Shift workers, fatigued driving and the impact on road safety –

An investigation involving police service employees

by

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Intellectual Property and Publications

The candidate confirms that the work submitted is her own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

The work in **Chapter 5** of the thesis has appeared in publication as follows:

Taylor, Y., Merat, N., & Jamson, S. (2019). The Effects of Fatigue on Cognitive Performance in Police Officers and Staff During a Forward Rotating Shift Pattern. *Safety and Health at Work, 10(1), 67-74*.

The candidate contributed substantially to the conception and design of the study and was responsible for performing the literature search, submitting key ideas, primary contributions, experimental designs, recruiting participants, data collection, data analysis and interpretation. The study was conducted under the supervision of Natasha Merat and Samantha Jamson, who provided critique, advice and proof-reading during the drafting stages of the paper.

Dedication

To my Dad

James Bryan Legerwood Anderson

24/10/1936 – 02/11/2007

Acknowledgements

A study of this nature would not have been possible without the help and support of various people along the way, which I would now like to formally acknowledge.

I am indebted to my academic supervisors, Professor Natasha Merat and Professor Samantha Jamson, and would like to extend my sincerest thanks for their invaluable support, guidance and encouragement throughout this eventful and very challenging personal journey. I know I have tested your patience on numerous occasions, but you held things together for me, constantly reminding me that this was within my reach, during some very difficult times when I consistently doubted myself, and when I felt it was all falling apart, and for that I am eternally grateful.

Particular thanks must go to my husband, Dave Taylor, for his support, and for putting up with the mess in 'my half' of the study and across the dining room table – yes, I will now tidy up the study and you can have it back! I also will no longer say "I'm trying to write" on every occasion when you ask what we are doing on a rare day off together, and I look forward to spending more time together, on many adventures, again.

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Thank you all!

Abstract

Fatigue can result in cognitive impairment and reduced vigilance, and driver fatigue is believed to be a significant contributing factor to road traffic collisions. In addition, fatigue-related road traffic collisions are more likely to result in fatalities. Identification of fatigue-related collisions is not easy; however, these types of incidents more often occur in the very early hours of the morning, or to a lesser degree, in the early afternoon. This is due to the circadian rhythm, influencing the natural sleep and wake periods of humans.

Due to the time of day that these incidents are more likely occur, those who work irregular hours, or shift work, are potentially more at risk of driving whilst fatigued, and therefore being involved in a fatigue-related incident.

Police officers and civilian police staff are one group who work irregular hours or rotating shifts and are therefore potentially more vulnerable to driver fatigue. The extent to which driver fatigue is an issue amongst this group has not previously been explored in this manner, in the UK. In addition, sleep duration whilst working shifts, and cognitive performance has not previously been tested with this group.

This thesis describes two studies conducted with serving police officers and civilian staff. A questionnaire study was utilised in order to explore the experiences of those working in the policing organisation, in relation to commuting habits and road traffic incidents. This was then followed up with an empirical study that investigated a particular shift pattern, common in UK policing, in an attempt to identify sleep duration, and differences in cognitive performance and vigilance during the different shifts worked.

Questionnaire responses identified that the particular group of participants in the first study reported a high prevalence of driver fatigue whilst travelling to and from work, which often resulted in road traffic incidents. The second study revealed that sleep duration following night shifts was significantly reduced. In addition, overall, the results indicated that participants coped well with the particular shift pattern studied.

This research makes a valuable contribution to the literature around shift work and driver fatigue in UK policing. It provides potential for learning in respect

of favourable shift patterns, and opportunities for training and change, where it is imperative in relation to staff wellbeing.

Future research needs to consider the influence of alternative shift patterns on fatigue and related road traffic incidents, using a larger number of participants, in differing policing areas. This approach would also be beneficial for other emergency services and large shift working organisations, to reduce the number of fatigue-related driving incidents in all shift-workers.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ANOVA	Analysis of Variance
APP	Authorised Professional Practice
BAC	Blood Alcohol Concentration
BMM	Biomathematical models
DfT	Department for Transport
DSST	Digital Symbol Substitution Task
EEG	Electroencephalogram
EMG	Electromyogram
EOG	Electrooculogram
ESS	Epworth Sleepiness Scale
EU	European Union
FI	Fatigue Index
FOIA	Freedom of Information Act
FRI	Fatigue and Risk Index
FRMS	Fatigue Risk Management System
HMIC	Her Majesty’s Inspectorate of Constabulary
HoW	Hours of Work
HSE	Health & Safety Executive
HUM	Humberside Police
KSS	Karolinska Sleepiness Scale
LGV	Large Goods Vehicle
MEDRT	Median Reaction Time
MFRRT	Mean of Reciprocal of Fastest 10% of Reaction Time
MPT	Motor Praxis Task
MRRT	Mean Reciprocal Reaction Time
MSLT	Multiple Sleep Latency Test

NBACK	Number Back
NREM	Non Rapid Eye Movement
NYP	North Yorkshire Police
OHS	Occupational Health and Safety
OSA	Obstructive Sleep Apnoea
PCV	Passenger Carrying Vehicle
PFEW	Police Federation of England and Wales
PSG	Polysomnography
PSQI	Pittsburgh Sleep Quality Index
PTSD	Post-Traumatic Stress Disorder
PVT	Psychomotor Vigilance Task
RCMP	Royal Canadian Mounted Police
REM	Rapid Eye Movement
RI	Risk Index
RT	Reaction Time
RTC	Road Traffic Collision
SD	Sleep Deprivation
SWAP	Shift Work Awareness Programme
SSS	Stanford Sleepiness Scale
SWAP	Shift Work Awareness Programme
SWSD	Shift Work Sleep Disorder
SYP	South Yorkshire Police
VOLT	Visual Object Learning Task
VSA	Variable Shift Arrangement
WYP	West Yorkshire Police
WTR	Working Time Regulations
YatH	Yorkshire and the Humber

Preface

I have been a police officer for over 25 years, working in a variety of different roles across the counties of North Yorkshire and West Yorkshire, in the UK.

Many years ago, as a young ‘probationer’ within the first two years of my police service, I had a driving incident on my commute home from a night shift. I was almost home, almost at the end of my 22-mile, 30-minute commute, when I momentarily fell asleep whilst driving. It was at a critical point in my journey, the top of a very steep hill, with not much in the way of barriers to keep me on the road, should the worst have happened. Luckily, I bumped the nearside kerb which quickly woke me up and I was able to drive the remaining mile or so to get home safely. I knew I was tired, but I didn’t think I was so tired that I would fall asleep whilst driving. This incident frightened me and was a secret I kept to myself, for many, many years! I was young and fairly inexperienced at working night shifts, I hadn’t worked shifts prior to joining the police, I didn’t consider how to prepare for working shifts, particularly night shifts, and I was given no introduction to shift work or information from the organisation around how best to prepare.

Over the years, I have worked at a variety of different bases, across two very different counties and my commute has been as little as 10 minutes, or as long as over an hour in duration. In the main, I have worked where I have been ‘posted’, although there has been the odd occasion when I have chosen a particular role, knowing it involved a greater commute, but believing it was worth it for my job satisfaction and my career. Knowing what I know now, I have tried my utmost to ensure I am prepared for shift work, and to get enough, good quality sleep in between times, but of course, the unpredictable nature of policing sometimes makes that difficult, and, in addition, we cannot ‘force’ ourselves to sleep at odd times of the day, when it goes against our circadian rhythm, or we are simply not tired.

I have never forgotten that incident whilst very young in terms of policing experience, and it was one of the catalysts for my interest in road safety, my drive to keep colleagues safe, and ultimately my chosen specialism of driver impairment, fatigue and shift work.

Chapter 1
Introduction

Chapter 1 introduces the research context and highlights the background to the research conducted, providing a brief overview of the problems associated with shift work and driving whilst fatigued. An outline of the following chapters is also provided.

1.1 Statement of the problem

Shift work is common in numerous industries, many of which are safety critical, such as emergency services, road transportation, or the airline industry (Oexman et al., 2002). Many industries choose to operate around the clock for financial reasons (Monk and Folkard, 1992); however, others must do so, due to the service they provide, and policing is one of those.

The main function of policing is to protect life and property, to prevent and detect crime and to keep the peace (Crawford, 2012). Therefore police officers, and some civilian police employees, need to be in a position to respond to calls for help from the public, in the event of an emergency relevant to their role, regardless of the time of day or night (Boulton et al., 2017). This dictates that policing needs to operate on a 24-hour basis, with in-built shift patterns, in order to operate efficiently, and service incoming demand, as well as the pro-active prevention, reduction and detection of crime and disorder (Boulton et al., 2017).

There are many and varied shift patterns employed in policing, with each individual police force dictating the particular pattern(s) they will follow, usually based on organisational needs, and more recently on the peaks and troughs of service demand (Richbell et al., 1998). However, in UK policing, all forces employ some form of rotating shift pattern, where each frontline employee works a variety of day shifts, afternoon shifts and night shifts as part of a team, and each team is replaced by another, in order to provide continuous cover around the clock (Richbell et al., 1998; Kingshott et al., 2004).

Shift work, particularly night shift or rotating shift work, is known to cause sleep reduction and disturbances, and is therefore associated with increased physiological sleepiness, as well as increased risk of performance degradation, impaired decision making, accidents and various health problems (Åkerstedt, 2003; Knutsson, 2003; Vila, 2006; Kecklund et al., 2016; Scholarios et al., 2017). Currently, there is no universally agreed, ideal shift system that will suit all shift workers and eliminate the associated problems. However, there are suggested recommendations that will minimise the adverse effects of these working patterns. For example a rapid forward rotating system, which has few consecutive night shifts, sufficient time for rest between shifts, and the avoidance of extended shifts, may be preferable (Knauth and Hornberger, 2003).

Despite the suggested recommendation of a rapid, forward rotating system, specified above, (which will not work for all organisations), the fatigue associated with shift work can still be problematic, causing safety concerns, including those related to driver fatigue for police officers and other police employees, and indeed any shift worker (Akerstedt, 1990; James and Vila, 2015).

Fatigue can be particularly problematic when it affects a driver, where it can cause performance decrements or result in serious or fatal road traffic collisions (Summala and Mikkola, 1994; Knipling and Wang, 1994; Horne and Reyner, 1995a; Reyner and Horne, 1998; Sagberg, 1999; Horne and Reyner, 2001a; Dorrian et al., 2017). Those having to drive for work purposes are potentially at higher risk of being involved in a fatigue-related collision (Broughton et al., 2003; Clarke et al., 2005; Robb et al., 2008; Clarke et al., 2009). The reasons for this are not fully understood; however, sleep restriction and circadian disruption, are believed to be a contributory factor amongst shift workers (Broughton et al., 2003; Clarke et al., 2009; Lee et al., 2016).

1.2 Importance of the study

As of the 31st of March 2019, the number of police employees in the 43 territorial police forces in England and Wales was 202,023. Of that figure, 123,171 were police officers, and 103,347 of those were in frontline policing roles (Home Office, 2019). The frontline has been defined by Her Majesty's Inspectorate of Constabulary (HMIC) as *"those who are in everyday contact with* *the public and who directly intervene to keep people safe and enforce the law"* (O'Connor, 2011). Although exact numbers of those working shifts are not available, in line with the definition provided above, it is anticipated that those in the above defined frontline roles would be the officers providing that round-the-clock, response service; there to respond to emergencies, whatever the time of day or night. There are, of course, also the civilian staff members, who are included in the overall police workforce figure, such as control room staff, employed in roles such as answering emergency telephone calls from the public, and despatching police officers to calls, who also work shift patterns in their role (Alderden and G. Skogan, 2014). These staff would be classed as *"middle office"* (O'Connor, 2011). All of these personnel are working long hours, around the clock, often at times when it is not customary to be awake (Horrocks and Pounder, 2006). These frontline or middle office staff and officers often have to make rapid decisions under time pressure, or are required to drive under stressful conditions, for example, having to respond to emergency calls in busy cities (Vila, 1996). On other occasions, they may simply be driving to and from work, sometimes after experiencing the stressful situations outlined above.

Shift workers suffer from more fatigue whilst travelling to and from work, than those who do not work shifts (Rogers et al., 2001). Vila (2006) suggests that police officers are a group of workers which are of concern with regard to their risk of fatigue. However, their experiences could also be similar to those in other occupational groups who work long hours or extended shifts (Caruso et al., 2006). The figures presented above, relating to frontline policing roles, account for a small proportion of the overall number of shift workers in the UK, which is stated to be in excess of 3.5 million (Madouros, 2005). Shift work, extended hours and fatigue are all thought to increase the risk of impaired performance, accidents and road traffic collisions (Horne and Reyner, 2001a; Barger et al., 2005; Vanlaar et al., 2008).

Fatigue, as a causation factor, is believed to be under-represented in road traffic collisions statistics, often attributed to other causes, such as driver distraction (Horne & Reyner, 2001a) and it is thought to contribute to up to 20% of serious collisions in the UK (Maycock, 1995; Cook and Albery, 1995; Jackson et al., 2011). With these high numbers of shift workers, coupled with the road traffic collisions attributed to this group, there are real road safety concerns, and it is therefore important to understand the experiences of shift workers and attempt to mitigate the dangers they may face whilst driving.

Fatigue, along with irregular and disrupted sleep, are often seen as “normal” aspects of policing (Vila, 1996), and police shift workers are often sleep deprived and in a chronic state of *“shift lag”*, which is a term that refers to the associated disruption to circadian rhythms. However, these topics have traditionally been given little attention, possibly because managers typically have little knowledge or awareness of the effects of shift work (Oexman et al., 2002). This lack of knowledge about the area has implications for the health and wellbeing of police employees, and also affects the wider organisation, as it often results in increased instances of stress-related illness and work absences (Johnson et al., 2005; Scholarios et al., 2017).

Occupational Health and Safety (OHS) was identified as a key focus area within the European Union (EU) and many directives have been established in an attempt to safeguard the health and safety of employees (Gagliardi et al., 2012; Verra et al., 2019). Amongst these directives were the Working Time Regulations (WTR) in order to provide minimum standards for health and safety requirements in organising working time. These regulations include those working in the police service (The Working Time Regulations, 1998).

A large number of OHS incidents are preventable (Hassard et al., 2012), hence there is a need to proactively promote healthier lifestyles (Aires et al., 2010), and to improve organisational support for policing officers and staff, in terms of wellbeing (Bullock and Garland, 2019).

Fatigue is a term recognised in policing and police publications (Vila, 1996; Amendola et al., 2011; Violanti et al., 2018). In addition, it has recently been highlighted in a national survey reaching in excess of 34,000 police officers, where it was reported that almost half of participants reported insufficient sleep and feelings of fatigue (Graham et al., 2019). Fatigue is the terminology used in this thesis, and is defined as “impairment of both mental and physical function, including sleepiness, affected physical and mental performance, depressed mood and loss of motivation” (Moore-Ede et al., 2007).

Assessing the personal experiences of those working shifts and identifying best practice in terms of shift patterns, is a step closer to improving overall wellbeing for those working shifts, as well as road safety, and to assisting organisations in encouraging open discussion and providing fatigue management guidance to their staff. The overarching aims of the research are outlined in the following section.

1.3 Thesis aims

Driver fatigue and the link to serious and fatal road traffic collisions is well established (Fletcher et al., 2005; Baulk et al., 2008), and is a cause for concern in many industries, not least in emergency services, such as policing, with suggestions that fatigue is a contributory factor in 20% of road traffic collisions (Maycock, 1995; Horne and Reyner, 1995b; Jackson et al., 2011). There is still a dearth of research related to shift work and driver fatigue in UK policing, and in particular, research relating to the commute to and from the work place.

This thesis therefore investigates the relationship between shift work, fatigue and road safety in UK police service employees. The research and studies presented within are intended to explore existing practices within policing, and to examine shift worker experiences and performance. This will prove useful to those both working and designing shift patterns, and also to those considering policies and practice to improve employee wellbeing.

Given the gaps in the existing literature, which will be outlined in Chapter 2, the overarching aims of this thesis, therefore, are to explore driver fatigue amongst UK police officers and civilian staff, to establish if fatigue is a problem for them when commuting, and to test cognitive performance during shift work. The desire was also to highlight any good practice within policing, and to establish means with which to mitigate any risks identified amongst those shift workers.

1.4 Thesis outline

The following paragraphs provide an overview summary of the structure and content of this thesis;

Chapter 1 has set the scene and provided the background to the thesis by outlining the current problems associated with shift work and the importance of the study. In addition, the thesis aims are outlined here.

Chapter 2 reviews the relevant literature and provides a general background overview of the complexities of fatigue, shift work and the driver fatigue problem.

Chapter 3 examines the current operating arrangements of UK policing and explores the Police Roll of Honour data in relation to police officer line of duty deaths. It also examines the current recording procedures in relation to police employee involvement in road traffic collisions, policies and procedures for managing fatigue, and the wellbeing practices in UK policing.

Chapter 4 describes the first of two studies in this thesis. It reports on a questionnaire study conducted with police officers and staff, examining the different shift patterns of four police forces in the Yorkshire and Humber region in the north of England, and explores police officer and staff experiences of shift work and driving whilst fatigued.

Chapter 5 describes the second study, which is an empirical study that explored differences in sleeping patterns and duration, along with cognitive performance at varying stages of the forward rotating shift pattern adopted by North Yorkshire Police at the time of the study. This study was conducted in the workplace and home environment of the participants, whilst they kept to their usual routines.

Chapter 6 summarises and concludes the thesis by examining and discussing the main findings, along with addressing the initial research questions posed. Based on those findings, some questions and recommendations for further studies are suggested.

Chapter 2
Literature Review

This Chapter provides a review of the existing literature and research relevant to how fatigue affects driving. It begins by giving an overview of sleep, sleepiness and fatigue, and how sleep can be measured. It then goes on to highlight what shift work is and how shift work interferes with good sleep, before introducing the driving task, the cognitive skills required of a driver and how fatigue can interfere with these. The final section outlines relevant road traffic legislation and aspects of road safety. The aim is to highlight the link between sleep disruption, fatigue, shift work and road safety, and provide the current understanding of why these topics are important to the impact on driving and driver safety.

2.1 An overview of sleep, sleepiness and fatigue

Sufficient, restorative sleep is necessary for promoting and maintaining physical and mental health (Lund et al., 2010). Conversely, sleep disruption is associated with poor physical and mental health, general reduced quality of life, as well as increased accidents and absenteeism from the workplace (Léger et al., 2006).

2.1.1 Understanding sleep and wakefulness

Sleep is simply regarded as a recovery process from fatigue and sleepiness (Dawson and Mcculloch, 2005) and good sleep is essential to normal brain function, cognitive performance, good health and wellbeing (Maquet, 2001; Tobler, 2005; Alhola and Polo-Kantola, 2007; Buysse, 2014). For example, Maquet (2001) states that sleep is necessary for energy conservation and tissue recovery, as well as being essential for cognitive performance, particularly memory consolidation. It is a complex, reversible state (Harrington and Lee-Chiong, 2012), characterised by a loss of conscious awareness, a reduction in responsiveness, and a lack of physical activity (Shneerson, 2006; Thienhaus and Cardon, 2008), and humans generally sleep lying down, and with the eyes closed (Shneerson, 2006). Sleep serves multiple purposes (Rechtschaffen, 1998) and there are changes to numerous physiological processes during sleep, such as lowering of heart rate, blood pressure and body temperature (Harrington and Lee-Chiong, 2012). However the organ showing most changes when asleep is the brain (Sejnowski and Destexhe, 2000) and most parts of the brain are active during sleep (Shneerson, 2006). For example, the brain controls the transition between sleep and wakefulness and sends signals to relax the muscles, controlling limb movements and posture. This assists in generally preventing us from physically acting out our dreams (Shneerson, 2006; National Institutes of Health, 2014).

Almost all humans experience sleepiness at least once in any 24-hour period (Johansson, 2012) and as a result, sleep usually occurs regularly in that 24-hour period, typically at night. The need for sleep varies considerably between individuals (Shneerson, 2006). However, sleep generally dominates around one third of our lives (Sejnowski and Destexhe, 2000), hence, adult humans should generally sleep for between 7 and 9 hours a night (Sejnowski and Destexhe, 2000; Shneerson, 2006; Hirshkowitz et al., 2015), and loss of this regular sleep can result in changes in mood, hormone rhythms and cognitive impairment (Thienhaus and Cardon, 2008).

Normal sleep consists of a series of repeating cycles, where intensity changes from being awake, to light sleep, deep sleep and dream sleep, or Rapid Eye Movement (REM) sleep. All of these stages are essential for good health. There are usually 4-6 of these cycles during a normal night's sleep (Akerstedt and Kecklund, 2003; Shneerson, 2006; BaHammam et al., 2016), and as the sleep period progresses, the deeper sleep stages of Non-Rapid Eye Movement (NREM) sleep diminish (Shneerson, 2006). Figure 2.1 shows a typical 8-hour sleep period, as described above, where Stage W represents periods of wakefulness, Stage R illustrates periods of REM sleep, illustrated in black. The first REM sleep usually happens around 90 minutes after a healthy sleeper falls asleep and lasts around 10 minutes. Each subsequent REM stage gets progressively longer and the final one may be as long as one hour. Heart rate and breathing typically quickens during REM sleep and the brain is more active, leading to intense dreams. The remaining 3 stages of N1, N2 and N3 are varying intensities of Non-Rapid Eye Movement sleep (NREM). Stage N1 is the lightest sleep, where eyes are closed, but you are easily awakened. Stage 1 tends to last up to five minutes. In stage N2, you are in a deeper sleep, where body temperature drops, and heart rate slows. This stage lasts around 25 minutes initially; however, it tends to get longer with each successive cycle, where it eventually lasts around 50% of total sleep. Stage 3 is the deepest sleep stage, and is the most difficult to awaken from (BaHammam et al., 2016; Patel and Araujo, 2018). This is the stage where the body repairs itself. If someone is awakened during this stage, they will usually experience a period of sleep inertia (Patel and Araujo, 2018), as described below.

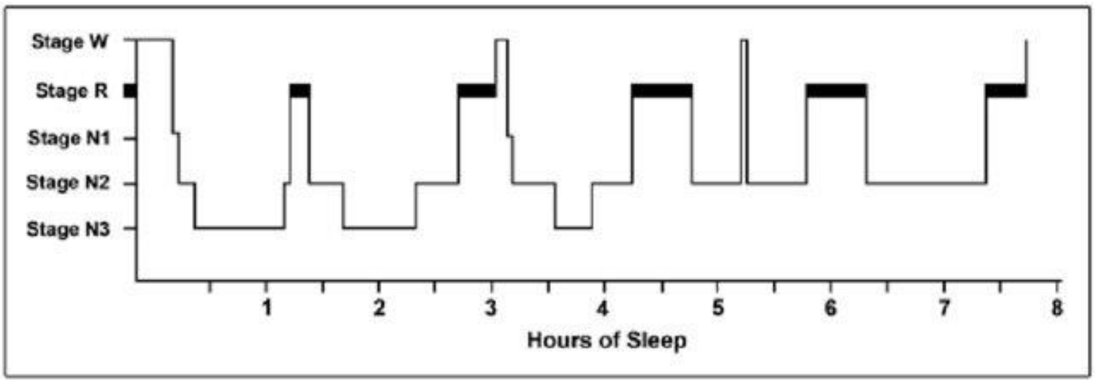

Figure 2.1 Sleep cycles during a normal night's sleep (BaHammam et al., 2016)

The transition between wakefulness and sleep is varied and is a gradual process (Shneerson, 2006). The time taken to fall asleep is referred to as *sleep latency* and this can be used as a measure of sleep propensity. As the propensity for sleep increases with time awake in the homeostatic process, the circadian process can interfere with sleep initiation (Juda, 2010). Sleep latency is shortest at times of circadian low and longest at times of circadian wakefulness (Carskadon and Dement, 1987).

Sleep inertia is the transitional state of sleepiness experienced immediately after wakening, producing temporary impaired cognition (Tassi and Muzet, 2000; Wertz et al., 2006), before obtaining maximum alertness. This period can last for just a few minutes, or a few hours after wakening (Dinges, 1990; Jewett et al., 1999). Sleep inertia increases with the depth of prior sleep (Dinges, 1990; Shneerson, 2006) and is most common after oversleeping or after daytime naps if the deeper sleep non-REM stage, shown as N3 in Figure 2.1 above, is entered (Shneerson, 2006).

In shift workers, the changes in circadian wakefulness pressure and homeostatic sleep pressure become desynchronised. During night shifts, the homeostatic pressure increases whilst awake, and the circadian pressure for wakefulness decreases, therefore increasing sleepiness across the night shift. However, whilst trying to sleep during the day, the opposite occurs, whereby the homeostatic sleep pressure decreases, and the circadian wake pressure increases. As a result, the shift worker awakens, before the sleep need has been satisfied, causing a “sleep debt” (Van Dongen, 2006).

This sleep debt can lead to Sleep Deprivation (SD). SD can either be total (acute) or partial (chronic), or a combination of both. Total SD is seen in people who have been kept awake continuously for long periods of time, whereas, partial SD generally involves restricted or reduced sleep time over several consecutive nights (Alhola and Polo-Kantola, 2007). Chronic, partial SD is common in modern everyday life, and more prevalent than total SD (Alhola and Polo-Kantola, 2007).

After around 24 hours of acute SD, alertness shows a marked decline, and performance impairment, such as increased reaction times or difficulties in maintaining attention, is in line with that of a blood alcohol concentration (BAC) of 100 mg of alcohol per 100 mL of blood (Dawson and Reid, 1997; Rajaratnam et al., 2013). This is above the current drink drive limit set in England and Wales, of 80 mg of alcohol in 100 mL of blood. In their study of performance degradation during chronic SD, (Belenky et al., 2003), enrolled sixty-six participants in a laboratory study. The study involved participants having different levels of restricted sleep for 7 days. The restrictions were 3, 5, 7 or 9 hours in bed daily. They found that speed on the performance task declined steadily in the group restricted to 3 hours; speed initially declined, but then stabilised in the 5 and 7 hour groups, and that speed remained at the baseline level for those participants who were allowed 9 hours in bed. From the results, they suggested that the brain adapts to moderate SD to sufficiently stabilise performance, albeit at a reduced level. In addition, when considering recovery from chronic SD, Belenky *et al.* (2003) found that 3 days of recovery sleep of 8 hours daily time in bed was not sufficient to restore performance to baseline levels.

2.1.2 Defining sleepiness and fatigue

There are numerous definitions of fatigue (Phillips, 2015), and both fatigue and sleepiness are complex, but can describe many states, including exhaustion, tiredness or lethargy (Tiesinga et al., 1996; Shen, et al., 2006).

Sleepiness is a feeling that a person experiences when they are susceptible to nodding off or falling asleep, and may be having difficulty staying awake (Curcio et al., 2001; Shahid et al., 2010; Hirshkowitz, 2013), and is defined as a physiological drive, or a biological need, resulting from sleep deprivation (Aldrich, 1989). Sleepiness can result from many factors, such as medical problems, sleep disorders (Shahid et al., 2010) or lack of sleep caused by irregular working hours, such as those experienced by shift workers (Åkerstedt, 1988).

In contrast, fatigue is difficult to define. It is defined as impairment of both mental and physical function, including sleepiness, affected physical and mental performance, depressed mood and loss of motivation (Moore-Ede et al., 2007). It is further defined by Grandjean (1979) as a gradual and cumulative process associated with a loss off efficiency, and a disinclination for any kind of effort. It is also described as a state of tiredness (Hirshkowitz, 2013; Rogers, 2008), feeling of exhaustion and lack of energy (Rogers, 2008), and described as tending to occur after long periods of performing a particular task or long periods of sustained wakefulness where fatigue increases the drive to sleep (Brown, 1982). As such, fatigue can generally be considered to be mental, physical or a combination of both (Bridger, 2008).

