*, 1997). This is the case in many public health facilities where most items needed for the management of injuries are not available. The impacts of the poor health care infrastructure are mostly felt by the low socioeconomic group, as these individuals cannot afford the medical care provided in private hospitals and have no other alternative but to use the public health facilities. The poor public health infrastructure means that patients do not always receive the appropriate care immediately (Elechi and Etawo, 1990). This delay can compromise the patient's recovery as there is a strong correlation between the likelihood of adverse health outcomes and long term disability occurring (Trunkey, 1990).

2.3.3 Public transport system

The public transport system in developing countries is not usually well developed (Odero *et al*., 2003). Instead an informal transport mode has evolved to fill this gap, consisting of privately owned buses, minibuses and pickup trucks (Nantulya and Reich, 2002). This mode of transport has become a major player in easing the burden on fare-paying members of the public in many countries. This mode of transport falls between the private automobile mode and the conventional public transport system and has both positive and negative attributes. On the positive side, this mode of transport is accessible to the low socioeconomic group and there is also the added convenience of stopping anywhere to pick up or drop off passengers with unfixed time schedules However, in many countries passenger overloading, aggressive acceleration and disregard for other road users are some of the negative attributes of this mode of transport (Van Schoor *et al*., 2001; Afukaar *et al.,* 2003; Zwi *et al.*, 2003). The drivers of these vehicles work long hours to pay vehicle owner’s daily fees, resulting in fatigue, sleep deprivation, overloading, reckless driving and high vehicle speeds (Nantulya and Reich, 2002). The combination of these factors predisposes the passengers to high risk of injury due to the high rates of involvement of these vehicles in fatal road crashes (Connor *et al.*, 2002). The failure to regulate the long distance bus industry has also produced some problems. The tendency to favour commercial gain over the safety of passengers has meant that overnight bus travelling has become the norm despite the high death toll caused by driver fatigue which is aggravated by overnight driving (Connor *et al.*, 2002)

2.4 Causes of traffic incidences in South Africa

Causes of traffic incidences are circumstantial and involve the interaction of a number of pre-crash factors that include human, vehicle and road environment. In South Africa human factors contributed more than 82% off all fatal crashes in 2009, followed by vehicle and road environment factors which contributed 10% and 8% respectively. It is very rare that a vehicle crash happens as a result of only one contributory factor. In most cases there is an interaction of all the different factors. Ninety five percent of all road accidents occur as a direct result of traffic offences or noncompliance with prescribed norms and standards.

2.4.1 Traffic incidences attributed to human actions

Within the human domain several factors have been identified as being responsible for most of the traffic incidences. Driving beyond the recommended speed limit, intoxication, and not obeying the traffic rules are some of causes of the traffic crashes. Information provided by the South African Department of Transport shows that within the human or driver factor group, as reported by the respective investigating officers, excessive speed or speed too fast for circumstances was a factor in 35% of fatal crashes; pedestrians jaywalking 32%,unsafe and un-lawful overtaking 7%, and 4% to driver fatigue (Road Traffic Management Cooperation, 2009).

According to numerous researches alcohol intoxication during driving is a serious problem in South Africa (Myers, 1977; Pluddemann *et al.,* 2004). According to the 2009 Road Traffic Report the percentages of intoxicated drivers was 1.6%, and for intoxicated pedestrian and cyclist it was 0.6% and 0.1% respectively. Therefore the figures do not appear to reflect the true situation taking place on South African roads. These figures are in contrast to the information provided by the Medical Research Council (MRC), 2007 which shows that 61% of pedestrians and 59% of drivers killed in road crashes were under the influence of alcohol. The differences in the percentages could be attributed to the fact that police and traffic officers are not always able to take alcohol breath samples on the incident scene. In other instances the driver or the passenger may have been seriously injured in the car crash making it impossible to take such test.

2.4.2 Traffic incidences attributed to vehicle factors

Although human actions contribute the most to all traffic accidents it would be unreasonable to only concentrate on human factors as crashes occur as a result of many factors. Not much research has been performed on vehicle factors, as more attention has been on human factors, as this type of research requires more manpower, man hours and logistical support (Van Schoor *et al.,* 2001). A study conducted by the National Institute of Road Research South Africa in 1986 found that vehicle factors alone contributed more than 2% to traffic related incidents (Pienaar, 1986). Faulty braking systems, un-roadworthy vehicles and tyre bursts were some of the factors that contributed to the traffic related incidents. A Potential Mechanical Defects Test PMDT was performed on small passenger vehicles and taxis (Van Schoor *et al.*, 2001). The (PMDT) was a road side survey which collected information with regards to the vehicle (make, model, year, and mileage) as well as the safety condition of the vehicle by actual inspection. The conclusion drawn from these tests was that the condition of the vehicles tested was identified as an area of concern, with tyres and breaks and overloading being the most prevalent. Overloading was a problem with the taxis on the high way whereas in sub-urban areas there was a higher prevalence of tyre and brake defects. Similar results were reported in 2009 where, tyre burst due to damaged and smooth tyres was a factor in 36% of fatal crashes; faulty brakes 25% and unsafe and faulty steering 24 % (Road Management Traffic Cooperation, 2009).

2.4.3. Traffic incidences attributed to road environmental factors

In the Road Traffic Report of 2009, sharp road bends contributed to 28% of fatal crashes; poor condition of the road such as potholes and rutting contributed to 20% and poor visibility due to fog, mist, rain and smoke contributed 15% (RTMC 2009). The vehicle and road factors given above are further aggravated by excessive speed and speed too fast for circumstances; drivers driving under the influence of alcohol, unfit vehicles and driving without a valid driving license or a professional driving permit. Additional factors include general reckless, negligent, and aggressive driver behaviour.

2.5 Driver fatigue and vigilance

Fatigue occurs as a result of an imbalance between resource utilisation and resource replenishment (Brigder, 2003). This imbalance leads to a situation where the resources are used up faster than they are replenished leading to fatigue. Fatigue increases with time on task and the countermeasure is rest (Fisher *et al.,* 1993). Despite the emphasis that has been placed on the concept of fatigue and its related negative consequences, the condition itself has no clear definition (Åkerstedt *et al*., 2003). It has been described as multidimensional in its origin and as such, is complex and difficult to objectively assess, as it is a very personal experience (Brown, 1982). In a broad sense, fatigue depicts the disinclination to continue the task at hand and a progressive withdrawal of attention from road and traffic demands (Brown, 1994). Thus it tends to be described in terms of its consequences rather than its causes (Brown 1994). There is however, a general recognition that fatigue results from not only prolonged activity but also from psychological, socioeconomic and environmental factors that affect body and mind (Brown,1994).

Vigilance is the state of readiness to detect and respond to certain specified small changes occurring at random time intervals in the environment (Mackworth, 1957). The ability to detect and respond to a specific stimuli, depends on the levels of alertness and being able to sustain and maintain this state of alertness, thus vigilance can also be described as the ability to maintain attention to a task for a period of time (Parasuraman, 1998). Fluctuations in vigilance and a decrement in particular, constitute a serious risk in traffic safety. Vigilance fluctuations have a negative impact on driving safety during daytime driving especially under monotonous conditions (Schmidt *et al.,* 2009).

2.6 Theories relating to fatigue and vigilance

2.6.1 Arousal theory

The arousal theory states that the decrement in vigilance during a vigilance tasks is a result of a lack of stimulation (Eysenck, 1982). Arousal is defined as a short acting, task-induced phasic change related to the level of stimulation (Pribam and McGuinnes, 1975). Stimulation is required to sustain attention and when this stimulation is not sufficient a decrease in alertness will be observed (Smit *et al.*, 2004). Arousal is seen as a function of the stimulation from the task and environment, and therefore performance decrements observed during prolonged monotonous tasks can be explained as a reduced stimulation from a virtually unchanging or repetitive task environment (Brown, 1982). Fatigue is reported to occur when an individual is in a state of reduced attention capacity (Desmond and Hancock, 2001), with attention being affected by a reduced state of non-specific arousal (Mascord and Heath, 1992). This reduction arises from two distinct conditions: either an individual’s attention is depleted by a constant, unavoidable demand placed on it, or a chronic under-stimulation occurs, where attention decreases in an adaptive response to the reduced sampling of the environment (Desmond and Hancock, 2001).

According to the arousal theory when driving in a non-stimulating environment, such as driving in a monotonous road, a decline in performance should be expected (Schmidt *et al.*, 2009). However an increase in arousal does not necessarily imply better performance because there is a threshold of acceptable arousal after which attention decreases. Performance in vigilance tasks follows an inverted U-shape function of arousal. Figure 2.1 shows the inverted U- shape function of arousal indicating that when arousal is either too low or very high, then driving performance would be poor (Thiffault and Bergeron, 2003b).

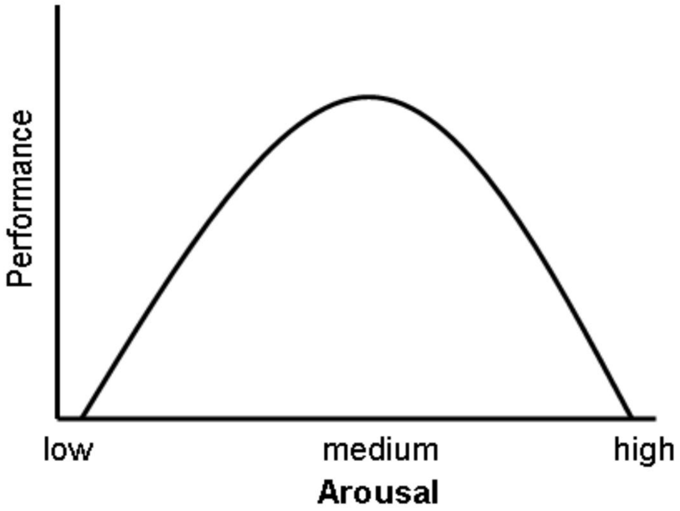

Figure 2.1: The Inverted U-shape function of arousal (Schmidt and Wrisberg, 2000 pg 16.)

The arousal theory also takes into account the uniqueness of each individual, and acknowledges that not all individuals will have the same reaction to low arousal. Optimal levels of arousal depend on the individual (Verwey and Zaidel, 1999).

2.6.2 Habituation theory

The habituation theory states that vigilance cannot be maintained under conditions of repetitive stimulation due to perceptual habituation (Parasuraman, 1985; Stroh, 1971). According to Mackworth (1969) monotonous situations create habituation, which ultimately results in a decreased arousal response of the cortical activity. This reduces the ability to detect critical signals causing a vigilance decrement. The first presentation of a stimulus or the presence of a novel or incongruous stimulus in the environment, leads to an increased arousal and mobilisation of attention. After several repetitions of the stimulus, the responses tend to decrease and disappear. However, a change in stimulus leads to a reappearance of the response, with a corresponding increase of arousal and attention. The process of habituation is dynamic in nature therefore making it distinct to fatigue (Schmidt *et al.*, 2009). A change in the stimulation can result in an immediate improvement of performance whereas fatigue requires rest to regain performance (Shen *et al.*, 2006). This theory extends its knowledge from the arousal theory in the area of monotonous tasks. It highlights the fundamental difference between the impact of monotony and fatigue and suggests that different driving counter measures should be applied to deal with these conditions. Applying this theory to the driving task implies that when driving in a monotonous environment could lead to driver fatigue by decreasing arousal and attention (Dalziel and Soames-Job, 1997). A change in stimulation or the introduction of a novel or incongruous stimuli could lead to temporary increase of arousal and attention.

2.6.3 Information processing model

Wickens (1980) explained how humans interact with information on a basic level and conceptualises this process as a sequence of information processing stages. This model describes a qualitative model of human information processing that incorporates stages which are used to perceive sensations, transform data and choose each action. Each stage takes time to perform, and any additional considerations such as uncertainty can extend performance time (Wickens, 1980). Information collected in the environment by the five human senses has to be sent to the brain for information processing. The sensory memory is concerned with the visual and auditory senses of the eyes, ears and the proprioceptive or kinaesthetic senses of the body and limb position. Therefore the information collected by the senses goes to the sensory memory. Wickens (1992) posits that all processes that follow this stage may be influenced, as each sensory system has a unique limitation which influences the quality and quantity of information that may be originally registered. Information from the sensory memory is passed to stages of perception, at which point the stimulus is identified or categorised in terms of previously learned or stored neural codes in the brain (Wickens, 1992).

The perception stage is processed automatically and requires little attention. Perception is driven by both sensory inputs and long term memory inputs. Following recognition, information is passed to decision and response selection and execution processes in which its implications for actions are assessed, including the choice of a response (Wickens, 1992). Cognition is distinguished from perception by the amount of time required to process information as well as mental effort or attention involved (Louw, 2010). As with most closed loop feedback systems, this system is in dynamic interaction with the external world and is driven by feedback signals. Wickens (1992) describes the attentional aspects of the system as being represented by the model labelled attentional resources (figure 2.2). Resources are needed during task performance and these resources are limited in their availability (Wickens, 1984). Attentional capacity or attentional resources are often applied to explain performance in multiple component tasks such as driving. Performance decrement is reported when there is an insufficient quantity of resources available to match the demands for the resources made by the task or tasks performed (Smit *et al*., 2004). Prolonged performance on tasks is thought to deplete the pool of resources (Parasuraman, 1985) although the mechanism for this depletion is not known (Matthews *et al*., 2000). Moreover, as tasks become more difficult, they require more resources.

Information processing can operate in two different modes: automatic and controlled modes. Automatic processes are performed without awareness and are usually established over longer periods of time. Automatic processes require limited attention resources, are not affected by interference and are difficult to modify once learned, as in the case of driving. Controlled processes are intended and can be easily established and altered (Wickens, 1992). Controlled performance is closely related to perceptual and kinaesthetic feed-back which can only be achieved by applying effort and allowing for variation in levels of alertness (Wertheim, 1991). However after experience and training, skilled performance becomes possible and automatic processes are favoured where external feedback is no longer required (Thiffault and Bergeron, 2003).

Performance under the automated mode relies more on internal motor programs and very little external feedback is required, very little effort can be invested, reducing the opportunity to increase feedback at will. This situation can lead to a decrease in alertness and arousal. As a consequence, when driving on a monotonous or highly predictable road, performance becomes automatic, limiting the need for external feed-back as well as the investment of effort which could lead to an increase of arousal (Thiffault and Bergeron, 2003). During automated performance drivers may fail to pick up the relevant external cues and as a result fail to respond appropriately to road situations. Although this theory has its limitations, it stands as a useful simplifying framework for interpreting human performance in simple and complex tasks. Figure 2.2 shows a schematic diagram for the information processing model.

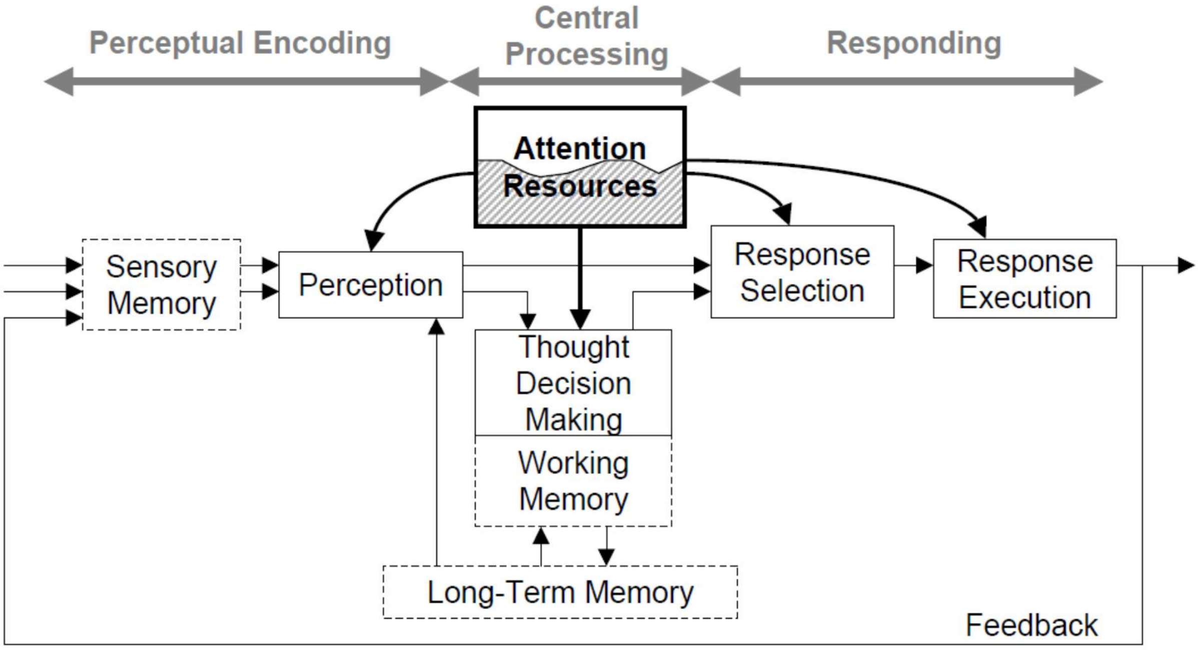

Figure 2.2: Model for human information processing (Wickens, 1992, Pg 56)

2.7 Factors favouring the development of fatigue

Several factors have been identified as being directly responsible for the development of fatigue. These factors have been classified as either being endogenous or exogenous. Endogenous factors are those factors that stem from within the organism and exogenous factors are linked to the task itself or the interactions between the driver and the outside environment.

There is a continuous interaction between exogenous and endogenous factors and it is the joint influence of both these factors that ultimately determine the alertness and vigilance at any point during driving.

This implies that both exogenous and endogenous factors need to be looked at when investigating vigilance. Figure 2.3 gives a summary of all the factors favouring the onset of fatigue.

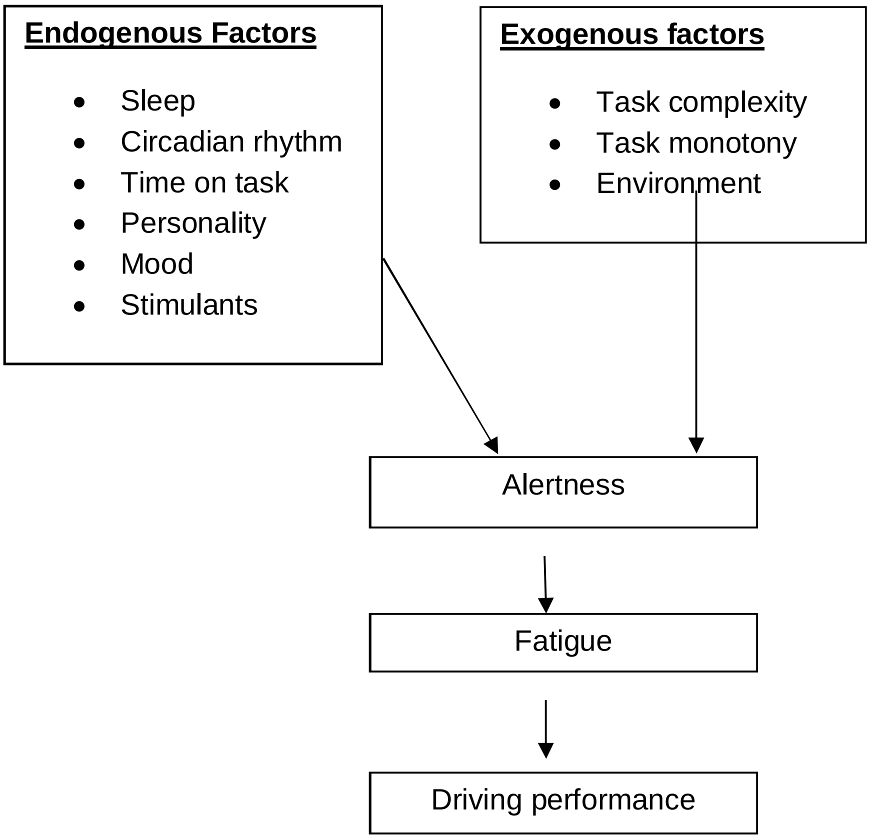

Figure 2.3: Summary of factors favouring the development of fatigue

2.7.1 Endogenous factors

Endogenous factors emanate from within the organism and are associated with long term fluctuation of alertness of the organism. Endogenous factors are reported to impact directly on the preparation state of the individual when performing the task (Thiffault and Bergeron, 2003). Besides the endogenous factors summarised in Figure 2.3 other endogenous factors include both physical and mental fatigue. Personality dimensions mood, introversion or extroversion and sensation seeking levels are all considered as endogenous factors (Zuckerman *et al.,* 1971). Caffeine and other stimulants as well as the cognitive demands are also considered as endogenous factors.

2.7.1.1 Time of day and age

There is a strong relationship between driving at certain times of the day and the risk of accidents. Individuals, between the ages of 18 and 25 years seem to be at an increased risk of being involved in fatigue related accidents late at night and during the early hours of the morning (Summala and Mikkola, 1994). For the young driver, fatigue peaks between midnight and 06:00. This period corresponds with the circadian trough, where arousal is naturally lower. Moller *et al*., (2003) state that during the night and early morning (22:00 to 06:00) young drivers are at an increased risk of being involved in collisions because of the natural dips in the body's circadian rhythms. In a driving simulator study done to investigate the effects of time of day on driving performance at six periods over a day, most impairments in driving were reported during the early morning (02:00 and 06:00) and in the early afternoon (Lenne *et al*., 1997).

Young drivers have a better capability of resisting fatigue in comparison to older individuals, however this ability is masked by the fact that younger individuals do not avoid driving at night when circadian and task related fatigue are at a naturally higher level (Summala and Mikkola, 1994). Moreover younger drivers are more sensitive to motivational pressures, as a consequence are more inclined to avoid or delay taking a break from driving, despite feeling fatigued (Summala and Mikkola, 1994). On the other hand when older drivers drive at night they are more likely to take a break when they are fatigued (Summala and Mikkola, 1994).

Summala and Mikkola, (1994) reported that young truck drivers were involved in more fatigue related accidents in comparison to older drivers. Young truck drivers also showed a peak in fatigue cases at night. This might be due to the fact that with increasing age older drivers might avoid night driving leaving the younger drivers to do it. With increasing driving experience, older drivers might have more efficient and effective ways of dealing with fatigue which might not be the case for younger truck drivers (McDonald, 1984).

Older individuals are not immune to fatigue related accidents, but their accidents peak at a different period. During the day older drivers are expected to suffer from more attentional lapses attributable to fatigue (Summala and Mikkola, 1994). Older persons suffer from circadian fatigue in the afternoon especially after a meal, as a result the task demands during the afternoon peak traffic may exceed their capacity (Hakamies-Blomqvist, 1993). With increasing age driving ability tends to decline with the associated health declines (Wood, 2002). The decline is related to the changes that occur in the visual, auditory, and cognitive pathways which have a negative impact on various driving related actions (Llaneras *et al.,* 1993). Older drivers are often cognisant of the difficulties entailed with the driving task and self-regulate by driving only under conditions in which they feel safe (Reimer *et al*., 2007). Although the older individual has less capacity to deal with fatigue in comparison to younger individuals, their driving experience can sometimes compensate for this reduced capacity (Hakamies-Blomqvist, 1993). In circumstances where there is reduced visibility older drivers compensate by driving slower Therefore it is advisable that this group of drivers should avoid driving at the periods of the circadian dip which occurs between 14:00 and 16:00 as they are more vulnerable to the effects of fatigue during this period.

2.7.2.2 Alcohol

Alcohol use is the other factor that might increase the risk of fatigue related accident in younger individuals at night (Reimer *et al*., 2007). This might be an important consideration for countries like South Africa where alcohol related accidents are reported to contribute to 78% of accidents that occur at night (RTMC, 2009). According to Horne and Reyner (2001), alcohol might be twice as potent at night and early hours of the morning where circadian rhythms of daily alertness are low. Although Blood Alcohol Concentration (BAC) might be the same, the effects on the brain are different when the person is already sleepy or fatigued. Therefore the interaction between alcohol and fatigue might place the young driver at an increased risk especially when driving at night. Alcohol seems to have a multiplying effect, the more one suffers from the midnight dip, the more potent the effect of alcohol will be (Horne and Reyner, 2001).

2.7.1.3 Gender

Males are more vulnerable to fatigue related accidents during low alert periods of the day (Chipman and Jin, 2009). One of the possible explanations in countries such as South Africa is that more males in comparison to females have a driver's license and are driving on the roads (RTMC, 2009). Most professional truck drivers are males, thus are more vulnerable to fatigue related accidents because of their increased exposure to the roads. Moreover males are more prone to taking risks and drive late at night under the influence of alcohol during early hours of the morning (Liang and Lee, 2010).

2.7.1.4 Time on task

When performing a dynamic task such as driving, attention must be maintained for an extended period of time against effort cost, if motivation to invest effort is low, performance may deteriorate. Therefore in this context time-on task refers to the deterioration of driving performance while performing a driving task that requires sustained attention.

An important question researchers have tried to answer is the time it takes for this deterioration to occur. Knowledge of the exact time it takes for the development of fatigue can assist in creating guidelines, which regulate the amount of time professional drivers can spend behind the wheel (Vanlaar *et al.,* 2008). In the USA drivers are required to drive 8 hours with an hour break (Brown, 1982). Nilsson *et al.,* (1997) reported that subjective fatigue symptoms can develop after 60 minutes of driving. Lisper *et al.,* (1986) and Miller and Mackie (1980) reported that it took between 7 and 12 hours for the development of fatigue related symptoms. Under controlled laboratory conditions, one can observe indications of fatigue in some subjects after 60 minutes of driving or vigilance task (Galinsky *et al*., 2000). O'Hanlon (1981) investigated the time it took to observe declines in driving performance. He reported a decline in steering performance within half an hour of driving, in drivers who had no sign of being exhausted prior to the commencement of the drive. Long distance driving has been identified as being a serious problem since reaction time is shown to decrease with each hour of driving (Philip *et al*., 2003).

2.7.1.5 Sleepiness and sleep deprivation

Sleep is a state that comprises a complex combination of physiological and behavioural processes. Santos *et al*., (2007) indicated that sleep has some manifestation such as a cyclic pattern, relative immobility and increased threshold to external stimuli. Sleepiness is a concept that is still not widely used or clearly understood. Some confusion still exists about what individuals consider sleepiness Sleep is sometimes considered to be a state involving feelings of tiredness or fatigue and the subjective changes that precede sleep onset (Hoddes *et al*., 1973). Sleepiness is also defined as a physiological drive usually resulting from sleep deprivation (Aldrich, 1989) or as a physiological need state that leads to an increased tendency to fall asleep (Roth *et al*., 1989). It is reported that the presence and intensity of this state can be inferred by how readily sleep onset occurs, how easily sleep is disrupted or how long sleep endures (Murray, 1993). Although the term sleepiness is used and accepted, no clear definition of what the term means actually exists (Davy, 2010). Sleepiness can be described from a physiological, subjective and behavioural point of view. From a physiological perspective, sleepiness is defined as a need for sleep which is driven by physiological processes, which ultimately reflect the difference between being aroused and awake and from being sleepy and drowsy (Maldonaldo *et al*., 2004). From a behavioural point of view, sleepiness is usually associated with impairments in judgment and decision making abilities, perceptual skills and reasoning abilities (Dinges and Kribbs, 1987). Subjectively, it refers to an individual’s perception of a hypoactivated state, reported through self-evaluations with the aid of sleepiness scales (Curico, 2001).

The great importance of sleep becomes evident during sleep deprivation since deprivation promotes several alternations, including a marked increase in production of stress hormones such as catecholamines and cortisol, a reduction in cognitive capacity and a reduction in the state of alertness, among other things (Carskadon and Dement, 1994). It is generally accepted that any individual needs to get at least 8 hours of sleep to fulfil basal sleep needs (Van Donges *et al*., 2003). A lack of sleep can result in a state of sleepiness. Sleepiness can have causes, such as sleep disorders or sleep restriction from doing shift work (Babkoff *et al.,* 1988).

Sleep loss and drowsiness contribute significantly to accidents and impaired work performance (Oken *et al*., 2006). Several studies have investigated the effect of sleep restriction or sleep deprivation on driving performance. Lenne *et al*., (1997) conducted a study where drivers completed a 20 minute drive every three hours between 08:00 and 20:00, after either 8 hours of sleep or complete sleep deprivation. Sleep deprivation led to greater lane position variability and reaction times were greater for the sleep deprived group. Philip *et al*., (2004) reported similar results in the real highway driving study. The participants slept either 8.5h or 2h. The sleep restricted group had more inappropriate line crossings and their mean reaction time and subjective sleepiness were greater.

Truck drivers who are forced to work long irregular hours at night, often suffer from sleep deprivation. Chronic sleep loss is common among night shift workers, rotating shift workers and on-call workers and is compounded by circadian rhythm disturbances (Åkerstedt, 1998). Night workers typically report high levels of subjective and objective sleepiness (Åkerstedt, 2003). Night workers often suffer from chronic sleep loss, a condition that develops over a number of days without sleep. Sleep loss has been associated with impaired performance on a number of monotonous and passive tasks that are relevant to long distance driving (Van Dongen and Dinges, 2000). These include reaction time (Phillip *et al*., 2005), mental performance (Van Dongen *et al*., 2003), vigilance, hand-eye co-ordination and visual discrimination (Williamson *et al*., 2001). Chronic sleep loss, often leads to cognitive and performance deficits, particularly during the overnight and midday circadian peaks of sleep pressure (Oken *et al*., 2006).

2.7.2 Exogenous factors

Exogenous factors stem from the interaction between the individual and the environment. Task monotony and complexity are some of the exogenous factors important during driving. Environmental factors such as noise, vibration, ambient temperature, frequency, variation of stimulation and environmental pollutants can also be considered as exogenous factors. In this review only task monotony will be discussed in detail as the current aim of the study is to investigate the impact of breaks during long distance monotonous driving.

Monotony refers to the type, amount and degree of sensory stimulation in any situation (Thiffault and Bergeron, 2003). Monotony is usually defined with reference to the sensory stimulation that is present in a specific situation. A situation is considered to be monotonous when the stimuli occur in a repetitive or predictable manner (Thiffault and Bergeron, 2003). Monotony contributes to the onset of fatigue. However, fatigue does not contribute to monotony (Brown, 1982). According to Wertheim (1991) monotony in driving is caused by a lack of alerting stimulation and high predictability of the situation.

Grandjean (1979) expressed the difficulty in determining whether a monotonous repetitive task is merely boring or whether the excessive vigilance demands of the task are fatiguing. Hypovigilance is the failure in alertness and can be caused by fatigue but hypovigilance can also be caused monotony (Grandjean, 1979). Although hypovigilance is believed to occur as a direct result of fatigue (Brown 1982), this is not always the case; hypovigilance can occur independent of fatigue. This is supported by the notion that vigilance lapses can be experienced by the most well rested individuals (Sussman and Coplen, 2000), reiterating the fact that monotony can contribute to hypovigilance. Hypovigilance due to monotony or fatigue are interlinked, as both conditions can influence each other and result in a decrease in arousal and ultimately a decline in performance.

It has been suggested that it is possible to distinguish between fatigue and hypovigilance due to monotony. Monotony is the reaction of the central nervous system to a lack of or repetitive stimulus (Laurie, 2010). When a stimulus is first presented, it leads to increased attention and arousal, however repetitions of these stimuli will reduce the response until it disappears (Thiffault and Bergeron, 2003). If a change occurs in the stimuli, the response will reappear and arousal and attention will increase again (Thiffault and Bergeron, 2003). This principle can be used to distinguish between monotony induced hypovigilance and fatigue. In the case of fatigue, even if a change in the stimulus occurs the performance will remain constant or worsen.

Tasks that have a low cognitive demand are likely to contribute to monotony whereas tasks that have a high cognitive demand tend to reduce monotony but induce fatigue. High cognitive workload creates fatigue, whereas low cognitive workload leads to hypovigilance due to a disinclination to continue the task and not necessarily fatigue (Laurie, 2010). It has been reported that a high workload causes a vigilance decrease due to resource depletion and not necessarily a lack of stimulation (Smit *et al.*, 2004). Smit *et al*., (2004) found that in comparison to low demanding tasks, performance was affected mostly during high demanding tasks, which proved that high cognitive workload tasks are more fatiguing because they deplete the available resources.

It has been shown that driver fatigue and hypovigilance are likely to occur on highways where the environment is monotonous (Desmond and Matthews, 1997). Numerous explanations have been proposed to explain the decline in performance. According to the ecological theory, straight flat roadways with little variations in landscape content may be seen as a deficiency hazard because the lack of sensory stimulation can lead to a reduction of arousal to extremely low levels and result in attention lapses and drowsiness (Nelson, 1997). The reduction in arousal is attributed to the panoramic sceneries caused by the monotonous environment where environmental hazards can be easily identified, leading to a state of relaxation. Therefore an environment characterised by hills, trees and curves would have the effect of adding interest to the landscape, reducing the effects of boredom and monotony. Another explanation that has been explored is the highway hypnosis which describes this phenomenon as the “tendency of the automobile driver to fall asleep and become drowsy during uneventful highway driving” (Wertheim, 1978). This is due to the fact that oculo-motor control shifts from ”attentive” to “inattentive” modes under highly predictable visual environments. The shift from one mode to the other can influence psychological functioning which is crucial for the driving task.

Eoh *et al*., (2005) investigated the impact of monotony on driver vigilance by using an oval track where some sections were curved and others straight. It was found that driving on the curved sections of the road placed higher cognitive demands in comparison to driving on the straight sections. Curved section required more concentration, thus better performance was observed in these sections. The electroencephalogram activity increased on the curved sections showing an increase in cognitive activity.

Desmond and Matthews (1997) conducted a simulator study where they studied the effects of road geometry. These authors found that performance decrements were greater on a straight road than a curved road. This implies that monotony can induce early onset of fatigue, leading to decreased vigilance and alertness which may result in an accident due to human error. Alternatively the straight monotonous road could have led to hypovigilance which is also characterized by a decrease in alertness. The study by Desmond and Matthews highlights an important distinction that needs to be made when doing simulator studies in monotonous situations. The decline in performance can either be as a result of fatigue and hypovigilance together or hypovigilance alone. Understanding what occurs during monotonous long distance driving is vital for designing effective interventions to counteract the effects of fatigue and hypovigilance. Monotony results in physiological and psychological changes where physiological changes refer to tonic variations and an increase in parasympathetic activity causing a drop in activation (Thiffault and Bergeron, 2003). When experiencing hypovigilance due to monotony it will be accompanied by feelings of boredom, drowsiness and reduced motivation to perform the task (Grandjean and Kogi, 1975). According to Brown (1982) fatigue is characterized by reduced alertness characterised by impairment in the capability and willingness to perform the task.

2.8 Types of fatigue

May and Baldwin (2009) differentiate between two types of fatigue namely sleep related fatigue and task related fatigue. They further categorise task related fatigue into active and passive fatigue. Active fatigue results from prolonged exposure to high workload, caused by continuous and prolonged perceptual-motor adjustments (Desmond and Hancock, 2001). Passive fatigue, on the other hand, is associated with conditions of underload, where little or no perceptual-motor response is required (Liu and Wu, 2009; Desmond and Hancock, 2009). Although fatigue can be categorised into sleep related fatigue and task related fatigue, it is important to be cognisant of the fact that sleep related fatigue can be exacerbated by task related fatigue

Identifying the correct type of fatigue has important implications for the design of effect fatigue countermeasures. For fatigue countermeasures to be effective it must take into consideration which type of fatigue it should counteract, whether it is task or sleep related fatigue. As both these conditions have different origins, thus different countermeasures must be employed to effectively deal with them. Figure 2.4 gives a summary of the two main types of fatigue.

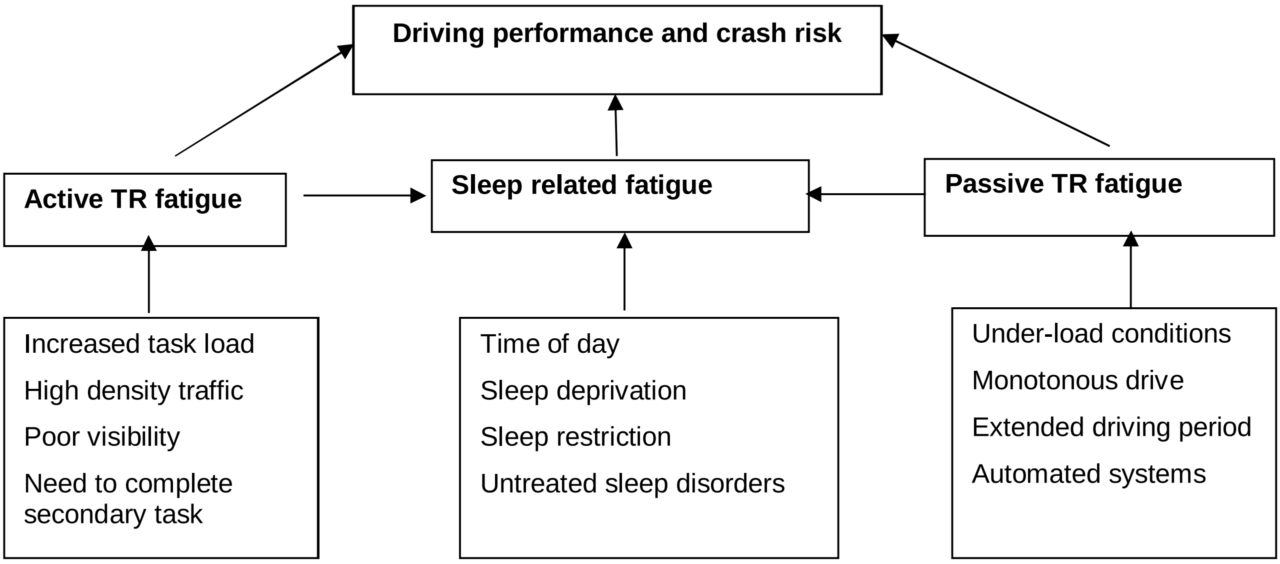

Figure 2.4: Model of fatigue (Adapted from: May and Baldwin 2009)

2.8.1 Sleep related fatigue

Sleep related fatigue can be influenced by the circadian rhythm as individuals are prone to feel sleepy during certain times of the day which correspond to the so called circadian dips (Tepas and Mahan, 1989). It has been reported that an increased amount of vehicle accidents occur between 02:00 and 06:00 as well as between 14:00 and 16:00 (Pack *et al.,* 1995). Sleep deprivation has also been reported to have an effect on sleep related fatigue (Phillip *et al.*, 2005). Dinges *et al.,* (1997) quantified the relationship between lack of sleep and performance by using a psychomotor vigilance task (PVT). The psychomotor vigilance task was performed at the same time after the subjects had slept for varying durations of time ranging from 0 to 8 hours. The results showed that performance improved as the hours of sleep increased. Another study by Graw *et al.,* (2004) which investigated the effect of a 40 hour sleep deprivation showed that PVT performance decreased as the homeostatic pressure for sleep increased. In another study conducted on shift workers which looked at driving performance following a night shift and after a normal night sleep, it was reported that driving after a night shift was associated with nine times more accidents and less time before the first accident (Åkerstedt *et al*., 2005). These authors found that Karolinska Sleepiness Scale (KSS) ratings were significantly higher after the night shift and these ratings increased with time on task. In their experiment, ratings of 7 on the KSS were reached only after 15 minutes of driving following the night shift in comparison to a rating of 5.5 after 65 minutes of driving after a normal night sleep. These studies showed that sleep deprivation can have serious consequences for driving performance.