Mental fatigue is a state of tiredness occurring after long periods of being awake, (sleep-related) or engaged in cognitive task activity (task-related) and is associated with cognitive impairment. These feelings generally involve a decrease in level of commitment to the task in hand (Boksem and Tops, 2008; May and Baldwin, 2009). Sleep-related fatigue can be caused by sleep restriction, sleep deprivation and circadian rhythms (May and Baldwin, 2009), hence shift workers may be prone to this (Miller et al., 2020). Task-related fatigue, is caused by the environment and the task (May and Baldwin, 2009). In addition, task-related fatigue can be either active or passive, where active fatigue is as a result of prolonged task-related repetition or high workload, and passive fatigue develops over a number of hours of wakefulness, whilst an individual is apparently doing very little or nothing at all (Hancock and Desmond, 2000; Saxby et al., 2008; May and Baldwin, 2009).

Physical fatigue is usually as a result of sustained physical exertion and results in muscle fatigue and discomfort (Aaronson et al., 1999). However, physical fatigue can still contribute to impaired co-ordination and increased chances of accidents (Lal and Craig, 2001).

Fatigue is subjective and difficult to quantify (Shneerson, 2006), and both fatigue and sleepiness are also complex phenomena, that are often used interchangeably, due to the difficulty in separating them because of their similar features (Shen et al., 2006; Rogers, 2008; Jackson et al., 2011; Hirshkowitz, 2013). For example, Shen et al. (2006) state that the terms are often merged under the more general lay term of ‘tired’. Sleepiness and fatigue can coexist as a consequence of sleep deprivation, in addition to fatigue being related to a number of mental or physical catalysts (Rogers, 2008).

Individuals working nights or rotating shift patterns rarely obtain sufficient sleep (Rogers, 2008) and fatigue is a frequent complaint from those working these irregular hours, but it remains extremely difficult to measure (Harrington, 2001). Sleep loss is cumulative, and as time goes on, the sleep debt may be sufficient to impair decision making, planning and vigilance (Harrison and Horne, 2000; Alhola and Polo-Kantola, 2007). Persistent sleep loss or disturbance leads to physical and / or psychological effects of SD (Kheirandish and Gozal, 2006), including increased negative mood, loss of energy and confusion (Goel et al., 2009). These effects are insidious and not usually recognised by the individual until they are severe (Rosekind et al., 2001). The difficulties with shift work will be further discussed in section 2.4.

As fatigue and sleepiness are interlinked and can co-exist, for the purposes of this thesis, the term ‘fatigue’ will be used to incorporate both sleepiness and fatigue. The definition of fatigue provided by Moore-Ede et al. (2007) outlined early in this section is the preferred definition for this thesis, as it includes the multi-faceted nature of fatigue. In addition, anecdotally, when related to drivers, the term “driver fatigue” is perhaps more readily recognised.

There are a number of simple practices that can assist in alleviating sleepiness and fatigue and these will be discussed in the following section.

2.1.3 Practicing good sleep hygiene

The quality, quantity and timing of sleep are affected by many everyday attitudes and activities, such as consumption of caffeine, or irregular sleeping schedules (Irish et al., 2015), such as those found in shift workers. *Sleep hygiene* broadly refers to the practice of adopting behaviours that facilitate sleep and likewise, avoiding behaviours that interfere with good sleep (Riedel, 2000; Gellis and Lichstein, 2009; Shriane et al., 2020). Sleep hygiene is an inexpensive lifestyle choice in order to improve sleep quality or minimise sleep disorders (Shneerson, 2006; Irish et al., 2015) and recommendations can be easily delivered to the public, including employers and employees, in a variety of media, ensuring a wide distribution and understanding (Morin, 2010).

The most common sleep hygiene recommendations include avoiding caffeine or alcohol close to bedtime, avoiding nicotine, stress management and regular sleep timings where possible (Irish et al., 2015; Shriane et al., 2020).

Caffeine and nicotine are known stimulants associated with sleep disturbances (Boutrel and Koob, 2004; Irish et al., 2015), and alcohol is also know to interfere with healthy sleep, resulting in lighter and fragmented sleep in the latter stages of the night (Roehrs and Roth, 2001; Stein and Friedmann, 2006).

Stress is known to cause worry and physiological arousal, which both disrupt sleep and oppose sleep initiation (Morin, 2010). The homeostatic sleep drive and circadian system work together to promote stable patterns of sleep and wakefulness, hence regular sleep timings, where possible, promotes these natural nocturnal sleep periods (Dijk and Czeisler, 1995).

When considering shift workers, although it is still possible to avoid nicotine and alcohol, some of the recommendations discussed above, such as regular sleeping times, are not always possible, due to the irregular working hours associated with shift work. However, scheduling time for sleep should still be a priority amongst shift workers (Wilson and Nutt, 2013), and it is still possible to establish a successful sleep routine, such as trying to have a lie in before the first night shift, or making use of napping (Horrocks and Pounder, 2006).

In a study of Australian paramedics, Shriane *et al.* (2020) found that 84.2% had little knowledge or understanding of sleep hygiene. Thus, this could be similar in other shift working cohorts. As such, there may be opportunities for employer delivered training, or self-education amongst shift workers.

Understanding your own individual chronotype, and when the best opportunities are to take advantage of napping can be beneficial in assisting with obtaining sufficient good quality sleep, and this is described in the following section.

2.2 Chronotypes and sleep regulation

Individual differences when people sleep, with regard to local time, is often known as chronotype (Roenneberg, 2012), and these are attributed to differences in the interacting circadian process (Roenneberg et al., 2003). The circadian and homeostatic processes are the rhythmic processes that regulate sleep (Borbély, 1982; Deboer, 2018) and these factors are described in more detail below.

2.2.1 Chronotypes

There is a natural tendency for people to be more alert either early in the morning or late at night, often referred to as Morningness / Eveningness preference, or larks and night owls (Alward, 1988). This is the individual chronotype, or biological rhythm (Stolarski et al., 2013), and the tendency to be either one or the other can be assessed using different scales. Morning types have a natural tendency to go to bed early and wake up early, and conversely, Evening types tend to go to bed late and wake up late (Adan et al., 2012), hence the lark or night owl description. Around 40% of the adult population are in either one of these two group, with the remaining 60% being neither one of the extremes (Adan et al., 2012).

The Horne and Ostberg self-assessment Morningness / Eveningness Questionnaire (MEQ) (1976) is the most widely used measure of identifying Morningness or Eveningness (Adan et al., 2012). This was the first instrument developed for assessing sleep timing preferences, where a score is derived from the answers selected by individual participants. The chronotype is subsequently derived from the score provided (Roenneberg, 2012; Adan et al., 2012). Numerous studies have reported on the reliability of the measure (Adan and Natale, 2002; Adan et al., 2012). In their study to analyse Morningness /

Eveningness preferences by gender, Adan & Natale, (2002) utilised the MEQ in a student population of 2135 participants, with an age range of 18-30 years. They found that men demonstrated a higher tendency to be Evening types and confirmed the distribution of participants with either Morning / Evening types to be consistent with previous studies utilising the MEQ.

Alternatively, the Munich Chronotype Questionnaire (MCTQ) uses self-reported individual sleep times and self-assessed chronotype, taking into account both work and free days (Roenneberg et al., 2003; Levandovski et al., 2013) and is based on sleep behaviour, rather than preference. The chronotype is derived based on the midpoint between sleep onset and the time of awakening (Levandovski et al., 2013).

Chronotype does have a genetic component, but also depends on other factors, including age and gender (Roenneberg and Merrow, 2007), hence comparison of chronotypes is not straightforward. Adolescents are generally Evening chronotypes; however this changes with age, with adults progressing more towards Morning type by old age (Shneerson, 2006; Roenneberg, 2012). In the absence of external pressures, people tend to follow their own preferences, hence when there are external pressures, such as the irregular working hours of shift work, workers are forced into something that isn't natural and difficulties, such as sleep debt, arise (Zavada et al., 2005).

The MEQ is free to use, with instant results upon completion of the questionnaire. In addition, as stated above, it is reportedly the most widely used measure (Adan et al., 2012), with many studies reporting on reliability (Adan and Natale, 2002).

The next sections will move on to introduce the circadian and homeostatic process in more detail.

2.2.2 The circadian process

Even the simplest living organisms have regular, daily rest periods, overseen by an internal 'body clock' (Horne, 2006). The internal body clock is the circadian process that regulates the brain and body's daily rhythms (Wilson and Nutt, 2013) and cycles over an approximate 24-hour period, strongly influenced by the natural cycles of light and dark. The circadian rhythm is the most prominent pattern of human behaviour (Zavada et al., 2005), where people are normally active during the day and asleep at night (Zavada et al., 2005; Juda, 2010). At night, many of the processes that are active during the day start to slow down as our bodies prepare for sleep, when the circadian process also stimulates night-time release of the ‘sleep hormone’ melatonin, which has the effect of lowering alertness and increasing the desire for sleep (Horrocks and Pounder, 2006). Sleep in adult humans is usually taken as a single episode at night (Calogiuri et al., 2013), with the exception of Mediterranean countries, who often adopt a biphasic sleep pattern, with a siesta in the afternoon (Shneerson, 2006). This pattern follows the two main sleepiness peaks for humans over the 24-hour period; these times vary slightly, but are generally around 0300-0500 hours and 1400-1600 hours (Horrocks and Pounder, 2006). In addition to following the circadian tendencies, there is likely to be a cultural element to this pattern, avoiding physical activity during the hottest time of the day (Shneerson, 2006).

The sleepiness that results from these neurological processes occurs regardless of training, occupation, education or commitment to stay awake: Only sleep can reduce sleep debt (Connor, 2009). Working irregular shifts, or at night, is therefore likely to disrupt these rhythms, disturbing alertness when the body is ready for sleep (Horrocks and Pounder, 2006) and it is at these times that we experience our worst physical and mental performance of the day (Alhola and Polo-Kantola, 2007). It is also during these times of peak sleepiness that there is an increase in fatigue-related road traffic collisions (Horne and Reyner, 2001b; May and Baldwin, 2009) as people with sleep loss usually also experience a decline in cognitive performance (Alhola and Polo-Kantola, 2007). Hence shift workers need to try to understand sleep and the methods to counteract negative effects of working shifts (Folkard et al., 2005) in order to stay safe and optimise alertness and performance.

2.2.3 The homeostatic process

The homeostatic process is the drive to sleep that increases in proportion to the time awake (Wilson and Nutt, 2013). As time awake increases, sleep pressure increases, thus the feelings of sleepiness increase (Shneerson, 2006; Jackson et al., 2011; Wilson and Nutt, 2013; Boivin and Boudreau, 2014). It usually reaches a maximum after around 16 hours of wakefulness, and then decreases whilst asleep, reaching a minimum at the natural waking time in the morning (Wilson and Nutt, 2013).

If the sleeping period has been shorter than usual, or shorter than required by the individual, a ‘sleep debt’ exists. This, in turn, increases the drive for sleep further (Wilson and Nutt, 2013).

Morning types have a higher sleep efficiency; however they are unable to sleep late in the morning and can only gain longer sleep by going to bed earlier (Shneerson, 2006). Evening types obtain greater sleep by waking later in the morning, rather than going to bed earlier, tend to have more irregular sleep times and generally adapt better to shift work than morning types (Shneerson, 2006).

The circadian system and homeostatic process work together to promote stability in sleep and wakefulness (Dijk and Czeisler, 1995). Figure 2.2 illustrates the interaction between the circadian and homeostatic processes. It demonstrates the homeostatic drive for sleep, shown as the “sleep load” increasing during the day, until the time around a habitual bedtime, when sleep is initiated. The circadian drive for alertness, shown as the “alerting signal” peaks in the evening, and then subsides during sleep at night, before beginning to increase again in the morning.

Following on from this description of different chronotypes and the regulation of sleeping patterns by the circadian and homeostatic processes, different methods of measuring sleep are discussed in the next section.

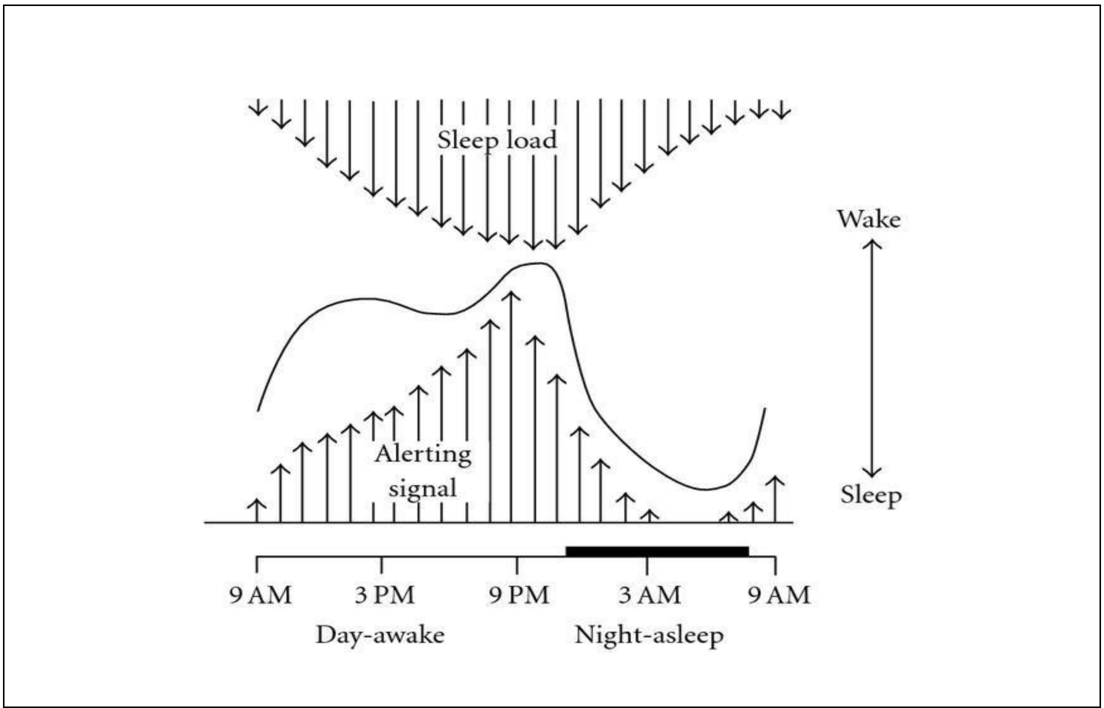

Figure 2.2 The interaction between the circadian and homeostatic processes (Dijk & Edgar, 1999)

2.3 Methods of measuring sleep quality, duration and sleepiness

There are different subjective and objective methods available for measuring sleep and wakefulness, ranging from polysomnography conducted in purpose built sleep labs, to actigraphy, to self-completed questionnaires or sleep diaries, (Sadeh and Acebo, 2002; Sadeh, 2011). These are briefly outlined below.

2.3.1 Polysomnography

Polysomnography (PSG) is the monitoring of numerous neurophysiological and cardiorespiratory functions, in order to study normal and disturbed sleep (Pandi-Perumal et al., 2014). The processes involved utilise surface electrodes on the scalp in order to record parameters, such as brain activity by Electroencephalogram (EEG), heart rate and breathing, blood oxygen levels, eye movements by Electrooculogram (EOG) and muscle activity by Electromyogram (EMG) during sleep ((Marino et al., 2013). Electrodes are attached to the scalp in a standard manner, in accordance with the internationally recognised Rechtschaffen and Kales, (1968) 10-20 method (Morley et al., 2016).

Polysomnography is seen as the gold standard in sleep research; however, it is expensive and labour intensive (BaHammam et al., 2016). It is often not favourable amongst participants, due to having equipment attached to them via wires and straps, and also as studies are conducted in sleep laboratories, away from the comforts and convenience of their own home (Marino et al., 2013; Zinkhan et al., 2014).

Although polysomnography provides the most reliable results, it is not always desirable to use this method of examining sleep, as it is not always readily accessible to researchers, it may not be desirable to participants, and requires experts in the field in order to interpret results (Pandi-Perumal et al., 2014). As such, alternative methods, that do not rely on attendance at a sleep lab, are often preferable, and are discussed below.

2.3.2 Actigraphy

Actigraphy is the recording of movements using a cost-effective, non-invasive, body worn device, often a watch, or wearable technology device, usually worn on the non-dominant wrist (Ancoli-israel et al., 2003; Lichstein et al., 2006; Martin and Hakim, 2011). The technology infers sleep or wakefulness from the absence or presence of wrist movement (Lichstein et al., 2006). Actigraphy has become a popular, affordable, increasingly used method of recording sleep and activity (Sadeh and Acebo, 2002; Sadeh, 2011) in certain research areas. As humans fall asleep, they virtually stop moving, this allows the device to distinguish between periods of wakefulness and movement, and sleep or rest whilst immobile (Pollak et al., 2001). A number of studies have investigated the use of actigraphy as an alternative to the 'gold standard' PSG, some of these are discussed below.

Pollak *et al.* (2001) collected data from fourteen young (21-35 years) and old (70-72 year) participants in a laboratory setting over 7 days. Participants did not have access to time of day, and they initiated mealtimes, bedtimes and other activities whenever they chose. During this period, each participant wore sleep-recording electrodes and 2 wrist movement recorders continuously (with the exception of washing / bathing times). The hypothesis was that PSG could be emulated by movement data collected via the wrist movement recorders, which is easier to obtain. Pollak *et al.*, (2001) concluded that actigraphy was limited in predicting sleep-wake activity, due to overestimation of sleep; however, it was a valid means of detailing rest-activity levels.

Kushida *et al.* (2001) conducted a study in sleep-disordered patients, to compare PSG, actigraphy and subjective assessment of sleep. One hundred participants (69 men, 31 women) were included in a sleep laboratory study where PSG and actigraphy data were gathered simultaneously over one night. Subjective data were derived from questionnaires given to the participants the following morning. Kushida *et al.* (2001) found that total sleep time and sleep efficiency were overestimated in approximately three quarters of the cases when utilising actigraphy data alone, and in half the cases when utilising subjective data alone. However, when the minimum value of the combined data was compared with the PSG data, it did not differ significantly. As such, the authors recommended the use of subjective data, in addition to actigraphy data, in studies related to sleep efficiency.

In their study, de Souza *et al.* (2003) utilised twenty one healthy volunteers (14 women and 7 men) to conduct research involving a night of adaptation in a sleep laboratory, followed by a night recording PSG and actigraphy data. The authors found that the actigraphs underestimated awakenings, such as when the user wakened, but did not move. Overall, they concluded that the accuracy of actigraphy was satisfactory, and that it was a useful method for assessment of sleep.

Lichstein *et al.* (2006) conducted an actigraphy validation study related to insomnia. Fifty seven volunteers, with varying insomnia conditions spent one night in a sleep lab, being monitored by PSG and actigraphy. In addition, they were required to complete a sleep diary. Lichstein *et al.* (2006) found that actigraphy was validated for number of awakenings, total sleep time, sleep efficiency and wake time after sleep onset. In addition, although sleep onset latency was not significantly different between actigraphy and PSG, in this study, there was a weak correlation between the two. The authors concluded that actigraphy was a satisfactory objective measure for the parameters validated, for the particular algorithms utilised in that study.

Paquet, Kawinska and Carrier (2007) evaluated the ability of actigraphy to detect wakefulness in fifteen participants, in three different sleep conditions, compared to PSG. Studies were conducted over two attendances in a sleep laboratory, where each session consisted of one night time sleep, followed by one night of sleep deprivation, followed by one daytime recovery sleep. All participants wore an actigraphy device and underwent simultaneous PSG recordings. The results found that actigraphy had a low ability to detect wakefulness, and therefore overestimated sleep time. The authors concluded that the results cast doubt on the validity of actigraphy use in clinical studies or in situations where the sleep-wake cycle is challenged, such as in shift workers or cases of jet lag.

To study the agreement between two different actigraphs, located on the wrist and the hip, with self-reported sleep data and PSG, Zinkhan *et al.* (2014) recruited members of the general population across four different German towns. Actigraphy and PSG data were recorded during one night in a sleep laboratory, along with self-reported sleep data. Self-reported sleep data were also recorded the morning after the night in the sleep laboratory. Participants wore three actigraphy devices simultaneously, two placed on the right side of the hip and one on the wrist of the non-dominant hand. The analysis population was 100 participants. Zinkhan *et al.* (2014) found that the data collected from the actigraphy devices placed on the wrist showed more agreement with the PSG data gathered, than those of the actigraphy devices placed on the hip. They concluded that wrist actigraphy and self-reported data could be recommended when total sleep time or sleep efficiency were of interest, although clinical usage was limited.

In summary, there are differences in findings in studies performed in this area. Some have found that use of actigraphy is limited (Pollak et al., 2001; Paquet et al., 2007), or should be used in conjunction with other means of recording sleep-wake activity, such as subjective means (Kushida et al., 2001; Zinkhan et al., 2014). Others have found it a satisfactory method of sleep assessment, despite underestimating awakenings (de Souza et al., 2003), or that it was validated for number of awakenings, total sleep time, sleep efficiency and wake time after sleep onset (Lichstein et al., 2006). All of the studies discussed were conducted in a sleep laboratory setting. The studies conducted by Pollak *et al.* (2001), de Souza *et al.* (2003) and Paquet, Kawinska and Carrier (2007) all had limited numbers of participants, (ranging from 14 to 21), whereas Lichstein et al. (2006) had 57 participants, and those conducted by Kushida *et al.* (2001) and Zinkhan *et al.* (2014) included 100 participants in each study. The studies utilising greater numbers of participants produced results more in favour of the use of actigraphy.

Paquet, Kawinska and Carrier (2007) concluded that actigraphy was not recommended for shift workers. However Calogiuri, Weydahl and Carandent (2013) explored methodological issues around rest and activity, and concluded that actigraphy was particularly helpful in assessing sleep disturbances experienced by shift workers. This is because it is possible to monitor participants for several days, giving highly reliable and reproducible data.

In general then, actigraphy has been found to be particularly useful in examining night-to-night variability of sleep and in demonstrating sleep disturbances when sleeping at unusual times during the circadian period (Ancoli-israel et al., 2003; Martin and Hakim, 2011). Actigraphy is well-accepted as a useful method of examining day to day (or night to night) variability in sleep duration, and is well tolerated by users, due to the ability to obtain unobtrusive measurement of sleep, compared to PSG (Marino et al., 2013). It has been found to be more accurate than manually recorded sleep logs, due to inconsistencies in participants' ability to recall sleep duration and disturbances, it allows data to be captured over a number of days and nights in the home, is a practical, user friendly method of capturing data (Ancoli-israel et al., 2003) and has been positively validated against PSG (Kushida et al., 2001; So et al., 2005).

In the absence of any equipment, with which to record sleep, there are still some simple means of subjectively recording data, such as the manually recorded sleep logs as touched on here. These other methods are discussed in the following sections.

2.3.3 Subjective methods and sleepiness scales

Subjective methods for recording time asleep, such as questionnaires, sleep diaries or charts are also available, and can provide useful information for researchers and clinicians. These methods focus on sleep duration and latency as recorded by the participant and although helpful, potentially do not offer sufficient reliability (O'donnell et al., 2009) due to inaccurate recall of awakenings (Kushida et al., 2001; O'donnell et al., 2009). A questionnaire is potentially easier to complete; however, that depends very much on the questions included; and diaries or charts provide information on day to day variation over longer periods (Johns, 1971).

Kushida *et al.* (2001) found that when subjective data was combined with actigraphic data, that results were not significantly different from PSG data, hence the recommendation to use combined subjective and actigraphic data when evaluating time asleep and sleep efficiency.

In a study of 669 adults, (Lauderdale et al., 2008) compared sleep recorded by way of actigraphs, with that recorded in sleep logs by the participants. They found that average sleep recorded using the actigraph was 6 hours, whereas average self-reported sleep was 6.8 hours. However, this was a moderate correlation between the two methods of recording sleep, despite over-reporting for self-recorded sleep duration.

In addition to methods of recording time asleep, as discussed above, there are also a number of sleepiness scales and tests that have been devised and utilised to assist in identifying sleepiness in a number of situations. It is beyond the scope of this thesis to review all of these methods; however, some of the more widely known self-administered methods of indicating different levels of sleepiness are discussed below.

The Epworth Sleepiness Scale (ESS) was devised by Dr Murray Johns in 1990 to measure daytime sleepiness. It is a self-administered questionnaire with 8 questions related to normal activities. The questionnaire asks participants to rate their chance of falling asleep, on a simple, four point scale, from 0 for no chance of dozing, up to 3 for a high chance of dozing, whilst engaged in these listed activities during the day. The scores are combined to provide a score for each participant, which can assist in identifying those with high levels of daytime sleepiness. The ESS does not record subjective feelings of sleepiness at particular times of day, or over continuous periods, and it does not record how often, or for how long a participant may actually sleep during the day. In addition, it generally does not usually enable predictions of level of sleepiness and hence collision risk, when driving, so may not be ideal for use in these types of study.

In the development study, Johns (1991) found that scores greater than 16, indicating a high level of daytime sleepiness, were found only in participants with diagnosed moderate or severe sleep disorders. Wide-ranging lower scores amongst control participants in the study indicated that some healthy adults, without any recognised sleep disorder, still remain sleepier than others (Johns, 1991).

Table 2.1 shown below, from Johns (1991), illustrates the activities studied in ESS and the associated scoring key.

Table 2.1 Epworth Sleepiness Scale, (ESS), (Johns, 1991)

Situation	**Chance of dozing**
	0 - 3
Sitting and reading	
Watching TV	
Sitting, inactive in a public place	
As a passenger in a car for 1 hour without a break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after lunch without alcohol	
In a car while stopped for a few minutes in traffic	

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

The Karolinska Sleepiness Scale (KSS) measures subjective levels of sleepiness at particular times during the day. It is a self-report measure, incorporating a 9-point scale, where each point represents a statement regarding the participants own level of sleepiness over the previous few minutes, from extremely alert at point 1, right through to very sleepy, fighting sleep at point 9 (Åkerstedt and Gillberg, 1990). It is not widely used in clinical settings, but has been successfully used in studies involving shift workers, or investigating driving ability, as it has been shown to be helpful in assessing variation in sleepiness due to circadian rhythm and environmental factors (Shahid et al., 2011). The KSS is shown in Table 2.2 below.

Table 2.2 Karolinska Sleepiness Scale (KSS) (Åkerstedt and Gillberg, 1990)

KAROLINSKA SLEEPINESS SCALE

Please, indicate your sleepiness during the 5 minutes before this rating through circling the appropriate description

1 = extremely alert
2 = very alert
3 = alert
4 = rather alert
5 = neither alert nor sleepy
6 = some signs of sleepiness
7 = sleepy, but no effort to keep awake
8 = sleepy, some effort to keep awake
9 = very sleepy, great effort to keep awake, fighting sleep

The Pittsburgh Sleep Quality Index (PSQI) was initially developed for use in psychiatric clinical settings to identify good and poor sleepers. It is a self-report questionnaire that assess sleep quality over a retrospective one month period. The PSQI generates seven scores, from nineteen questions, related to subjective sleep quality, latency, duration, sleep efficiency, disturbances, use of sleep medication and daytime dysfunction. Results obtained using the PSQI relating to good or poor sleepers, compared favourably with polysomnography (Buysse et al., 1989). However, despite its favourable results, it was designed for use in the clinical environment, rather than for field research, and the nineteen questions make it a lengthy process. As such, it is not as convenient for use, is more time consuming and may not reflect night to night variations as accurately as other means, such as post-sleep methods that are done when participants have a fresh memory (Buysse et al., 1989).