According to Horne (2001), the best cure for sleep related fatigue is sleeping. Although available research suggest that taking 15 minute naps and drinking caffeine can help with sleep related fatigue, Horne (2001) warns that this should only be used for short durations until the driver can find a safe environment to stop the vehicle to get some sleep. Drinking caffeine should not be used by drivers to extend their journey.

2.8.2 Task related fatigue

Task related fatigue can be either passive or active and is caused by the driving task and environment (Desmond and Hancock, 2001). Passive fatigue is related to under load driving conditions, whereas active fatigue is related to overload driving conditions. Passive fatigue is produced when a driver is mainly monitoring the environment over an extended period of time or when the entire actual driving task is automated (May and Baldwin, 2009). Drivers may experience passive fatigue when the road is predictable, especially in cases where the road is monotonous or when there is little traffic.

Active fatigue refers to situations where the driver would be overloaded with information without having enough time to process the information. The use of vehicle information systems is believed to lead to an overload situation, where the driver needs to attend to the information on the navigator at the same time is required to attend to the situation on the road. Dual tasks deplete resources at a faster rate especially if both tasks utilise the same sensory channels such as tasks that require both visual and auditory resources. There are many theories which explain the drop in performance for the overload situation. According to Smit *et al*., (2004) the decline in performance is caused by the depletion of resources. They showed that in comparison to low demanding tasks, the high demanding task which had similar stimulus presentation as the low demanding task but with different instructions had a greater decline in performance. This seems to indicate that the decline in performance while performing a hard mental task was due to resource depletion.

Matthews and Desmond (1997) proposed that the dynamic models of stress and sustained performance which can be used to explain the observed decline in high demanding tasks. According to the model individuals are often able to compensate for dynamic variation in workload and environmental factors at moderate levels of stress. In a study done in air traffic control operators, it was reported that sometimes they were able to regulate the amount of effort as workload increases (Matthews and Desmond, 1997). In a fatigued state matching the effort to task demands may be impaired because fatigue reduces the range or efficiency of strategies available for effort regulation (Brown, 1994). Desmond and Matthews (1997) conducted a driving simulator study to investigate the induction of fatigue in drivers. The drivers were asked to drive on a straight and on a curved section of the road. On the curved section, performance improved dramatically compared to the straight sections of the road. These findings suggest that when a task is relatively difficult fatigued drivers are able to deal with the increased demands but when it is easy performance tends to decline. This implies that fatigued drivers are not able to mobilise the effort effectively (Desmond and Matthews, 1997). Therefore complacency might be increased as a result of fatigue.

The use of cellphones and navigators while driving has been associated with an increase in workload. It has also been suggested that the use of these devices might have a negative effective on driving performance and safety (Draskoczy, 1993). However in a fatigued state, drivers might fail to mobilise their effort effectively thus the use of these devices might be beneficial by increasing workload and as a consequence decreasing complacency (Desmond and Mathews, 1997). However Louw (2010) found that the introduction of a secondary task while driving led to a detoriation in performance. This was in line with Kahneman's (1973) theory which states that resource availability was variable. Therefore, it can be concluded that, mental effort and resource utilisation increases as task demands increase.

2.9 Countermeasures for fatigue

Numerous strategies are employed by professional as well as non-professional drivers to try and counteract the effects of fatigue. The strategies frequently used include taking short naps, talking to passengers, listening to the radio, opening windows, drinking stimulants (Gershon *et al.,* 2010). According to a survey conducted by Royal (2003) the most frequently used coping behaviours included pulling over to take a nap (43%), opening the window(26%), drinking a hot or cold caffeinated drink (17%), pulling over or getting off the road (15%), increasing the radio volume (14%),stopping for a stretch and/or exercise (9%), switching drivers (6%), eating (3%), and singing or talking to one self or others (3%). The examination of the countermeasures, Horne and Reyner (2001) found that only naps and caffeine provide temporary relief. All the other countermeasures have no scientific basis to support their effectiveness. Besides drinking coffee it has also been reported that functional energy drinks such as Red Bull also provide temporary relief against fatigue (Reyner and Horne, 2002).

Drivers have extensive knowledge with regards to fatigue and the factors affecting fatigue while driving and most of them are aware of the effectiveness that different methods have in counteracting the effects of fatigue (Nordbakke and Sagberg, 2007). Despite this knowledge and in order to comply with time constraints, drivers often tend to continue driving while fatigued and take various strategies that are only partially effective in coping with fatigue (Oron-Gilad and Shinar, 2000). It seems as if coping behaviours are influenced by the age and experience of the driver (Nordbakke and Sagberg, 2007). Older drivers tend to use more valid methods such as stopping for a nap whereas younger drivers tend to adopt coping methods that are easy to manage and do not require stopping the car.

It is also important to distinguish between the coping behaviours used by professional and non-professional drivers. The fundamental difference between these two types of drivers is that nonprofessional drivers deal with fatigue at a very tactical level, they do not anticipate being fatigued and deal with it when they actually experience it (Gershon *et al.*, 2011). On the other hand professional drivers relate to fatigue on a strategic level of driving and therefore use a much larger repertoire of coping behaviours that include stopping and pre-planning of their driving routine (Gershon *et al.*, 2011). From a survey conducted by Gershon *et al.,* (2004) it was found that indeed drivers dealt with fatigue on different levels, and this is reflected in the coping strategies chosen by the different groups of drivers. The methods used mostly by nonprofessional drivers include talking on a cellular phone or talking to passengers (Gershon *et al.*, 2004). These coping strategies are usually aimed at helping them pass the time, reduce their feelings of boredom and don’t require advance preparation. Additionally, most nonprofessional drivers seldom stop for a short nap in order to cope with fatigue. It seems this group of drivers prefers methods that do not require stopping the vehicle. Similar findings were reported with military who viewed stopping for a nap or to exercise as an effective coping behaviour, but the usage was relatively low because these required stopping, reiterating the fact that drivers are not keen on using coping behaviours that require stopping (Oron-Gillard and Shinar, 2000).

Coping behaviours chosen by most professionals include stopping for a short nap, drinking coffee, shelling and eating sunflower seeds, smoking, stopping to exercise and washing the face. All these behaviours require advance planning and stopping (Oron-Gillard and Shinar, 2000). This should be expected from professional as driving is part of their work and getting fatigued forms part of the job. Therefore it is important for them to use effective coping strategies, as falling asleep due to fatigue can have serious negative consequences. Moreover, due to the experience gained from being on the road for extend periods of time, it is expected that these drivers should know which methods are effective and which are not.

However although these group of drivers choose to employ different coping methods, it is interesting to note that listening to the radio and opening the window were perceived by both groups as being effective and used frequently. These coping behaviours are popular because they are easily accessible and don’t require pre-planning and stopping the car. This is an important consideration that needs to be made when designing effective in vehicle countermeasures for fatigue. These measures must be easily accessible to drivers and must not require pre-planning or stopping the car to be accepted by drivers and this applies to both professional and nonprofessional drivers.

2.9.1. Driving breaks

Driving breaks have long been identified as an effective countermeasure against fatigue. The big argument among researchers is whether or not rest breaks should form part of a schedule and should be controlled or drivers should have the liberty to choose the time best suited for them to take the break (Lombard, 2009). The argument put forward is whether individuals have the ability to effectively monitor their own levels of fatigue in order to choose the time that will be most beneficial and afford the most recovery. Drivers are able to cope with fatigue more efficiently when they have the freedom to arrange the timing of breaks to coincide with periods of fatigue (Feyer and Williamson, 1995). Although taking rest breaks may seem intuitive, this is not always the case. Drivers do not always choose the optimal rest schedule, and it has been reported that the use of systematic breaks can improve performance significantly (Bechtold and Janaro, 1985).

A driving simulator study which investigated the impact of breaks on driving performance study Drory (1985) reported that incorporating a 30 minutes pre-planned break to a 7 hour simulated driving task resulted in improved fatigue management and performance unaffected. One of the disadvantages of pre-determined breaks is that often the breaks do not coincide with the individual's perceived need for a break (Tucker, 2003). When individuals are given the freedom to choose their own rest schedule, they often work beyond the point at which their performance begins to decline, perhaps continuing until subjective feelings of fatigue become intolerable (Tucker, 2003). Rest breaks taken at the point where performance begins to decline are less likely to promote recovery (Murrell, 1979) with only temporary respite from the decline in performance being achieved. However Stave (1977) found contradicting results, reporting that a 4 minute break from a 3 hour journey at the point which coincided with the occurrence of gross errors led to an almost complete eradication of errors following the break.

Drivers could potentially benefit more from managing their own break schedule, as this can enable the drivers to better regulate the effects of fatigue on their performance, and the experience of stress (Lombard, 2009). However, it has been concluded that individuals may not always be the best judges of the most appropriate rest schedule (Tucker, 2003). Moreover when such breaks are regulated on a discretionary basis by the individuals it becomes questionable whether such breaks are of sufficient or occur frequently enough or early enough to prevent the ensuing fatigue duration (Bechtold and Janaro 1985; Henning *et al*., 1989).

2.9.2 Activities undertaken during driving breaks

The effectiveness of breaks in counteracting the effects of fatigue while driving is widely accepted. The emerging evidence has shown that the activity undertaken during the break may be crucial in determining the amount of recovery afforded. Compared to a rest break that involved doing nothing, rest breaks that involved some kind of an activity are more effective in delaying the onset of fatigue(Taylor, 2005).

Reyner and Horne (1997) reported that taking a nap of less than 15 minutes and drinking coffee during the break might be more beneficial than doing nothing. Other research done outside the field of driving has shown that drinking 150 to 200 mg caffeine improves alertness (Lorist *et al*., 1994; Bonnet and Arand, 1995). Caffeine is reported to block the brain adenosine receptors, and adenosine is believed to be a powerful sleep promoter (Muelhbach and Walsh, 1995). Drinking Red Bull, a well-known functional energy drink (FED) has also been found to be beneficial in maintaining alertness during monotonous driving (Reyner and Horne, 2001).

2.9.3 Exercise during breaks

Exercise during the breaks has also been suggested as way of maintaining alertness. Breaks might have longer lasting impacts due to changes in heart rate, blood pressure, core body temperature and stress hormones, enhancing the alertness state of the individual, potentially for a longer period of time than a simple rest break. These exercises could include taking a walk or performing a few stretches while taking a break from driving. The effects from these types of exercises are very short lived and can last for about 10 minutes (Horne and Foster, 1995). In other fields, outside of driving exercises has proven to be beneficial. Taylor (2005) proposed an alternative method which is geared at ensuring the short rest break has a more positive inter-break effect. The proposed method involved incorporating a series of short exercises and stretches into the break period in an attempt to enhance alertness, decrease musculoskeletal discomfort, and provide alternatives to sedentary rest breaks. Taylor (2005) defines the booster break as “organised, routine work break intended to improve physical and psychological health, enhance job satisfaction, and sustain or increase work productivity”. The booster break consists of a simple combination of stretches and exercises for an approximate duration of 8 minutes every hour during the shift cycle (Taylor, 2005).Booster breaks which were first introduced by Taylor (2005) have had some positive effects during night shifts in industrial settings.

Optimum rest schedules should be specific to the nature of the work activity being done. Therefore rest schedules should take into consideration the demands of the task and variation in the individual’s state (ability, motivation, sleep debt) and trait (Tucker, 2003). When designing rest schedules for drivers, the nature of the driving task should be considered. Optimal rest breaks should be a function of the task demand, and the total duration of the task (Fisher *et al*., 1993). Driving is a highly sedentary task, involving low levels of physical activity and a relatively high degree of vigilance monitoring. However in comparison to many industrial workers, drivers have more flexibility and choice in the timing of their rest break.

Available evidence indicates that short breaks reduce fatigue and performance can benefit from relatively short breaks (Tucker 2003). Jones (1919); Wyatt and Fraser (1925) reported that dividing the total rest time within a work period into more frequent shorter breaks, greatly improved productivity (Tucker 2003). According to Rohmert (1973), the exponential increase in fatigue which potentially occurs over the work period can be prevented by short, frequent rest breaks. Many authors concur that the use of frequent rest breaks is one of the effective means of alleviating mood disturbances, static loading of the musculoskeletal system, musculoskeletal system discomfort as well as repetitive strain injuries (Henning *et al.*, 1997; Tucker, 2003). Moreover, frequent short breaks have been shown to increase productivity, improve worker wellbeing and improve eye, leg and foot comfort. Short rest breaks capitalise on the rapid rate of recovery that occurs during the initial portion of a rest period (Rohmert, 1973). Short rest breaks have the potential to disrupt the flow of the task done and care needs to be taken to ensure that productivity doesn’t suffer. The length of the rest break is also important. In a study done by Lisper and Eriksson (1980), where they compared the effects a 15 minute rest break compared to 60 minute rest breaks on driving performance, they found that it had no effect on driving performance. The effectiveness of a particular short rest break is influenced by the nature of the work routine and is not be the same for different working environments (Tucker, 2003).

2.10 Fatigue countermeasures in vehicle

Fatigue countermeasures in vehicles refer specifically to technological devices that provide in vehicle countermeasure to prevent fatigue. Literature on human performance shows that there are three main reasons which support the implementation of technological fatigue countermeasures in vehicles (Brown, 1994). Firstly, fatigue is a persistent occupational hazard for long distance driver, especially professional drivers. Summala and Mikkola (1998) found that nonprofessional drivers are often involved in fatigue related accidents. Fatigue is often cited in accidents involving young drivers and truck drivers (Lliang and Lee, 2010). Professional drivers offer a special challenge to legislators and researchers, as this group often believes that training and experience in driving has equipped them with skills and knowledge to deal with fatigue in an acceptable manner. Secondly, work pressures and schedules placed on drivers often force them to ignore the symptoms of fatigue they might be experiencing (Brown, 1997). Lastly, fatigue impairs cognitive skills needed, therefore this might affect the driver's own ability to assess and monitor their fitness to continue driving safely (Brown, 1997). This impairment occurs in both situations of high as well as low workload, increasing the likelihood of perceptual and attentional errors (Davies and Parasuraman, 1982). It seems that fatigue leads to a situation where the driver fails to regulate effort properly (Desmond and Matthews, 1997). For these in vehicle technological countermeasures to work effectively they should fulfil some criteria. Firstly it must provide a valid indication of fatigue, rather than impairment. Secondly, the stimulus delivered when the impairment is detected must successfully restore performance of whatever task components may have deteriorated because of fatigue (Desmond and Matthews, 1997).

2.10.1 Technological countermeasure

Fatigue technological countermeasures can be classified into three categories. Technological countermeasures are classified based on the types of fatigue, namely sleep related fatigue and task related fatigue. Head nodding technology which is sensitive to head positions and eye closure technology which monitors blink frequency and duration, are used to monitor the onset of sleep and are more suitable for sleep related fatigue. Countermeasures designed for active task related fatigue would include automated systems, such as lane departure warning systems and cruise control which aim to reduce the driver workload, by taking over some components of the driving task.

In this review only those countermeasures used for passive task related fatigue will be discussed in detail. Passive task related fatigue can develop from the underload driving situation either by driving on a monotonous road or use of automated systems. Secondary tasks such as monitoring an in-vehicle guidance system may benefit the fatigued driver's when other task demands are low (Matthews and Desmond, 2002). The extra task load may prevent under mobilisation of effort, and maintain the driver active engagement with the task. Gershon *et al*., (2009) investigated the use of interactive cognitive task (ICT) which is an auditory-motor task based on the simply principles of a knowledge game also known as a trivia during a monotonous driving task. The use ICT during monotonous driving is based on the perception that fatigue or hypovigilance might be due to lowered arousal levels due to a lack of stimulation. Therefore the introduction of an attention demanding secondary task might increase arousal levels and improve driving performance (Oron-Gilad *et al*., 2008). The ICT has been designed to counteract the effects of fatigue and enable the driver to increase or maintain adequate levels of alertness during a prolonged drive (Gershon *et al.*, 2009). When the ICT was activated, it had an immediate but localised effect on the levels of alertness, indicated by a decrease in heart rate variability (HRV), an improvement in driving performance and increased subjective feelings of alertness.

A similar device known as “car mate” was used in a study by Verwey and Zaidel (1999) to prevent drowsiness. The ‘carmate’ was an auditory and verbal device designed to give the driver an opportunity to play 12 different games. The driver had the choice to interact with the car mate at any time when driving and most drivers used it during the second half of the driving. The use of the ‘carmate’ led to a reduced number of accidents, incidents and line crossing events. The device delayed the onset of errors and also improved the quality of course keeping for drivers without accidents.

A similar device is the Knight-Warrior Sleep Alarm which is activated by the driver. When a driver starts to experience fatigue symptoms this system emitted a sound at specified time intervals and the driver had 1 to 3 seconds to respond to the alarm (May and Baldwin, 2009). If the driver fails to respond appropriately within the allocated time, a secondary wake-up siren was sounded in an effort to wake up the driver.

All these in vehicle devices were based on the assumption that drivers would be able to monitor their alertness levels and switch them on when they start to feel fatigued. However Schimdt *et al*., (2009) has shown that under monotonous driving conditions drivers might not be able to assess their fatigue status effectively. In an investigation by Schimdt *et al*., (2009) drivers reported subjective improvements in vigilance towards the end of a 3 hour drive. This was in contradiction with the objective measurements of reaction time, electroencephalogram and heart rate which consistently showed a reduction in vigilance. The increase in subjective measures during the last phases of a task has also been reported in other studies. Davy (2010) found that towards the end of an 8 hour shift subjective measurements increased. This observation is believed to be attributed to excitement of the participants going home soon or circadian phase. This implies that drivers might be vulnerable to misjudgements of their objective vigilance state and as a consequence, might delay interacting with alertness maintaining devices to such a point that their use might not be beneficial in alleviating fatigue symptoms. Moreover, in vehicle fatigue countermeasures which reduce the driver's perceptions of task demands are likely to accentuate under mobilisation of effort in fatigued drivers (Desmond and Matthews, 1997).

2.11 Common methods for the assessment of driver fatigue

Several measurements are used for the assessment of fatigue. This is due to the fact that fatigue is a multi-dimensional and complex phenomenon, no one standard measure can be applied. The measurement techniques investigated included physiological, performance, subjective, and neurophysiological methods. Only assessment methods used in the presented study are included in the following review section.

2.11.1. Heart rate and heart rate variability

Heart rate and heart rate variability are the most common physiological measurements used for the assessment of cognitive fatigue. Heart rate is defined as the amount of times the heart contracts in one minute (Tortora and Derrickson, 2006). Fluctuations in heart rate can be used as an indicator of effort (whether physical or mental). Psycho emotional status has also been linked to heart rate with heart rate being altered by stress, anxiety and fatigue (Andrianov and Vasilyuk, 2001). Heart rate variability (HRV) refers to the measure of variation in the beat to beat (RR) interval of heart rate (Davy, 2010). HRV is used for the investigation of cardiovascular autonomic control, and reflects the control exerted by both the parasympathetic and sympathetic nervous system (Mourot *et al*., 2004). HRV is as a result of changes in autonomic control with two main sources of this variability being the respiratory sinus arrhythmia and spontaneous fluctuations predominantly related to short-term blood pressure control. The use of HRV has disadvantages but numerous authors concur that HRV is an accurate and reliable measure for the assessment of autonomic activity and function (Pumprla *et al*., 2002; Sluiter, 2009).

Autonomic activity has been show to exhibit circadian pattern, with the sympathetic system being prevalent during the day and the parasympathetic being dominant at night. Reduction in sympathetic tone has been associated with a decrease in alertness and vigilance (Furlan *et al*., 2000). HRV has been used in many studies to show mental workload (Brookhuis and de Waard 2010). HRV is a measure of the variability in the interval between consecutive heartbeats; irregularities in heart rate are caused by a continuous feedback between the central nervous system and peripheral autonomic receptors (de Waard, 1996). Heart rate variability has been used in the field of human factors as a measurement of mental workload in both laboratory studies and in operational contexts (Lin *et al.*, 2008). It has been found to increase as a function of time-on-task, while a decrease in HRV is often found as task complexity increases (Mascord and Heath, 1992). HRV is usually less sensitive than heart rate to autonomic influences (Mascord and Heath, 1992), and a decrease in HRV is more sensitive to increases in workload than an increase in heart rate (de Waard, 1996).

2.11.1.1 Time domain Analyses

Time-domain variables that can be calculated include the mean normal-to-normal (NN) interval, mean heart rate and difference between the shortest and longest NN interval. From these measures, statistical time-domain measures can be derived. The standard deviation of the NN intervals (SDNN) i.e. the square root of variance, which reflects all the cyclic components responsible for variability in the period of recording. The square root of mean squared differences of successive NN intervals (RMSSD); and the number of interval differences of successive NN intervals greater than 50 ms (pNN50) expressed as a percentage of the total amount of NN intervals. It is expected that all three of these measures would be statistically significantly lowered in the presence of lowered heart rate variability.

It is important to note that while HRV is sensitive to task-rest effects, once the participant is performing a task it is very difficult to reduce HRV any further by simply manipulating the characteristics of the task (Jorna, 1992). Jorna (1992) noted that only major changes in task structure (such as single-dual task or automatic versus controlled processing) seem to induce significant HRV effects. Mulder (1986) found that HRV was only able to differentiate between tasks if they differ significantly in terms of controlled processing. This type of analysis is also unable to account for the sources of variance influencing HRV, and therefore spectral analysis techniques are considered the preferred method (Jorna, 1992).

The disadvantage of using heart rate and heart rate variability is that the response does not hold under all circumstances and the most stable results are obtained during short-duration laboratory tasks. A further disadvantage is that speaking and sighing has effects on the heart rate variability due to the sensitivity for changes in the respiratory pattern.

2.11.1.2 Spectral analysis

Spectral analysis decomposes HRV into three different frequency ranges, namely very low frequency (0-0.04 Hz), low frequency (0.04-0.15 Hz) and high frequency (0.15-0.4 Hz) (Lin *et al.*, 2008). The very low frequency band is related to the regulation of body temperature, low frequency to short-term regulation of blood pressure, and the high frequency band reflects respiratory sinus arrhythmia, or momentary respiratory influences on heart rate (Jorna, 1992). The low frequency component of HRV is thought to reflect complex processes of blood pressure regulation resulting from the interplay between sympathetic and parasympathetic influences, mediated by the baroreflex. Suppression of the low frequency component is often demonstrated under conditions of increased cognitive demand, and the high-frequency component (functioning as an indicator of parasympathetic activity, or vagal tone) tends to decrease when task demand is high (Fairclough *et al.*, 2005).

Increasing mental load and attention have been shown to cause a decrease in both the time and frequency domain estimates of HRV, especially in the low frequency component of spectral analysis. Mascord and Heath, (1992) have found the low frequency band to be sensitive to fatigue, with an increase in spectral power occurring during conditions of fatigue, and a decrease in spectral power depicted during cognitive processing. Gershon *et al.,* (2009) found HRV (calculated from the total spectrum between 0- 0.4 Hz) to increase with time-on-task for a 140 minutes simulated driving task, as well as the post-task rest value being higher than the resting value taken prior to the test. They also found that HRV decreased during the intermittent addition of an interactive cognitive task; however HRV rapidly increased again once the additional task was removed. While often the low frequency band alone is used to indicate increases in mental workload, some authors (Miyake, 2001; Zhang *et al.*, 2009) have suggested the use of a low frequency/high frequency ratio, suggesting that it reflects sympathetic modulations.

2.11.2 Core body temperature

Kleitman (1963) was the first to suggest a relationship between performance and temperature, stating that body temperature was an underlying mechanism regulating performance. Kleitmain (1963) further postulated that there is an underlying chemical phenomenon and proposed two interpretations for the relationship between performance and temperature. The first explanation brought forward was that mental processes represent chemical reactions in themselves. Alternatively, the speed of thinking depends upon the level of metabolic activity of the cells of the cerebral cortex, and increasing body temperature indirectly speeds up the thinking process. Performance has been reported to be better when body temperature is high or near its circadian maximum and worse when body temperature is low or near its circadian minimum (Wright *et al*., 2002). It has been reported that cognitive function is improved by increasing body temperature slightly above 37 degrees Celsius and that cognitive function is reduced by decreasing body temperature below normal (Rogers *et al*., 1998).

There exists a positive relationship between daily rhythms and body temperature and neurobehavioural and alertness in humans (Wright *et al*., 2002). Under constant conditions, body temperature and neurobehavioural performance follows a circadian pattern, with higher levels during the day and lower levels at night (Johnson *et al*., 1992). Human body temperature has a circadian rhythm that presents itself by a variation of between 0.8 degrees Celsius and 1.0 degrees Celsius over the day and night (Baker *et al*.,2001). Although body temperature exhibits a circadian rhythm pattern it is also influenced by other factors such as physical activity, food intake, ambient temperature, light exposure, posture and drug intake (Wright *et al*.,1998).

Different types of equipment exist to measure core body temperature (CBT). Infrared temperature thermometer (ITT) is a relatively new piece of equipment which has been introduced in the past years and is a striking example of the recent revolution in measuring devices in emergency medicine. The ITT measures non discriminating infrared radiation from the auditory canal and converts this information into body temperature (Yaron *et al*., 1995). Depending on the mode selected, a numerical constant known as an offset is added to the measured value (Craig *et al*., 2002). These thermometers offer the advantages of ease of use, speed, improved hygiene, non-invasive and painless temperature measurements (Chamberlin *et al*., 1995). Despite the usefulness of this device, questions have been raised about its accuracy. Some conflicting evidence exists with regards to the accuracy of this thermometer. Chamberlin *et al.,* (1995) concluded that it is an accurate means of assessing normal body temperature. However in another study the ITT was inaccurate when it was compared to the electronic rectal thermometer, only moderate agreement was found between the two devices (Yaron *et al*., 1995). It has been suggested that errors in technique may be responsible for the different results. The ear temperature may also be influenced by the ambient air (Johnson *et al*., 1991). The presence of otitis media or cerumen in the auditory canal may also contribute to errors in ear thermometry (Yaron *et al*., 1995).

2.11.3 Performance measures

Performance is defined differently by different scientists but according to Hockey (2000), performance refers to the mental processes that underpin mental performance. Specifically, performance refers to a set of different aspects of human ability, namely perception, cognition, psychomotor processes, and the physiological and biomechanical processes that facilitate the interaction with the environment (Davy, 2010). Poor performance has been reported to reflect the impact of fatigue on the effectiveness of task performance and does not reflect a decline in efficiency of performance (Hartely, 2001). Any activity if pursued long enough will render a person unable to maintain skilled performance (Nilsson *et al*., 1997). Performance is often used in many studies to infer fatigue; this is due to the fact that fatigue or lapses in vigilance manifests itself in performance decrements.

In the field of driving research, driver fatigue is observed on the basis of driving performance (Mackworth, 1957). Popular performance measures include lane deviation, reaction time, deviation lateral position, and steering wheel movements. Driving simulators are often used to quantify driving performance. In comparison to real world driving; simulators are safe and can be used in a controlled laboratory environment.

A trade off exists between the realism of on the road studies and the need for environmental control simulation or test track studies (Reimer *et al*., 2007). Driving simulators offer a more robust and cost effective method for studying driving behaviour. However it is often pointed out that even the most advanced motion based simulator lacks some of the physiological and emotional simulation of real vehicle (Ranney *et al*., 2002). Driving performance in a fixed based simulator has been found to be sensitive to both a within-subject factor and a between subject factor, in a manner that is consistent to on-road findings (Green, 2000). Comparisons between simulated driving and real world driving are most meaningful when the simulation software and simulator hardware together are validated against real world measures (Reimer *et al*., 2007).

2.11.4 Subjective sleepiness scales

Subjective sleepiness scales have been described as a state involving feelings of tiredness or fatigue and the subjective changes that immediately precede sleep onset (Hoddes *et al*., 1973). Sleepiness is also seen as a subjective state of low alertness (Babkoff, 1991). Researchers have reported that although fatigue and low levels of alertness may signal the need for sleep, these measures do not provide a useful measure of the likelihood of falling asleep (Murray, 1993). Feeling drowsy or sleepy has been identified as one of the symptoms that develop over time during simulated driving (Nelson, 1997). Subjective sleepiness scales such as the Stanford Sleepiness Scale and Karolinska Sleepiness Scale are used to provide an indication of the level of sleepiness experienced by the individual at that moment and is not related to the individual’s propensity to fall asleep (Murray, 1993). These scales are based on the assumption that individuals are able to monitor their own fatigue or sleepiness levels, as they are based on the individuals own projections.

2.11.4.1 Karolinska Sleepiness Scale

The Karolinska sleepiness scale (KSS) is a nine-graded scale originally developed to constitute a one-dimensional scale of sleepiness (Åkerstedt and Gillberg, 1990). The KSS has been widely used in studies for subjective assessment of fatigue, as it is quite easy to use the scale. The KSS has been validated against alpha and theta electroencephalogram (EEG) activity as well as electro-oculograpahic measures of slow eye movement (Åkerstedt and Gillberg, 1990). In a simulator study conducted by Åkerstedt *et al*., (2005), which examined driving performance following a night shift and after normal night sleep. This study showed clearly that driving following a night shift was associated with increased levels of subjective sleepiness, as well as increased eye closure and other reductions in driving performance. In a related simulator study, Horne and Reyner (1999) reported similar levels of subjective ratings of sleepiness and increased sleep intrusions evident from EEG tracings in young, experienced drivers whose sleep had been restricted or completely deprived.

2.11.4.2 Wits Sleepiness Scale (WSS)

The Wits Sleepiness Scale is a language independent pictorial sleepiness scale based on cartoon faces (Maldonado *et al*., 2004). Several factors led to the development of this scale. Prior to this scale the available subjective sleepiness scale, such as the Stanford Sleepiness Scale (SSS) and the Karolinska Sleepiness Scale (KSS) required some form of literacy and are not always appropriate for some population groups. The Wits Sleepiness scale is particularly useful when working with children or uneducated population, as cognitive complexity is low and has no semantic element that requires comprehension of English or any other language. This scale is particularly useful in the South African population whose home language is not English, as this scale does not require comprehension of any language in particular. Similarly to the KSS and SSS, the WSS is used as a tool that measures instantaneous perceived sleepiness. The scale is quick, simple and easy to complete.

It has been reported subjects differing in age and ethnicity are able to relate to the cartoon faces in the scale and the faces have shown good agreement with other scales such as the SSS and KSS (Maldonaldo *et al*., 2004). In a study done with night drivers on a night shift, the scale was able to reflect the well documented increase in sleepiness observed on the night shift, particularly from 04:00 to 06:00 (Maldonaldo *et al*., 2004). Moreover, the increase in sleepiness which is associated with time on task was clearly reflected on the scale as well

2.11.5 Neurophysiological measures

Driving fatigue research has utilised a number of neurophysiological tools to quantify the effect of fatigue on driving performance. Neurophysiological measures attempt to create a link between brain activity or variations in brain activity to alertness, sleepiness and drowsiness. Some of the popular neurophysiological measures include electroencephalography, electro-oculograms and derivatives thereof (Lal and Craig, 2001). Neurobehavioral variables seem to exhibit circadian rhythm pattern, similar to the pattern seen in alertness, fatigue and performance (Van Dongen *et al*., 2003). Therefore it can be expected that the neurobehavioural responses would reflect the natural circadian rhythm pattern over the course of the 24 hour day (Lombard, 2009).

Critical flicker fusion frequency (CFFF) indicates the frequency at which a flickering light is perceived to be steady source of light. CFFF is a well-established neurophysiological technique which has been extensively studied in young and elderly healthy volunteers (Curran and Wattis, 1998). It has been used as an operational definition of the central nervous system's ability to process information. In general, a threshold is defined as the minimal amount of information required for the accomplishment of the task (Dember and Warm, 1979). The CFFF threshold is the lowest frequency of flickering light (measured in Hz) that is required to produce the appearance of steady light to the observer (Luczak and Sobolewski, 2005). Hence, when a light is flickered at rates equal to or greater than the CFFF threshold, the individual flashes cannot be resolved and the light is indistinguishable from a steady, non-flickering light, and this would represent the threshold and signify the end point of the test (Lombard, 2009). CFFF is characterised by an ascending and a descending threshold. Ascending threshold represents the lowest frequency (Hz) at which an individual perceives a steady light instead of the flickering light. The descending threshold indicates the highest frequency of light at which flicker starts to appear. It has been suggested that ascending and descending CFFF should be treated as different phenomena (Luczak and Sobolewski, 1995).

Flickering light influences cortical activity pronounced in the occipital region (Kogi and Saito, 1971). Therefore CFFF can be used an indicator of cortical activity, with the perception of the light influenced by the levels of stimulation in the retina and on the processes occurring there (Luczak and Sobolewski, 1995). Rammsayer (1995) has stated that CFFF is a valid and reliable indicator of the level of cortex arousal and activation.

The efficiency and fidelity of the visual system is believed to be related to the frequency at which an individual can perceive the flicker. CFFF is also an accepted marker of fatigue and work over or underload. A relationship exists between mental fatigue and CFFF values, which can be used as an indicator of fatigue, not at the periphery of the visual system but for fatigue at the centre of the visual system or mental fatigue (Iwasaki *et al*., 1989; Curran *et al.,* 1990). The central nature of flicker perception is also supported by evidence that threshold values are higher when measured with binocular vision rather than monocular vision and that exposure of only one eye to flicker alters the threshold sensitivity of the other eye. Perception of flicker is thus an important and fundamental component of visual perception.

Arousal levels and consciousness levels in the brain are sometimes used as a marker for mental fatigue, thus a decrease in CFFF values might be correlated with mental fatigue (Baschera and Grandjean, 1979). Available evidence suggests that the CFFF threshold is affected by natural circadian rhythms. In a study conducted by Luczak and Sobolewski (2005) with night shift workers, they reported extremely low CFFF values during the night shift (between 04:00 and 06:00 hours. CFFF values are much higher at the beginning of the day shift when compared to values at the end of the night shift (Matsumo *et al*., 1987). These studies showed that CFFF is a function of work fatigue as well as circadian rhythm of the overall arousal level (Luczak and Sobolewski, 2005).

Several factors have been found to influence CFFF values. Stimulants such as caffeine and nicotine will have an impact on the CFF threshold (Roback *et al.,* 1952). Luminance around the stimulus has also been shown to affect CFFF values. As the luminance around the stimulus increases, the threshold will decrease, therefore it is crucial to keep the surroundings as dark as is possible. Age has also been shown to have an impact on CFFF values, with a negative correlation observed between age and CFFF values (Hosokawa, 1997). Older individuals with ages between 26 to 31 years seem to have smaller values compared to a younger group with age’s between19 to 25years (Hosokawa, 1997).

CHAPTER III:
METHODOLOGY

3.1 Research concept

The primary objective of the current investigation was to assess the impact short duration breaks would have on driving performance during long distance monotonous driving at different times of the day. The concept behind the introduction of breaks during driving was twofold. Firstly, to determine whether short duration breaks are an effective countermeasure against performance related fatigue. Tucker (2003) suggested that short duration breaks taken frequently are effective at alleviating fatigue related symptoms. Grandjean (1979) expressed the difficulty associated with determining whether the performance decrements experienced during driving are as a result of down-regulation caused by performing a monotonous task or that the monotonous task is fatiguing. Therefore the introduction of the breaks was seen as a way to differentiate between passive fatigue or down regulation due to monotony.

A secondary objective was to determine the time of day the breaks were mostly effective at counteracting the effects of performance related fatigue. Determining the time of day the breaks worked best was based on the fact that during different times of the day different types of fatigue might be experienced. When performing a monotonous task during the day, the decline in driving performance might be attributable to passive fatigue. However at night sleep related fatigue might be more pronounced. Therefore the investigation aimed to assess whether short duration breaks were effective against both task related fatigue and sleep related fatigue.

Driving performance and physiological measures were collected during extended monotonous tasks with and without the breaks during the day and night. The experiment was performed as a repeated measure design. The participants were required to track the middle white line with the tip of the arrow which represented the bonnet as accurately as possible, while driving at a constant speed.

3.2 Research hypotheses

With the inclusion of a short duration breaks during monotonous day and night time driving in the current study, the following was expected:

- Taking breaks will have an effect on driving performance and affect response measures in comparison to the no break condition during the day and during the night.

- It is expected that there will be a difference between day and night time without and with breaks driving performance and measured responses

Based on the research concept the following statistical hypotheses were devised:

Hypothesis 1:

The null hypothesis proposed that there will not be a difference in all variables measured between the intervention condition and the control condition during the day.

Hypothesis 2:

There will not be a difference in all the variables measure between the intervention condition and the condition at night.

Hypothesis 3:

There will be no difference between driving without breaks during the day in comparison to driving without breaks at night.

Hypothesis 4:

There will not be difference between driving with breaks during the day in comparison to driving with breaks at night.

3.3 Experimental design

The aim of the study was to determine whether the inclusion of breaks during a monotonous drive would delay the onset of performance related fatigue, when driving at different times of the day. The length of the drive, length and frequency of the breaks as well as the activity to be undertaken during the break, were all considered during the design of the current investigation.

Several studies have been conducted to answer the question of how long it took to induce fatigue using a driving simulator. Miller and Mackie (1980) reported increases in fatigue symptoms and changes in various physiological measures when driving for more than 8 hours. In another study with truck drivers an increase in accident rate was observed after 4 hours of commencing to drive (Madsen, 1982). Under controlled laboratory conditions, marked indications of fatigue can be observed in some participants after only 60 minutes of driving task (Galinsky *et al.,* 1993). Thiffault and Bergon (2003a) exposed participants to 80 minutes of monotonous driving to induce fatigue. In another study done by Gershon *et al.,* (2009), a total of 104 minutes was needed to induce fatigue symptoms. The variability in the relationship between time and the development of fatigue can be explained partly by the different methodologies applied to induce fatigue and the driving simulator utilised. Differences were found in literature which regard to the amount of time it took to induce fatigue, using a driving simulator (Nilsson *et al.,* 1997). The vast differences in the reported times could be attributed to the different techniques that were used to induce the fatigue. Secondly, for active task-related fatigue (overload situation) and passive task related (underload), the development of fatigue would vary. The overload situation tends to favour a rather rapid development of fatigue whereas the underload situation tends to favour hypovigilance due to monotony. Therefore, studies that investigated the different types of fatigue would be expected to come to different conclusions about the duration for fatigue development. Since simulators differ with regards to the software used, it was crucial to pilot for the specific software used in the simulator used in the current study. Based on pilot studies that were carried on the current study, 90 minutes was deemed to be sufficient to induce performance-related fatigue in a monotonous driving environment.