The Stanford Sleepiness Scale (SSS) is another quick and simple, self-administered measure of sleepiness, similar to the KSS, often used in both clinical settings and for research purposes and can be used with any adult population. It consists of one scale, from 1-7, where the participant selects just one of the statements related to their own perceived level of sleepiness at a particular time (Shahid et al., 2011). The SSS has been found to be sensitive in predicting alertness related to total sleep deprivation; however, it was found to be not so sensitive to partial sleep deprivation (Broughton, 1982; Shahid et al., 2011). The SSS, and associated scale, is shown in Table 2.3 below.

Table 2.3 Stanford Sleepiness Scale (SSS) (Hoddes et al., 1973)

Degree of Sleepiness	Scale Rating
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not at peak; able to concentrate	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7
Asleep	X

Each of these sleepiness scales has both positive and negative aspects, depending on the purpose and studies for which they are used. The ESS measures trait sleepiness, which is a more stable level of daytime sleepiness, and more relevant from a clinical perspective. Conversely, the KSS and SSS are measures of state sleepiness, which is the level of sleepiness at a particular time.

These are more useful for research purposes as they can be used for determining differences, as a result of, for example, circadian factors (Shen, et al., 2006).

In summary, the ESS is a measure of daytime sleepiness, the KSS is specifically not for use in clinical settings and has been shown to be successful in shift work and driving studies. The PSQI was designed for use in clinical psychiatric settings, relies on memory for the past month and specifically asks about a regular bedtime, indicating it may not be ideal for shift workers. The SSS has been shown to be good for total SD, but may not be sensitive to partial SD.

2.3.4 Summary of sleep measurement methods

It can be seen that there are many methods, both objective and subjective, of measuring and assessing sleep and fatigue. Each method has its own advantages and disadvantages as summarised in Table 2.4 below.

Table 2.4 Advantages and disadvantages of sleep measurement methods

Method	Advantages	Disadvantages
Polysomnography	Detailed objective information obtained	Expensive; usually conducted in a laboratory setting; labour intensive
Actigraphy	Cost effective; Non-intrusive; Can be conducted at home / in the workplace for extended periods	Only measures rest / activity which when awake and motionless, could be mistaken for sleep
Subjective measures / self-recorded scales	Cost effective and can include additional data requested by researcher	Can be influenced by participant; Inaccuracy of recall

Due to the cost effectiveness and convenience of actigraphy and subjective measures, along with the suggestion of combined accuracy (Kushida et al., 2001; Zinkhan et al., 2014), these methods are ideal for studies conducted in the workplace.

Following a summary of these methods used to measure fatigue and sleepiness, the next section will provide an overview of shift working regimes, and the influence of these patterns of work on fatigue, as well as general health.

2.4 Shift work and associated difficulties with sleep and health

More than 3.5 million people are employed as shift workers in the United Kingdom (Madouros, 2005) and it is estimated that around 20% of the working population of the world are engaged in some sort of shift work (Wright Jr et al., 2013). These individuals work in a wide variety of industries including, but not exclusively, the emergency services, healthcare and manufacturing (Madouros, 2005). Shift work is often essential to societies because many operations are either ineffective, economically unviable or simply impossible to run without relying on round the clock operations (Monk and Folkard, 1992).

Shift work can be broadly defined as a pattern of work outside the standard working day and standard working week, where one employee usually replaces another on the same task within a 24-hour period (Knutsson, 2004; Richbell and Chan, 2011). The standard working day and week are usually associated with the Western world office practices of recent years, assuming a working week of Monday to Friday, eight hours per day, usually during daylight hours (McCormond, 2004). Although the term 'standard working day' is commonly used, alternative working hours such as shift work are becoming the norm (Wilson et al., 2007). Shift working can follow a variety of patterns; however, shift-workers normally work in teams or groups of workers who make up separate shift teams. Shifts can either be fixed, where employees work the same shift regularly, depending on the needs and demands of the business or service, or they can be varied and rotating (Harrington, 2001; McOrmond, 2004; Richbell and Chan, 2011).

2.4.1 Shift schedules and adjusting to irregular hours

There are different ways in which to cover the 24-hour working window with the required personnel. This is usually by way of 8 or 12 hours shifts (Smith et al., 1998). Irregular shifts, such as 9 or 10 hour shifts are also used, although this would not cover the full 24-hour period, unless there is a handover period or an overlap for busy periods or times of greater demand, depending on the type of business (Smith et al., 1998; Härmä et al., 2002). Those shifts longer than 8 hours are generally classed as extended shifts (Lerman et al., 2012).

Fixed shift schedules involve working the same working hours and days each week. This allows those who work fixed shifts to try to adjust to them, (Oexman et al., 2002). For example, an employee may work permanent night shifts, 4 nights per week, with 3 days off.

Rotating shifts have varying start times (Coleman, 1995) and can rotate either forwards or backwards. In rotating shift systems, each team will regularly change its hours of work and rotate day, afternoon, and night shifts. The forward rotating system begins with day shifts, before then moving to afternoon shifts and night shifts, and the backwards rotating system uses the opposite pattern, beginning on nights shifts and rotating through afternoon shifts and finally day shifts (Oexman et al., 2002). Forward rotating shifts are believed to be easier to adjust to than backward rotating, as it is easier to delay the onset of sleep, as opposed to trying to bring sleep forward (Lavie et al., 1992; Barton and Folkard, 1993; Knauth, 1993; Van-Amelsvoort et al., 2004). In addition, forward rotating shift patterns usually allow for around a 24-hour break in between a shift change, which, in theory, provides ample time for rest and for recovery sleep (Van-Amelsvoort et al., 2004).

There are numerous shift patterns, utilised by different organisations, dependent on their particular needs (Richbell et al., 1998). Table 2.5 illustrates three examples of 8-hour shift patterns, over a 28 day period, where 'D' represents day shifts, 'A' represents afternoon shifts, 'N' represents night shifts and 'R' represents rest days. All 3 examples in the table are rotating shifts in one way or another, with a forward rotating, backward rotating and quick forward rotating pattern illustrated. Table 2.6 illustrates two examples of different 12-hour shift patterns, shown over a 16 day period. The first is a forward rotating pattern, where employees work 4 day shifts, followed by 4 rest days, followed by 4 night shifts, followed by 4 rest days. The second example is a quick, forward rotating pattern, where employees work 2 day shifts, followed by 2 night shifts, followed by four rest days, on a constantly repeating pattern.

Table 2.5 Examples of 8-hour shift patterns (Tucker et al., 1998)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Forward rotating pattern	D	D	D	D	D	D	D	R	R	A	A	A	A	A	A	A	R	R	R	N	N	N	N	N	N	N	R	R
Backward rotating pattern	N	N	N	N	N	N	N	R	R	A	A	A	A	A	A	A	R	R	D	D	D	D	D	D	D	R	R	R
Quick forward rotation pattern	D	D	D	A	A	N	N	R	R	D	D	A	A	A	N	N	R	R	D	D	A	A	N	N	N	R	R	R

Table 2.6 Examples of 12-hour shift patterns (Tucker et al., 1998)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Forward rotating pattern	D	D	D	D	R	R	R	R	N	N	N	N	R	R	R	R
Quick forward rotating pattern	D	D	N	N	R	R	R	R	D	D	N	N	R	R	R	R

Different combinations of schedules, such as those suggested above, have been used for rotating shifts. However, research suggests that rotating shift workers are prone to more problems, such as circadian rhythm disruption and accidents, than fixed shift workers (Gold et al., 1992; Dembe et al., 2006). This is considered to be due to sleep deprivation and misalignment of circadian phases. For example, self-reporting questionnaire studies of hospital based nurses showed that when compared with day shift nurses, those working rotating shifts had more sleep disruption and were more prone to nodding off at work. This group of nurses were also more likely to nod off while driving home, or were involved in more reportable vehicle collisions and errors associated with sleepiness (Gold et al., 1992). Further, a study by Stutts *et al.* (2003) found that those involved in sleep-related road traffic collisions were more likely to work unusual work patterns, or night shifts.

On the other hand, a comparison of a more traditional backwards rotating shift system, with a fast rotating, forward system shown in Figure 2.3, found that the fast rotating, forward shift pattern actually had positive effects and improved perceived wellbeing and alertness, and reduced complaints due to lack of sleep (Härmä et al., 2006). In Figure 2.3, ‘M’ represents morning (or day shifts), ‘N’ represents night shifts and ‘E’ represents evening (or afternoon) shifts. The number of consecutive shifts worked in this study (three) before having rest days (two) was not altered from the previous schedule. The perceived improvements the shift pattern yielded was thought to be because the forward rotating system is preferable for the circadian rhythm, i.e., the forward rotating pattern offered more time in between each shift, and there was a potentially faster recovery rate, having worked a single night shift prior to rest days.

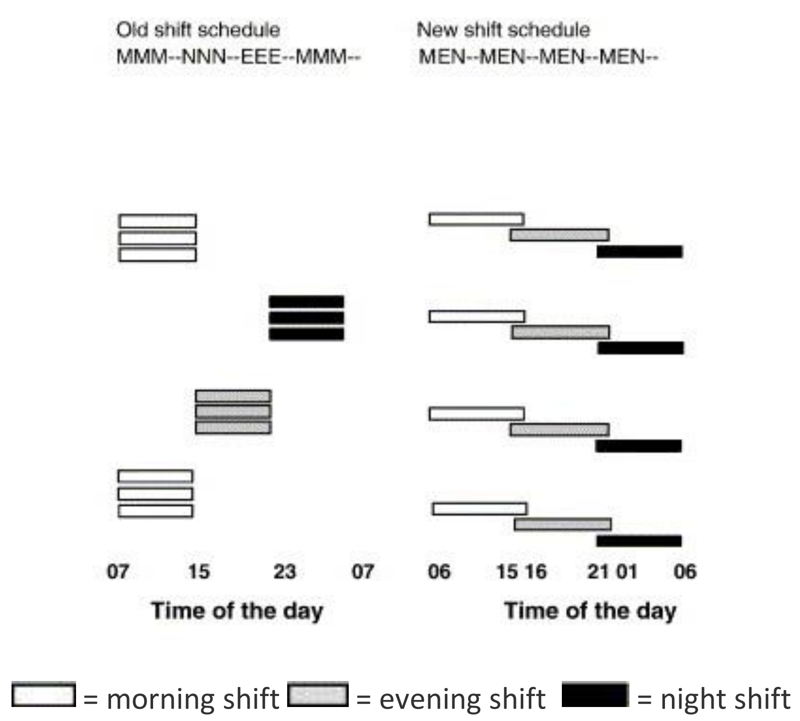

Figure 2.3 Illustration of the shift systems in the study by (Härmä et al., 2006)

Continual shift systems provide cover 24 hours a day, seven days a week, and conversely, intermittent shift systems cover shorter periods, for example five, 24-hour periods in seven days (Doyle, 1991). In intermittent shift systems, for example, an employer may require employees to follow a shift system to cover 24 hours a day, Monday to Friday, but do not require any operations and therefore any employees working at weekends.

There are advantages and disadvantages for different shift lengths, for example, by working longer shifts, it is possible to continue to work full time hours, over fewer working days (Tucker et al., 1996) and benefit from having more days off. Tucker, Barton and Folkard (1996) studied two groups of male chemical workers, one group working 8-hour shifts, and the other working 12-hour shifts. Both groups completed self-reported questionnaires in relation to health and wellbeing. The authors concluded that there were advantages for those working 12-hour shifts; however, there were safety related implications, due to drops in alertness, amongst this group. Other studies have also found that extended shifts are often associated with higher fatigue levels (Macdonald and Bendak, 2000; Baker and Ferguson, 2004), higher risk of falling asleep (Sallinen et al., 2003) and a reduction in safety towards the end of a shift, due to the time since the last sleep (Baker et al., 1994; Tucker et al., 1998).

Shift system design is complex and depends on the needs of the individual organisations, the employees and the actual service provided or work tasks involved (Ferguson and Dawson, 2012). There is no ideal shift system that suits all, but there are suggestions that make some shift systems more favourable in terms of physiological and psychological wellbeing (Knauth, 1993), such as forward rotating systems (Lavie et al., 1992; Barton and Folkard, 1993; Knauth, 1993; Van-Amelsvoort et al., 2004), rapid rotating systems, with a shift change every few days (Hakola and Härmä, 2001; Harrington, 2001; Härmä et al., 2006) and limiting the number of consecutive night shifts (Knauth, 1993), along with limiting the hours worked on night shifts (Knauth, 1993; Knauth and Hornberger, 2003). These suggestions are all thought to help with the human body adapting to a schedule.

Working Time Regulations (WTR) that limit the number of consecutive days at work and stipulate a minimum of 11 hours between shifts, have also assisted in ensuring workers have enough time between shifts in order to gain sufficient rest and sleep (Morris-Stiff et al., 2005; Cairns et al., 2008).

Some of the difficulties of shift work, in relation to health, disturbed sleep and obtaining sufficient sleep are discussed in the following section.

2.4.2 Disturbed sleep amongst shift workers

Disturbed sleep and fatigue are perhaps the major negative outcome of shift work (Bonnet and Arand, 1995; Axelsson, 2005). Working shifts, particularly night shifts, not only affects the quality of sleep (Harrington, 2001), but has also been shown to reduce average quantity of sleep by around 2 hours in any 24-hour period, compared to the average sleep recorded for those working during the day (Torsvall et al., 1989). The effects of shift work have also been compared to a traveller working on the West Coast of the United States of America and returning to the United Kingdom for rest days (Harrington, 2001). It can therefore be seen how this could produce a cumulative effect of sleep loss and fatigue (Knauth, 1993).

Poorly designed shift-working arrangements and long working hours that do not balance the demands of work with time for rest and recovery, result not only in unhappy staff and a poor work output (Woolfenden, 2006), but also in fatigue, accidents, injuries and ill health (Smith et al., 1994; Madouros, 2005). In addition, poorly designed shifts increase the possibility of falling asleep whilst at work (Shen, Barbera, et al., 2006), and working at night, regardless of the shift pattern, increases the risk of making poor decisions and making mistakes (Horrocks and Pounder, 2006).

Complaints from shift workers are usually related to the inability to get enough good quality sleep after a nightshift (Bajraktarov et al., 2011) and the duration of sleep for rotating shift workers is often reduced whilst on both night shifts and day shifts (Akerstedt, 1990). Whilst on night shift, shortened sleep duration is due to the difficulties previously mentioned when trying to sleep during the day. Sleep length is often reduced prior to day shifts too, due to the requirement to get up earlier than one would perhaps ordinarily want to. Nightshift work is associated with an increased number of sleep disorders, mental health problems, dissatisfaction with the workplace and increased work absences (Muecke, 2005), and sleep disturbances are one of the major problems of shift work (Axelsson, 2005). As a result, a combination of both acute and chronic SD may be present in shift workers, as they may have total SD at times during their shift pattern, such as following the first night shift, when they may have been awake for 24 hours or more. In addition, they may have an additive effect of chronic SD, which is not unusual nowadays (Alhola and Polo-Kantola, 2007), as described in section 2.1.1.

Many employees, such as police service employees and other emergency service personnel, are expected to work at night, and all have to cope with the fact that working at night causes sleep deprivation and fatigue (Harrington, 2001). This is because the human body is designed to sleep at night. Nightshift workers are trying to function when alertness, vigilance and cognitive reasoning are at their lowest (Horrocks and Pounder, 2006). Those shift workers who don't adjust quite so successfully may experience insomnia when trying to sleep after a nightshift or on their days off, others experience excessive sleepiness whilst at work. The ability to adapt to shift work becomes less with age and that is seen commonly in police and other emergency service employees (Wilson and Nutt, 2013).

When people try to remain awake and alert at times when they would ordinarily be asleep, sleep propensity increases, and sleep latency decreases (Connor, 2009). In addition, problems, such as dips in cognitive performance, low mood and microsleeps can occur when we disrupt our natural sleep cycles; this disruption and fragmentation also cause sleep debt, even when sufficient hours are spent in bed (Durmer et al., 2005). This is often the issue encountered by shift workers, who experience disturbances whilst trying to sleep through the day, leading to insufficient sleep. Even after years of working nightshifts, the human body is still programmed to sleep at night and be awake through the day (Horrocks and Pounder, 2006). The duration of sleep obtained is often less than required, that is when there can be a sleep debt (Shneerson, 2006). When we start to reduce the amount of sleep we get, we accumulate this sleep debt. When this happens, we have a greater tendency to fall asleep the following day, and the longer the sleep debt, the greater the tendency to fall asleep (Connor, 2009; Rogers, 2008).

Shift workers, therefore, are more likely to have less sleep and more sleep disturbances, than non-shift workers. Disruptions to the circadian rhythm are associated with impaired attention and performance and slower reaction times (Niu et al., 2011). Sleep deprivation, therefore poses significant risk in performing tasks such as driving (Durmer et al., 2005), and over 50% of shift workers report severe decreased alertness when at work (Akerstedt, 2005). Aside from the problems with sleep disturbances, there are also other health risks associated with shift work. These are discussed in the next section.

2.4.3 Health problems associated with shift work

There are a number of social challenges and health concerns for any shift worker, not least trying to sleep at times that others would see as peculiar. As it does seem peculiar to most to sleep at these times, society appears to place less importance on protecting the sleep of night workers during the day (Monk and Folkard, 1992). For example few people would consider making a telephone call in the middle of the night; however the same consideration is perhaps not applied when calling a nightshift worker through the day (Monk and Folkard, 1992). Due to the circadian pressures, as well as the social pressures, shift workers therefore tend to have shorter periods of sleep during the day, with poorer sleep quality, along with increased sleepiness during nightshifts (Kecklund et al., 2016).

Those working irregular hours over a number of years can develop chronic circadian and sleep disruption, sometimes resulting in Shift Work Sleep Disorder (SWSD) (Booker et al., 2018). This is common in shift workers, and caused when the internal body clock does not adjust to the shift work schedule (Schwartz and Roth, 2006; Thienhaus and Cardon, 2008). In a study of 2570 participants, representative of the community, of which 360 worked rotational shifts and 174 worked nightshifts, Drake *et al.* (2004), suggested that approximately 10% of those working rotational and night shifts had SWSD. Relatively few shift workers are aware of SWSD, the short term symptoms of which can be unrefreshing sleep, excessive sleepiness when required to be awake, insomnia when not at work, and sleep deprivation leading to impairment at work and when commuting. Longer term, this can lead to obesity, cardiovascular diseases and type 2 diabetes (Kecklund et al., 2016). Those at higher risk of SWSD include females, those with a predisposition to sleep disturbance or impaired alertness, and those of increasing age (Richardson, 2006).

Despite the potential risk of SWSD with those of increasing age, there are also inter-individual differences in sleep and sleepiness that impact upon tolerance to shift work (Costa, 2003; Van Dongen, 2006), and this can have important consequences for productivity and safety (Van Dongen, 2006). Studies have suggested tolerance to shift work varies with age, personality traits and some genetic influence (Saksvik et al., 2011). Many studies have found adverse health effects of shift work with increasing age (Harma, 1993), and there are often increased incidents of insomnia and OSA in older adults (Roepke and Ancoli-Israel, 2010). Despite these factors, tending to suggest older drivers are more at risk of adverse incidents, in a number of studies involving young, male drivers, it has been found that they are more susceptible to sleep-related collisions (Cook and Albery, 1995; Flatley et al., 2004). Åkerstedt and Kecklund (2001) reported young drivers had a much greater risk of late night collisions when compared with an intermediate age group and older age group, and Lowden *et al.* (2009), found that young drivers (18-24 years) showed increased sleepiness, when compared to older drivers (55-64 years). In addition, in a comparison study of young male drivers, with older male drivers, Filtness, Reyner and Horne (2012) found that the effects of sleepiness took longer to develop in the older drivers and that the young drivers showed more lane drifting, and concluded that the young males were more vulnerable to sleep restriction.

In addition to SWSD, there are other sleep disorders and psychological factors that are linked to shift work, that can affect fatigue, and potentially exacerbate the existing difficulties associated with working shifts (Rajaratnam et al., 2013). Some of these are outlined below.

Insomnia is a sleep disorder that is characterised by difficulty falling and / or staying asleep, along with day time sleepiness (Carey et al., 2005; Roepke and Ancoli-Israel, 2010). It can be either short term or long term and can be affected by many things. Short term insomnia can be the result of, for example, emotional disturbance, such as stress and anxiety, or long haul travel and the resulting jet lag. Long term insomnia sometimes has no known cause, but can be linked to causes such as SWSD ((Drake et al., 2004), as discussed above. Both short term and long term insomnia can adversely affect driving performance (Biggs et al., 2007; Garbarino et al., 2017).

Obstructive Sleep Apnoea (OSA), is an increasingly common sleep disorder that causes the upper airway to repeatedly collapse during sleep, leading to sleep disruption and fragmentation, and oxygen desaturation (Jordan et al., 2014). Although OSA is estimated to affect 1.5 million adults in the UK, only around one-fifth of those are diagnosed with and treated for the condition (Rejón-Parrilla et al., 2014).

When considering personality traits, Tamagawa, Lobb and Booth, (2007) found in a study of New Zealand police officers, that tolerance of shift work was significantly associated with personality traits. They noted that those scoring highly on trait anxiety, negative mood and repressive emotional style, showed lower levels of tolerance to night work and rotating shift work.

In an Australian study of night workers, it was discovered that 32% suffered with SWSD (Di Milia et al., 2013). In a further study of American police officers, it was found that over 40% had at least one sleep disorder (Rajaratnam et al., 2011), hence suggesting that this is not unusual. Overall, it is accepted that sleep disorders are more prevalent amongst shift workers and this can lead to performance impairment and increased risk of road traffic collisions (Rajaratnam et al., 2013).

If there is no alternative to shift work, and in many areas of employment there is not, then society needs to protect those workers, as best as possible, through legislation and education (Monk and Folkard, 1992). An example of legislation in this regard would be the Working Time Regulations (WTR) (Police Federation of England & Wales, 2006), that limit the number of consecutive days at work, along with rest hours between shifts. In addition, regardless of which particular group of workers is most at risk, employers are obliged to protect their workers (Gagliardi et al., 2012) and there are clear policy directions in Europe to promote workplace health and safety, along with healthier lifestyles (Aires et al., 2010). Means of integrating this in clear policies are discussed in the following section.

2.4.4 Managing fatigue in the workplace

Employers have a duty to protect the health, safety and welfare of employees. This includes ensuring employees don't work excessive hours, they have a safe working environment, areas for rest and relaxation, and they also have means of raising and reporting concerns (Noone and Waclawski, 2018). When excessive fatigue is experienced in the workplace, it has a potentially negative effect on health, safety and productivity (Lerman et al., 2012). Despite this, Hours of Work (HoW) are the traditional, and often the only means of managing fatigue in the work place (Fourie et al., 2010). HoW restrictions can incorporate shift patterns, with set duty hours and rest periods, or other limitations, such as those placed on drivers' hours for Large Goods Vehicles (LGV) or Passenger Carrying Vehicles (PCV). These are often brought about by legislation, such as the Health and Safety at Work Act 1974 and Working Time Regulations 1998. However, HoW alone, can perhaps be considered too simplistic, as they do not take the nature of the business or any specific risk factors associated with that particular business, into account (Fourie et al., 2010). For example, the times of business operations, and employees working in conflict with circadian rhythms, or the type of work being undertaken. As such, they are not always effective, in isolation, for managing fatigue risk (Fourie et al., 2010; Gander, 2015).

2.4.4.1 Fatigue risk management and shift work awareness

Safety management has traditionally been a reactive process, where incidents may have been investigated after the event, with findings communicated for the purposes of "learning the lessons" (Lerman et al., 2012). In addition, despite the existence of health and safety policies, there may be no clear accountability for fatigue risk (Fourie et al., 2010). In recent years, many organisations have sought to incorporate Fatigue Risk Management Systems (FRMS) into their own corporate policies (Moore-Ede, 2010) in order to drive a more pro-active approach to risk mitigation and safety. FRMS are evidenced based alternatives, or additions, to HoW limitations that aim to manage employee fatigue, in an appropriate way, whilst having an honest and open culture regarding the reporting of fatigue-related issues (Fourie et al., 2010). As such, a FRMS may incorporate;

- a fatigue management policy,
- fatigue reporting systems for employees,
- incident investigation,
- training and education for all employees,
- a risk management programme,
- sleep disorder management,
- an auditing process (Lerman et al., 2012).

Fatigue is both an occupational and a personal risk factor (Schutte, 2010), hence FRMS are a shared responsibility between an organisation and employees. The organisation should provide schedules and rotas that provide enough opportunity for rest and recuperation, along with training and procedures for managing fatigue. Employees are responsible for using their free time appropriately, to ensure they are well rested and prepared for work. In addition, they are responsible for attending any training provided and to report any instances of undue fatigue (Lerman et al., 2012).

Monk and Folkard (1992) suggested introducing Shift Work Awareness Programmes (SWAP), incorporating training, in order to educate both management and employees, along with the development of support services, involving Occupational Health, and Health and Safety departments. This is a step towards an overall FRMS. In addition, FRMS have been developed in the transport sector, to complement HoW. However, they are perhaps limited in other areas (Barger et al., 2018). Barger *et al.* (2018) conducted a review and meta-analysis of 18 studies, in order to examine fatigue training in shift workers. They concluded that fatigue training improved health and safety outcomes, and that programmes including fatigue training and sleep health and hygiene input were beneficial for shift workers.

In respect of police officers, a pilot study to evaluate training interventions, was conducted by James, Samuels and Vincent (2018) amongst employees of the Royal Canadian Mounted Police (RCMP). The study gathered self-reported sleep, health and wellbeing data from the 61 participants. A fatigue management training package was then provided for participants, and the self-reported data collection was repeated. This was the first study of its kind, and the findings suggested that the training programme resulted in improved sleep quality, increased sleep satisfaction, along with improved mental and physical health.

In summary, FRMS or SWAP are a consideration for organisations, as a proactive means to mitigate risk and improve overall health and safety.

2.4.4.2 Biomathematical models of fatigue

Biomathematical models (BMM) are widely used in many shift working organisations, in order to explore and minimise the impact of fatigue (Dawson et al., 2011; James et al., 2018). A number of different models have been developed, all generally accounting for those factors that contribute to fatigue, such as time awake, time of day and sleep history (Horrey et al., 2011). The models are all based on the same principles of circadian and homeostatic processes and produce predictions of performance, fatigue or risk impairment for different shift patterns (Dawson et al., 2011). This can be useful when planning shift schedules (James et al., 2018).

On the other hand, BMM are only designed to predict average group figures, and do not take into account any individual factors or the nature of the work being undertaken (Gander et al., 2011). There are therefore limitations, which need to be recognised by the user. It is recommended that these BMM should not be used in isolation in order to make operational decisions regarding fatigue and risk management, and instead, should be incorporated as part of a wider FRMS (Civil Aviation Safety Authority, 2014).

The Fatigue and Risk Index (FRI) was designed on behalf of the United Kingdom. Health and Safety Executive (HSE) (Spencer et al., 2006). It is primarily for comparing alternate work schedules (Spencer et al., 2006; Civil Aviation Safety Authority, 2014). It includes two separate indices, a Fatigue Index (FI) and a Risk Index (RI). The FI predicts the probability of high levels of sleepiness and the RI provides the relative risk of an error that may result in injury or accident (Spencer et al., 2006). The advantages of the FRI include that it is free and simple to use, and it provides estimates of both fatigue and risk (Civil Aviation Safety Authority, 2014).