The study consisted of four independent conditions, namely the day with breaks condition, day without breaks condition, night break condition and the night without break condition. The without breaks conditions were similar except that they occurred at different times of the day, one session at night and the other session during day time, as was the case for the conditions with breaks. Each participant had to attend four 90 minutes experimental sessions, two sessions during the day and two sessions at night. The day sessions occurred between 11:30 and 13:00, and the night sessions took place from 23:30 and 01:00. All four conditions were identical although they occurred at different times of the day. During the break condition the drivers had breaks at certain intervals during the drive. In the control conditions (without break condition), the participants drove for the entire 90 minutes without any breaks. Table 1 gives a breakdown of the different conditions that were investigated in the study.

Table 1: Breakdown of the conditions

Condition	Design	Total time requirements
1	Day Break Condition	90 minutes
2	Day No Break Condition	90 minutes
3	Night Break Condition	90 minutes
4	Night No Break Condition	90 minutes

3.3.1 Break conditions (Conditions 1 and 2)

The 90 minute drives was broken up into 10 minute drive with 2 minute breaks in between. For the break condition it was important to consider the duration of the break as well as the frequency of the breaks. According to the available literature shorter, more frequent breaks are more effective for fatigue recovery (Tucker, 2003). Although shorter duration breaks offer more positive benefits, Tucker (2003) pointed out that these breaks have potential of disturbing the work flow, in this case the driving task. Thus a fine balance needs to be maintained between the driving task and the frequency of the breaks.

The length of the breaks was also influenced by the fact that, the breaks would be taken, while the driver was inside the simulator. In essence the driving simulator would not be stopped during the breaks, instead it was put on auto pilot mode, while the driver was having the break. It has been argued that the use of an assistance system can lead to complacency, by making the driving task too easy (Matthews and Desmond, 1997). In the case of the underload situation where drivers might already be suffering from hypovigilance the use of an assistance system might be detrimental for driving performance. In driving, complacency is particularly dangerous because in comparison to the aviation industry where auto pilot systems have been in use on aircrafts, the driving environment is extremely dynamic, in the sense that the driving situation can change at any moment (e.g. animal jumping into the road). Therefore the driver needs to be alert at all times and must be able to take over from the driving system when the need arises. Complacency to an automated system has been suggested to develop after prolonged exposure. Therefore the assistance system took over for only two minutes, while the driver had a break from the driving task.

Numerous theories exist to explain the degradation of driving performance during monotonous driving. Two of those theories include the arousal and resource theory (Brown 1982; Staal, 2004). Based on the arousal theory (Brown, 1982) the decline in performance associated with vigilance task is caused by a lack of stimulation, thus a change in the surroundings or task can lead to increased stimulation, which in turn may result in improved performance. Therefore short duration breaks might provide that change in stimulation or disrupt the monotony that is experienced while performing the task, resulting in improved performance. The resource theory suggests the existence of a general reservoir of mental resources that can be drawn from in order to assist an individual in performing a task (Staal, 2004). The individual can therefore be characterised by a limited supply or capacity for both attention and processing (Oron-Gilad and Hancock, 2005). Decrements in performance efficiency are said to occur when the amount of available resources is insufficient to meet the demand presented by the task (Oron-Gilad and Hancock, 2005). Early research by Kahneman (1973) presented a capacity model suggesting a general resource pool used by all tasks. This pool is said to have a finite limit, based on the degree of arousal of the individual (Kahneman, 1973). The resource theory attributes the poor performance to a depletion of the pool of resources (Kahneman, 1973) and rest is needed for recovery. In line with this theory it is assumed that breaks of two minutes would not offer enough time to recover the depleted resources.

According to the arousal theory, hypovigilance is brought about by exposure to the same stimulus, which causes habituation over time, thus a change in simulation has been suggested to increase alertness levels. Therefore the two minute break might give the driver a chance to disengage from the driving task, breaking the repetitive exposure to the same monotonous driving scenario. During these breaks the simulator was operating on auto driving, thus the simulator did not stop. Brown (1997) states that one of the main reason driver fatigue is a major challenge is because of tight schedules and deadline, forcing drivers to ignore symptoms of fatigue and continue driving. Therefore a break that could be taken inside the vehicle could mean that the driver can have a break without losing time from their journey. The activity that would be undertaken during the break had to be considered as well. Several activities were considered, including eating, drinking water, listening to music, talking on the cellphone and performing light exercises. According to Reyner and Horne (2002), there is no scientific evidence suggesting that the above mentioned activities are effective at delaying the symptoms of fatigue, although the activities are quite popular to drivers. In the current study, the main interest was the effects of the breaks alone and not combinations or any other activity. Whichever activity that was applied needed to mimic driving behaviour. Gershon *et al*., (2011) reported that professional and nonprofessional drivers prefer countermeasure that do not require prior planning and are easily accessible. Using the breaks was chosen as it met these criteria. Another motivation for using the breaks alone was that all the other activities have the potential to influence the physiological measures in the study and this would mask the effect of the actual break. It was therefore decided that the driver could not get out of the seat, as they would not be able to get out in a real vehicle. The drivers were allowed to stretch as they would while they were seated in a real vehicle. However they were prohibited from using any devices, which might increase alertness levels such as cellphone, ipods.

Breaks taken at the point where fatigue symptoms start to appear might not be as effective at alleviating the symptoms, thus the first break was scheduled 10 minutes after commencing the drive. Several different break schedules were investigated during the pilot studies and the 10 minute drive and 2 minutes break was seen as the most suitable drive- to- break ratio for the experiment. In line with the arousal theory short duration breaks were short enough to break the monotony but not long enough to offer recovery from resource depletion.

3.3.2 Driving performance

A driving simulator (see Figure 3.1) was used since a method that would fatigue the participants was needed as real driving does not require maximum performance from drivers. The elementary driving task was following a road line which corresponds to a compensatory tracking task. The driving task used in the current study was a tracking task. The participants were required to follow a centre line displayed on a tracking path as accurately as possible. Driving reliability and safety correlates directly to tracking and to reaction performance (Göbel, 1998). The tracking task requires full attention since it is a continuous performance measure requiring participants to act at their upper performance limits by requiring minimum target deviation and minimum reaction time. It has been suggested that in such situations, tracking performance directly corresponds to resource allocation and information processing capacity (Bubb, 1993).

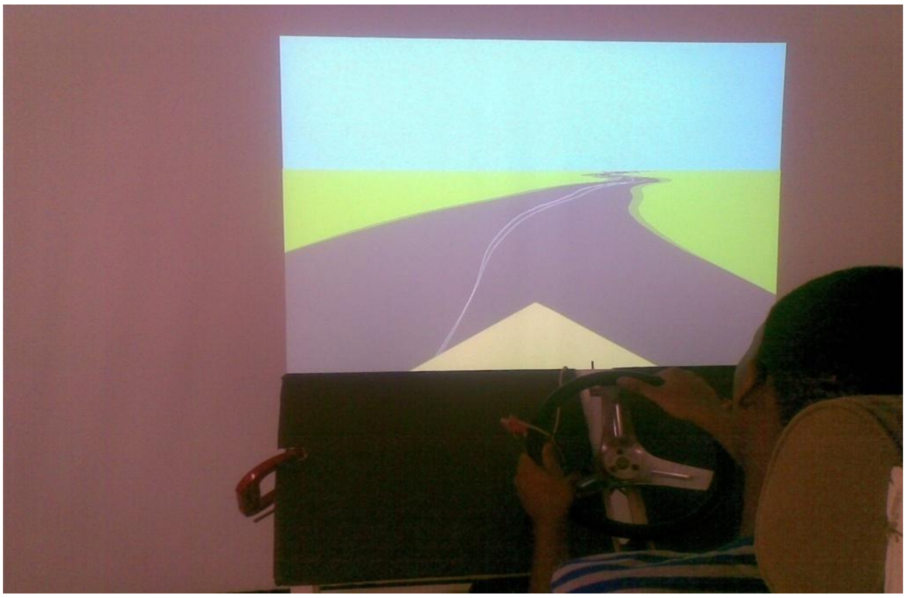

Figure 3.1: Drivers view of driving simulator

3.3.2.1 Simulator design

The driving simulator presented a curved road with an arrow at the bottom of the screen representing the bonnet of the car (see Figure 3.1). The participant was required to track the middle white line with the tip of the arrow as accurately as possible. In order to describe the tracking quality, the simulator measured the mean deviation values of all the crossed road segments. The amount of deviation was calculated relative to the instant the segment was crossed. The scenario of the simulator was visually designed according to real traffic proportions. The tracking path used was grey coloured path to resemble a real road. A vehicle seat attached to a square metal frame was used as the driver's seat. The seat was fully adjustable and could be reclined backwards. The road was projected on to a white screen which was in front of the driver by a Liesang digital projector which was placed on top of the square metal frame. The projector was connected to a central computer which ran the driving simulator software which processed the road scene visuals. Joystick to Mouse software was used to connect the steering wheel to the central computer via a USB Port.

3.3.2.2 Simulator software

The driving simulator software used in the current study was adapted from software used by Göbel (1998). The tracking task required participants to use the steering wheel of the car to maintain the static yellow arrow (representing the bonnet of the vehicle) on to the moving white line in the middle of a simulated road. The speed during the driving task remained constant at 4 km/h. The distance covered was dependant on the time it took for each condition to be completed. While there were variations in time and distance, these were not relevant since the focus of this investigation was on performance. The simulator software allowed for the parameters for the route as well as the perspective parameters to be altered, however in order for consistency the parameters were kept constant.

The driver perspective was adjusted such that it simulated the most realistic street situation. The viewing angle for the road ("viewing skew") was set at 7° in order to correspond with the real seat position in a car. The effect of eye height was negligible and was therefore not a consideration. The colour of the street, the display area and the sky replicated natural conditions. The perception of speed, street width and the steering sensitivity in the simulator was dependent on the factors of the design and perspective of the street.

3.4 Dependent variables

The measurements that were recorded in this study included physiological, performance, subjective and neurophysiological. Physiological measures included heart rate and heart rate variability (both time and frequency domain). Tympanic temperature was measured using the Braun ThermoScanExacTemp® infrared emission detection thermometer. The ThermoScan was set in “equals” mode so as to measure ear temperature without adding an offset (Chamberlain *et al.,* 1995). The ThermoScanExacTemp measures temperature by recording eight measurements per second and displays the highest temperature in degrees centigrade. Performance was quantified by mean deviation from a centre line. Two rating scales were used: Karolinska sleepiness scale and the Wits sleepiness scale were used for the measurement of subjective sleepiness.

3.4.1. Heart rate

Heart rate (HR) has been considered for many years as an index of arousal, task involvement, anxiety and, more recently, mental load and effort (Jorna, 1992). It has been reported to vary as a function of the mental load imposed by the task by increasing as the cognitive demands on the operator increase (Brookings *et al.*, 1996; Wilson and Russell, 2003) and decreasing during tasks of low difficulty and fatigue (Mascord and Heath, 1992; Jorna, 1992). Both sympathetic and parasympathetic processes influence the heart's inter-beat-interval. Sympathetic acceleration of HR results from the release of noradrenaline usually increased during emotional excitement and exercise, while parasympathetic activity increases vagal tone and causes a deceleration in heart rate (Mascord and Heath, 1992). Jahn *et al.,* (2005) noted that HR lacks sensitivity as a mental workload measure, as it is also sensitive to changes in emotional strain and physical activity, as well as varying with respiration.

3.4.2 Heart rate variability

The HRV was measured using Suunto T6 memory belt was used to record cardiac responses during the test session. The electrode strap was placed around the mid-chest, at the inferior border of the pectoralis major muscle in line with the apex of the left ventricle. Conductive gel was applied to the sensors, in order to ensure the signal was not lost due to lack of moisture, or friction between the electrodes and the skin. All data stored within the belts was downloaded via the docking station and Suunto Training Manager 2.2.0.8 software after the test was completed. The Suunto heart rate belts allow for a detailed beat-to-beat analysis, and also provide R-R intervals and ratios which are important for the calculation of heart rate variability (HRV) parameters. Heart rate (HR) was calculated from the inter-beat-interval. The data was filtered by accepting a minimum heart rate of 50 bpm and a maximum of 180 bpm. The maximum variation between beats was set to 200%.

Heart rate variability **(**HRV) has been found to correlate with various human responses to their environment including but not limited to both mental and physical stress and attention (Berntson *et al*., 1997). Studies have shown that heart rate HRV is an important quantitative marker of cardiovascular regulation by the autonomic nervous system (Barbieri *et al.,* 2005) and was initially measured during controlled laboratory conditions (Akselrod *et al*., 1981, Hayano *et al*., 1993). HRV measurements during various interventions have since been widely used as a tool to assess human autonomic function (al-Ani *et al.,* 1996, Goldberger et al., 2001). HRV reflects the continuous oscillation of the R-R intervals around its mean value and provides non-invasive data about the autonomic regulation of heart rate in real-life conditions (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Mental effort is indicated by a lowering in HRV (Wood *et al*., 2002).

3.4.2.2 Frequency domain analysis

A further method for evaluating HRV includes power spectral density (PSD) analysis, which provides the basic information of how power distributes as a function of frequency (Malik *et al.*, 1996). In HRV analysis, the PSD estimation is generally carried out using either fast Fourier transform (FFT) methods or parametric autoregressive (AR) modelling methods. The AR technique was used during this study. The FFT approach could be considered a descriptive method while the AR approach would be more consistent with a statistical approach.

Three main spectral components are distinguished in a spectrum calculated from short term recordings such as those recorded during the current research; very low frequency (VLF), low frequency (LF) and high frequency (HF). It should be noted that VLF assessed from short term recordings is an uncertain measure and should be avoided if possible (Sluiter *et al.,* 2009). HF power is controlled by the parasympathetic activity to the sinus node, whereas LF power reflects the mixed modulation of parasympathetic and sympathetic activity (Mourot *et al*., 2004). Changes in the LF/HF ratio reflect a change in sympathetic activity, but the ratio may also be an index of sympathovagal balance (Mourot *et al*., 2004). For the current research LF, HF, and the ratio between LF and HF (LF/HF ratio) were selected for further analysis.

3.4.3 Core temperature

Core body temperature has been shown to follow a circadian pattern which can also be observed in human performance and mood (Matsumo, 2003). Tympanic infrared temperature thermometer is an easy, quick and non-invasive method of measuring body temperature. The tympanic infrared thermometer measures core body temperature by measuring the infrared radiation from the tympanic membrane of the ear.

3.4.4 Karolinska Sleepiness Scale (KSS)

Karolinska Sleepiness Scale (Åkerstedt and Gillberg, 1990) is a validated 9-graded verbally anchored scale. The scale has 9 options ranging from very alert to difficulty staying awake. The scale is scored from 1-9. The scale was used because all the subjects that participated in the study had high levels of literacy, as they were all university students, and have an understanding of the language used in the scale.

The participants indicated on the 9-graded scale the description-step that best reflected the psycho-physical state they were experiencing at that current moment. The KSS scale ranges from 1 equalling extremely “alert” to 9 being “very sleepy, great effort to stay awake, fighting sleep” (the KSS is presented in Appendix A). Participants simply pointed to the value which best described their level of sleepiness at the time of test administration. The use of the KSS within similar shift work settings has been validated by Blatter and Cajochen (2007); Lombard (2009) and Davy (2010) in measuring similar parameters as in the present study. The results indicated from these studies provide backing for using such a measure within the scope of the present study.

3.4.5 Wits Sleepiness Scale (WSS)

The WSS (Maldonado *et al*., 2004) is a validated pictorial scale using 5 cartoon faces and provides a subjective measure of instantaneous perceived sleepiness (see figure 3.2). The inclusion of this scale in current study was supported by the fact that the scale has been validated within a South African context and the use of cartoon faces requires very little literacy. In addition to this, the scale does not require comprehension of any particular language (Maldonado *et al.,* 2004).

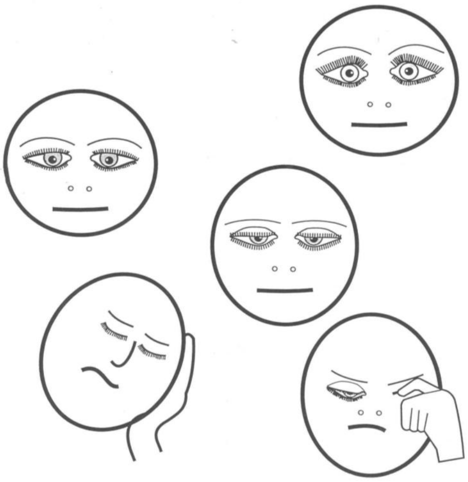

Figure 3.2: Pictorial sleepiness scale based on cartoon faces (WSS) (Maldonaldo *et al.,* Pg 542)

3.4.6 Critical flicker fusion frequency

Critical flicker fusion frequency (CFFF) was used to measure mental fatigue and fatigue at the centre of the visual system. The appearance of fatigue and the deterioration of arousal and consciousness levels of the brain have been associated with a decrease in CFFF values. According to Luckaz and Sobolewski (2005) CFFF is an acceptable measure of fatigue. Moreover CFFF follows the circadian rhythm pattern, thus any fluctuation in the circadian rhythm will be reflected in the CFFF values.

A pair of modified bifocal binoculars was used to measure the CFFF ascending threshold. The binoculars were modified in such a way that the distal ends had covers to block any light from the environments entering the eye. The right lens of the binoculars was fitted with a light emitting diode (LED) that produced a white light. Therefore the subjects had a monocular of the flickering light, on the right, while on the left side had total darkness. The researcher controlled the flickering light of the LED by increasing the frequency (Hz) value until the light was perceived as a steady non flickering light by the participant. The measure was taken both at the beginning and end of the testing session, and three measurements were taken each time in order to ensure the participant reached a similar point each time average of the three instances was used in the final evaluation.

3.5 Experimental procedure

3.5.1 Participants

A total of 16 non-professional drivers participated in this study (8 females and 8 males). Participants were recruited from the Rhodes University student population and were between the ages of 18 and 27 years, with a mean age of 21.3 (± 1.4) years. All participants were required to be in possession of a valid driver's license. Participants were only admitted into the study if they were currently healthy and reported no form of sleeping disorders. Subjects were also excluded if they had a history of epilepsy or any similar conditions, due to the graphic properties of the driving simulator. Participants were required to complete a demographic questionnaire (Appendix A). Information collected included age, gender, race, education background, driving experience and years with driver's license. In addition to the demographic questionnaire participants were required to complete the Morningness-Eveningness Questionnaire (MEQ) (Horne and Ostberg, 1976) (Appendix A). Morningness-Eveningness or Chronotype refers to an individual's specific preference in sleep timing. The MEQ is a 19 item questionnaire with statements or question aimed at determining an individual's preferred rising and bed times, favoured times for exercise and mental performance and the extent of subjective alertness before and after sleep (Davy, 2010). The inclusion of the questionnaire enabled the researcher to screen the participants so no one chronotype will be over represented. This would ensure that the results obtained would not be confounded by one particular chronotype. The majority of subjects (9 of 16) fell “both” category and the rest were classified as having a “moderate” chronotype.

In addition to the MEQ the participant also had to complete the Epworth Sleepiness Scale (ESS). The ESS (Presented in Appendix A) is a self-administered 8 item questionnaire that has been proposed as a simple method for measuring daytime sleepiness or sleep propensity (Johns, 1991). In essence the scale measures the probability of falling asleep in a variety of situations. The fundamental difference between subjective scales such as the KSS and WSS is that they measure subjective sleepiness, which is the level of sleepiness at a particular moment, whereas the ESS measures the general level of sleepiness. ESS requires the participant to rate on a 0-3 scale the chances that over recent times they would have dozed off in 8 specific situation that are commonly met in daily life. Participants are asked to characterize retrospectively, part of their usual behaviour in a variety of situations that are more or less soporific. Participants need to distinguish feelings of dozing off from feelings of tiredness. ESS is a sum of 8 item scores and can range from 0-24.The inclusion of this scale was seen as important because one of the exclusion criteria for the current study was that participants should not suffer from any sleeping disorders. ESS has been used successfully for the assessment of sleep disorders by measuring the level of sleepiness during the day in adults. The level of daytime sleepiness is an important characteristic for the diagnosis of sleep disorders. Based on the ESS, none of the subjects suffered from any sleep related disorders.

3.5.2 Informed consent

This study was approved by the ethics committee of the Human Kinetics and Ergonomics and Department of Rhodes University prior to any testing taking place. Prior to testing, participants were informed about the aims of the study, the procedures involved and what was required of them both verbally and in writing. After asking any possible questions, the participants signed consent forms in order to agree to voluntarily participate in the study (see Appendix A).

3.5.3 Ethical considerations

Each participant was identified using a code, rather than first names, in order to keep measurements confidential. Participant data was kept until statistical analysis had been completed, after which it was deleted.

Experimental procedure of the current study consisted of four sessions, namely two night sessions and two day time sessions. Each session was 90 minutes long and was performed at the Human Kinetics and Ergonomics Department. The subjects in the study were recruited by means of posters, e-mails and student networking. Information with regards to the research was provided, including the exclusion criteria from participation in the study. Participation in the study was completely voluntary and participants were informed of their right to withdraw from the study at any time without any negative consequences.

For participation in the current study, subjects had to meet certain criteria.

- Participants must not suffer from any sleep related disorders: Sleep disorders may negatively impact night time driving performance due to the build-up in sleep pressure. Also some sleeping disorders are associated with extremely high levels of day time sleepiness and this could also affect day time driving results

- Participants were also required to be in possession of a valid driver's licence. According to the South African law each driver must have a driver's license to be able to drive on the roads.

- Consumption of stimulants: Regular users of alertness enhancing compounds such as caffeinated drinks were excluded from the study. Pigeau *et al*., (1995) has reported that the use of these compounds has been associated with improved performance in neurobehavioural performance and alertness levels.

- Smokers: Smokers were excluded in the study as substances contained in cigarettes are known to have a stimulating effect which might "mask" the endogenous circadian rhythm (Blatter and Cajochen, 2007).

From the participants who had volunteered to participate in the study only the individuals who met the above mentioned criteria were chosen. Once this initial screening process was finished, a habituation session was arranged with the subjects individually.

3.5.4 Habituation

The habituation session was 40 minutes in duration, and took place at a time convenient to the participant. During this session the procedures of the study were explained to the participants and they were familiarised with equipment to be used. The participants were also exposed to the driving simulator used in the research. The participants got an opportunity to drive the simulator for 20 minutes during the session. Any questions that the participants might have with regards to the research procedures were addressed during this session.

3.5.5 Testing procedure

On the day of testing the participants were requested to arrive 30 minutes before the actual testing time. For day time testing they were requested to arrive at 11:00 as testing started at 11:30 and for the night time testing they were asked to arrive at 22:30 as testing started at 23:00. On the day of testing subjects were asked to refrain from any strenuous activity or exercise and be up from bed at least an hour or more before their day time testing session to avoid the effects of sleep inertia. If participants were having a testing session at night they were requested not to take a nap during the day.

When subjects arrived at the testing laboratory they signed a consent form and the testing procedure was explained to them again. They were then asked to sit down on the driving simulator sit and rate their subjective levels of sleepiness on the WSS and KSS which was placed in front, they did this by pointing onto a statement on the scale which best described how sleepy they felt at that moment and the number of the statement was recorded by the researcher. The same procedure was followed for the WSS scale.

After these measurements were taken the participant was asked to stand up, and was instrumented with the heart rate memory belt. The memory belt was placed around the mid chest at the inferior border of the pectoralis major muscle. After the belt was properly fitted and was activated the participant was asked to a sit in the driving simulator. The participant had to sit still for 5 minutes to measure their reference heart rate. After the first 5 minutes the driving simulator was activated. At the end of the driving task the heart belt was removed and the data was downloaded with an aid of a docking station and Suunto® training manager 2.2.0.8 Software. Participants were required to remain seated until the belt was removed as posture changes have the potential to affect HR responses.

Depending on the condition performed, for the break condition, the driving simulator was activated for 10 minutes, after 10 minutes the driving would automatically stop and auto-driving would take over while the driver had a break. This was repeated 9 times to make up the 90 minutes. For the control condition the simulator was activated for the entire 90 minutes. When the 90 minutes was up, the simulator stopped automatically. The participant was asked to remain seated while the heart rate memory belt was removed, as changes in posture would affect the results. The CFFF threshold, tympanic temperature and subjective ratings on the WSS and KSS measurements that were taken at the beginning of the drive were repeated at the end. The same procedure was followed for both day and night time experimental conditions.

3.6 Data analysis

A data reduction tool developed by Rhodes University Human Kinetics and Ergonomics Department was used for the analysis of performance and physiological measures. All experimental data was imported into a Statistica Version 8 Software (StatSoft® Inc. 2008) for generating of statistical analyses. A general linear model was applied for the analyses of variance (ANOVA) tests ($p<0.05$) to determine if there were significant differences in the driving performances for the experimental conditions. A confidence level of 95% with a corresponding alpha level of 0.05 (5%) was chosen. A student t-test ($p<0.05$) was used to determine if there were significant differences for performance in the driving performance, physiological, neurophysiological and subjective responses for the experimental conditions.

CHAPTER 4
RESULTS

The investigation of the effect of short duration breaks during long distance monotonous driving at different times of the day considered performance indicators, neurobehavioral and subjective responses, when compared to no break conditions. In addition the study aimed to establish whether the short duration breaks would be effective at delaying the onset of fatigue during the day and at night. Four conditions were designed for this investigation. Each condition had a duration of 90 minutes. The conditions were composed of two break conditions and two no break conditions which occurred at different times of the day. The day and night conditions occurred at 11:30 and 22:30 respectively. The break condition was the 90 minute drive which was broken up into 10 minute shorter driving intervals which had 2 minutes break in-between.

To quantify performance, participants were required to complete a tracking task. The tracking task required participants to use the steering wheel of the car to maintain the static yellow arrow on-to the moving white line in the middle of a simulated road. The quality of the tracking was measured by mean deviation. Physiological measurements were recorded for heart rate and heart rate variability and tympanic temperature. The ascending threshold of the critical flicker fusion frequency (CFFF) was used to assess neurophysiological activity. The Wits sleepiness scale (Maldonado *et al*., 2004) and the Karolinska sleepiness scale (Åkerstedt and Gillberg, 1990) were used to assess subjective sleepiness. The basic descriptive statistical analysis was generated for the data using Statistica 8.0.

4.1 Physiological parameters

The physiological measurements that were analysed in the study included heart rate and heart rate variability results for the frequency domain.

4.1.1 Heart rate

A summary of the basic descriptive statistics for heart rate data is presented in Table 2 for the entire sample group. The results show that the no break conditions had a higher heart rate compared to the break conditions.

Table 2: Summary of heart rate data for the entire sample group

Experimental condition	Mean (b/min)	Standard Deviation (b/min)
Night without breaks	75.8	1.8
Night with breaks	70.8	1.2
Day without breaks	79.3	2.7
Day with breaks	72.2	3.0

The three way ANOVA was calculated for the heart rate data to determine whether there were statistical significant differences among experimental conditions. The statistical analysis indicated that there was a statistically significant ($p<0.05$) time on task and the interaction between the conditions (break and no break) and time on task.

Table 3: Three factorial ANOVA for heart rate with the factors condition (with and without break) time of day (night or day) and time on task

Interaction of conditions	**SS**	**Degree of freedom**	**MS**	**F**	***p***
Condition (with and without break)	11899	1.4	11899	0.494	0.520736
Time of day (night or day)	20621	1.4	20621	1.464	0.292899
Time on task	6464	89.4	73	3.173	P<0.05*
Condition vs Time of day	29	1.3	29	0.006	0.942742
Condition vs Time on task	1868	89.4	21	1.304	0.048651*
Time of day vs Time on task	971	89.3	11	0.759	0.941373
Condition vs Time of day and Time on task	2028	89.3	23	1.228	0.099514

The heart rate data for driving without breaks was compared with the heart rate data for driving with breaks. Figure 4.1, indicated that driving without break was characterised by a higher heart rate and the driving with break condition had a lower heart rate.

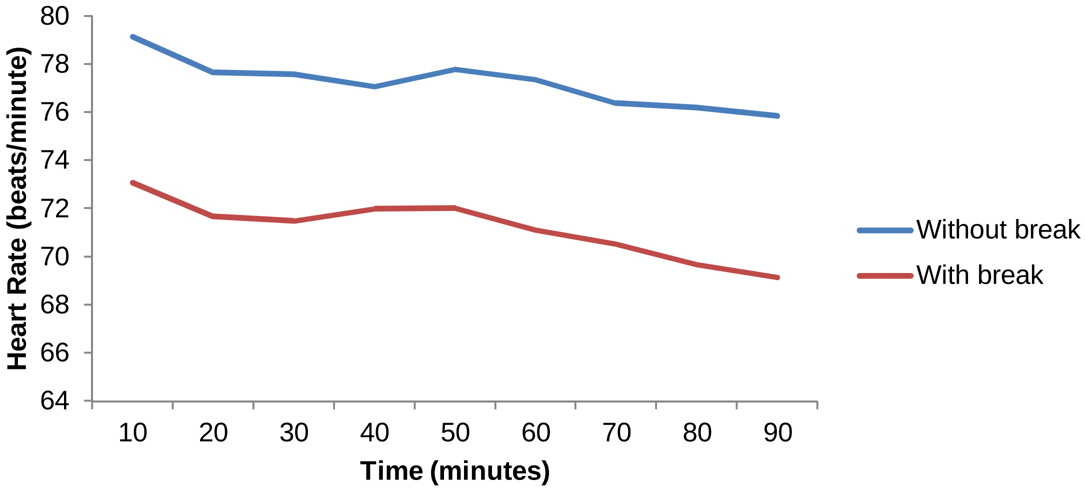

Figure 4.1: Heart rate fluctuations for condition (without and with break) over the 90 minute driving task

A significant time on task effect was found for heart rate as presented in Table 3 above. Heart rate gradually decreased over the 90 minute drive, for the first ten minutes heart rate declined and was constant between 20 and 60 minutes and then gradually declined after the first 60 minutes as shown in Figure 4.3.

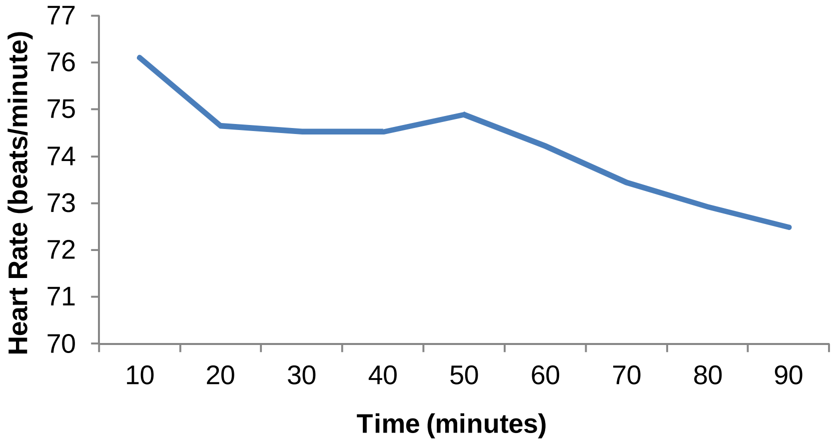

Figure 4.3: Gradual decline in heart rate over the 90 minute driving task.

4.1.2 Heart Rate Variability

In order to obtain an indication of sympathetic and parasympathetic activity, the frequency domain of heart rate variability was analysed. A significant difference was found for the interaction between time on task and condition (Table 4) for the high frequency band. Figure 4.2 graphically shows the changes for the high frequency of heart rate variability.

Table 4: Three factorial ANOVA for high frequency domain with the factors condition (with and without break) time of day (night or day) and time on task

	SS	Degree of freedom	MS	F	*p*
Condition (with and without break)	1055.72	1.5	1055.72	4.0092	0.101641
Time of day (night or day)	4.50	1.5	4.50	0.0348	0.859350
Time on task	208.21	8.5	26.03	2.0126	0.069683
Condition vs Time of day	896.32	1.5	896.32	2.0699	0.209756
Condition vs Time on task	264.06	8.40	33.01	3.0257	0.009380*
Time of day vs Time on task	118.69	8.40	14.84	1.1309	0.364187
Factors condition vs Time of day and Time on task	137.66	8.40	17.21	1.3138	0.264687

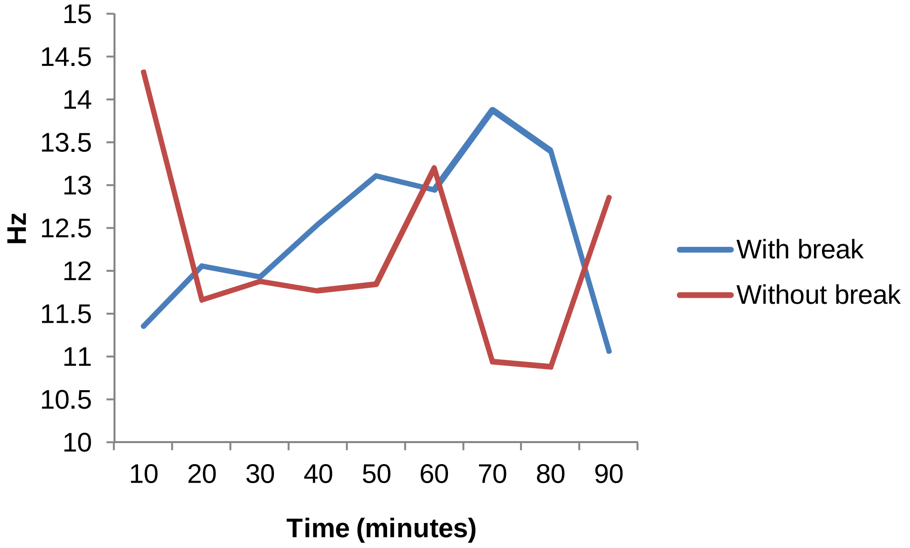

Figure 4.2: Fluctuation in High Frequency band over the 90 minute driving task

4.1.2.2 LF/HF Ratio

The LF/HF power ratio provides an indication of the balance of cardiac autonomic nervous activity by taking into account both the low frequency bands and high frequency bands. An increase or decrease in the ratio value reflects the normal circadian changes over a 24 hour period. Table 5 presents the significant ($p<0.05$) results of the three way ANOVA for LF/HF Ratio.

Table 5: Three factorial analysis of variance for LF/HF ratio with the factors condition (with and without break) time of day (night or day) and time on task

	SS	**Degree of freedom**	**MS**	**F**	***p***
Condition (with and without break)	2.8039	1.5	2.8039	0.47367	0.521927
Time of day (night or day)	20.3330	1.5	20.3330	1.50759	0.274153
Time on task	20.8166	8.40	2.6021	3.96312	0.001567*
Condition vs Time of day	1.3941	1.5	1.3941	0.17502	0.693050
Condition vs Time on task	2.0965	8.40	0.2621	0.39731	0.915436
Time of day vs Time on task	6.5958	8.40	0.8245	1.15275	0.350974
Condition vs Time of day and Time on task	1.9497	8.40	0.2437	0.39600	0.916179

Figure 4.4 shows changes in in LF/HF Ratio over the 90 minute driving task. For the first 10 minutes there was an increase in the LF/HF Ratio, followed by a decline between 10 and 50 minutes. During the last 30 minutes of there was a steep increase in the LF/HF Ratio.

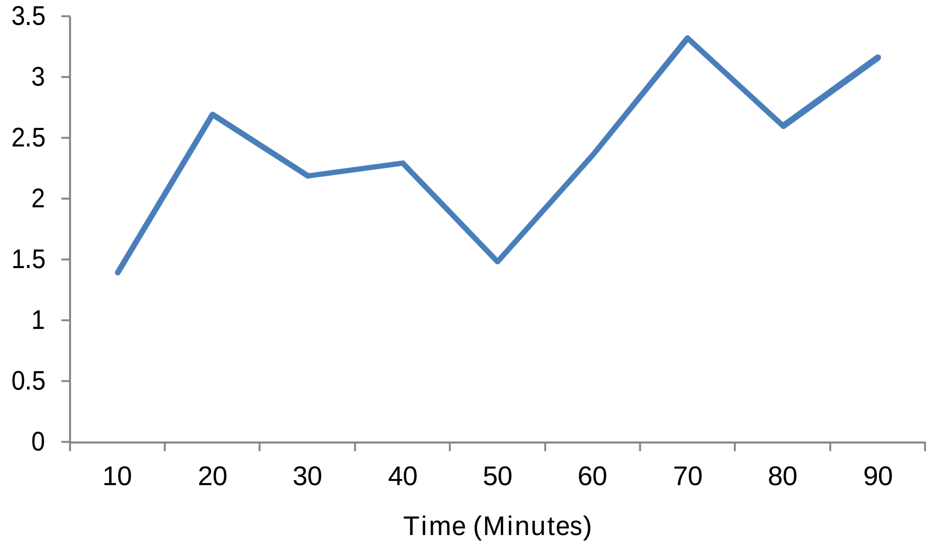

Figure 4.4: Fluctuation in LF/HF ratio over the 90 minute driving task

4.1.3 Body temperature

A summary of the descriptive statistics for body temperature data is presented in Table 6. The Three-way ANOVA for the entire sample group found no statistical significant differences among the different experimental conditions.

Table 6: Summary of temperature results

Condition	**Mean** Degrees Celsius	**Standard Deviation**
Day without break	34.7	0.8
Night without break	34.8	0.9
Day with break	34.9	0.5
Night with break	34.6	0.9

4.1.4. Critical flicker fusion frequency

Critical flicker fusion frequency (CFFF), specifically the ascending threshold was assessed using a pair of modified bifocal binoculars to determine the impact of the different experimental conditions on the perception of flickering light and the frequency at which the flickering disappears. A summary of the descriptive statistics for CFFF is presented in Table 7. The three-way ANOVA for the entire sample group found no statistical significant differences among the different experimental conditions and is included in Appendix C.

Table 7: Summary of critical flicker fusion frequency results

Experimental condition	**Before**		**After**	
	Mean	SD	Mean	SD
Day with breaks	51.7	5.3	54.1	5.8
Day without breaks	54.5	10.3	50.8	4.8
Night with breaks	54.3	5.6	51.0	2.5
Night without breaks	55.6	6.1	50.8	4.2

4.2 Subjective sleepiness

Two rating scales were used for the measurement of fatigue, namely the Karolinska sleepiness scale and the wits sleepiness scale.

4.2.1 Karolinska sleepiness scale

Table 8 presents the results of the three way ANOVA for the Karolinska sleepiness scale ratings. A significant difference was observed in the subjective sleepiness ratings before and after the driving task as well as the interaction between the condition (with break and without break) and time.