The next section will move onto examine the driving task and decrements in driving ability as a result of fatigue.

2.5 The driving task

Driving is a complex, divided attention task, requiring drivers to process a variety of visual, auditory and tactile information (Jackson et al., 2013), and react appropriately to the stimuli around them in order to interact safely with other road users and the road environment (Lengenfelder et al., 2002). Therefore, for activities such as driving, we require maximum levels of concentration (Radun, 2009). The driving task is discussed in more detail in the following sections.

2.5.1 Hierarchical decision making whilst driving

The purpose and challenge of driving is generally to get safely from one place to another (Shinar, 2017). In order to do so, a driver has to make numerous decisions, that can be illustrated in a hierarchical system, such as that suggested by Michon, (1985) and shown in Figure 2.4. The system has three levels: firstly the strategic (planning) decision level, where, for example, the decision to drive or route planning decision making takes place, followed by the intermediate tactical (manoeuvring) level where the navigational decisions are made, then the operational (control) level (Michon, 1985; Shinar, 2017).

In relation to the driving task, decisions at the strategic level include well thought out planning decisions, such as the choice of route and the time dedicated to the journey. The tactical decisions are made whilst driving, and include judgements in relation to, for example, avoiding obstacles, lane changing or overtaking and choice of speed. The decisions at the operational level are usually quick-time, unconscious decisions (to the experienced driver), relating to actions prompted by various stimuli, for example the physical actions of stopping, accelerating, signalling, checking mirrors or responding to an emergency unfolding in front. The three levels are not distinctly separate, and decisions at all levels can be carried out at all times. For example, the model includes feedback loops, which allow for changes in plans during a journey, such as changes in navigational decisions due to road closures, or a decision to stop and take a break from driving (Shinar, 2017). This can make overall driver behaviour, and interaction with other road users fairly complex (Shinar, 2017).

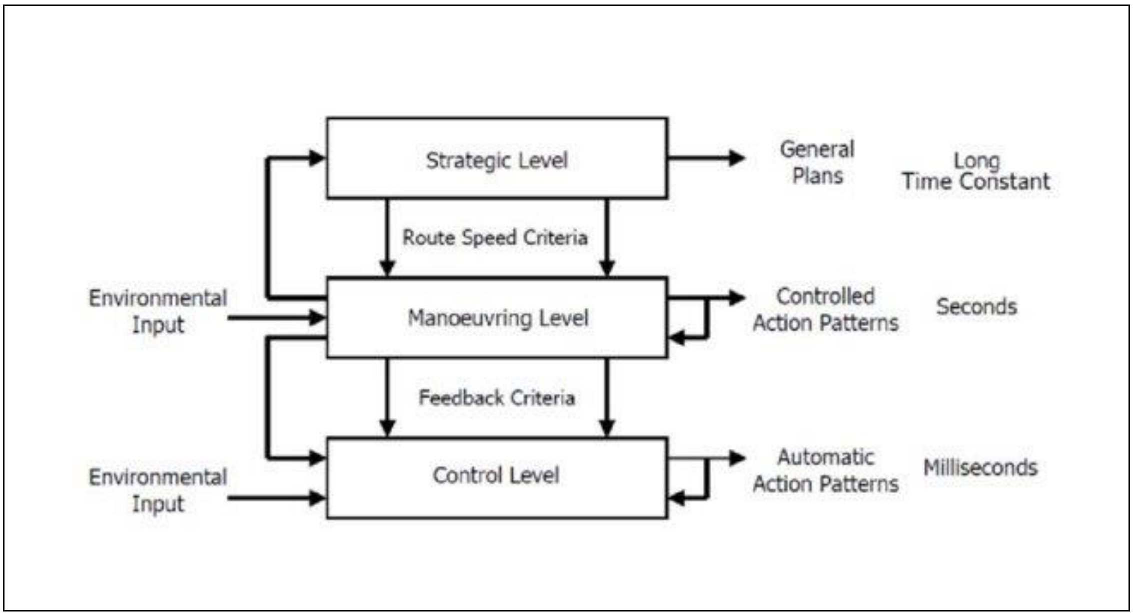

Figure 2.4 Hierarchical structure of the driving task (Michon, 1985)

2.5.2 Fatigue and driving performance

Humans need rest and sleep in order to work and function effectively; when this is reduced, so too is our ability to function normally and carry out tasks efficiently and safely (Horne, 2000; Tobler, 2005). A fatigued person will be less alert, less able to process information, will have slower reaction times and less interest in working, when compared to a person who is not fatigued (Folkard et al., 2005).

Fatigue and sleep deprivation can become problematic when experienced in many day to day situations; however, when fatigue affects a driver, it causes extreme danger, bringing high risks of road traffic collisions, often resulting in serious or fatal collisions (Pack et al., 1995; Horne and Reyner, 1999; Rajaratnam and Jones, 2004; Smith et al., 2005; Nordbakke and Sagberg, 2007). A fatigued person is less alert and so is less able to process information and to react appropriately (Folkard et al., 2005). There is also evidence to show that sleep restriction or fragmentation, such as that found in shift workers, negatively affects cognition and cognitive performance (Bonnet and Arand, 2003; Alhola and Polo-Kantola, 2007; Goel et al., 2009; Lerman et al., 2012), thus the link established between shift work and the prevalence of accidents, injury and making mistakes (Madouros, 2005; Horrocks and Pounder, 2006). In general, cognitive performance becomes progressively worse with time on task or time awake (Wilkinson, 1968).

The reasons for tiredness or fatigue amongst drivers can be varied, perhaps the driver was not well rested prior to beginning their journey, maybe they have simply been driving too long or maybe it is related to shift-work and hours of employment (Knipling and Wang, 1994). Driver fatigue has been defined by Williamson et al. (1996) as a state of reduced mental alertness, which can impair performance of a range of psychomotor and cognitive tasks, including driving.

Fatigue can affect any driver, but those who drive as part of their job, or who are shift workers, are more at risk (Thiffault and Bergeron, 2003b), and there has been reported increased road collision incidents whilst driving home from a night shift (Gold et al., 1992; Stutts et al., 2003). In a driver simulator study, involving ten shift workers, Åkerstedt *et al.* (2005) also found that there were increased incidents of lane drifting and decreased time until first collision when driving following a nightshift, when compared with driving after a normal night's sleep.

Fatigue does not just mean falling asleep whilst driving; driving ability can be seriously affected long before this, when physiological arousal is decreased, and motor functions and information processing becomes impaired (Williamson et al., 1996; Lal and Craig, 2001). Difficulty in concentrating, excessive blinking, yawning and the vehicle wandering, or driver over-steering are all signs of fatigue.

When drivers begin to notice or struggle with fatigue, they are already impaired (James and Vila, 2015).

Shift work induced fatigue has been clearly identified as a significant risk factor increasing the likelihood of accident and injury (Dawson, et al., 2011), and shift work also increases the possibility of falling asleep on the job and increases workplace accidents (Shen, et al., 2006). The impairment associated with alcohol and the dangers of driving whilst under the influence are well known and have been well publicised over the years, and driving whilst fatigued is as risky as driving whilst drunk (Fletcher et al., 2005; Zhang et al., 2014), yet fatigue is insufficiently recognised as a cause (Brown, 1994; Ramey et al., 2019).

A self-reporting survey conducted in the USA (Richardson et al., 1989) of rotating shift and regular day workers at a manufacturing plant found an increased incidence of motor vehicle accidents or 'near misses' in which sleepiness was cited as a cause: 22% of rotating shift workers compared to 7% of day-only workers. Complaints of poor sleep and increased sleepiness during hours of wakefulness were also significantly more common in shift workers than day workers. Shift workers reported higher caffeine and alcohol consumption, and were more likely to use alcohol as a sleep aid (Richardson et al., 1989).

The UK Government identified driver fatigue as a main area of driver behavior that needs to be addressed, including work-related fatigue (Jackson et al., 2011). Despite this, little publicity exists surrounding the deadly consequences of driving whilst tired. In the UK, there has been the THINK! Campaign (Department for Transport, 2005) that provided television advertising, along with campaign literature, to inform drivers on the dangers of driver fatigue (amongst many other road safety challenges). Fletcher *et al.*, (2005) conducted a review of public awareness campaigns relating to driver fatigue and concluded that there could be improvements made by personalising risks to drivers and developing simple guidance for fatigue self-assessment. For example, campaigns for raising awareness of fatigue-related collisions should be tailored towards those groups who are statistically more likely to be involved in such a collision, such as shift workers and specific occupations, including emergency service workers (Steele et al., 1999; Fletcher et al., 2005).

Sleep-related collisions, can be expected to occur more often during the sleepiness peaks identified in the circadian rhythms discussed above, so typically will occur around 0300-0500 hours and 1400-1600 (Pack et al., 1995; Thiffault and Bergeron, 2003a). Due to this, many of these types of collisions may be work-related (Maycock, 1995; Stutts et al., 2003) and recent research also shows that long driving hours in the early hours of the morning can exacerbate fatigue-related driver impairment (Jackson et al., 2011).

However, are driver's aware when they become sleepy or fatigued? Humans are usually aware of feeling tired or sleepy, it matters not what they are doing at the time, so even if driving, they should be aware that they are sleepy (Horne and Reyner, 1999). Following this, they either make a conscious decision to carry on driving or to find somewhere safe to stop and take a break, have a nap, drink coffee or any number of other things that they may find useful to potentially relieve the symptoms of feeling tired or fatigued (Horne and Reyner, 2001a). Reasons why drivers may continue to drive could include little understanding of the fatigue-related collision risk, pressure to reach their destination, or choosing to ignore the warning signs of fatigue (Baranski et al., 1994; Fletcher et al., 2005).

Reyner and Horne (1998) conducted a simulator study assessing the association between subjective sleepiness and driving impairment in young adult drivers. They found that increasing sleepiness was closely associated with an increased number of driving incidents. Despite this, some participants underestimated the likelihood of actually falling asleep, even when feeling very sleepy. Nabi *et al.* (2006) collected data by way of a self-reporting questionnaire, distributed to employees of a large French, power company. They collected data on the frequency of self-reported driving whilst sleepy, along with driving incidents reported. They found that self-assessed driving while sleepy was a powerful predictor of serious road traffic collisions. Hence drivers should take heed of their own personal assessments. Similarly, Williamson *et al.* (2014) conducted a driving simulator study, where 90 drivers participated in a 2 hour, monotonous, afternoon drive, having had a shorter than normal sleep the night before. In this study, the authors found that drivers self-detected changes in their own sleepiness levels and were capable of making the decision to stop safely.

Sleep does not occur spontaneously without warning. Drivers falling asleep are often unlikely to recollect having done so, but will be aware of the precursory state of increasing sleepiness; probably reaching a state of fighting off sleep before an incident (Horne and Reyner, 1995a; Horne and Reyner, 1999).

Vanlaar *et al.* (2008) gathered data on the perception of the problem of fatigued driving by means of a public opinion poll. In that poll, 14.5% of drivers stated they had actually fallen asleep, and 2% were involved in a fatigued driving related collision. Despite the dangers associated with fatigued driving, they found there was little concern about the issue amongst drivers. They found that there is still a need to effectively educate the public of the dangers in order to find effective prevention methods (Vanlaar et al., 2008). Jackson *et al.* (2011) suggest that, in addition to some drivers failing to identify the risks in driving whilst fatigued, there may be a belief that the rewards of completing the journey can out way the risks.

2.5.3 Cognitive function related to driving

Cognition refers to a range of human mental processes such as thinking, reasoning, understanding and planning (Mishra, 1997; Dror and Harnad, 2008). These processes enable people to understand their environment and adapt to it accordingly (Mishra, 1997). Driving is both an information processing task, as well as a motor task. It is automated to a certain degree for the experienced driver, due to well-learned, routine behaviours. However, when something unexpected happens, and the traffic situation becomes more complex, the driver needs to be in a position to switch between automatic processes and controlled processes (Lundqvist, 2001). Most information that the driver needs to process and react to, is received visually. Whilst driving, we have limited time to identify the relevant information, process it and make a decision how to deal with it, before physically acting on it (Shinar, 2017). Driving therefore involves a number of skills and cognitive processes working in harmony (Jackson et al., 2013) in order to successfully make the decisions at all three levels described in section 2.5.1 above, and undertake the driving task. These skills include executive function, memory, attention, working memory skills and psychomotor skills (Zicat et al., 2018).

Executive functioning is goal-directed behaviour, incorporating planning and decision making skills at the strategic level, necessary for safe driving (Zicat et al., 2018). In order to be in a position to implement the plans made, drivers also need to rely on memory, in order to recognise familiar landmarks and successfully navigate to their destination (Luna et al., 2004; Zicat et al., 2018).

Attention, or vigilance, is the ability of the driver to deal with numerous simultaneous stimuli, processing those that are relevant to the task in hand and filtering out others. This usually has to be done in a very short period of time (Lundqvist, 2001).

Working memory skills assist in visual information processing, to determine one's own position in relation to other environmental aspects. During controlled processing, information needs to be processed within a short time, and is used for judging the current traffic situation and to act appropriately. Hence, information needs to be held within the working memory, and processing speed is dependent on that working memory (Lundqvist, 2001).

Lastly, are the psychomotor skills required, such as reaction time and coordination of visual and motor skills in order to safely and effectively control a vehicle, and react quickly, safely and appropriately to events unfolding (Jackson et al., 2013; Zicat et al., 2018).

There are a variety of cognitive tasks that can be utilised to replicate the required skills and demonstrate cognitive performance during the driving task. In particular, where the driver needs to remain vigilant and be in a position to change task or take on an additional task, as and when required (Meuter et al., 2005). In order to illustrate differences in performance due to fatigue, any assessments conducted need to be reliable indicators of those wakeful functions that are affected by lack of sleep (Meuter et al., 2005). Measures such as decision making, vigilance, working memory and psychomotor speed are therefore often used, with the overall reaction time recorded as the dependent variable (Goel et al., 2009). There are numerous cognitive tasks currently used to indicate decline in performance and there has been an increase in demand for batteries of tests to utilise in this context (Gur et al., 2010). These tests provide a safe alternative to on-road testing of fitness to drive in a variety of situations (McKenna, 1998) and the decrease in attention and working memory due to SD is well established and is most noticeable in simple, monotonous tasks that need reaction speed and vigilance (Alhola and Polo-Kantola, 2007). Some of the frequently used tasks are outlined below, along with studies that have investigated performance.

2.5.3.1 Attention tasks

The Psychomotor Vigilance Test (PVT) is among the most widely used task for assessing alertness (Basner and Dinges, 2011). It is reportedly the most sensitive to sleep deprivation effects, is simple to perform and has the least subject learning effects (Balkin et al., 2011). It is a simple reaction time task that repeatedly presents a visual cue at random intervals, usually between 2 and 10 seconds. The participant simply has to press a button or screen (depending on the presentation of the test), as quickly as possible to register their response (Killgore, 2010). In addition, it is short to perform, usually with a 10-minute psychomotor vigilance test, and is frequently used in the laboratory setting to measure fatigue (Baulk et al., 2008). However, a shorter test has been found to be acceptable and a high level of correlation has been shown between results for the 10-minute PVT and a shorter alternative (Roach et al., 2006; Basner et al., 2011).

Roach et al. (2006) and Basner et al. (2011) stated that the 10-minute PVT could be considered impractical in applied field settings. Roach et al. (2006) recruited sixteen participants, who spent a night in a sleep laboratory, where they remained awake for 28 hours, from 0800 hours onwards. Every two hours, the participants completed three PVTs, of 10 minutes, 5 minutes and 90 seconds. They found that performance was more strongly correlated between the 10 minute and 5 minute PVTs, than the 90 second PVT and concluded that the 5 minute PVT may provide a reasonable substitute where a shorter test was required. Basner et al. (2011) developed a 3-minute version of the test and validated it in controlled laboratory studies, with 74 healthy participants. The studies they utilised involved either total SD or partial SD. Both versions of the test were conducted regularly during the study. They found that the 3-minute test may be useful tool for assessing alertness, where the 10-minute test is considered impractical.

Härmä *et al.* (2006) conducted a controlled on-site intervention study at a maintenance unit of an airline company. The employees were working a backward rotating 3-shift system, comprising three night shifts, followed by two rest days, three evening shifts, followed by two rest day, three morning shifts, followed by two rest days. The shift pattern was changed to a quick, forward rotating system, comprising of one morning shift, one evening shift, one night shift, followed by two rest days. This shift pattern can be seen in Figure 2.3. Utilising subjective sleepiness measures, actigraphy and PVT, the shift change was found to have positive effects on sleep, alertness and wellbeing.

In the study conducted by Howard *et al.* (2014), the researchers compared performance changes in acute sleep loss between professional and non-professional drivers. 20 volunteer professional, and 20 volunteer non-professional drivers participated in the study, which consisted of a simulated driving task and PVT, during 24hours of continuous wakefulness. They found that there was an increase in PVT reaction times and lapses, after participants had been awake for over 17 hours, and that there was no difference between the professional and non-professional drivers.

The above studies indicated that sleep deprivation was detrimental to PVT reaction times. In addition, the studies by Roach et al. (2006) and Basner et al. (2011), indicated a shorter version of the PVT was acceptable.

2.5.3.2 Working memory tasks

Cowan (1998) describes working memory as *"the collection of mental processes that permit information to be held temporarily in an accessible state, in the service of some mental task. The nature of the task can vary widely and can include immediate recall, reading or listening comprehension, reasoning, or problem solving".*

Working memory is the most widely studied cognitive domain in the field of sleep deprivation, along with attention (Alhola and Polo-Kantola, 2007). Working memory tasks have included Number Back (NBACK) style tasks, amongst others, with varying levels of demand. In the NBACK task, participants are presented with a series of visual stimuli and are asked, for each stimulus, if it matches the stimulus *'n'* trials before. For example, in a 2-back task, the participant has to decide if the image they are presented with matches the image in trial *'n-2'*. At the same time, irrelevant information has to be filtered out (Gajewski et al., 2018). The Visual Object Learning Task (VOLT) assesses memory in relation to complex figures. Participants are asked to memorise a number (for example, 10 figures) of sequentially displayed, 3 dimensional figures. They are then shown a set of more (for example 20 figures) of these figures, again sequentially displayed, and are required to select those that they memorised from the original trial (Moore et al., 2017). The studies discussed below, utilised the tasks outlined to examine working memory in different fields.

Smith et al. (2002), utilised a visual NBACK task to examine the impact of sleep loss on working memory. Sixteen healthy adults participated in laboratory studies that included an NBACK style task. The authors found that responses were slower, more variable, and more errors occurred within one hour after participants normal bedtime. They concluded that moderate sleep loss affected working memory tasks.

Choo *et al.* (2005) studied twelve healthy subjects, after 24 hours of SD. A verbal NBACK task, utilising 1-back, 2-back and 3-back variations, was used to examine changes in task performance. The authors identified reduced accuracy and slower response times following SD in all tasks.

In their study, McKenna *et al.* (2004), used a shape perception task, similar to a VOLT as part of a test battery, in a study of 142 participants referred for driving assessments due to brain injury or pathology. The intention was to identify those who were unsafe to drive, and the authors concluded that these types of test can be used to inform decisions relating to driver safety following brain injury.

In the above studies, both Smith et al. (2002), and Choo *et al.* (2005) utilised the NBACK task in order to examine the impact of sleep deprivation, finding that sleep deprivation had detrimental effects on speed and accuracy of performance. However, the study conducted by McKenna *et al.* (2004), utilising a different task (VOLT), but also examining working memory, examined participants with a brain injury. This was still in relation to road safety, and lower scores in simulated tasks, such as this, are associated with higher collision risk (Arnedt et al., 2005).

2.5.3.3 Visuomotor tasks

Visual processing and processing speed are further cognitive process that are linked to the driving task, and decrements in performance, such as linked to sleep deprivation, are associated with driving collision risk (Jackson and Van

Dongen, 2011). The Motor Praxis Task (MPT) is utilised as a measure of processing speed. It is a simple task, whereby participants are instructed to click on squares that appear in random locations on the screen presented. Each successive square is smaller, and has moved location on the screen, thus making it more difficult to track (Moore et al., 2017). The Digit Symbol Substitution Task (DSST) requires participants to refer to a displayed legend of a number of specific symbols. One of those symbols will appear on the screen and the participant is required to select the correct one from the legend as quickly as possible (Moore et al., 2017).

In the following studies, visuomotor tasks were included in test batteries, designed to investigate effects of sleep deprivation or individual differences in cognitive performance.

In their study, Chang *et al.* (2011) recruited sixty-two nurses, who were allocated to different 3-shift rotating shift patterns, comprising two, three or four consecutive night shifts. The study assessed cognitive performance of each participant, between 3 a.m. and 4 a.m. on the last night shift and included a DSST, as part of a test battery. The study found that greatest impairment occurred in those who worked the two night shift fast rotation pattern and concluded that a fast shift rotation may increase medical errors.

Jackson *et al.* (2013) conducted a study examining simulated driving and cognitive performance following one night of sleep deprivation. The study involved nineteen, healthy, professional drivers, aged between 23 and 62 years. A battery of cognitive tasks was utilised, which included a DSST and PVT. The study found that DSST was not significantly affected by SD; however, PVT was significantly affected.

Kosmadopoulos et al. (2017) evaluated sensitivity of a number of neurobehavioural tasks under sleep restricted conditions. Thirty-two healthy males with a mean age of 22.8 (±2.9) years participated in the study. The tasks included DSST, as well as PVT. The study found that performance in all tasks was adversely affected, particularly around the circadian nadir. The authors concluded that the impact of sleep loss on driving and neurobehavioural performance is more detrimental during the night. In addition, Kosmadopoulos et al. (2017) recommended a battery of validated tasks, capturing a range of skills and processes, in order to determine fitness to drive.

Gur *et al.* (2010) presented a cognitive domains test battery, that provided accuracy and speed measures for a number of domains. All tests selected had previously been scientifically linked to specific brain functions. Amongst those tests utilised were a Mouse Practice Task, that tested psychomotor speed and visual tracking. In addition, an N-BACK task and VOLT, examining working and special memory, and similar to those discussed in section 2.5.3.2 were included. The battery took, on average, one-hour for completion and was conducted on a computer, in the presence of a research assistant. The researchers concluded that the test battery was suitable for use in research.

Findings from the above studies were mixed, with Jackson et al. (2013) finding that the DSST was not significantly affected by sleep deprivation. On the other hand, Chang *et al.* (2011) found in their study that DSST showed impairment, and that this was greatest in those working a fast-rotating shift pattern. This was supported by the findings of Kosmadopoulos et al. (2017), who found that DSST was adversely affected by sleep loss and the timing of the tests.

2.5.4 Methods of observing and assessing driving performance

RTC data or naturalistic studies are useful for examining past or present driver behaviour, along with association between risk factors and RTCs. However, these types of study have their limitations (Boyle and Lee, 2010). As outlined in previous sections, fatigued drivers are at greater risk of RTCs and injury (Dawson, et al., 2011). This produces an obvious risk to all road users. It is therefore undesirable to conduct experimental research, with fatigued drivers in live traffic situations on public roads. For this reason, other methods are often sought which provide safe, ethical, practical and controlled environments (Calhoun and Pearlson, 2012; Wynne et al., 2019).

Some of these methods include full laboratory-based driving simulators, desktop driving simulators or simple cognitive function tests that simulate elements of the driving task.

Laboratory-based driving simulators, allowing vehicle-based measures and often vision-based measures, have been utilised to explore many driving behaviours, including fatigue and driver distraction, such as mobile phone use (Sahayadhas et al., 2013; Choudhary and Velaga, 2019). They provide highly controlled environments, where variables such as traffic density can be controlled in order for each participant to be faced with exactly the same conditions (Boyle and Lee, 2010). However, issues with any such laboratory-based experiment include reliability to report consistent results over time and the extent to which real-life driving performance is emulated (Wynne et al., 2019). Technological advances have allowed the development of "high-level" simulators that more closely resemble real driving, at least in those simulators that incorporate the use of full or partial vehicle body and motion platform (Bouchner, 2016; Wynne et al., 2019). In comparison, "low-level" desktop simulators may have a single monitor with more simplistic controls, such as a keyboard and floor pedals (Kaptein et al., 1996).

Advantages of driving simulators include the controllability and reproducibility of conditions, the ease of data collection and perhaps most importantly, removing the possibility of live time dangerous driving manoeuvres. The disadvantages include the real world can never be perfectly reproduced, a false sense of safety due to participants knowing the scenarios are not real, and simulator sickness (Caird and Horrey, 2011; De Winter et al., 2012).

There is an established relationship between cognitive function and the driving task (Zicat et al., 2018). The cognitive domains identified as important components of the driving task are outlined in section 2.5.3 above. As such, simple tasks, such as those on iPad based test platforms provide scientifically recognised cognitive test batteries to use in any environment (Basner et al., 2015). The present study was particularly concerned with commuting. As such, a means of testing cognitive performance as close as possible to those commuting times was desired. Travelling to alternative testing facilities was not desirable or practicable, and utilising iPad based cognitive test batteries was therefore selected for use in the study outlined in Chapter 5.

Having outlined the driving task, methods or observing and assessing driving, and some of the reasons why drivers may be fatigued, the next section outlines attempts at legislation in different countries, the difficulties in identifying fatigue-related road traffic collisions, and some of the challenges around road safety.

2.6 Legislation, investigations and road safety

Every country and state has its own individual driving laws, legislation and guidance related to road safety; however few legislate specifically for driver fatigue (Jones et al., 2005). This could be due to difficulties experienced by police and prosecuting agencies in proving that an incident or collision is directly related to fatigue (Radun et al., 2013). Those that have chosen to try to legislate specifically for fatigue include the American state of New Jersey, and the Nordic countries of Finland, Sweden, Norway and Denmark (Radun et al., 2011).

In New Jersey, Maggie's Law allows for conviction of drivers who are knowingly fatigued, having been without sleep for in excess of 24 hours and who go on to kill others in road related collisions (Sateia, 2005).

In Finland, Article 63 of the Finnish Traffic Law specifies that a person who does not meet the requirements for driving, due to illness, fatigue or another similar reason must not drive (Radun and Radun, 2009; Radun et al., 2011; Radun et al., 2012; Radun et al., 2013). Swedish, Norwegian and Danish traffic law is very similar to Finnish Law (Radun et al., 2011).

Given the difficulties in identifying fatigue, there is no definition of how fatigue is measured and no guidance relating to the practical application of any of the legislation (Radun and Radun, 2009; Radun et al., 2013).

In the UK, legislation relating to road safety is covered by the Road Traffic Act (Road Traffic Act, 1988). This covers everything from the most serious offence of causing death by dangerous driving, right through to minor road traffic infringements, and everything in between. There is nothing in the UK specifically legislating for fatigued or sleepy driving, and instead, prosecution of drivers in these circumstances would generally be under legislation incorporated in dangerous or careless driving sections of the Road Traffic Act (Jones et al., 2005). If a death or serious injury is caused, there is also specific legislation incorporating this within the Road Traffic Act, (1988). The legislation is complex; however, the meaning of both dangerous and careless are specified within the

Road Traffic Act, (1988). As such, a person is regarded as driving dangerously if the way in which he / she drives falls far below what would be expected of careful and competent driver, and, it would be obvious to a careful and competent driver that driving in that way would be dangerous, or it would be obvious to a careful and competent driver that driving the vehicle in its current state would be dangerous. Dangerous can refer to danger either of injury to any person or of serious damage to property. A person is regarded as driving without due care and attention if the way he / she drives falls below what would be expected of a careful and competent driver.

The facts of each case would ultimately be examined individually, depending on the severity of the incident and officers assigned to investigate. The fact remains that it is still exceedingly difficult for investigators to prove that fatigue caused a collision (Radun and Radun, 2009). It is often a case of ruling out other factors such as drugs or alcohol, or a medical episode (Lyznicki et al., 1998). The following section goes on to explore the difficulties in identifying fatigue-related road traffic collisions and some of the identified signs and symptoms of driver fatigue.

2.6.1 Difficulties associated with identifying fatigue-related collisions

Fatigue-related collisions have occurred in almost every mode of transport, and likewise, accidents related to fatigue have occurred in virtually every industry. Official investigations into high profile accidents such as the Challenger Space Shuttle, the Chernobyl nuclear accident and the grounding of the Exxon Valdez, along with the subsequent oil spill, have identified fatigue as a contributory factor in all cases (Mitler et al., 1988; Rosekind et al., 2002). In addition, the rail crash at Great Heck, near Selby, in the UK in 2001, caused by a fatigued car driver, remains the worst rail crash in the UK this century (Rajaratnam and Jones, 2004). In this case, much of the evidence relied on eliminating other causes for the collision (Rajaratnam and Jones, 2004), such as the factors identified by Horne and Reyner, (1995b) and discussed further below.

Despite research showing fatigue could account for up to 20% of all serious road traffic collisions (Maycock, 1995; Horne and Reyner, 1995b; Jackson et al., 2011), it is still believed that fatigue-related collisions are under reported (Akerstedt, 2000; Hynd et al., 2015).

Maycock (1995) conducted two surveys, one a postal questionnaire of male drivers, the other an interview survey of male LGV drivers. The study explored the relationship between collisions and daytime sleepiness. The surveys revealed that 29% of drivers reported having felt close to falling asleep whilst driving in the preceding 12 months and concluded that between 7 to 10% of collisions that participants had been involved in, were due to fatigue.

In their study using both Police data and surveys administered by police to drivers involved in collisions, Horne and Reyner (1995b) identified sleep-related vehicle collisions under the following criteria;

Breathalyser / blood alcohol readings below the legal driving limit; The vehicle either ran into the back of another vehicle or ran off the road; No sign of braking beforehand; No mechanical defect with the vehicle; Good weather and clear visibility; No indication of excess speed or driving too close to the vehicle in front; Attending police officers suspected sleepiness; For several seconds immediately before the accident, the driver could have seen clearly the point of run off or the vehicle hit; The driver may or may not have admitted having fallen asleep. All of the criteria had to apply for the data to be acceptable as a sleep-related vehicle collision.

These listed criteria can assist in identifying a sleep-related collision, but it is difficult to prove beyond reasonable doubt that a driver fell asleep at the wheel. Horne and Reyner (1995b) were cognisant of the fact that data was collated at distressing times for the drivers involved, and reliant on police officer observations and reporting of the circumstances. However, they found that from the collisions attended by police, 16% of those on major roads in the South-West of England and 20% of those on motorways in the Midlands region were sleep-related. They also found that the peak times for these sleep-related collisions were 0200, 0600 and 1600 hours, and around half of all collisions involved male drivers under 30 years of age.

Flatley et al. (2004) conducted an analysis of sleep-related collisions attended by the police, on 15 different sections of road. These included monotonous sections of both rural and urban motorways, single and dual-carriageway roads, and single carriageway roads. In their analysis, they utilised the criteria previously applied by Horne and Reyner (1995b), as specified above, to identify those collisions that were sleep-related. Following their analysis, they concluded that 17% of road traffic collisions resulting in serious injury or a fatality were sleep-related. In addition, they concluded that proportions varied between 3% and 30%, dependent on road type, such that the proportion of sleep-related RTCs increases as traffic volume decreases.

In another study by Vanlaar *et al.* (2008) it was noted, following a public opinion poll of drivers in Ontario, Canada, that the following were signs of fatigue whilst driving;

Blinking or yawning frequently; Closing eyes for a moment or going out of focus; Having wandering or disconnected thoughts; Realising that you have slowed down unintentionally; Braking too late; Not being able to remember driving the last few kilometers; Drifting over the centre line onto the other side of the road.

Whilst any combination of the above could contribute to a collision, in this study, Vanlaar *et al.* (2008), concluded that it was necessary to increase driver awareness and educate drivers in the problems surrounding driver fatigue. In addition, many of these signs would be known only to the driver, and potentially a passenger, but other than the end result being a collision, or signs of the vehicle wandering being seen by a third party, these signs won't assist investigators in recognising a collision as fatigue-related. Whether the particular collision will be recorded as sleep-related or not, usually depends solely on police officers opinions (Radun and Radun, 2009), and fatigue remains under-recognised and reported as a causation factor in road traffic collisions (Brown, 1994).

Supporting the earlier publications, Horne and Rumbold (2015) reported that of all collisions attended by the police, at least 10% were sleep related, increasing to 23% of motorways and monotonous roads (Horne and Reyner 1995b). In addition, these authors reported that this increases to 50% of such collisions, in the early hours of the morning.

Figures published by the Department for Transport (DfT) in Reported Road Casualties Great Britain: 2014 Annual Report, (Lloyd et al., 2015), indicated fatigue was a contributory factor in just 2% of all recorded road related collisions. The data published by the Department for Transport are obtained from the collision reports completed by police officers who attend road traffic collisions.

The police are the lead agency for collision investigation on UK roads, and specifically have a duty to investigate the circumstances surrounding collisions that result in death or involve life changing injuries (College of Policing, 2019a). In these circumstances, a road policing lead investigator should be appointed, who has overall responsibility for the management of the investigation and will build a suitable investigation team (College of Policing, 2019a), likely to include specialist roads policing officers and forensic collision investigators. Within such a specialist team, the causation factors are likely to be more thoroughly investigated (Radun, 2009). However, with regard to collisions involving a fatality or life changing injuries, the College of Policing specify only that the lead investigator should have road policing expertise / operational competence and that those investigating such collisions should have completed learning in accordance with College of Policing standards (College of Policing, 2019a). However, it does not specify what this may be.

Other than in the case of collisions involving a fatality or life changing injury, there are no specific guidelines (known to the author) on investigation of less serious collisions. When officers attend at less serious incidents, the completed data are only as good as the officer completing the relevant forms and the information they are able to gather from the scene, therefore if the officer does not recognise any signs of fatigue from the collision scene, such as those discussed above, as identified by Horne and Reyner, (1995b), and no disclosure or admission is forthcoming from the driver, it is highly unlikely that fatigue will be recorded as a contributory factor, with an alternative, such as “driver inattention”, more often than not, wrongly recorded (Horne and Reyner, 2001a).

UK road traffic legislation is specific with regard to circumstances in which drivers must stop, report collisions and provide information or driving documents as required (Road Traffic Act, 1988). As such, there are also circumstances where there is no requirement for police officers to attend a road traffic collision in the UK, as they may do in many other countries. For example, police officers would not necessarily have to attend incidents involving a single vehicle, or a collision where no injury is sustained, unless there were additional, aggravating factors, such as a road blockage affecting the free flow of traffic, or an allegation of drink or drug driving. Therefore, if an incident is not reported to the police or police officers do not attend the scene, then it stands to reason that no data are collected and recorded.

Lyznicki *et al.* (1998) reported that little was known regarding police officer training with regard to investigating fatigue as a cause of road traffic collisions. Anecdotally, training, expertise and competence currently varies by individual police force in the UK, where the standards of road policing and emphasis on roads policing and road safety differ, and police officers are given little, if any, training in recognising fatigue as a contributory factor in collisions. Jackson *et al.* (2011) also identified a lack of formal training for police investigators in how to identify fatigue as contributing factor and recommend working with police to develop a course in identifying and investigating driver fatigue collisions. This differs in Queensland, Australia, where it was reported that police officers obtain training to identify fatigue-related collisions (Committee, 2005). This training is delivered as part of recruit training, and the content of the training, along with its effectiveness, is unknown (Committee, 2005).

In a Canadian survey study of 800 police officers by Robertson et al. (2009), more than half of participants (56.6%) felt they had not received sufficient training regarding the identification of drivers who were fatigued, in order to determine the role that fatigue played in road traffic collisions. However, 92.4% of those officers stated they had stopped a driver they believed to be impaired (through alcohol or drugs), only to discover they were fatigued instead. The study does not reveal if this was through drivers self-disclosure of fatigue. Police officers in this study believed driver fatigue was a serious problem, and despite the number of participants stating they did not receive sufficient training, it was suggested that their belief it was a serious problem, was due to officers experience with road traffic collisions and their ability to recognise the dangers around driving whilst fatigued. In addition, the officers who participated in this study also identified themselves as being at a heightened risk of driver fatigue, due to shift work and long hours spent driving.

In a study by Radun *et al.* (2013) that explored experiences of police officers and prosecutors in Finland, with similarities to the Canadian study, almost every police officer had stopped a driver they believed was intoxicated, due to their manner of driving, only to discover that the driver was instead fatigued. In addition, 66% of traffic officers, and 79% of local police officers had investigated a road traffic collision where it was suspected the driver had fallen asleep. The study does not elaborate on the specifics of these collisions, or the level of training of the individual investigating officers. However, it does state, that only 23% of traffic officers and 8% of local officers had received training regarding driver fatigue, with 95% overall suggesting that the training was useful. Again, the study does not elaborate on what the training consisted of in order for the officers to find it useful. With regard to individual officer awareness, the study revealed that over 70% of officers believed that the average, healthy person does not fall asleep spontaneously, without experiencing increased fatigue beforehand. This potentially suggests that officers who participated in this study, were familiar with the feelings of fatigue themselves, and indeed Radun *et al.* (2011) and Radun *et al.* (2013) state that many police officers have experienced fatigue whilst driving during night shifts and are consequently more aware of the dangers of driver fatigue.

Despite technological advances now assisting some drivers with detecting fatigue whilst driving (Dawson et al., 2014), there is no simple way for police officers to identify fatigue in a driver, either during a routine stop or following a collision; there is no device, such as the breathalyser, used for detecting alcohol, (Baulk et al., 2008; Obst et al., 2011) that can assist in anyway, other than ruling out alcohol as a contributory factor. Instead, investigating officers have to rely on their own knowledge and investigation skills, along with other information from the drivers themselves, witness accounts and the physical evidence at the scene. Investigating officers do not usually have access to information regarding the condition of the driver or their manner of driving prior to the incident and their post-incident condition may not assist, as they are likely to be alert, often due to the incident itself (Radun, 2009; Taylor et al., 2019). In addition, Horne and Baulk, (2004) reported that most drivers involved in sleep-related collisions, deny having fallen asleep. This could be due to embarrassment, fear of prosecution or loss of insurance indemnity, or due to a genuine belief that they did not fall asleep (Horne and Reyner, 1995a; Horne and Reyner, 1999). Hence, whether the particular collision will be recorded as sleep-related or not often depends solely on police officer opinion, based on criteria, such as those discussed, that exclude other factors, before concluding a collision is due to driver fatigue and is therefore a subjective assessment of those investigating officers (Radun, 2009; Hynd et al., 2015).

2.6.2 Work related and commuter road safety

A Department for Transport publication highlighted the need for up to date research into fatigue and road safety, with UK specific research, work related collisions in the UK, and commuting journeys, being specifically identified as having a large research gap. In addition, there was a recommendation to develop information campaigns in relation to high-risk groups, including shift workers (Jackson et al., 2011).

Fatigue can affect any driver, but those who drive as part of their job, or who are shift workers, or work unusual schedules, are more at risk (Stutts et al., 2003), and shift work induced fatigue has been clearly identified as a significant risk factor increasing the likelihood of accident and injury (Dawson, Ian Noy, Härmä, et al., 2011). In their study, Stutts *et al.* (2003), contacted drivers involved in road traffic collisions where police involvement was required. There were 1403 participants in total, which included 312 drivers who had a collision because they were asleep, 155 who were fatigued when they had a collision, 529 who had a collision for other reasons and 407 who had not been involved in a collision. Results showed that those drivers involved in sleep-related collisions were more likely to work unusual schedules or night shifts. In addition, research has shown that those who drive for work purposes are at higher risk of having a collision (Clarke et al., 2005; Clarke et al., 2009), and collisions whilst commuting were found to be a major cause of death (Harrison et al., 1993; Personick and Mushinski, 1997). There are also other groups, who are still likely to be a part of the working and driving population, who are at heightened risk. These include younger drivers, particularly male drivers, those with undiagnosed, underlying sleep disorders and those who are taking medication (Stutts et al., 2003).

Recent years have seen an increase in irregular working hours, shift working, and apparent trends for reduced sleep hours which combine to increase driving risk, particularly with night driving amongst those shift workers (Alford, 2009). Many organisations require their staff to work around the clock, and there are a wide range of workers, from many different industries, now working shifts. Some may work through the night within a factory environment, and although may not typically suffer from driving fatigue, may suffer from fatigue due to 'time on task' with monotonous or repetitive work, or simply due to the number of hours they have been awake. This may then cause difficulties during the commute home from work. Others may be driving for long periods throughout the night and may find it difficult to sustain wakefulness (Åkerstedt et al., 2005) whilst at work.

Key problems associated with work related road safety therefore include extended waking or driving hours, reduced sleep, and working during the night, at times of circadian low. Education is of primary importance so that drivers are aware and can take appropriate steps to reduce the impact of these factors, including avoiding driving at vulnerable times (Alford, 2009) where possible. Avoidance is not always possible with those who are shift workers; however, and have to drive during these vulnerable times. More education of employers and employees is needed regarding the planning of non-emergency journeys, the dangers of driving while sleepy, and driving at vulnerable times of the day (Higgins et al., 2017).

Sleep-related road traffic collisions can be expected to occur more often during the sleepiness peaks identified in the circadian rhythms discussed in section 2.2 above, so typically will occur around 0300-0500 hours and 1400-1600. Due to this, many of these types of collisions may be work-related. Research also shows that long driving hours in the early hours of the morning can exacerbate fatigue-related driver impairment (Jackson et al., 2011).

In relation to police or other emergency service drivers, Clarke *et al.* (2009) suggested that although emergency vehicles were one of six classes of vehicles likely to be involved in road traffic collisions, the drivers showed 'low blameworthiness' with regard to their involvement. In other words, a third party was more often than not, the cause of the collision. Whilst this may account for on duty involvement in collisions, it does not consider what happens during the commute to and from the workplace.

In a questionnaire study involving shift workers, Rogers et al. (2001) found that this group self-reported higher sleepiness whilst travelling to work for early shifts, to and from night shifts, and are more at risk of falling asleep at the wheel, compared with non-shift workers. In a study conducted in rural Australia, Di Milia et al. (2012), identified that night shift workers commuted significantly longer distances, experienced greater sleepiness and obtained less sleep, compared to those who did not work night shift. Similarly, in a study involving nursing staff, Ftouni *et al.* (2013) found that rotating shift nurses reported higher levels of sleepiness when compared with permanent night shift nurses. In addition, both groups self-reported sleepiness was greater during the commute home from a night shift, when compared with the commute before a night shift.

Commuting is of particular interest, due to the number of journeys undertaken on a daily basis to get to and from work, and the fact that commuting is not included within the definition of work related driving (Jackson et al., 2011). According to the Department for Transport, 62% of total journeys taken in 2017 were by car, and around 27% of total journeys taken were for commuting or business purposes (Department for Transport, 2018). The study reported in Chapter 4 considers commuting amongst serving police officers and staff. The next section will consider the range of countermeasures available to fatigued drivers, and the effectiveness of these measures.

2.6.3 Continuing to drive whilst fatigued and the use of countermeasures

There are three main types of countermeasures to tackle driver fatigue, these are driver related, vehicle related and road related (Merat and Jamson, 2013). However, prior to consciously using driver related countermeasures, drivers need to first recognise that they are tired. Horne and Reyner (1999) state that drivers are likely to be aware of feeling sleepy and should recognise these signals. Following this, the driver either makes a conscious decision to use one or more of the available types of countermeasure in order to take corrective action (Anund, 2000; Johansson, 2012).

Typically, self-administered countermeasures by drivers themselves include actions such as opening a window, turning the radio volume up, moving the seat position, or smoking, for example (Anund, *et al.*, 2008). These are widely used actions by drivers (Anund, *et al.*, 2008), yet they have been shown to be effective for only a very short period of time, of around 15 minutes (Horne and Reyner, 2001b), if at all (Horne and Reyner, 1999; Nordbakke and Sagberg, 2007).

Horne and Reyner (1996) found that just taking a break from driving was ineffective; however, consuming 150 mg of caffeine in coffee and also a short nap of under 15 minutes, separately, significantly reduced driving impairments in a one hour drive in a driving simulator study. In a further study by Reyner and Horne (1997), it was found that these interventions combined, taken in a 30 minute break from driving, eliminated both subjective, as well as EEG measures of sleepiness in a two hour drive following the break.

Caffeine has been shown to help improve alertness, vigilance and accuracy of decision making (Brice and Smith, 2002) and this combination of caffeine consumption, along with a nap, has proved useful for drivers. Restricting the nap to around 15 - 20 minutes avoids the post-sleep inertia, better known as the groggy feeling, upon wakening (Kubo et al., 2010; Lovato and Lack, 2010).

However, this action involves the driver stopping and taking a break from the driving task, in order to have a nap, and this is something that they may choose not to do (Jiang et al., 2017), preferring instead to continue driving, whilst resorting to the aforementioned self-administered countermeasures. In their study related to planned behaviour, Jiang *et al.* (2017), conducted a questionnaire with 214 drivers in China. These authors found that drivers with poor sleep quality and a history of fatigue, tended to be the ones who continued to drive whilst fatigued. They also found that young drivers were more likely to continue driving whilst fatigued. This is also in line with the findings of Watling et al. (2015), who found that those under 30 years of age were more likely to continue to drive whilst sleepy, than those over 30, despite experiencing more warning signs of sleepiness, such as yawning, frequently changing seating position or difficulty concentrating.

Data gathered from a public opinion poll in Canada revealed that 58.6% of drivers admitted to occasionally driving whilst fatigued. In that same poll, 14.5% of drivers stated they had actually fallen asleep, and 2% were involved in a fatigued driving related collision (Vanlaar et al., 2008). Some of this could be avoided by adopting preventative measures, such as not starting a drive whilst fatigued or having a good night's sleep prior to a planned, long drive (Stutts et al., 1999; Nordbakke and Sagberg, 2007), or for those who are shift workers, having a longer nap, for example from 2pm until 5pm, prior to beginning a night shift (Akerstedt et al., 1989; Macchi et al., 2002). The only overall safe and effective countermeasure is to stop driving and obtain sufficient restorative sleep (Åkerstedt and Kecklund, 2000).

Despite the dangers associated with fatigued driving, Vanlaar *et al.* (2008) found there was little concern about the issue amongst drivers, and that it was still necessary to educate the public further, in order to find effective prevention methods. Drivers may still continue to drive, perhaps mistakenly believing that they won't be involved in a fatigue-related collision, or due to time or proximity to their destination (Jiang et al., 2017) and awareness is just not enough to motivate drivers to adopt self-protective behaviour (Nordbakke and Sagberg, 2007; Armstrong et al., 2010).

Nowadays, there are many varieties of vehicle related, in-car technologies that can detect fatigue, using, for example, eye closure or tracking or head nodding movements (May and Baldwin, 2009). Eye closure systems, calculate the proportion of time that the eyelid covers a certain percentage of the pupil, with higher figures indicating greater sleepiness (May and Baldwin, 2009). In a 3 hour, simulator drive, Kozak *et al.* (2005), found that sleep deprived participants had higher values, that also increased over the length of the drive. Head nodding occurs as muscles relax if a driver begins to fall asleep. Technology identifying this is available, and provides an audible alarm to alert the driver (Hartley et al., 2000). There are also technologies that assist with measuring steering wheel movements, acceleration and lane keeping, for example. Instead of measuring physical indicators of fatigue, these systems detect potential performance decrements, as another possible result of fatigue (Hynd et al., 2015).

Some of these methods are late in alerting the driver, and identify driver fatigue, when the driver is significantly affected and transition to sleep has begun (May and Baldwin, 2009). This then relies on the driver to take action. Despite these technologies being available, drivers may still choose to disable the systems (Hynd et al., 2015), or alternatively, to ignore the warning provided and continue to drive, knowing they are fatigued (Balkin et al., 2011; Jackson et al., 2011).

Lastly, there are road related measures, such as 'rumble strips' that can alert drivers as the vehicle drives over them (Mahoney et al., 2003; Anund, Kecklund, Vadeby, et al., 2008). Despite research suggesting that drivers proactively rely on these measures (Nordbakke and Sagberg, 2007), a reduction in fatigue-related collisions as a result of these road related measures has been noted (Griffith, 1999; Hanley et al., 2000; Mahoney et al., 2003; Räsänen, 2005).

The following section now moves on to discuss road safety campaigns relating to driver fatigue and their effectiveness amongst drivers.

2.6.4 Road safety campaigns relating to driver fatigue

In addition to the countermeasures discussed in section 2.6.3, there are public awareness, road safety campaigns that have been utilised in an attempt to educate drivers in the dangers of many risky driving behaviours, including driver fatigue (Forward et al., 2009). The purpose of such campaigns is generally to raise awareness of a problem, educate drivers and invoke behaviour change (Fletcher et al., 2005). There are both local and national campaigns, and often individual police forces in the UK have conducted their own road safety campaigns, such as those illustrated in Figure 2.5. These photographs were taken during a road safety campaign conducted around 1970, in the North Yorkshire Police area in England. Campaigns such as this were designed for drivers to have clear sight of police vehicles, in a bid to adjust driver behaviour, with the overall aim of encouraging safer driving (Sheppard and Spink, 1967).

The main national campaign in recent years in the UK was the THINK! Campaign. The UK government has led road safety campaigns for over 75 years, and the THINK! Campaign was established in 2000 (Department for Transport, 2012). The campaign challenged many aspects of road safety; however, the fatigue aspect was launched in 2008, in a bid to target those (in the main) driving for work purposes. The campaign aimed to increase awareness of the dangers of driver fatigue, increase awareness of the signs of driver fatigue and encourage drivers to take a 15 minute break every 2 hours. The key message of the campaign was “Tiredness kills” (Department for Transport, 2012). The campaign was withdrawn in 2018; however, the reasons for this are unknown to the author.

The United States *Drive Alert – Arrive Alive* is another example of a national campaign, utilising a combination of media in order to reach out to the public (Fletcher et al., 2005). Other countries including Australis, New Zealand, South Africa, France and Germany, have also demonstrated some commitment to educating drivers in fatigue (Fletcher et al., 2005).

Australia and New Zealand have utilised various methods, from national distribution of brochures identifying the dangers of driver fatigue, to television advertising campaigns, to billboard messages. In addition, other countries, such as France, Germany and South Africa, have also utilised leaflets and billboard advertising in an attempt to educate drivers (Fletcher et al., 2005).

Whilst increased numbers of campaigns may have been introduced, these are infrequently supported with any rationale outlining the choice of methods or messages utilised (Jackson et al., 2011). Information with regard to the effectiveness of such campaigns is limited, with evaluation rarely being conducted (Hoekstra and Wegman, 2011), hence it is unknown if these campaigns are ultimately effective. One-off, isolated campaigns are considered least effective (Richard et al., 2018). In addition, whilst education and information provide awareness in relation to potentially unsafe driving behaviour, it is suggested that they do not instil an attitudinal change in the driver (Nordbakke and Sagberg, 2007; Jackson et al., 2011). As a result, it is suggested that future campaigns personalising the risk to drivers and combining a variety of different approaches, could lead to maximum impact and therefore improvement in overall road safety (Fletcher et al., 2005; Jackson et al., 2011).

Figure 2.5 Driver fatigue campaign conducted by North Yorkshire Police, circa 1970
Photographs reproduced with permission of the Chief Constable of North Yorkshire Police

2.7 Summary and conclusions

This Chapter has introduced sleep and fatigue and the associated difficulties posed by lack of sleep whilst employed in shift work. Following on from this are the risks to road safety from driving whilst fatigued. Despite various definitions existing for sleepiness and fatigue, and suggested crossover between the two, with the terms often being used interchangeably, the use of 'fatigue' has been selected for this thesis. The reasons for this are outlined in section 2.1.2.

From an examination of the literature, there is no doubt that shift work can cause sleep disruption and interfere with circadian rhythms, where workers are expected to operate during times when they should be sleeping (Bonnet and Arand, 1995; Axelsson, 2005). This, in turn, causes fatigue (Knauth, 1993), which can lead to ill-health, accidents, injuries and road traffic collisions (Madouros, 2005; Smith et al., 1994). Practicing good sleep hygiene can assist in alleviating ill-effects of shift work.

A variety of methods exist with which to measure sleep, some are more practical and reliable than others. These are discussed in section 2.3; however, it is concluded that actigraphy is currently the most reliable method for using 'in the field'. Actigraphy has been found to be particularly useful for examining night-to-night variability in sleep duration and where irregular sleep patterns are involved. With supplementary use of sleep diaries, these methods have been found to be as reliable as PSG (Pollak et al., 2001).

UK specific research in driver fatigue, particularly amongst shift workers, along with commuting journeys, and naturalistic driving studies, have been highlighted by Jackson et al. (2011), as an area requiring further research; however there is still a dearth of information in this area. Commuting is of particular interest as it does not appear to be included within work-related driving definitions, and it accounts for around 27% of total journeys taken (*Transport Statistics Great Britain, 2018 Edition*, 2018). In particular, the author is not aware of previous studies in the UK that have researched police officer and staff commuting behaviour and experiences, whilst working different shift patterns.

Numerous studies have examined performance under sleep deprived conditions, utilising various cognitive tasks, as described in section 2.5; however, most of these have been conducted in laboratory settings as opposed to in participants usual working environment. In addition, the author is not aware of any practical studies conducted in the field, in the UK, with serving police personnel.

Chapter 3 will go on to introduce and describe UK policing procedures, and some of the challenges and differences between police forces. It will explain the shift work arrangements in policing and explore road safety issues, in particular, figures related to road death incidents, specifically related to police officers and staff.

Chapter 3
UK Policing Procedures

Chapter 2 provided an overview of current research linked to driving whilst fatigued. Chapter 3 now links this further, to shift work in the policing context. It outlines the current operating position of policing in the United Kingdom, and examines line of duty deaths within policing, with a focus on road related, in service deaths (on duty or whilst commuting). It also examines the current recording procedures in relation to police employee involvement in road traffic collisions, and the wellbeing practices in UK policing. The aim of this Chapter is to briefly describe the policing role, in order to highlight where the potential conflicts are between the unique role conducted, the standards of professional behaviour, and the wellbeing and driver safety of those officers and staff employed in shift working.

3.1 Organisation and primary duties of policing services in the UK

The Metropolitan Police was the first organised police force within England and Wales. It was established in London in September 1829 by the then Home Secretary, Sir Robert Peel (Lentz and Chaires, 2007; Emsley, 2012), with the introduction of the Metropolitan Police Act 1929 (Lentz and Chaires, 2007). The Metropolitan Police Act 1929 replaced the previous system of disorganised watchmen, became the model for national police reform, and introduced a unified system of policing (Lyman, 1964).

Today, there are 49 police forces in the UK, including 4 classed as special police forces. There are 39 territorial forces in England, 4 in Wales and a national police force in both Scotland and Northern Ireland. The territorial forces are usually responsible for day to day policing in areas with similar boundaries to local government geographical areas (Police Reform Act 2002). In addition, the 4 national, special police forces are British Transport Police, Civil Nuclear Constabulary, Ministry of Defence and National Police Air Service (Murphy et al., 2017). The territorial police forces in England and Wales are shown in Figure

3.1.