Table 8: Three factorial analysis of variance for the Karolinska sleepiness scale with the factors condition (with and without break) time of day (night or day) and before and after driving

	SS	Degree of freedom	MS	F	p
Time	1.0417	1.11	1.0417	1.1224	0.312101
Condition	1.5000	1.11	1.5000	1.2941	0.279463
Before and After driving	30.3750	1.11	30.3750	52.4118	0.00001*
Condition x Time	4.1667	1.11	4.1667	5.3398	0.04124*
Time x Before and After test	0.0417	1.11	0.0417	0.3793	0.550504
Condition x Before and After test	0.1667	1.11	0.1667	0.8800	0.368343
Time x Condition x Before and After test	0.0000	1.11	-0.0000	-0.0000	1.000000

The three-way ANOVA indicated that there was a statistical significant difference in subjective sleepiness levels between ratings before and after the 90 minute driving task for day with breaks and day without breaks as well as night with breaks and night without breaks. Figure 4.5 provides a comparison of all the four experimental conditions mean values before and after the 90 minute drive.

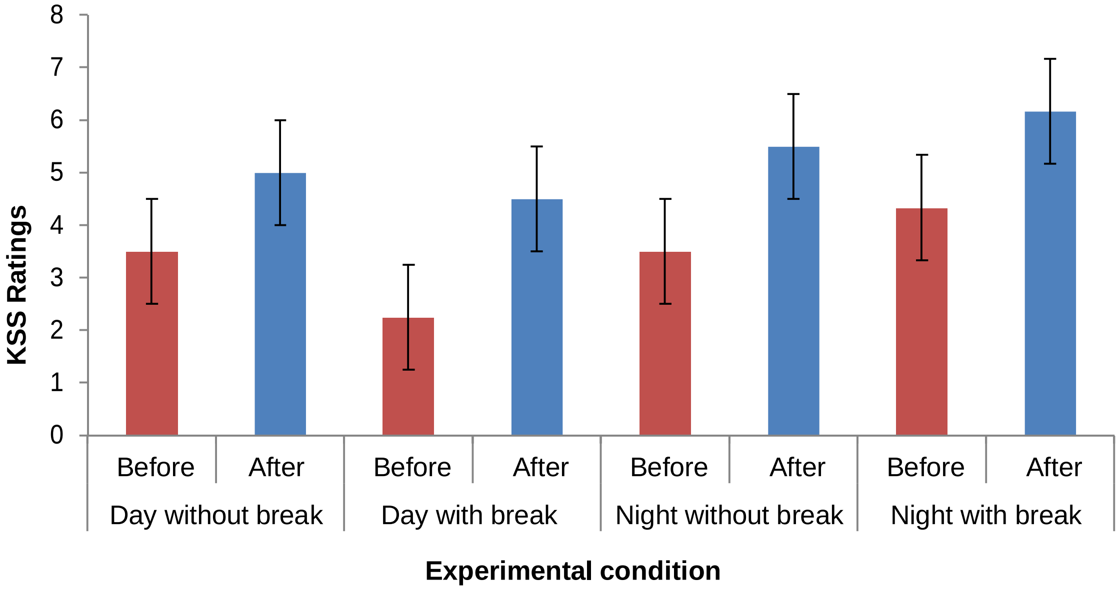

Figure 4.5: KSS for the experimental conditions before and after the driving task

As shown in figure 4.5 for all the experimental conditions the subjective ratings were higher after the 90 minute monotonous driving task ($p< 0.05$) compared with the ratings before the driving task. The interaction between the time of day and condition (with break and without break) produced significant results (Table 8) and graphically represented in Figure 4.6.

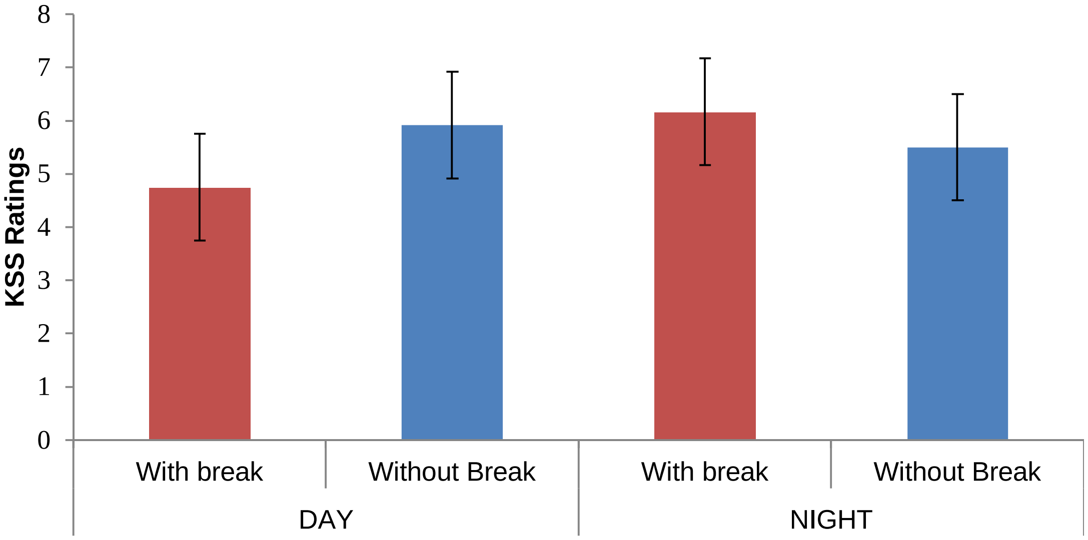

Figure 4.6: The effect of time of day on conditions (without break and with break)

When comparing the effect of the break condition on subjective sleepiness, (Figure 4.6) shows that the break condition during the day had a positive effect on sleepiness levels. However at night the sleepiness levels were higher for the break condition compared to the no break condition. From the results it can be concluded that during the day the break had positive effect on sleepiness levels, at night however the breaks had a detrimental effect on sleepiness levels.

4.2.2 Wits sleepiness scale

The results obtained for the Wits Sleepiness scale are similar to the Karolinska sleepiness scale result. Table 9 presents the results of the three way Anova for the Wits sleepiness scale ratings. A significant difference was observed in the subjective sleepiness ratings before and after the driving task.

Table 9: Three factorial analysis of variance for Wits sleepiness scale with the factors condition (with and without break) time of day (night or day) and before and after driving

Effect	**SS**	**Degree of freedom**	**MS**	**F**	**p**
Time	0.2604	1.11	0.2604	0.3231	0.581141
Condition	3.0104	1.11	3.0104	2.4323	0.147149
Before and After test	25.0104	1.11	25.0104	88.3311	P<0.05.*
Condition x Time	2.3437	1.11	2.3437	2.6358	0.132764
Time x Before and After test	0.5104	1.11	0.5104	2.6552	0.131489
Condition x Before and After test	0.8438	1.11	0.8438	2.1679	0.168946
Time x Condition x Before and After test	0.2604	1.11	0.2604	1.2115	0.294547

The three-way ANOVA indicated that there was a statistical significant difference in subjective sleepiness levels between ratings before and after the 90 minute driving task for day with breaks and day without breaks as well as night with breaks and night without breaks. The results indicate that the monotonous driving task fatigued the participants. Figure 4.5 provides a comparison of all the four experimental conditions mean values before and after the 90 minute drive.

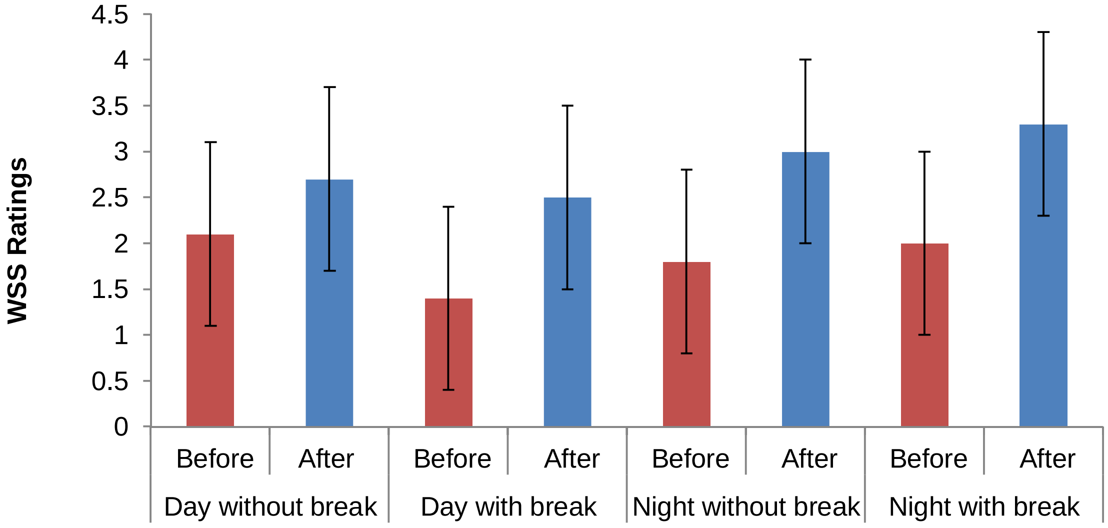

Figure 4.7: WSS ratings for the experimental conditions before and after the driving task

The night conditions generated higher subjective sleepiness levels in comparison to driving during the day. Driving at night fatigued the drivers and this is mirrored by the elevated subjective sleepiness levels. During the day the break condition resulted in lower subjective sleepiness levels in comparison to the no break condition (Day without breaks). At night the opposite of what occurs in the day was be observed. The break condition (Night with breaks) at night is characterised by higher levels of subjective sleepiness in comparison to the night no break (Night without breaks) condition.

The change in fatigue levels over the 90 minute driving task was determined by subtracting the sleepiness ratings values at the completion of the driving task from the subjective sleepiness values after the driving task. The difference between the two was taken as an indication of how fatiguing the driving task was. The two-way ANOVA indicated that there was no significant difference the change in fatigue levels between the conditions. Therefore no experimental condition was more fatiguing in comparison to the other conditions.

4.3 Driving performance responses

The mean deviation was used to quantify driving performance. Basic descriptive statistical analyses were generated for the data to determine the mean values and standard deviation (SD) for mean deviation ratings. A summary of the descriptive statistics is presented in Table 10 for the entire sample group.

Table 10: Summary of descriptive statistics for mean deviation

Condition	Mean(M)	SD
Night with breaks	0.0163	0.0026
Night without breaks	0.0160	0.0024
Day with breaks	0.0173	0.0040
Day without breaks	0.0226	0.0043

The day conditions (with break and without break had the highest deviation, indicating that the driving performance was worse when driving during the day compared to driving at night (with break and without break) as presented in Table 10.

Table 11: Three factorial analysis of variance for mean deviation with the factors condition (with and without break) time of day (night or day) and time on task

	SS	**Degree of freedom**	**MS**	**F**	***p***
Condition (with and without break)	0.000449	1.5	0.000449	0.02603	0.878153
Time of day (night or day)	0.001174	1.5	0.001174	0.13974	0.723871
Time on task	0.010767	89.4	0.000121	2.53225	P<0.05*
Condition vs Time of day	0.000505	1	0.000505	0.05660	0.821391
Condition vs Time on task	0.004788	89.4	0.000054	1.21382	0.107412
Time of day vs Time on task	0.002472	89.4	0.000028	0.50314	0.999935
Condition vs Time of day and Time on task	0.003006	89.4	0.000034	0.69623	0.981130

Time on task refers to the effect time spent performing the task had on driving performance. Figure 4.6 graphically represents the mean deviation over the 90 minute driving task. The graph shows a deviation for the entire 90 minute driving task.

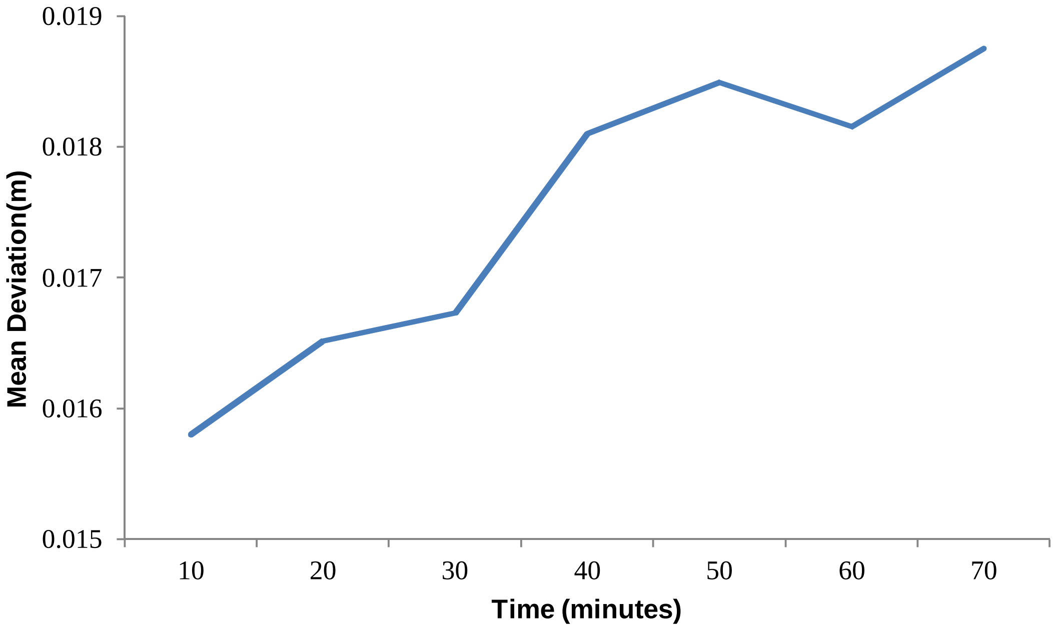

Figure 4.9: Changes in driving performance of the 90 minute driving task.

4.4 Response to hypotheses

The null hypothesis (hypothesis 1) had stated that that there will not be a difference in all variables measured between the break condition and the control condition during the day. However, it was found that sleepiness ratings were significantly lower when driving with intervention and without intervention during the day (figure 4.6). Heart rate and the high frequency band of heart rate variability showed a significant difference for driving with and without intervention (figure 4.2) during the day. Therefore the null hypothesis was tentatively rejected.

The null hypothesis (hypothesis 2) had stated that that there will not be a difference in all variables measured between the break condition and the control condition during the night. However, it was found that subjective ratings differed significantly when driving with intervention and without intervention during the night (figure 4.6). Heart rate and the high frequency band of heart rate variability showed a significant difference for driving with and without intervention (figure 4.2) during the day. Therefore the null hypothesis was tentatively rejected.

The null hypothesis (hypothesis 3) had stated there will be no difference between driving without breaks during the day in comparison to driving without breaks at night. No differences were found when driving without break at night and driving without break during the day. Therefore the null hypothesis was tentatively accepted

The null hypothesis (hypothesis 4) had stated there will not be difference between driving with breaks during the day in comparison to driving with breaks at night. However a significant difference was found for subjective ratings when driving with breaks at night and driving with break during the day. Therefore the null hypothesis was tentatively rejected

The null hypothesis (hypothesis 5) had stated that time on task would have no impact on all the measured variables. However a significant effect for time on task was found for heart rate, LF/LH ratio and for mean deviation. Therefore the null hypothesis was tentatively rejected.

CHAPTER 5
DISCUSSION

The aim of the study was to investigate whether the introduction of short duration breaks would delay the onset of performance related fatigue during long distance monotonous driving at different times of the day. The onset of fatigue was quantified using changes in performance, physiological as well as subjective sleepiness levels experienced during the driving task. The introduction of the short duration breaks was also used to investigate the cause of the decline in driving performance during monotonous driving. Firstly, whether the decline observed during driving is attributed to fatigue, in which case the only way to remedy that is through rest. The alternative is down regulation due to the nature of the task which could be alleviated by an introduction of a novel stimulus. Therefore the introduction of the breaks during regular intervals would serve as the stimulus.

5.1 The effect of time on task

When performing a task such as driving, attention must be maintained for an extended period of time against effort cost, if motivation to invest effort is low, performance may deteriorate. Time on task has been identified as one of the key factors contributing significantly to vehicle incidents.

In the study it was hypothesised that there will be a decline in tracking performance over time. An increase in time spent performing the driving task was accompanied by an increase in driving deviations which was indicative of the fatigued state of the drivers. A decline in performance is often seen as a characteristic of fatigue with a continuous workload, and associated with a slowing of sensorimotor performance (Zhang *et al.*, 2009). These results are supported by several studies; Nilsson *et al.,* (1997) reported that fatigue symptoms started developing after 60 minutes of monotonous driving. Under controlled laboratory conditions, one can observe indications of fatigue in some subjects after 60 minutes of driving or vigilance task (Galinsky *et al*., 2000). De Gray Birch (2012) has shown that a 120 minute tracking task leads to increased errors over time.

The second hypothesis stated that there will be a difference in the onset of performance related fatigue for driving with breaks and without breaks and for driving at different times of the day. It was hypothesised that driving with breaks would delay the onset of performance related fatigue but this was not reflected in the results, the results showed that the performance in the tracking task declined regardless of the time of day or whether the drivers had a break or not. It was also expected that night time driving would be characterised by greater tracking deviations, compared to driving during the day but this was not the case.

The third hypothesis stated that there would be a change in physiological and subjective measurements over time. The results show time on task had a significant effect on heart rate, heart rate variability and subjective measures. Heart rate declined over the 90 minutes driving task which is indicative of the fatigued state or low arousal/activation levels of the drivers. Heart rate in the current study was used to make inferences to activity levels or effort investment by the participants. A decrease in heart rate is taken to indicate a decline in activity levels or investment of effort. The decline in heart rate is synonymous with the activation of the parasympathetic nervous system, which is dominant during periods of down regulation of the body.

The results for the LF/HF were significant for time on task (see figure 4.4). The results show that throughout the 90 minute driving task, there was an interchange between the sympathetic and the parasympathetic branches of the autonomic nervous system. A decline in the LF/HF power ratio implies a weakening in the sympathetic and strengthening of the parasympathetic branches of the autonomic nervous system. This is typically associated with an increased need to sleep and the down regulation of the circadian system. An increase in the LF/HF ratio signifies greater sympathetic activation and a potential slowing of the parasympathetic branch. This is associated with periods of higher arousal and lower fatigue levels. From figure 4.4 it can be seen that for the first 10 minutes the LF/HF ratio increases and this was expected as this occurred at the start of the 90 minute drive and the drivers were still alert. After this period the LF/HF ratio decreased, this might have been due to down regulation and not necessarily fatigue. Toward the end of the task, the ratio increased again this could indicate that the participant investing more effort into the driving task in order to complete the driving task.

The subjective results also showed that the driving task was fatiguing. The subjective ratings were higher for both the KSS and the WSS after the drive compared to the start of the drive. Increased subjective ratings have been reported to increase as fatigue levels increase, KSS subjective ratings have been reported to correspond closely to EEG levels during periods of increased fatigue. Although there was no significant difference for the interaction between time on task and the time of day, the results showed that the subjective ratings were higher after driving at night than when driving during the day.

Therefore this could mean that the hours spent by drivers behind the wheel should be strictly regulated to avoid fatal vehicle accidents. In England, the Industrial Fatigue Research board was tasked to explore ways of dealing with fatigue-related human errors. The board was successful in reducing production errors by reducing the number of working hours per shift number (Brown, 1994). Although time on task has been identified as one of the significant factors contributing to the development of fatigue, time of day has also been identified as a key factor in the development of fatigue. The times that have been associated with greater sensation of fatigue and with exacerbated effect of time-on-task include early morning hours and post lunch periods.