The law enforcement systems are organised separately, based on the legal systems in the countries of the UK, with both Scotland (Keating et al., 2003) and Northern Ireland (Ellison and Mulcahy, 2001), having their own systems, separate to that of England & Wales. The differences in these legislative systems and the political nature of the current landscape are beyond the current scope of this thesis.

Figure 3.1 Police forces in England & Wales

Police officers in England and Wales all hold the “Office of Constable” regardless of their rank. The Office of Constable provides police officers with additional legal powers in order to control and arrest the public. These powers are given to officers directly from a sworn oath and warrant. The Office of Constable ensures impartiality, integrity and accountability. Constables are not employees, but do have access to most statutory employment rights afforded to employees. However, there are some differences, for example, it is illegal for police officers to take industrial action (Police Federation of England & Wales, 2018).

The primary duties of police officers have not altered greatly over the years (Crawford, 2012), and the Statement of Common Purpose and Values for the Police Service in England & Wales, adopted in 1990, stated that *"The purpose of the police service is to uphold the law fairly and firmly; to prevent crime; to pursue and bring to justice those who break the law; and to keep the Queen's Peace; to protect, help and reassure the community; and to be seen to do all this with integrity, common sense and sound judgement"* (ACPO, 1990).

In order to fulfil the function and deliver a suitable provision of service in line with demand, policing, as with other emergency services, operates on a 24-hour basis, with frontline officers and some members of police staff working a round-the-clock shift pattern (Stone et al., 1993). The numbers of officers and staff working round-the-clock varies by individual police force and the role of each officer. For example, officers responding to emergency calls from the public would need to be available at all times, whereas others engaged in different roles, such as neighbourhood policing tend to be engaged in public reassurance, visibility and longer term problem-solving in their communities (Myhill and Quinton, 2010). Those in non-response roles would therefore be working at times when the public would generally have access to them for non-emergency duties, which is more often during sociable hours, and not through the night.

Shift systems have changed and developed in policing over the years, as they have in other industries, and the nature and changing situation of police service shift patterns are discussed in the next section.

3.2 How police service shift patterns have evolved

Police officers in England & Wales usually work shifts for a large proportion of their career (often for their entire career), but particularly in the early years, when officers who are young in service begin reinforcing their theoretical learning. During this period, officers will put this learning into practice, initially under the guidance of a tutor or mentor constable, usually on a response team, in order to learn about the area they are to patrol (Peace, 2006). Those other officers working shifts are also on response teams, or specialist departments, such as roads policing or firearms teams, with the need to provide immediate assistance to the public, as and when required. Police staff members, depending on the role they fulfil, can also work round-the-clock shift patterns. For example, those working in force control rooms, need to be present in order to take incoming calls from the public and ensure officers are despatched to calls as necessary.

Often, joining the policing family will be the first time that officers or staff have worked shifts or irregular hours. Due to this, they may be unaware of many of the risks associated with lack of sleep and the disruption of the circadian rhythm that is caused, particularly whilst working night shifts (Horrocks and Pounder, 2006).

Shift patterns are many and varied and there is no such thing as a good shift pattern (Mason, 1999), particularly in policing, where it is a difficult balance of managing public demand, organisational need, and officer and staff welfare in most cases (Mason, 1999). In shift patterns followed by police forces in England and Wales, each team regularly changes its hours of work, providing continuous cover for 24 hours a day, seven days a week. This continuous cover is essential as police work involves a number of both proactive and reactive responses, depending on numerous factors including crime trends and demands for service from the public.

In a similar context to shift systems outlined in section 2.4.1, the policing organisation needs to provide staff 24-hours a day, hence a variety of shift patterns are in existence. Traditional police shift systems in England and Wales provided continuous, 24-hour cover to the public, by working a ‘regulation backward rotating shift pattern’ of 8 hour shifts, covering nights (2200-0600 hours), afternoons (1400-2200 hours) and days (0600-1400 hours) (Stone et al., 1993). This effectively involved teams working 7 night shifts, 7 afternoon shifts and 7 day shifts on rotation, and was originally believed to be the most effective method of covering the 24-hour period, ensuring the unsocial hours were equally distributed between teams (Stone et al., 1993). This pattern required four teams of officers and can be seen in Table 3.1.

Table 3.1 Regulation police shift system

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	Night	Night	Night	Night	Night	Night	Night
2	Rest Day	Rest Day	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon
3	Afternoon	Afternoon	Rest Day	Rest Day	Day	Day	Day
4	Day	Day	Day	Day	Rest Day	Rest Day	Rest Day

Shift patterns in policing, have historically only taken into account the needs of the organisation and the need to provide round-the-clock cover, without considering the needs of their employees (Mason, 1999), or any crime trends or operational demands (Simpson and Richbell, 2000).

Over the years, the effectiveness of the regulation shift pattern was brought into question and shift systems have changed many times to meet the needs of territorial police forces. This was, in the main, to try to improve efficiency and effectiveness, by matching police resources to crime patterns, in order to deploy resources where and when they were required (Richbell et al., 1998). For example, by providing longer shift length, it allowed a shift overlap at times of greatest demand, such as in the evenings when the afternoon shift and night shift teams overlapped (Totterdell and Smith, 1992). Some police officers also complained of insufficient recovery periods after night shifts on the traditional shift pattern (Stone et al., 1993). However, in policing as in many other industries, shifts require a fine balance between organisational needs, demand from the public, staff welfare and other social and domestic pressures (Mason, 1999).

Trials of alternative patterns began within some police forces in 1989. These trials involved various forms of 8 hour shifts, continental shifts and compressed working week systems. The system introducing a compressed working week, with longer shifts in some cases, allowing for greater rest days, known as the “Ottawa shift system” was most favoured by staff (Stone et al., 1993). The “Ottawa system was first used by Canadian police, hence the adopted name for the pattern (Totterdell and Smith, 1992; Stone et al., 1993; Richbell et al., 1998). The Ottawa system required 5 teams of officers and is shown in Table 3.2. The idea of the Ottawa system was to retain 8-hour night shifts, but to extend the day and the afternoon shifts to 10-hour duration, in order to provide additional time for the 6-day rest period following night shifts (Totterdell and Smith, 1992). This system also allowed for a 0700 hours day shift start time, as opposed to the 0600 hours start time on the regulation shift pattern (Stone et al., 1993). As such, the shift times for the Ottawa system were generally 0700-1700 day shifts, 1400-0000 or 1700-0300 (Thursday, Friday and Saturday) afternoon shifts, and 2230-0700 (Saturday to Thursday) or 2300-0700 (Friday) night shifts (Stone et al., 1993).

Table 3.2 Ottawa shift system

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	Rest Day	Rest Day	Day	Day	Day	Rest Day	Rest Day
2	Afternoon	Afternoon	Afternoon	Rest Day	Rest Day	Day	Day
3	Day	Day	Rest Day	Rest Day	Night	Night	Night
4	Night	Night	Night	Night	Rest Day	Rest Day	Rest Day
5	Rest Day	Rest Day	Rest Day	Afternoon	Afternoon	Afternoon	Afternoon

In trialling alternative shift systems such as this, police forces stepped outside the regulation shift pattern of 8 hour shifts, which officers had to approve and agree to (Stone et al., 1993).

In their study of the Ottawa system, when compared with the regulation shift pattern, Totterdell and Smith (1992) found that those officers working the Ottawa system reported a significant improvement in wellbeing, reduced disruption of personal life and an increase in average sleep duration. However, Totterdell and Smith (1992) also suggested that due to officers only attaining an average of 6.4 hours sleep duration between night shifts, a review of the block of 7 night shifts may be required. A systematic review of the Ottawa system was conducted by Stone *et al.* (1993). The review found no conclusive evidence that the system brought any financial savings, nor improvements in operational effectiveness. However, from an officer wellbeing point of view the review indicated that officers perceived improvement in both work and home life, as a result of the change, which was in agreement with the findings of Totterdell and Smith (1992). This was also found by Richbell *et al.* (1998) in their case study involving officers in the South Yorkshire police area. As a result of the perceived improvements in work and home life, many forces retained or introduced the Ottawa pattern.

Following on from the 1993 examination of police shift systems (Stone et al., 1993), where the Ottawa system featured heavily, in 2004, a study of police resource management for response teams was undertaken on behalf of the UK Home Office (Home Office, 2004). One of the objectives of the study was to consider and make recommendations on more effective deployment of police officers, particularly those frontline response officers, by better designing shift patterns. From a sample of UK police forces, this report revealed five common shift patterns, as follows;

- Regulation eight hour shifts, as discussed above. Two forces operated this pattern.
- Ottawa shift systems, as discussed above. Four forces operated this pattern.
- Variable Shift Arrangements (VSA) where shift lengths and start and finish times vary. This provides overlap and additional staff at times of peak demand. In comparison to the block of 7 night shifts in the Ottawa system, this shift arrangement splits that week into 2 blocks, one of 3 night shifts and one of 4 night shifts. This can be seen in Table 3.3. Fifteen forces operated this pattern, demonstrating that forces had potentially taken heed of the suggestion by Totterdell and Smith, (1992) that the 7 night shifts in the Ottawa system may need to be reviewed, and this pattern had largely superseded the Ottawa pattern (Home Office, 2004).
- 12 hour shift patterns, with two 12 hour shifts to cover the 24 hour period, with no shift overlap. The pattern usually operates two day shift, two night shifts, or blocks of four consecutive shifts, followed by four rest days. Five forces followed this pattern.
- 2x2x2 patterns, covering two day shifts, two afternoon shifts and two night shifts, followed by four rest days. Seven forces followed this pattern.

The remaining 10 territorial police forces worked a different mixture of shift patterns, not specifically identified in this report.

Table 3.3 Example of VSA shift system

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	Night	Night	Night	Night	Rest Day	Rest Day	Rest Day
2	Afternoon	Afternoon	Afternoon	Rest Day	Rest Day	Day	Day
3	Day	Day	Rest Day	Rest Day	Night	Night	Night
4	Rest Day	Rest Day	Rest Day	Afternoon	Afternoon	Afternoon	Afternoon
5	Rest Day	Rest Day	Day	Day	Day	Rest Day	Rest Day

The Home Office (2004) study revealed very little research had been done on a national basis in relation to shift patterns, with forces conducting their own local investigations instead, citing that their own area was unique in relation to demands for service. The study revealed this was not the case, and indeed, although demand varies across the police forces, the pattern of demand, based on calls for service and the times at which they are received, is very similar across the forces.

The Home Office (2004) study calculated HSE FI for the shift patterns studied. The scores were taken into account when making their recommendations for preferred shift patterns. Taking into account the call demand, manageability of shift patterns, welfare needs and external factors, such as relationships with the community and other partner agencies, the Home Office (2004) report, along with the Home Office, (2010) circular regarding police officer shift arrangements, put forward a number of observations and recommendations, which included the following information;

- The most effective and efficient shift systems were either the VSA or 2x2x2 patterns.
- Shift length should ideally be between 8 and 10-hours. Twelve hour shifts are not recommended, as significant concern exists around health and safety implications of 12-hour shifts.
- Shifts should be forward rotating (days, afternoons, nights). This assists in minimising circadian sleep disruption. Backward rotating shift patterns are not recommended for the opposite reasons, i.e., it reduces opportunity for sleep in between shifts, particularly for those who have lengthy commutes.
- There should be no more than 6 consecutive shifts before rest days, and no more than 4 consecutive night shifts in any shift pattern.
- Day shifts should start as late as possible, for example, 0700 hours is better than 0600 hours.
- Rest days should be in blocks of no less than two consecutive days, and predictable patterns are generally considered positive.

Little additional research has taken place regarding United Kingdom police shift patterns. However, in policing, 80% of budgets are spent on staffing. As such, if agreement can be reached regarding favourable shift patterns, then it follows that safety, welfare and officer morale should improve, leading to a better quality of service being delivered to the public and more efficient use of resources (Home Office, 2004). Favourable shift systems would include, but are not limited to, forward rotating patterns, scheduled rest breaks, night shifts limited to 8 hours duration, sufficient rest periods between shifts, and paid annual leave (Home Office, 2004).

In a study by Amendola *et al.* (2011), of American police officers working different shift lengths, it was found that officers working 10-hour shifts reported having more sleep and a better quality of life, than their colleagues who were working 8-hour shifts. However, if shift length is extended to 12-hours those officers reported greater levels of fatigue, and lower levels of alertness, when compared with those working 8-hour shifts. As such, it seems that a compressed working week, with 10-hour shifts, suggests some compromise and wellbeing advantages, over the shorter, or longer alternatives ((Amendola et al., 2011).

All shift systems have some advantages and disadvantages and there is no system that suits all industries and all those who work them (Knauth, 1993). However organisations still have much to learn about shift systems in general, including the negative effects that working shifts may have on health, psychological wellbeing, and performance, errors and accidents (Mason, 1999; Vogel et al., 2012; Caruso, 2014). As such, shift patterns are still developing accordingly (Costa, 1997). In addition, it is unknown if FRI are widely used when comparing UK policing shift schedules. Anecdotally, it is known to the author that these have been utilised, on occasions, when reviewing shift patterns in North Yorkshire Police.

In recent times, austerity has also been a driver for forces seeking to improve efficiency and effectiveness across all areas of policing, and this has resulted in many changes in shift patterns (Rogers and Gravelle, 2012; Barton, 2013). There is now considerable variation in shift patterns in UK police forces with each force setting its own shift patterns in accordance with organisational need, financial cost, calls for service, local geography and officer numbers; There is no “one size fits all” approach to policing (House of Commons Home Affairs

Committee, 2008), and some shift patterns currently in existence, such as 12-hour shifts, do not appear to take into account the best practice recommendations of the Home Office (2004) and Home Office (2010) reports.

In 2017, as part of this research, a request for information was submitted to all police forces in England and Wales under the Freedom of Information Act (2000) (FOIA), and via chief officer support teams, requesting information about current shift patterns for frontline response police officers. The FOIA gives provision for the disclosure of information held by public authorities, and can be a useful means of obtaining information from these authorities, such as police forces (Kingston et al., 2019). An applicant for information has the right to be told if the information they requested is held or not. If it is held, it should be provided to the applicant, subject to cost limits or other legal exclusions. There are cost limits involved with any FOIA requests, that allow organisations to refuse to provide information. Section 12(1) of the Freedom of Information Act 2000 provides that – *"Section 1(1) does not oblige a public authority to comply with a request for information if the authority estimates that the cost of complying with the request would exceed the appropriate limit."*

At the time of this specific request, the FOIA responses revealed the shift patterns followed by the frontline response officers in police forces in England and Wales amounted to the following;

- 26 forces following the 2x2x2 pattern
- 11 forces following a VSA pattern
- 3 forces following a 12-hour pattern
- 3 forces following their own, individual pattern

Some police forces operate different shift patterns for different departments, for example the standard frontline response officers may work x 2x2x2 pattern, with roads policing department officers working a 12-hour pattern. The information requested was specifically for the most prevalent pattern followed by the majority of response officers in each force.

From these figures, it would appear that most police forces are following best practice guidance provided by the Home Office, (2010), by providing either the 2x2x2 pattern, or the VSA pattern. The reasons why the remaining six police forces have chosen either a 12-hour pattern, or their own individual pattern, against the Home Office (2010) guidance are unknown. However, the guidance does not stipulate any particular shift patterns must be in operation.

In summary, today's 24/7 policing places a lot of forces and officers under increased pressure (Houdmont and Elliot-Davies, 2016) and shift patterns need to be reviewed regularly to ensure that the best possible balance of health and welfare can be achieved, whilst also meeting the demands of providing a 24-hour service (Doyle, 1991). It should be noted that some patterns have changed over the duration of this research, so may differ already, from the date on which the information was provided. In addition, some forces operate a variety of different shift patterns between different departments. Shift patterns are likely to continue to be reviewed periodically by individual police forces.

In addition to suitable shift patterns, the next section will explore the responsibilities of the policing organisation in relation to all general aspects of staff health, safety and wellbeing, and how this links to shift work.

3.3 Staff health, safety and welfare

The Health and Safety at Work Act (1974) and the Police (Health and Safety) Act 1997, impose a duty of care on employers in respect of employee physical and mental health, safety and welfare, including working practices and working hours (Health and Safety at Work Act 1974; Police (Health and Safety) Act 1997). In addition, there are also duties on employees to co-operate with their employer, and to take reasonable care of themselves and others. In order to do so, employers and employees need to understand what that actually means. As such, useful definitions of health, safety and welfare are provided by (Hughes and Ferrett, 2011), as follows;

- **Health** – The protection of bodies and minds from illness resulting from the materials, processes or procedures used in the workplace.
- **Safety** – The protection from physical injury.
- **Welfare** – The provision of facilities to maintain the health and wellbeing of individuals in the workplace.

One element of the relevant legislation is the requirement of safe working systems, including working times and practices, staffing levels, and supervision and training. Legislation also specifies the need for employers to consult with employees regarding the introduction of measures likely to affect health and safety, such as, for example, a change in shift patterns (Health and Safety at Work Act 1974).

Occupational health and safety affects all aspects of work, and the objective of legislation is to ensure that the risks to health and safety of employees are properly controlled. Organisations are encouraged to demonstrate the importance of health and safety, improve health and safety management systems to reduce ill health and injuries, and report publicly on any issues within their organisation (Hughes and Ferrett, 2011). In addition, effective management of health and safety is necessary for employee welfare, can enhance the reputation of the organisation and can be financially beneficial to the organisation. For example, poor standards in health and safety practices can lead to injuries or accidents, and subsequently fines and compensation payments (Hughes and Ferrett, 2011).

In addition to the existing legislation at the time, the Working Time Regulations (WTR) were introduced and incorporated into British law in 1998, as a result of European Working Time Directives (Morris-Stiff et al., 2005; Cairns et al., 2008). The purpose of the WTR was to assist in regulating and monitoring the working hours of employees in order to provide safe and healthy working environments. As a result, there were restrictions placed on the maximum average number of hours worked per week (currently 48 hours), a minimum time period of 11 hours set between shifts, and a stipulation that a night worker's normal hours of work should not exceed an average of 8 hours in each 24-hour period (The Working Time Regulations, 1998; Morris-Stiff et al., 2005). Employers were (and still are) required to take all reasonable steps to provide this protection. For the purposes of these regulations, the "Office of Constable" is treated as employment, which means that the regulations also apply to police officers. There are partial exemptions from the directives when it comes to policing, where there are peculiarities in relation to some operations, such as spontaneous public order incidents, where it cannot be determined how long these may last, and therefore how long officers may be on duty (Wardman and

Mason, 1999). Most shift patterns currently followed in policing have night shifts in excess of 8-hours duration. As discussed, some forces are actually working 12-hour shifts. In addition, it is known personally to the author that breaches in TR are occurring unnecessarily.

The introduction of WTR also facilitated a timely review, and changes to some police shift patterns followed, to allow sufficient rest periods between shifts. Although police officers are also governed by the Police Regulations that provide a statutory framework for working time, stipulating normal periods of duty and rosters and the WTR have not changed this (Police Federation of England & Wales, 2006). This means that in some respects, the Police Regulations are considered more favourable than WTR because they also provide for annual leave, weekly rest and daily rest breaks. For example, WTR allow for 2 days rest per fortnight, and Police Regulations allow for 2 rest days per week. However, these provisions are subject to exigencies of duty, similar to the exemptions under the WTR, should an unforeseen event occur, in which case, usual patterns of work fall by the wayside (Police Federation of England & Wales, 2006). There is also an individual right to 'opt out' of the regulations, and those who do choose to opt out, often do so for financial reasons, as this then allows them to work more overtime, beyond the recommended 48 hour maximum week (Barnard et al., 2003).

Despite these timely reviews of shift patterns, health, safety and welfare problems with shift work can remain. The disturbed sleep and health problems associated with shift work are discussed in section 2.4. However, James et al. (2018) state that fatigue is a particularly critical problem in policing, and a high proportion of Canadian and American police officers have reported fatigued driving episodes (Vila, 2000; Rajaratnam et al., 2011).

In the Demand, Capacity and Welfare Survey conducted by the Police Federation of England and Wales (PFEW) in 2018, 64.4% of respondents stated they found it difficult to carry out certain duties at work because they were too fatigued, and 67.8% agreed that fatigue posed a significant risk to officer safety. In addition, 57.9% were unhappy with their current sleeping pattern (Elliott-Davies, 2019). The National Police Wellbeing Survey conducted in 2019 also highlighted self-reported sleep disturbance and reduced sleep duration amongst officers and staff (Graham et al., 2019).

Vila (1996), suggests that fatigue has largely been ignored in police settings, and that excessive fatigue could also put other members of the public at risk, if officers make ill-informed judgement calls when, for example, handling firearms, or driving at high speed, and under pressurised conditions (Vila, 1996; Vila et al., 2000). In their study of 379 officers in four local police agencies in the USA, Vila *et al.* (2000) measured the extent of fatigue on police patrol officers, in a bid to identify relationships between fatigue, and health, safety and performance. This was done by a variety of means, including self-report, interviews, focus groups and more objective physiological measurements, such as pupil response time. They found that 59% of officers reported having less than 7 hours sleep per day, and that there was concern amongst the group regarding fatigued colleagues. In addition, the authors concluded that officers should receive training in relation to managing fatigue, relevant policies should be put in place regarding working hours, and employees should be involved in any policy implementation.

Police officers also often perform emotionally and physically demanding roles in a high pressure environment, and have been found to experience psychological distress and be at high risk of developing post-traumatic stress disorder (PTSD) (Green, 2004). This can come about due to repeated exposure to physically or emotionally distressing and difficult scenes, or work demands such as extended shifts (Haslam and Mallon, 2003; Kinman et al., 2012). In this respect, it is perhaps all the more important that work-life balance and officer welfare needs to be considered by employers when designing and implementing any changes to shift patterns (Eriksen and Kecklund, 2007). Flexible working patterns are also sometimes available, and this can assist in providing part-time hours, job share or condensed hours opportunities, which could lead to a more well-rested, motivated and productive workforce and often reduced sickness due to stress (Eriksen and Kecklund, 2007). It should be noted that officers do not currently necessarily have a right to a flexible working pattern, but they do have the right to make a request for this type of work, and if granted, the argument is that it should work for the organisation as well as the individual (Tuffin and Baladi, 2001). All of these issues outlined above fall under the umbrella of health, safety and welfare.

In terms of welfare and wellbeing, the agenda is relatively new to policing and has been introduced as a result of research into specific wellbeing issues in policing and the prevalence of PTSD. In addition to the specific health and safety legislation discussed at the beginning of this section, the onus for welfare and wellbeing is on the organisation, and Chief Constables hold a statutory responsibility to manage the welfare of officers and staff (Home Office, 2018). The UK Home Office are striving to ensure that every member of policing feels that their welfare and wellbeing is actively supported by their police force, and that all individuals have access to appropriate support whenever it is needed (Home Office, 2018). The plan to assist in achieving this goal includes a culture focusing on support, prevention, and early intervention, with clear evidence-based standards throughout policing, including through occupational health departments, effective line management and relevant signposting to other providers, when required (Home Office, 2018).

This section has briefly described the current legislation governing health, safety and welfare, and the very recent introduction of an agenda in order to improve overall wellbeing in policing. In order to understand some of the restrictions placed on police officers, both on and off duty, the following section will introduce the required police standards of professional behaviour and fitness for duty.

3.4 Police standards of professional behaviour

Some shift workers in the UK are permitted to sleep whilst covering night shifts. The best example of this is probably some employees of the fire and rescue service, (West Yorkshire Fire & Rescue Service, 2016). Whilst the remit of the fire and rescue service has changed in recent times from a purely reactive service (Matheson et al., 2011) and they do now have several preventative and proactive arms, working in partnership with other agencies, these tend to operate during daytime hours (Bateman et al., 2015), just as some of the non-frontline roles in policing mentioned in section 3.1. The fire and rescue service operate a number of operational duty systems, some of which have personnel in ‘live in’ accommodation at the fire station site, when on duty between 5pm and 8am, others are ‘on call’ from their home address (West Yorkshire Fire & Rescue

Service, 2016). In these examples, personnel are permitted to sleep whilst effectively on duty overnight, although there is a necessity to mobilise necessary appliances in a timely fashion (West Yorkshire Fire & Rescue Service, 2016).

Police on the other hand, with responsibility for many prevention services, different to those of other services, such as fire and rescue, need to be alert, available, and on patrol during night shifts in order to prevent and detect crime, or respond to other calls for service (Charman, 2018), in line with their primary duties and responsibilities, outlined in section 3.1 (ACPO, 1990). This largely inhibits police officers and staff from sleeping during their night shifts, and indeed, sleeping on duty could be construed as being in conflict with the standards of professional behaviour (The Police (Conduct) Regulations, 2008).

The standards of professional behaviour are a framework outlining the expectations that the police and the public have regarding how police officers should behave. They are designed to enable everyone to understand what acceptable and unacceptable conduct is.

In particular, if officers sleep on duty, it could come into conflict with the following sections of (The Police (Conduct) Regulations, 2008) and the Code of Ethics, (College of Policing, 2014);

- Duties and Responsibilities – *"I will be diligent in the exercise of my duties and responsibilities"*
- Fitness for work - *"I will ensure, when on duty or at work, that I am fit to carry out my responsibilities"*
- Discreditable Conduct – "*I will behave in a manner, whether on or off duty, which does not bring discredit on the police service or undermine public confidence in policing"*

Police officers are required to behave in a manner which does not discredit the police service or undermine public confidence in it, whether on or off duty (The Police (Conduct) Regulations, 2008). Arguably, a police officer may not be diligent in the exercise of their duties and responsibilities if they are found to be asleep whilst on duty. It could also undermine public confidence in the police service and indeed there have been newspaper articles and online headlines showing outrage when an officer has been caught napping, for example *"Sleeping policemen – officers caught snoozing in their patrol car and now social* *media wants them sacked"* (Campbell, 2016) and *"Police officers caught sleeping in unmarked cop car during early morning stakeout"* (Express, 2017).

On the other hand, if officers comply with these expected standards of professional behaviour and do not nap on duty, they may be awake for many hours, sometimes in excess of 24 hours and at times when their natural circadian rhythm dictates that they should be asleep. This is then likely to put them at risk of excessive fatigue, experiencing poor physical and mental performance (Alhola and Polo-Kantola, 2007), along with the possibility of impairment levels in excess of the current drink drive limit in England and Wales (Dawson and Reid, 1997; Rajaratnam et al., 2013).

In their study, Dawson and Reid, (1997) measured cognitive psychomotor performance in 40 participants, who were either kept awake for 28 hours, or asked to consume 10-15g of alcohol at 30 minute intervals until their BAC reached 100 mg of alcohol per 100 mL of blood. Cognitive psychomotor performance was measured at half-hourly intervals, and it was found that performance decreased significantly under both conditions. This was to such an extent that after 24 hours of sustained wakefulness, it was found that performance impairment was equivalent to a BAC of 100 mg of alcohol per 100 mL of blood.

As the public service that upholds and enforces the law in relation to road safety, and being open to public scrutiny and accountability, policing organisations need to manage working hours with suitable rest breaks and staff wellbeing (Bullock and Garland, 2019), whilst educating their employees about the dangers of driver fatigue (Robertson et al., 2009).

In order to explore and understand the extent of in-service police officer deaths, and the potential reasons behind these, to try to understand if these are related to fatigue, the following section will examine police officer line of duty deaths, in particular those related to road deaths and commuting incidents resulting in a fatality.

3.5 Police officer line of duty deaths in the UK

The Police Roll of Honour is a record of all those UK police officers who have lost their lives in the line of duty, by whatever means (Police Roll of Honour

Trust, n.d.). The records are held on a computer database that is available to all through the website www.policememorial.org.uk.

An examination of figures obtained via the Police Roll of Honour, has revealed that since 1970, there have been a total of 1126 officers killed in the line of duty in the UK and of those, 495 lost their lives in road traffic incidents (Police Roll of Honour Trust, n.d.). At this time 'in the line of duty' includes travel to and from work. Figure 3.2 shows the overall numbers of road deaths per decade, from 1970 onwards. The overall numbers have reduced from 130 deaths in the 10-year period between 1970-1979, to 30 deaths in the 10-year period between 2010-2019. This is not dissimilar to figures reported for reductions in overall road casualties in Great Britain, where there were 7499 reported fatalities in 1970 and 1752 reported fatalities in 2019 (Keep and Rutherford, 2013; Department for Transport, 2019).

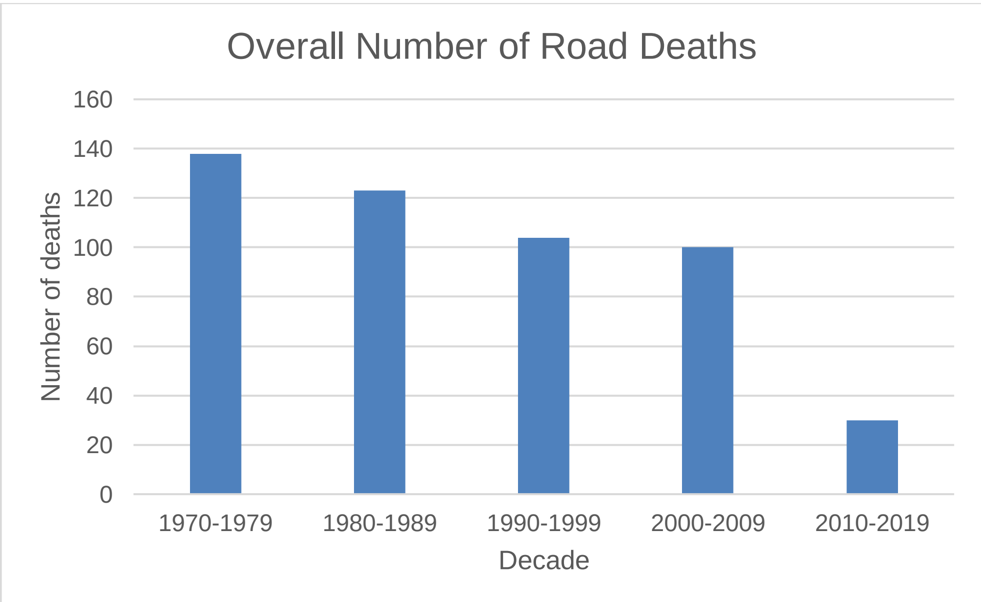

Figure 3.2 Police officer road deaths, 1970 – 2019

In more recent years, there has reportedly been an increase in the number of UK police officers killed in collisions whilst commuting to and from their place of work (Pertile, 2006). Between 2001 and 2005, there were 31 recorded accidental road deaths involving police officers commuting in either a car or on a motorcycle, an increase on the reported number of 11 between the previous 5 years of 1996 and 2000 (Pertile, 2006). Pertile (2006) did not specifically state if these deaths were due to fatigue. However, she did report that a prior call had been made by the Police Federation of England and Wales (PFEW) to provide officers with training regarding how tiredness affected the body. The author reported that it was not believed that any training had been delivered on this topic. In addition, the article reported on a Coroner's inquest into the death of detective constable Barrie Davies in 2005. DC Davies was killed when his unmarked police vehicle crashed while going off duty. The inquest touching on his death heard that fatigue could have played a part, as he had worked 110 hours in the 8 days prior to his death. This is not dissimilar to other recorded line of duty deaths.

Despite this reported percentage increase in officer road deaths, to date, research into driving and commuting habits amongst police officers and civilian support staff, working shifts within the policing organisation, has been rare. For example, other than anecdotal reporting, or quoting of figures related to officer deaths, this has not been examined in England and Wales.

In northern Italy, Garbarino *et al.* (2007) conducted a questionnaire study which examined commuting collisions amongst police officers. This study identified that 411 police officers were involved in 463 collisions in a 4 year period from 1999 to 2002. Of those, 51.9% were shift workers, and 36% complained of excessive daytime sleepiness. A significant relationship was found between the two.

Turnbull and Wass (2012) pointed out that as Crown servants, rather than employees, police officers can be commanded to perform extreme work. As well as the physically and emotionally demanding work that one would class as 'extreme', this also includes overtime and cancelled rest days. As such, long working hours have always been a feature of police work, creating more growing concerns about the impact of excessive and unpredictable hours of work on the health and wellbeing of employees, the strains it can impose on family life and work-life balance, and the adverse effects this has on the efficiency and effectiveness of the police service.

Police shift work may also be associated with a high prevalence of sleep disorders, adverse health outcomes, and self-reported drowsy driving incidents (Vila and Samuels, 2011; Rajaratnam et al., 2011). A total of 4957 police officers in the USA and Canada participated in the study by Rajaratnam *et al.* (2011). This was conducted by both online and on-site means, utilising surveys incorporating demographics, mental and physical health, and risk of sleep disorders. From the results, 28.5% of participants were identified as having excessive sleepiness, and 40.4% screened positive for a sleep disorder. In addition, 45.9% reported having fallen asleep or nodded off whilst driving, 56.9% (26.1% of the total participants) of those reported it happened once or twice a month, and 13.5% (6.2% of the total participants) of those reported it happened once or twice a week. Rajaratnam *et al.*, (2011) concluded that sleep disorders were common amongst this group of police officers and were significantly associated with an increased risk of self-reported adverse incidents, and health and safety outcomes.

In relation to police officers in England and Wales, a report by Blain and Martis (2008), described how a number of police officers reported they fell asleep whilst travelling home from work and therefore became a danger to themselves and other road users. However, the officers reporting such incidents could offer no easy solution to the issue.

In relation to all in-service deaths, Figure 3.3 shows the number of road deaths as a comparison with all other in-service deaths during this period. In general, the overall numbers of deaths (by any means) has reduced over this 50-year period, from 341 in the 10-year period between 1970-1979, to 67 deaths in the 10-year period between 2010-2019.

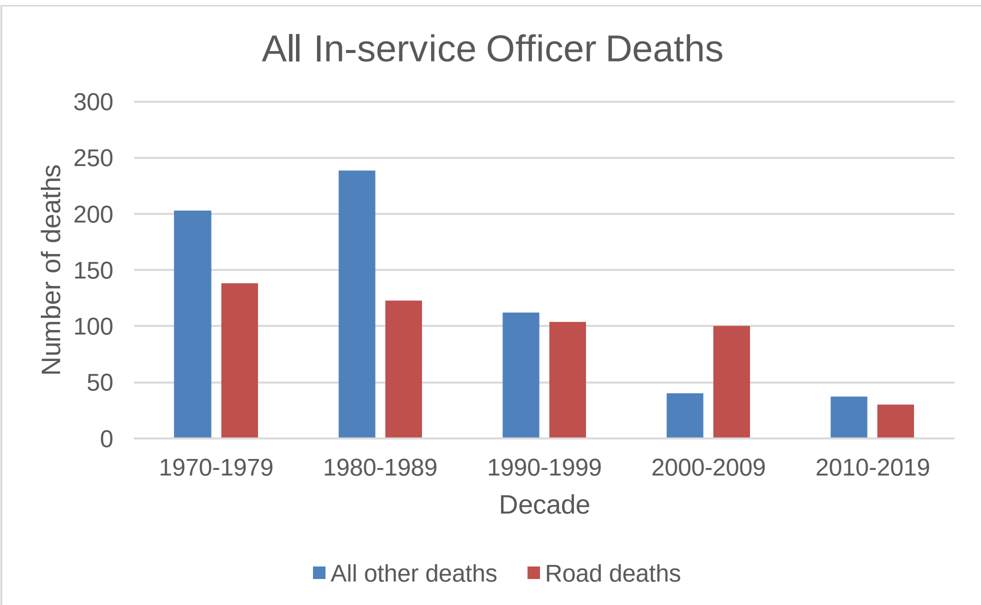

Figure 3.3 All in-service police officer duty deaths, 1970 – 2019

Figure 3.4 illustrates where the percentage of these road deaths were on duty, commuting to work or commuting from the workplace. In the 10-year period from 1970-1979, 82% of road deaths were on duty deaths, 9% were commuting to duty and 9% were commuting from duty. However, in the 10-year period from 2010-2019, 37% of road deaths were on duty deaths, 26% were commuting to duty and 37% were commuting from duty. This illustrates a trend towards the percentage of all road-related deaths decreasing. On the other hand, the percentage of those whilst commuting to and from duty, compared with on duty deaths has increased in recent years. These figures are in agreement with the report by Pertile (2006).

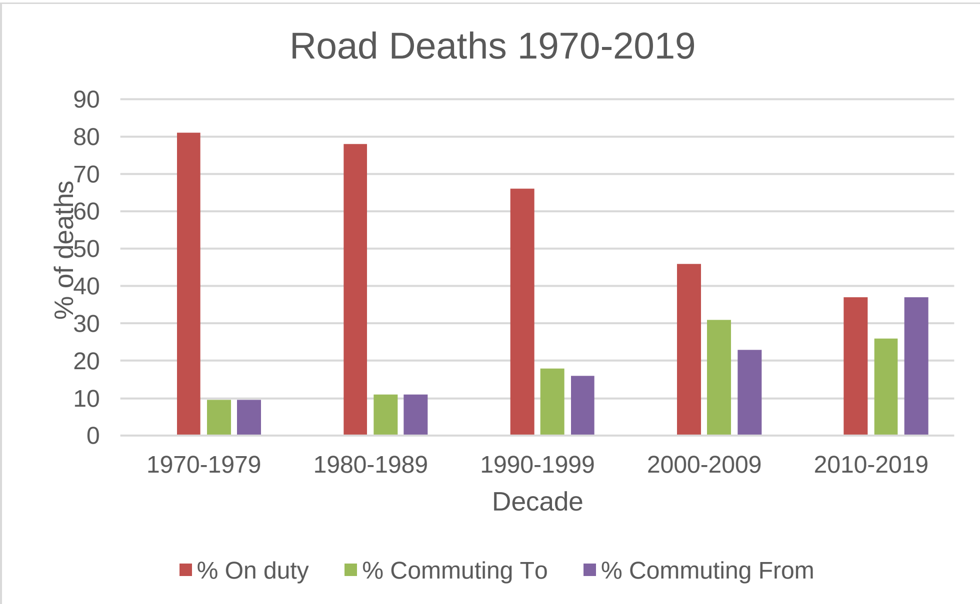

Figure 3.4 Police officer road deaths, showing percentage of those on duty, commuting to work and commuting from work, 1970 – 2019

It is unknown why this is the case, but there could be a number of reasons for these changing figures. Whilst figures for the overall number of officers involved in road traffic incidents at any time (i.e. including off duty incidents, as opposed to on duty or whilst commuting) are not available, it could be that improved vehicle safety features have reduced the number of fatalities amongst this group, as it has done amongst the general public (Mawson and Walley, 2014).

Historically, officers usually lived in the force area where they were employed, with this being stipulated within individual force policy. Often, they were provided with housing, which then allowed the force to easily relocate officers to other areas, within the same police force, with seasonal demand. When housing stock was sold off (Lashmar and Kelly, 2000), it became more difficult for Chief Constables to stipulate where officers should live and force policy was generally relaxed. It could be that officers are now taking advantage of this increase in freedom of choice in relation to the chosen location of their home and are choosing to reside out with the force area where they work, due to cheaper housing or other personal reasons. For example, figures reported by Berry (2016) indicated that 49% of Metropolitan police officers lived outside London. These lifestyle choices could, in turn, lead to increased commuting distances and potentially greater risk of an incident occurring (Stutts et al., 2003).

The causation for the fatal incidents published via the Police Roll of Honour Trust (n.d.), are also not always clear from the limited information available, although one could speculate from the brief circumstances outlined, that a number of the incidents, particularly those involving an officer commuting home from a night shift, are due to driver fatigue.

Officers and staff often drive for long distances and long periods of time, whilst on duty, depending on their role; Some may be part of specialist operations and be a force resource, effectively being available for very large geographical areas. It is also not unusual for officers to be single crewed for the duration of their shift (Houdmont et al., 2018), meaning there is no one else with whom to share the driving, and also no one with whom to converse, for long periods of time. Driving hours for such single crewed officers are not regulated as they would be for commercial drivers, with the onus in relation to driver safety left to the driver's own responsibility, and the call demand placed on them during their tour of duty. Include in this an increasing commute time and it can add up to a long period of wakefulness.

Changing shift patterns, resulting in longer shifts at work and increasing periods of wakefulness may also be a contributory factor in this increase in road related deaths whilst commuting. Or, it could simply be a combination of several of the factors discussed. The reasons are unknown, and as such are merely speculation at this stage.

There is a similar trend amongst law enforcement officers in the United States of America (USA), with Noh (2011) reporting that from the mid-1990s, there has been an upward trend showing that motor vehicle crashes have become the major cause of law enforcement officer fatalities. This report by Noh (2011), only takes into account those officers in a law enforcement vehicle, and effectively "on duty", as opposed to commuting, so can offer no further insight into the UK figures.

Following on from this overview of recorded information held by the Police Roll of Honour Trust (n.d.), in relation to in-service road death amongst police officers, the next section will examine police recording of road related incidents involving their own employees, with an emphasis on those related to driver fatigue.

3.6 Information relating to police officer or police staff involved collisions

The information recorded by the Police Roll of Honour Trust, (n.d.) provides limited details, specifically related to police officer fatalities whilst on duty or whilst commuting to and from the workplace. This has raised further questions related to information potentially recorded by police forces in relation to collisions involving their own staff (whether police officers or civilian members of staff).

3.6.1 Information recorded by territorial police forces in relation to officer and staff collisions

In order to explore this further and to establish what details police forces routinely record regarding police officer and staff involved in road traffic collisions (RTCs), a further request was sent to all police forces in England and Wales, in 2019, under the FOIA. The FOIA submission was developed in order to try to establish the following;

- What information do UK police forces collate in relation to police employee involvement in RTCs?
- Does the percentage of police employee involved collisions differ from the general public and if so, why?

The questions posed asked for the number of police officers (and police staff where recorded) who had a recorded, blameworthy RTC, over a 5-year period between 2012 and 2016, where fatigue had been listed as a contributory factor. Further details around date, time and duty shift were also requested.

The results from the request were as follows;

- 12 police forces did not respond in any way to the request for information.
- 13 police forces refused due to time and cost constraints of retrieving the information requested.
- 9 police forces stated the information was not held.
- 4 police forces provided limited information that was not directly related to the request.
- 2 police forces stated there were no incidents where fatigue was listed as a contributory factor.
- 1 police force stated there were two incidents during the relevant dates where fatigue was listed as a contributory factor.
- 1 police force provided details of police involved collisions where an injury was recorded. There were no collisions where fatigue was listed as a contributory factor; however, there were 2 collisions recorded where other impairment or distraction factors were recorded.
- 1 police force stated that fatigue was not specifically addressed within on-duty collisions as the driver would not be fit for duty if such was the case.

Despite the statutory requirement to disclose information, the reasons why 12 police forces did not respond to the request are unknown. It is possible that the request was overlooked, mistakenly deleted, or forces are simply overwhelmed with requests for information and are failing to comply with the Act. It does, nevertheless raise further questions around transparency of the organisations, and highlights the many variations in practice in supplying information requested under the FOIA across policing in England and Wales (Kingston et al., 2019). From the 13 police forces who refused due to time and cost constraints, the most common reason for this was that the information requested is not held in an easily retrievable format, it would require every individual RTC record scrutinising, and it would potentially take too much time in order to extract the information from the systems in which it is held, thus breaching the cost threshold (Kingston et al., 2019). In addition, the remaining forces that did respond, provided very little in the way of useful data as a result of the request.

In conclusion, from a total of 43 territorial police forces in England and Wales, only one force could provide basic information related to only 2 fatigue-related RTCs, involving their own officers and staff, over a 5 year period. The limited information provided is illustrated in Table 3.4. From the records provided, the police vehicle drivers were deemed to be 'blameworthy' on both occasions. One incident was in the early hours of the morning, typically at a time that could be associated with peaks in fatigue, as discussed in section 2.2.2. Both recorded incidents were on duty collisions and one of the incidents resulted in slight injury to the driver; however, no further details were available in relation to any causation factors involved in the RTCs, the particular shift patterns, or hours worked by the officers / staff members involved.

Table 3.4 Details of on-duty fatigue-related RTCs provided by one police force

Year	Time of day	Severity of injury
2012	05:40	damage only
2014	18:57	slight

The lack of comparable information available perhaps points towards these 43 territorial police forces all maintaining records on the same subject in different ways, demonstrating that the systems are inconsistent, and information cannot be collated in a meaningful manner (Kingston et al., 2019). Rather than gaining useful information related to police employee involved RTCs, as was hoped, the results obtained just highlighted that any information was incomparable and not possible to explore in any meaningful way, due to the differences in how information was stored and the differences in how individual police forces responded.

In relation to the individual police force that responded stating that fatigue was not specifically addressed within on-duty collisions as the driver would not be fit for duty, this highlights the need for education amongst officers, staff and managers. This comment simply reinforces that organisations potentially do not understand that fatigue can be caused by circadian and homeostatic pressures, as outlined in section 2.2. Officers and staff have a responsibility under the Code of Ethics, (College of Policing, 2014) to ensure they are fit for duty; however, despite their best efforts to obtain sufficient sleep and rest, they may be trying to do so at times when sleep is unnatural, and conversely trying to work and function at times close to the circadian troughs, and when the homeostatic driver for seep is at its highest, (Shneerson, 2006; Jackson et al., 2011; Wilson and Nutt, 2013; Boivin and Boudreau, 2014). It is not always simply a case of officers and staff failing to prepare sufficiently for duty. As explained in section 2.4.2., working at irregular times, and therefore trying to sleep through the day results in shorter periods of sleep, along with reduced quality sleep (Harrington, 2001).

3.6.2 Comparison with public road traffic collision figures

In order to try a different means of obtaining details related to police officers and staff involvement in RTCs, individual road safety partnerships in the Yorkshire and the Humber (YatH) police force areas were approached. The YatH region is a group of four police forces in the north east region of England and can be seen in Figure 3.5. Information was provided in relation to police related RTCs from all four YatH forces, for the five year period from 2012 – 2016. The number of recorded (injury) RTCs involving a police vehicle, for each of the five years, are shown in Table 3.5. Of the individual RTC records provided, not all can be attributed to the police driver being at fault. In addition, there were no recorded police RTCs that listed driver fatigue as a contributory factor.

Figure 3.5 Police forces in England & Wales, highlighting the YatH region
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This is in contrast to RTCs involving members of the public. The figures for total injury RTCs in the YatH region, that the general public were involved in were obtained from the Department for Transport, (2019) (DfT), for the same five year period. These are listed in Table 3.6, along with the number, and percentage, of those with driver fatigue listed as a causation factor. The total percentage of injury RTCs attributed to fatigue are far below the figure of 20% suggested by researchers (Maycock, 1995; Horne and Reyner, 1995b; Jackson et al., 2011). Some of the suggestions why this may be the case are discussed in section 2.6.1. However, in the main, these discrepancies are down to the difficulties in identifying fatigue related RTCs.

Table 3.5 Police involved injury collisions in the YatH region

Police involved Injury collisions, Yorkshire & Humber region data					
Year	**2012**	**2013**	**2014**	**2015**	**2016**
All police involved injury RTCs	280	265	190	184	255

Table 3.6 Road traffic collisions in the YatH region

Injury collisions, Yorkshire & Humber region data					
Year	**2012**	**2013**	**2014**	**2015**	**2016**
Total injury RTCs	13257	12461	12936	12808	12454
Injury RTCs where fatigue cited as contributory factor	130	139	163	168	160
Fatigue-related RTCs, as % of total	0.98	1.12	1.26	1.31	1.28

The next section will introduce police driver training and fatigue management training processes and investigate any areas of good practice already in existence within policing in England and wales, in order to mitigate and manage fatigue.

3.7 Police driver training and fatigue management

In excess of a quarter of all recordable road traffic incidents in the UK are thought to be work related (Department for Transport, 2019). In view of that, it may be prudent that those drivers who do drive for work receive some form of additional driver training and fatigue management education relevant to their particular role.

In a study by Gander *et al.* (2005), fatigue management training was delivered to vehicle drivers employed by a large oil company. At the beginning and end of each training session, drivers completed a survey in relation to causes of fatigue and use of countermeasures. Participants also received a follow-up questionnaire, the results of which indicated that a large percentage of them had made changes at both home (47%), and at work (49%) in order to better manage fatigue. These changes included improved sleep habits and napping habits.

Police drivers have different levels of driver training, depending on their role and requirement to drive within the organisation; however, all generally undergo some form of police-led driver training prior to driving police vehicles. The training is in line with the current recommended text included in “Roadcraft: The Police Driver’s Handbook” (Mares et al., 2013). The levels of training are generally classed as “basic”, “standard” or “advanced”, depending on the occupational role held and the requirements of that role. The “standard” and “advanced” levels are both based on the principles contained within the “Roadcraft” handbook (Dorn and Barker, 2005). The training involves both classroom based training, along with on-road instruction (Dorn and Barker, 2005). The text includes input on driver vulnerabilities and human factors, amongst many other topics (Mares et al., 2013). The College of Policing specify national learning standards for police driving through Authorised Professional Practice (APP), which include various goals for driver education. These goals point out that poor driver attitude and behaviours may undermine the reputation of the police and specify factors that may be influential in this, including both driving at night and fatigue (College of Policing, 2019b). The APP specifies that police drivers are expected to continually, dynamically self-assess actions and performance and should notify a supervisor if any of the factors, such as fatigue, affect them (College of Policing, 2019b). However, it remains that there is very little guidance on driver fatigue, whether on duty, or whilst commuting to and from the workplace.

Following on from the reported increase in deaths of police officers due to road traffic incidents whilst commuting (Pertile, 2006), Pertile and Blain (2008) reported that UK police forces did not have any policies in place to assist officers in getting home, when they are too tired following a night shift. Some forces did report having informal arrangements to look after officers, although it is unreported what these informal arrangements are.

In order to identify if changes had been made since that time, and also to identify if any form of FRMS, as discussed in section 2.4.4, were in use, a request for information was submitted to all police forces in England and Wales through a further FOIA request in 2019, with regard to policies and procedures relating to driver fatigue. The aim was to establish what force policies, procedures and guidance were now in place in relation to driver fatigue, what training staff were now receiving in relation to keeping themselves safe whilst driving and how police forces consistently deliver the road safety and wellbeing messages to their own employees.

The questions posed to all police forces were as follows;

- Does your force currently have a policy, procedure or guidance in relation to driver fatigue? If so, could I please be supplied with a copy?
- Over and above any policy, procedure or guidance in place, do officers and staff receive any further training / input in relation to keeping themselves safe whilst driving, particularly for night driving or whilst commuting?

Of the 43 territorial police forces in England and Wales, 4 did not respond to the Freedom of Information (FOIA) request. Again, the reasons for this are unknown; however, it may be for any of the reasons previously discussed in section 3.6. The vast majority of forces suggested that they follow the guidance provided in APP and trained in accordance with the principles of Roadcraft (Mares et al., 2013). There were 16 forces that indicated they had an individual force policy, procedure or guidance in place, related to the questions posed, in addition to APP. These forces and brief content of their policies is outlined below;

Bedfordshire, Cambridgeshire and Hertfordshire – These three police forces have a ''collaboration' in place for some functions and one response was received, representing the arrangements in all three police force areas. These forces have a "Fitness to drive" policy in place, specifying that individuals should not drive unless 'fit'. Responsibility for this is placed firmly on the driver.

City of London – A police driver policy is in place. This includes sections related to welfare and medical issues and specifically makes reference to driver fatigue and tiredness. In addition, officer training days include inputs on keeping yourself and other road users safe.

Derbyshire – Driving policy includes a specific, short section on fatigue and driving. This outlines vulnerabilities of shift workers and outlines the responsibilities of both staff and supervisors.

Devon & Cornwall – The police vehicle policy includes a brief section on tiredness and driving, and also signposts the reader to the Highway Code.

Kent – Policy includes driver's hours, fatigue and commuting fatigue. Driving courses also reportedly feature theoretical inputs on driver fatigue, shift work and commuting.

Lancashire – Policy makes reference to WTR and there is a brief section on safe driving policy, related to driver fatigue. The policy specifically advises drivers who are fatigued to stop in a safe place.

Leicestershire – Driving standards and vehicle usage policy includes a section on driver fatigue. It specifies driver responsibilities in relation to fitness to drive, both on duty and whilst commuting. The policy also recognises a collective responsibility and encourages officers to speak with a supervisor in relation to concerns in this area.

Lincolnshire – Local policy includes a section on driver fatigue, specifying personal responsibility around fitness to drive and also a collective responsibility via supervisors. There is also a link to the Highway Code, as well as a link to a separate policy on wellbeing for further advice in relation to lifestyle choices.

Merseyside – A driver policy and procedure document is in existence but does not include any reference to driver fatigue.

Northamptonshire – A driver training procedure document is in place that includes a section on driver fatigue. This includes reference to officer and staff responsibilities, but also to supervisory responsibilities in relation to ensuring the employee is fit to drive or can make alternative arrangements to get home safely at the end of duty.

North Wales – A police use of vehicles policy is in place, which includes reference to scheduling, journey planning and driver fatigue. The policy specifies that the individual is best placed to know their condition and has personal responsibility for fatigue awareness, particularly during hours of extended duty or following night shifts. In addition, officers receive training on night driving and fatigue when attending their response driving course.

Thames Valley – A driver policy is in place; however, there is no specific content relating to driver fatigue.

West Yorkshire – A driving and use of police vehicle policy is in place; however, this does not include anything in relation to the driver's condition or personal responsibility. All drivers attending a standard response driving course receive an input covering fatigue and are required to complete a written piece of work demonstrating their understanding.

Wiltshire – A driving and use of police vehicles policy is in place. This specifies that where a driver feels excessively fatigued, they must take personal responsibility and inform their line manager. In addition, a presentation is delivered to officers covering driver fatigue, driver trainers discuss this with officers and welfare checks are conducted on a regular basis.

The only forces, from those that provided a response to the FOIA request, that specifically included commuting considerations within the force policy, were Kent and Northamptonshire.

Table 3.7 summarises the positive responses, and illustrates what measures they each have in place. The first column shows the forces that responded indicating that they have a force policy / procedure / guidance in place. The middle column shows those who also advised they provide a training input, in addition. The final column shows those forces who, in addition to the previous considerations, also include commuting in their force policy.

Table 3.7 Procedures in place in relation to driver fatigue

Individual Force Policy / Procedure / Guidance	+ Training Input	+ Consider Commuting in Force Policy
Bedfordshire	City of London	Kent
Cambridgeshire	West Yorkshire	Northamptonshire
Hertfordshire	Wiltshire	
Derbyshire	North Wales	
Devon & Cornwall		
Lancashire		
Leicestershire		
Lincolnshire		
Merseyside		
Thames Valley		

There are a number of recommendations and considerations included that consider procedures and responsibilities, of the individual, along with supervisors or managers. However, Pertile (2006), recommended training for officers in driver fatigue, and Pertile and Blain (2008) identified a lack of policies in place related to driver fatigue. From the response to this FOIA request, it does not seem likely that the vast majority of UK police forces have acted on those recommendations, and very little appears to be in place in respect of FRMS.