5.2 Interaction effects

The study found no performance differences for driving at different times of the day and driving with and without breaks, however interaction effects were found for heart rate, heart rate variability and subjective measures. This might indicate that in order to maintain the same performance output more effort had to be invested into the driving task, when driving without break and at different times of the day. Adverse mismatches between task workload and processing capacity is usually perceived by the individual as stress and the resulting strain, if it persists is perceived as entry into a state of fatigue. Therefore the drivers experienced more stress when performing these tasks and as a result experienced more strain in order to maintain the same performance output. Stress may arise from a situation where their normal capacity from processing information is impaired such as in the case where they are fatigued.

There was significant interaction effect between the time of day and condition for both heart rate and the high frequency band of heart rate variability. The no break condition was characterised by a higher heart rate. However this finding was not mirrored in the driving performance results. It was expected that since the no break condition was characterised by a higher heart rate, then performance was expected to be better in this condition compared to the no break condition. This could indicate that the participants had to invest more effort when driving without a break and this brought about an increase in sympathetic activation which is reflected by the higher heart rate. According to Kahneman (1973) in order to increase the amount of available resources resulted in an increase in sympathetic activation.

The break condition had a lower heart rate, which could mean that the participant's activity level was lower for this task. These results were unexpected at it was expected that during this condition heart rate would be higher as the participants would be more alert because of the short break intervals. One of the explanations for these results could be related to the effect of automation on performance. The protocol of the study resembled an in-vehicle fatigue countermeasure system, which would allow the driver to take a break in the vehicle. Automation in this case caused the individuals to relax as this is reflected in the decreased heart rate. This raises a question about the impact of automated systems on driving, and whether automated systems have a positive or negative impact on driving. Although the automated system in the current study was supposed to prevent fatigue by providing breaks at regular intervals which would keep the drivers awake. However the results suggest that the breaks had a relaxation effect, which is not ideal as this could lead to the driver falling asleep and ultimately to vehicle incidents. This could be due to the fact that the no break condition was easier to perform and thus the drivers didn't invest as much effort into the task. Desmond and Matthews (1996) had suggested that in vehicle systems which reduce the driver's perception of the driving task are likely to accentuate under mobilisation of effort in fatigued drivers.

This demonstrates what might actually be happening on the roads and at times leads to fatal accidents. The only feedback drivers have about their state of fatigue is the driving performance, on the road this could refer to keeping to the right lane and on the right side of the road. Although physiological measures would clearly show that the drivers are getting fatigued on the road, drivers do not have access to this information, and can only evaluate their driving performance. This means that until the drivers observe a gross degradation in their performance (e.g., not keep to the right lane or driving towards oncoming traffic) they might continue with their journey although that might put themselves or other road users at risk. In terms of on-road fatigue monitoring physiological measures could provide more insight into the driver's fatigued state compared to on-road performance measures. Nelson (1997) defines fatigue as the condition an individual reaches as a result of sustained activity wherein he or she declares being unable to continue with the activity further. This statement suggest that individuals are aware of this state where they are unable to continue with their activity but due to work pressures and personal desires continue with their activity. Brown (1994) collected data on personal fatigue experience from a variety of professional seafarers who had to submit reports on conflicts and near accidents that could have been related to fatigue in some way. Their reports suggested that they experience some symptoms due to fatigue. However, in spite of symptoms they might be experiencing; they invariably continued performing their tasks to the end of the shift. This response exemplifies the conflict that Bartley and Chute (1947) concluded was an essential component of the fatigue syndrome. Fatigued individuals who are responsible for operation and control in transport systems inevitably experience conflict between a self-imposed need or externally imposed demand to complete their given tasks and their desire to preserve the safety of themselves and others. According to Brown (1994) resolving this conflict satisfactorily is the key to the avoidance of adverse fatigue effects on safety in the transportation system.

There was a significant interaction for condition and time of day, which meant that the impact of the break or no break condition did not have the same impact at different times of the day. During the day, the break had a positive impact on subjective sleepiness levels, as the subjective ratings during the break condition were lower when compared to driving without breaks. However at night the breaks had a negative effect on subjective sleepiness levels (see figure 4.6), as the driving with break condition at night had higher subjective ratings compared to driving without breaks at night. Interpreting these results from subjective ratings provides a bit of a challenge as these results are not reflected in any of the other measures used in the study. It could be concluded that the participants thought they were more alert during the day break condition, compared to the night condition. Schmidt *et al.,* (2009) reported similar findings from a study where participants reported after a 3 hour drive that they were still alert whereas the physiological measures proved otherwise, and these researchers concluded that individuals are not very accurate at monitoring their own fatigue state. If the fatigue level were lower for the break condition then it would be expected that an improvement in performance for this condition would have been observed and an increase in the activation of the sympathetic branch of the autonomic nervous system. However performance results have shown that performance declined regardless of the condition or time of day and the same was observed for heart rate.

At night the break condition could have had a negative effect because the duration of the break was short and as a consequence didn't offer enough time for recovery. Alternatively at night the breaks were not effective because participants could have been suffering from sleep related fatigue and thus the short breaks were not effective. At night they just wanted to finish the 90 minute drive and go home and they could have felt that the breaks prolonged the entire process.

With regards to differentiating between down-regulation and passive fatigue, the results seem to suggest that the drivers were suffering from passive fatigue. If it was down regulation the inclusion of breaks would have been able to restore performance at least for the period immediately following the breaks but this was not the case.

5.3 Fatigue countermeasure

The breaks introduced in the study were used to mimic a simple in-vehicle countermeasure system. From the results obtained it can be concluded that the breaks were not effective as a fatigue countermeasure. This could be related to the duration of the breaks and also the activity undertaken during the breaks. Road safety countermeasures in general are categorised as education, enforcement, or engineering. The in-vehicle countermeasure used in the study falls under the engineering category, although engineering countermeasures play a crucial role in counteracting the impact of fatigue, educating the drivers about the risks associated with fatigue still remains important. Given that fatigue is a subjective experience, drivers must have a clear understanding of its causes and symptoms, if they are to be in a position to implement one or more remedial actions before becoming accident involved.

The effectiveness of such educational countermeasures is still questionable as the majority of fatigued drivers complete their journey safely and this experience devalues the message “fatigue kills”. However this does not only apply to educating drivers about fatigue, other factors responsible for road incidents such as alcohol and driving over the speed limit still seems to fall on deaf ears. In South Africa the arrive alive campaign has been trying educate drivers about driving under the influence of alcohol and speeding but despite these efforts the death toll seems to be rising due to drunken driving and speeding (RTMC, 2009). This situation seems to suggest that drivers are aware of all the risk factors associated with driving while fatigued, or under the influence of alcohol. However it seems as if enforcement is lacking. It seems less of a challenge to enforce driving within the speed limit and not exceeding the speed limit than it is enforcing driving limits with regards to fatigue, as alcohol and speeding can be measured objectively on the road, no such measurements exist for fatigue.

The central dilemma is that fatigue is a subjective experience, best known by the individual in question, but in some cases that individual is often not the best person to rely on for safe and effective resolution of his or her fatigued state. The first step in curbing fatigue-related incidents on the road is to develop a reliable on-road measure for fatigue. In some countries professional drivers are required to carry a log book which states the number of hours driven and rest taken in an attempt to limit the time spent behind the wheel. However non-professional drivers do not have such log books and therefore it is not possible to monitor the time they have spent behind the wheel and they also suffer from fatigue while driving.

The major problem with fatigue countermeasures is finding a reliable and socially acceptable fatigue countermeasure which will limit further driving by dangerously fatigued individuals. Given the conflict that exists between the driver’s experiences of fatigue symptoms and their desire or employers demand to complete their journey a simple warning of fatigue onset would never be able to force drivers to abort their journey, although such warnings could serve an educational function. Stopping for a rest break along the side of the road could expose the drivers to other dangers as in many countries there are limited opportunities for resting places along the side of the road and in such circumstance safety becomes the main concern.

Engineering interventions such as the one used in the study require further research as taking a break while an automated system takes over some of the driving task could solve the conflict between the driver’s experiences of fatigue and their desire to continue with the driving task. If the breaks would be taken in-vehicle this means that the drivers would not take any time off to stop and therefore would not lose any time off their journey. Longer duration in-vehicle breaks could be explored as well as the activity to be undertaken during the break could also be investigated to establish whether in-vehicle breaks could be effective in delaying the onset of driver fatigue.

5.4 Reflection

Although every effort was made to ensure that all external factors, would not affect the outcome of the research, some factors were outside the researcher’s control. The time of day which the research was conducted was not ideal as early hours of the morning would have been ideal to elicit the expected response from the participant but this was not possible because of the student population which was used for the study. It is a well-known fact that heart rate variability is sensitive to many factors and that could have influenced the outcome of the results. Although the participants were informed of what to do and not do prior to participation there was no way of knowing with certainty if the participants adhered to these requirements. To avoid the influence of external factors a highly controlled experiment would have to be conducted where the subjects would have to be “quarantined” for at least a 24 hour period in order for the researcher to properly monitor the drinking, eating and exercise habits. Although the entire group of participants who took part in the study had driver’s licences, the tracking task used was different from the normal everyday driving task and therefore more time should have been spent habituating the participant.

CHAPTER 6:
SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

The research study sought to investigate the effect of short duration breaks in delaying the onset of fatigue during long distance monotonous driving at different times of the day. The physiological measurements of heart rate, heart rate variability and tympanic temperature; neourophysiological responses (CFFF), subjective sleepiness questionnaires (KSS and WSS) and mean deviation from the simulator driving task were used for gathering of the performance data. The study consisted of four independent conditions, namely the day with breaks condition, day without breaks condition, night break condition and the night without break condition. During the break condition the drivers had breaks at certain intervals during the drive. In the control conditions (without break condition), the participants drove for the entire 90 minutes without any breaks. A total of twelve participants completed the driving task under four experimental conditions: night without breaks, night with breaks, day without breaks, and night with breaks. The duration of the driving task was 90 minutes.

A thorough literature review was conducted in order to gather detailed information on the current study. The literature review focussed on three sections: The first section considered the prevalence of traffic incidents in developing countries, focusing on information pertaining to current trend in traffic incidents in South Africa. The second section considered the causes of traffic incidences in developing countries with emphasis on driver fatigue, types of fatigue and the common countermeasures used by drivers against fatigue. The last section reviewed the most common methods used for the analysis of driver fatigue.

6.2 Conclusion

Road traffic accident are a serious problem in South Africa besides sufferings associated with the loss of life, the South African economy is also burdened by the high death toll on the roads. In 2012 it was estimated that the cost of traffic accidents amounted to R34 Billion. Despite the attempts by the Arrive Alive campaign to educate drivers about fatigue, speeding and driving under the influence of alcohol the death on the road seem to be on the rise. Based on the figures released by the Minister of transport for the 2012 festive season which started from the 1 of December till the 8 of January 2013 there were 1422 fatal accidents on the road and from those fatal accidents 1462 people were killed on the roads (Road traffic report, 2013). This illustrates that road safety is a serious problem in South Africa and research is needed to provide solutions and interventions to change the current situation.

The aim of the current research project was firstly to establish whether short duration breaks would be effective in delaying the onset of performance-related fatigue; and secondly to differentiate between passive task-related fatigue and down- regulation due to task characteristics. Lastly to investigate at which time of the day are the breaks most efficient. With regards to the first objective it can be concluded that the breaks were not effective in delaying the onset of fatigue as the results clearly show that there was no difference in driving performance when driving with breaks and driving without breaks.

Based on the results it can be accepted that during night time the drivers were suffering from passive related fatigue rather than down-regulation because if it was down regulation the short duration breaks would have been able to restore performance at least for the periods that immediately follow the breaks but this was not observed in the results. The breaks seemed to have a relaxing effective rather than an alerting effect.

Lastly the subjective results seem to suggest that the breaks work better during the day than at night as this was reflected by lower subjective ratings from the Wits sleepiness scale and the Karolinska sleepiness scale during the day.

6.5 Recommendations

Future investigations into the effects of short duration breaks as a countermeasure against performance-related fatigue during monotonous driving tasks should consider the following recommendations:

1. Future investigation within the scope of the current research should consider a driving task of a longer duration with a different driving scenarios, which have varying levels of traffic and the introduction of either a visual or an auditory stimulus during the driving task to allow for a clear distinction between the effects of monotony or task related passive fatigue.

2. Different designs of the micro break should be considered, possibly by introducing either a motor or cognitive task during the breaks in an attempt to find the best possible design under these circumstances. Fatigue is usually associated with the depletion of resources. However clarity is needed with regards to which resources are depleted during driving, whether it’s only one resource or a combination of resources. Therefore if after the introduction of a cognitive task during the break, there is no improvement in driving performance. Then it could be concluded that driving indeed depleted the cognitive resources. This could imply that a different task which spares the cognitive resources should be used during the break, to allow for the replenishment of the cognitive resources. It is expected that the same would be true for the different type of tasks, whether motor, visual and auditory.

3. It should be noted that the driving task used was considered more of a simplistic perceptual-motor task than a realistic driving scenario. In this respect, future research should consider a more realistic driving situation in

order to evaluate whether the effects observed during this study can be applied in real life situations. Although this approach would have some advantages, safety of the drivers would be a concern during real life situations.

4. Finally, the results of this study pose some questions to car designers who are always trying to make the driving task easier by introducing automation. If breaks are to ever be introduced during the driving task, the results seem to suggest that, it should be done during the day. This could even imply that different types of breaks should be used during different times of the day or maybe breaks are just ineffective at night. However more research is needed in this area to determine whether breaks could help alleviate driver fatigue at night or whether sleep is the only cure for sleep related fatigue at night.

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APPENDICES

APPENDIX A

Letter to participant

Informed consent

Demographic Questionnaire

Morningness-Eveningness Questionnaire

Epworth Sleepiness scale

Dear participant

Thank you for agreeing to participate in this study. Your contribution is greatly appreciated. This document contains information regarding the research that will be carried out and how you will assist in this regard. Also attached to this document is a consent form which you have to sign prior to commencing with the testing. Please ensure you read everything carefully before signing. Should you be uncertain about anything or want further explanation, please do not hesitate to contact me and I will address any queries you might have.

PURPOSE OF THE RESEARCH

The aim of the study is to ascertain whether short duration breaks while driving can be used to delay the onset of performance related fatigue. This will be evaluated through driving performance, physiological, subjective variables.

Driving performance will be measured using mean deviation from a target line in a driving simulator. Heart rate and heart rate variability will also be measured using heart rate monitors. Day time driving performance with short duration breaks will be compared to day time driving performance as well. You will be required to attend an information session, where you will be familiarised with the experimental set up and the equipment. This session will precede the testing sessions. Anthropometric measures will also be taken during this session. For the testing sessions, you will be required to attend four sessions, two sessions will be during the day and the other two sessions will be at night.

In the interest of limiting the effects of extraneous variables you are requested to please refrain from the following 24 hours before coming for your data collection session:

- Consuming of alcohol
- Strenuous exercise/activity
- Medication such as stimulants or performance enhancers

If you have done any of the above, please inform the researcher

I,…………………………………………………………………….have been fully informed of the research project titled

Investigation of the effect of short duration breaks in delaying the onset of performance related fatigue during long distance monotonous driving at different times of the day.

I have read the information sheet and understand the testing procedures that will take place. I have been told about the risks as well as the benefits involved and what will be expected of me as a participant. I understand all information gained from this project will be treated confidentially, that I will remain anonymous at all times and that data obtained may be used and published for statistical or scientific purposes. All testing procedures, associated risks and benefits from partaking in this study have been verbally explained to me as well as in writing. I have had time to ask questions and to clarify any concerns or misunderstandings. I am satisfied that these have been answered satisfactorily.

In light of this and in ageing to participate in this study, I accept joint responsibility together with the Human Kinetics and Ergonomics Department, in that should any accident or injury occur as a direct result of the protocols being performed during the study, the Human Kinetics and Ergonomics Department will be liable for any costs which may ensue and will reimburse the subject the full amount (doctors, consultation, medication etc).

The department will however, waiver any legal recourse against the researchers of Rhodes University, from any and all claims resulting from personal injuries sustained whilst partaking in the investigation due to negligence on the part of the subject or researcher or from injuries not directly related to the study itself. This waiver shall be binding upon my heirs and personal representatives. I acknowledge that photographs may be taken for illustrative purposes but anonymity will be ensured by blocking my face in any reproduction of said material.

If I feel the need to withdraw from the study, I may do so at any stage without any consequences. Should I have any questions regarding the study, I will not hesitate to contact the researcher. I have read and understood the above information, as well as information provided in the letter accompanying this form.

I therefore consent to participate in the research project voluntarily

SUBJECT (OR LEGAL REPRESENTATIVE):

……………………….	……………………..	…………………
(Print name)	(Signed)	(Date)

PERSON ADMINISTERING INFORMED CONSENT:

………………………	…………………… …	…………………..
(Print name)	(Signed)	(Date)

WITNESS:

………………………	……………………….	…………………..
(Print name)	(Signed)	(Date)

Demographic Questionnaire

Name:

Email:

Cell:

Sex:

Age:

Education Background:

Years with driver's license:

Please Circle the relevant answer.

A. How many years driving experience do you have?

   1. 0-2 years
   2. 2-5 years
   3. 5+ years

B. How often do you drive long distance (over 1.5hours)

   1. Never
   2. Less than once a month
   3. More than once a month

C. Have you had any experience with the HKE driving simulator? If yes, how much?

   1. No experience
   2. Less than 1hr experience
   3. More than 1hr experience

Please note that you are exempt from this study if:

You do not have a valid driver's license

You wear glasses (contact lenses are acceptable)

You have any sleep disorders

You have a history of epilepsy

You have ADHD or similar disorders

MORNINGNESS-EVENING QUESTIONNAIRE

(Self Assessment Version)
Adapted from Horne and Ostberg, 1976

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

1. Approximately what time would you get up if you were entirely free to plan your day?
5. 5:00 AM – 6:30 AM
4. 6:30 AM – 7:45 AM
3. 7:45 AM – 9:45 AM
2. 9:45 AM – 11:00 AM
1. 11:00 AM – 12 noon

2. Approximately what time you go to bed if you were entirely free to plan your evening?
5. 8:00 PM – 9:00 PM
4. 9:00 PM – 10:15 PM
3. 10:15 PM – 12:30 AM
2. 12:30 AM – 1:45 AM
1. 1:45 AM – 3:00 AM

3. If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?
4. Not all at
3. Slightly
2. Somewhat
1. Very much

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. 5 hours starting between 4-8AM
4. 5 hours starting between 8-9 AM
3. 5 hours starting between 9AM – 2 PM
2. 5 hours starting between 2 – 5 PM
1. 5 hours starting between 5 PM – 4 AM

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

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

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

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

EPWORTH SLEEPINESS SCORE

NAME: ………………………………………… **DATE:** ………………………..

How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired?

For each situation below, give yourself a score of 0 to 3 where:

0 = would never doze	1 = slight chance of dozing
2 = moderate chance of dozing	3 = high chance of dozing

(If you have not been in a situation recently, think about how you would have been affected).

	SCORE
1. Sitting and reading	
2. Watching Television	
3. Sitting, inactive in a public place (e.g. a theatre, meeting)	
4. As a passenger in a car for an hour without a break	
5. Lying down to rest in the afternoon	
6. Sitting and talking to someone	
7. Sitting quietly after lunch (when you have not had alcohol)	
8. In a car, while stopped in traffic	
Grand TOTAL	

appendix B:

Karolinska Sleepiness Scale

Karolinska Sleepiness Scale

1 Extremely alert

2 Very alert

3 Alert

4 Rather alert

5 Neither alert nor sleepy

6 Some signs of sleepiness

7 Sleepy, no effort to stay awake

8 Sleepy, some effort to stay awake