James et al. (2018) conducted a study on 61 Royal Canadian Mounted Police (RCMP) officers, exposing them to a fatigue-management training programme, consisting of a 3-4 hour, face to face training input, with content including the science of sleep, sleep disorders, sleep apnoea and fatigue countermeasures. As a result of the training input, the researchers found that there were positive sleep health benefits realised, with improved satisfaction with sleep.

The next section provides a summary of the findings in this chapter, in relation to policing and the current policies and procedures in place, or otherwise lacking.

3.8 Summary and conclusions

The content of this Chapter has provided an introduction to UK policing, in the context of the role and shift work involved, popular shift patterns employed, standards of professional behaviour, and legislation related to police work and health and safety.

It has described that the basic principles of policing have not changed a great deal, since the introduction of the Metropolitan Police Act 1929. Shift patterns have evolved from the regulation shift pattern, simply covering the 24-hour period with equal numbers of staff, to a variety of different patterns, some are recommended by the Home Office (2010), and others are not. The decisions around individual shift patterns are ultimately left to each individual police force chief officer team. These shift patterns have evolved over time, initially to try to match resourcing to periods of demand, and latterly, in some cases, have begun to take wellbeing into account, in addition to the needs of the organisation. There have been no recent, national reviews of shift patterns. Instead, forces have conducted their own local reviews, citing local peculiarities to their particular force making this necessary. This has been found not to be the case (Home Office, 2004). Some forces were also found to be operating shift patterns that were specifically not recommended, i.e. 12-hour shifts and / or those that do not take account of higher demand profiles on certain days and times of the week (Home Office, 2004; Home Office, 2010).

The unique role of policing and the standards of professional behaviour, that limit opportunity for officers and staff working round-the-clock shifts to take advantage of napping whilst on duty have been outlined. No evidence has been found to suggest that there is currently any training or introduction to shift working provided to officers and staff on joining policing organisations. Due to the uniqueness of the roles, and the fact that joining the service is likely to be the first time that employees have worked shifts, this should be introduced, at the very least as part of initial training or induction. Additional inputs on driving courses, or as part of leadership training might also prove beneficial. High levels of self-reported fatigue, sleep disturbances and reduced sleep duration amongst police employees supports this need for education (Elliott-Davies, 2019; Graham et al., 2019).

The current information available in relation to line of duty deaths of police officers has been explored. This highlighted that whilst the overall numbers of line of duty deaths had reduced over the last 50 years, including road deaths, the percentage of those road deaths whilst commuting to and from work has increased in comparison to those on duty. The reasons for this shift are currently unknown; however, one could speculate in relation to reasons such as changes in the personal lives of police officers, such as those discussed, in relation to officers potentially living further away from the areas they police, with the subsequent increase in commuting time and distance as a result. Little information exists in relation to commuting habits of serving police employees. Only one such study was found, conducted with Italian police officers that identified a significant relationship between excessive daytime sleepiness and road traffic collisions (Garbarino et al., 2007). There is therefore scope for more recent, further investigation in UK policing populations in relation to commuting habits.

The College of Policing was established in 2012 as the professional body for everyone within policing in England and Wales. The three complimentary functions are knowledge, education and standards. APP sits under those functions and is designed and owned by the College of Policing. It is the official and most up to date source of professional practice, covering a wide range of policing activities (College of Policing, 2018). Not all policies, procedures or guidance will be included in APP. Individual forces may have more localised policies, for areas of business that may or may not be included in APP (College of Policing, 2018). This is an individual decision for each chief officer team.

Three separate FOIA requests were sent to all police forces in England and Wales, for different aspects of the current research. These requests addressed shift patterns, current policies and procedures in relation to the recording of road traffic collisions, and also driver training and fatigue training was submitted to all police forces in England and Wales. There is limited information available in relation to these topics, and lack of training, along with lack of relevant policies and procedures in place was evident, suggesting this is an area for improvement. This is in agreement with previous findings (Pertile, 2006; Pertile and Blain, 2008), suggesting that little progress has been made since that date.

For each request, there were varying degrees of compliance with the legislation. The reasons for this are unknown. It is possible that forces are overwhelmed with requests for information and are simply failing to comply, or that requests were mishandled resulting in their deletion. It is also possible that the topics of the individual requests were not a priority for particular police forces and there is a failure to address the issues raised.

The Home Office are now striving to ensure that there are clear plans for ensuring the welfare and wellbeing of every member of policing (Home Office, 2018). Road safety, fatigue management and coping with shift work is only a part of the overall wellbeing agenda, that is focussing on support and prevention. In excess of a quarter of all recordable road traffic incidents are believed to be work related (Department for Transport, 2019). As such, it is prudent that both employers and employees share responsibility for the safety of the workforce on the roads.

The primary motivation for conducting this study was the perceived lack of information regarding circumstances and consequences of fatigue amongst police officers. The literature search has confirmed there is a lack of research in relation to shift work and driver fatigue, amongst UK police officers, police forces do not appear to record meaningful information, in an easily accessible format, and there has been little examination of shift patterns and associated road safety within this sphere. The following Chapters will examine this in more details, paying particular attention to the police forces in the Yorkshire and Humberside region.

3.9 Research questions

To address the aims, as outlined in Chapter 1, and deliver the potential impacts of this work, this research focusses on a number of questions which will be addressed throughout the following chapters in this thesis and help direct the main study. The questions encompass a broad range of factors that form the basis of the research and will ultimately help this thesis to contribute to discussions around road safety, organisational policy, best practice and staff wellbeing. The research questions (RQ) addressed are detailed as follows;

Chapter 4

RQ1: To what extent is driver fatigue identified as an issue by officers and staff in the UK police service?

RQ2: In accordance with Home Office guidelines, and Fatigue and Risk Indices, what shift pattern is deemed most acceptable amongst those followed by this particular group of shift workers?

RQ3: What is the likelihood of a driving incident occurring, depending on the shift pattern followed?

RQ4: Are driver-related countermeasures utilised and are they effective in relieving fatigue?

RQ5: How does commuting and commuting time impact on incidents reported?

Chapter 5

RQ6: What is the difference in sleep duration following the different shifts worked in a fast, forward rotating shift pattern, common in UK policing?

RQ7: Is there a difference in cognitive performance (measured using a standardised test battery) during different shifts, for police officers and staff working a fast, forward rotating shift pattern?

Chapter 4
Study 1: Fatigue and Shift Work Related Road Traffic Collisions in Police Service Employees

This chapter reports on a questionnaire study conducted with serving police officers and staff in the Yorkshire and the Humber (YatH) region of England, exploring the shift patterns followed, the respondents experiences of working shifts, and details of self-reported collisions and near miss incidents.

4.1 Introduction

As we have seen in Chapter 3, road deaths whilst commuting to and from work have been the biggest killer of in-service police officers in recent years, and had trebled in the space of 5 years, with the numbers reportedly rising from 11 deaths between 1996 and 2000, to 31 deaths between 2001 and 2005 (Pertile, 2006). The reasons behind this rise were unknown, but it was hypothesised that it could be linked to long working hours. In addition, in 2008, in an online poll of 151 police officers, Pertile & Blain (2008) revealed that 99% of respondents stated they had driven home after a night shift when they believed they were too tired to be driving. It was also discussed that it can be difficult for those officers and staff currently working shifts to mitigate some of the risks involved with fatigued driving, due to lack of education and awareness, and also the potential limitations of the police code of ethics and standards of professional behaviour (College of Policing, 2014).

In a postal survey of 4621 drivers conducted by Maycock (1996), it was found that 29% of drivers had felt close to falling asleep at the wheel in the 12 months preceding the survey. Within this study, 21% stated this feeling had followed a long day at work, 15% stated it involved late night / early morning driving and 6% stated it was following a nightshift. In a more recent survey involving over 1600 Australian drivers, Armstrong *et al.* (2013) reported that 'near miss' incidents due to driver fatigue were reported by 19.1% of participants and 2.4% reported being involved in a fatigue-related collision. Of the most recent event (either near miss or collision), 28% were whilst commuting to or from work.

These two studies identified that there may be a particular problem with driving late at night or early morning, following a nightshift or whilst commuting. In a similar survey of 1121 Finnish drivers, Radun *et al.* (2015), found that 19.5% reported having fallen asleep at some time during their driving career. In addition, 15.9% reported having difficulty staying awake or having been close to falling asleep whilst driving during the previous 12 months. This demonstrates that the drivers involved in these studies were aware of their own fatigue, which is also in agreement with previous studies of this nature (Horne and Reyner, 1999).

Research into fatigue and road safety, particularly work related collisions and commuting, in the UK, is still lacking (Jackson et al., 2011). Recent decades have seen an increase in shift working and apparent trends for reduced sleep length which combine to increase driving risk, particularly with night driving amongst those shift workers (Alford, 2009). The police service is no different to many other organisations, with staff working around the clock in order to provide an emergency service to the public. In the police service, shift patterns have traditionally only taken into account the needs of the organisation, without considering the needs of their employees (Mason, 1999). Long working hours have always been a feature of policing, creating growing concerns about the impact of excessive, irregular and unpredictable hours of work on the health of the individual, the strains this can impose on family life and work-life balance, and the adverse effects this has on the efficiency and effectiveness of the police service (Turnbull and Wass, 2012). Police shift work is associated with a high prevalence of sleep disorders, adverse health outcomes, and self-reported drowsy driving (Vila and Samuels, 2011).

Despite research into effective shift patterns for the police service (Stone et al., 1993; Mason, 1999), and the recognition that shift work poses significant risk in performing tasks such as driving (Goel et al., 2009), little has been done to explore the extent that police employees suffer from driver fatigue and the resulting consequences of their irregular shift patterns on driver safety. Data are not routinely collected, in an easily retrievable format, hence this is currently unknown within police employees. In addition, the extent to which driver related countermeasures may be adopted in order to try to alleviate driver fatigue is also unknown amongst this population. Typical actions, such as opening a window, turning the radio volume up, or moving the seat position have been shown to be common driver related countermeasures, yet their effectiveness is questionable (Horne and Reyner, 1999; Nordbakke and Sagberg, 2007; Anund, *et al.*, 2008).

As previously discussed, there are many and varied shift patterns, utilised in policing and other industries. The patterns vary both across and within police forces. They may be reviewed and altered or adjusted periodically; however, this is generally to suit organisational and financial needs, as opposed to being as a result of reviews related to improving officer and staff wellbeing (Richbell et al., 1998; Mason, 1999; Barton, 2013). Studies of a range of shift patterns followed by some of the police forces in England and Wales have not previously been undertaken, in the manner examined over the following two chapters.

Numerous studies have been conducted over the years related to shift work, shift patterns, disturbed sleep and particular health problems associated with shift work; however, to the author's knowledge, Identifying the likelihood of a driving incident occurring, depending on a particular shift pattern followed, has not previously been explored. This is included below in research question 3, and will identify, from the shift patterns examined, which may pose greater risk, in respect of a diving incident occurring, to those following a particular pattern.

As outlined in Chapter 3, police officers were historically restricted to living in the police force area in which they served. There are no longer such restrictions placed on officers, who are now free to live where they choose. This may have led to increased commuting distances, potentially a change of transport choices and greater risk of a driving incident occurring (Stutts et al., 2003). For example, where an officer may have historically lived within walking distance of their posted station, they may now drive considerable distances to work.

This chapter therefore explores the relationship between commuting time and incidents reported, along with the other points highlighted, in further detail.

4.2 Study aims

This chapter reports on the first study of this thesis, which served as a first step to examining the experiences of police officers and staff working different shift patterns, and aimed to address the first five research questions presented in Chapter 3;

RQ1: To what extent is driver fatigue identified as an issue by officers and staff in the UK police service?

RQ2: In accordance with Home Office guidelines, and Fatigue and Risk Indices, what shift pattern is deemed most acceptable amongst those followed by this particular group of shift workers?

RQ3: What is the likelihood of a driving incident occurring, depending on the shift pattern followed?

RQ4: Are driver-related countermeasures utilised and are they effective in relieving fatigue?

RQ5: How does commuting and commuting time impact on incidents reported?

Official statistics regarding fatigue-related road traffic collisions are often not collated (Horne and Reyner, 1999). For example, in the event of a single vehicle collision, involving damage to that vehicle only, there is no requirement to record that type of collision in the UK and therefore no need for police attendance at the scene. In the Australian study by Armstrong *et al.* (2013), it was reported that police were not involved in investigating 55% of those fatigue-related collisions in the previous five years. As such, confidential driver surveys can be an indispensable source of information when investigating fatigue-related road traffic collisions (Armstrong et al., 2013; Radun et al., 2015).

The study reported in this chapter consisted of a self-reporting, confidential questionnaire regarding shift work and fatigue. The aim was to elicit participants' experiences of commuting to and from the workplace, focussing primarily on collisions and incidents during the commute. Due to the large number of potential participants in the study population across policing in England and Wales, the population involved in the current study focused only on members located within the four police forces in the Yorkshire and the Humber (YatH) region of England. The questions were designed to establish if this cohort experienced difficulties with driver fatigue during their journeys to and from work, and if this was more prevalent under any particular shift pattern.

In the present study, it was hypothesised that participants would report difficulties with fatigue and tiredness whilst commuting home from work, particularly following night shifts or extended shifts. It was further hypothesised that there may be a difference in incidents reported depending on the shift pattern worked and that the risk of incidents may increase with commuting time.

4.3 Methods

Data for this study were gathered by means of an online questionnaire that was made available to police officers and staff in the four police forces of the YatH region. The four police forces in that region are North Yorkshire, South Yorkshire, Humberside and West Yorkshire.

4.3.1 Questionnaire development

The questionnaire was created by the author and presented online using SurveyMonkey© software. Participants then accessed the questionnaire voluntarily via a web link. Development of the questions was informed by review of relevant literature. The manner in which it was presented allowed participants to complete the survey confidentially and anonymously, in their own time, and removed any possible influence by the researcher or the potential for socially acceptable answers being given (Lajunen et al., 1997).

The study was approved by the Ethical Committee of the University of Leeds, under ethics reference AREA 11-185.

The location of the four police forces selected for participation is shown in Figure 3.5, which also illustrates their geographical position in comparison to all other forces in England and Wales. The approximate numbers of police officers and police staff, obtained from UK Home Office figures, in each police force area (Home Office, 2019) are as follows;

- North Yorkshire Police, 1380 officers, 1408 staff
- South Yorkshire Police, 2501 officers, 2428 staff
- Humberside Police, 1836 officers, 1460 staff
- West Yorkshire Police, 5136 officers, 4398 staff

The questionnaire was developed and presented to representatives of the local Police Federation board to check for ease of access and use, via the online reporting mechanism. Feedback regarding the questionnaire was positive and no changes were made to the content or means of access. The resulting questionnaire is presented in Appendix A. The researcher was contactable directly to potential participants, via email, in the event of any queries or concerns raised.

4.3.2 Participants

Participants were recruited with the assistance of North Yorkshire Police Federation, who kindly provided the survey link to members, both within North Yorkshire Police and further afield, in the neighbouring forces of South Yorkshire, Humberside and West Yorkshire. In addition, the details were also distributed by word of mouth and emails to those known to have an interest in the topic. The survey was open to all police employees, whether police or civilian staff, in the four police force areas, and regardless of their hours of work.

Participants were advised that the questionnaire should take less than 10 minutes to complete.

4.3.3 Measures

The questionnaire presented a series of 52 questions, related to the individual participants and their employment, their working hours and shift patterns, arrangements for travelling to and from work and any driving incidents they had been involved in. These were categorised in four sections entitled;

- About you,
- Your shift pattern,
- Travelling to and from you place of work,
- Lifestyle

In addition to the questionnaire, Fatigue and Risk Indices (FRI) were also calculated for each of the four shift patterns in the four police force areas. This allowed a comparison between the different patterns, in relation to the potential fatigue risk presented.

The Health and Safety Executive (HSE) in the UK helps employers and employees to comply with workplace legislation and to be safer at work, and their overall aim is to prevent work-related injuries, ill health or deaths (Health and Safety Executive, 2006a). The HSE Fatigue and Risk Indices (FRI) were developed for shift workers, in order to assess risks associated with fatigue and different work patterns. The original version was developed in 1999 and has been widely used in various industries, including policing and the railway industry

(Rogers et al., 1999). In 2006, this was reviewed and revised, bringing it up to date with knowledge and findings of latest research at the time (Spencer et al., 2006). This latest version utilises mathematical model spreadsheets in order to provide a Fatigue Index (FI) or a Risk Index (RI) as required, which in turn can be considered by shift developers and reviewers and is useful when comparing different shift schedules (Folkard et al., 2007). The latest calculator takes into account important factors such as cumulative fatigue, time of day, shift length, rest periods, breaks and early starts to the day in order to consider chronic sleep reduction and possible patterns of recovery (Spencer et al., 2006; Folkard et al., 2007). A score is produced, from which a simple comparison can be made between different shift patterns.

The Fatigue Index is an average probability expressed as a percentage of high levels of sleepiness. For example, if a score of 40 is obtained on any given shift, then there is a 40% chance that workers will be fatigued to an extent where they may struggle to stay awake on that particular shift (Health and Safety Executive).

The Risk Index indicates the relative risk of an incident occurring on a particular shift, where a level of 1 would represent the average risk on a two-day, two-night, four off, 12-hour schedule, where shift start at 0800 or 2000 hours. A risk of 2, would therefore indicate double the risk (Spencer et al., 2006). It should be noted that the working day, for shift workers, within policing in the United Kingdom usually begins at 0700 hours.

There are other factors that contribute to fatigue and risk. However the FRI cannot take individual differences that naturally occur with shift workers, such as age, lifestyle or particular work related information into account (Folkard and Lombardi, 2004; Folkard, 2008), so these other individual differences must be kept in mind when assessing shift suitability.

Prior to calculating the FRI, defaults were set as follows for all four shift patterns;

Commute time: 30 minutes

Workload: moderately demanding, little spare capacity

Attention: most of the time

Breaks: every 5 hours

Length of break: 45 minutes

Longest period without a break: 6 hours

Length of break following longest period: 45 minutes

As discussed above, there are natural variations and some of the above details can change day by day, due to the nature of the job. It must also be considered that police officers, whilst entitled to refreshment breaks, do not always get them due to ongoing emergency calls and demand for service, and there is little that can be done under Police Regulations if officers do not get a break (Police Federation of England & Wales, n.d.).

4.3.4 Questionnaire procedure

Participants were required to click on the weblink provided to access the questionnaire. They were provided with information regarding the researcher and the study, given reassurance that answers provided were confidential and an indication of the duration of the study in order to inform their decision to participate.

4.3.5 Design and data analysis

This study utilised descriptive statistics, logistic regression and chi-square analysis using SPSS version 22 to examine the data collected with analysis of odds ratio estimates and goodness of fit.

The predictor variables were police force, gender, age, police officer or staff member, driving grade, commute time, use of countermeasures, and reporting of being sleepy, either on the way to work, or on the way home from work. The outcome was a driving incident occurring or not.

4.4 Results

Data collection for this study took place over a 6-week period from the end of July 2012 to beginning of September 2012. This allowed for the study to be publicised in the four police areas and gave participants sufficient time to consider the request and complete the questionnaire, taking into account holiday periods and the demands of shift work. Five hundred and twenty-three employees participated in the study, from across the four police forces of the Yorkshire and Humber region, with 492 of those fully completing the survey; 20.1% of the participants were from North Yorkshire, 6.1% from South Yorkshire, 44.9% from Humberside and 28.9% from West Yorkshire. This total number of participants was considered sufficient to draw valid conclusions regarding the wider police population, according to a simple power calculation suggested by Krejcie and Morgan, (1970). The total percentage of participants, by police force area, and whether a police officer or police staff member, is shown in Figure 4.1.

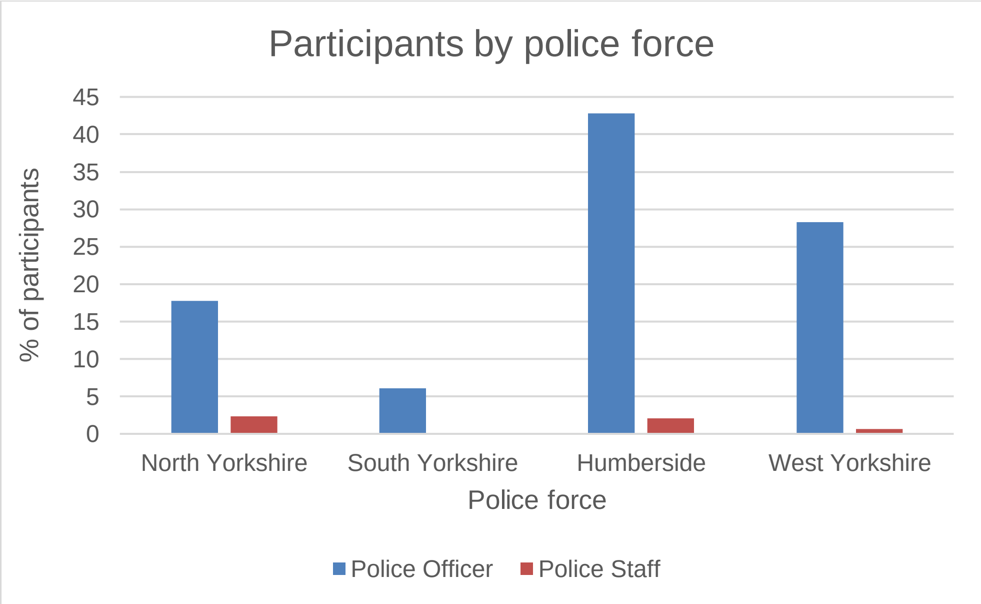

Figure 4.1 Percentage of participants by police force

The response rate by police force area is as follows;

- 3.8% of North Yorkshire Police officers and staff
- 0.7% of South Yorkshire Police officers and staff
- 7.1% of Humberside Police officers and staff
- 1.6% of West Yorkshire Police officers and staff

When considering these response rates, it needs to be considered that not every employee was contacted individually and made aware of the study.

4.4.1 Demographic information

This section was entitled "About you" in the original questionnaire and requested demographic information in relation to participants and their working life. Of the total number of participants, 95% were police officers and 5% were police civilian staff. The percentage of police officer and civilian staff participants by force area are as follows;

- North Yorkshire Police, 89% officers, 11% civilian staff
- South Yorkshire Police, 100% officers
- Humberside Police, 95% officers, 5% civilian staff
- West Yorkshire Police, 98% officers, 2% civilian staff

77.6% of participants in the study were male and 22.4% female. From Home Office figures, the proportion of female police officers in England and Wales stood at 32%, as at March 2018 (Gov.uk, n.d.). This does not separately take into account the ratio of males to females in civilian staff members, for which figures by force area are unavailable at this time. The participants by force area are shown below;

- North Yorkshire Police, 77% male, 23% female
- South Yorkshire Police, 90% male, 10% female
- Humberside Police, 76% male, 24% female
- West Yorkshire Police, 78% male, 22% female

The age of participants ranged from 22 to 61 years, the age range by police force area can be seen in Figure 4.2, and the age range of participants as a percentage of the total number of participants can be seen in Figure 4.3.

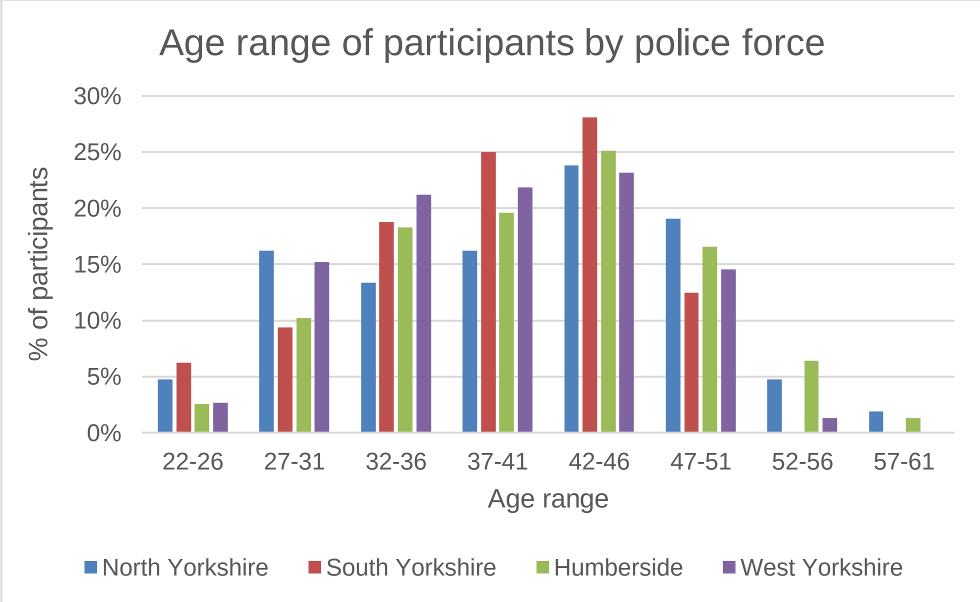

Figure 4.2 Age range of participants as % by force

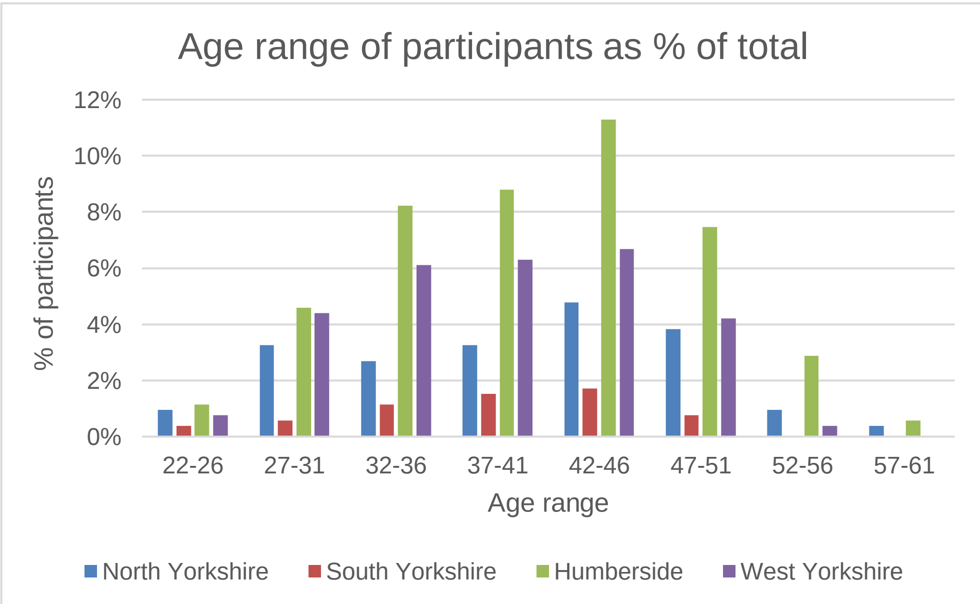

Figure 4.3 Age range of participants as % of total

The length of time participants had been employed as a police officer or member of civilian staff ranged from 2 years to 39 years. There was a wide range of expertise in roles, with responses from those within numerous departments, such as Response Officer, CID interview teams, Roads Policing, Safer Neighbourhood Patrol and Authorised Firearms Officers, to name a few. Police driving classifications included 35.8% advanced drivers, 60.4% standard drivers, 1.9% with no driving classification and 1.9% stating ‘other’. Advanced category drivers are usually those engaged in road policing roles or firearms support unit officers. Those who indicated this question was not applicable to their personal circumstances were not in a role that required them to drive any category of police vehicle whatsoever and those who selected 'other would usually have a basic 'A to B' permit to allow them to attend pre-arranged appointments, but not to respond to incidents.

4.4.2 Current working patterns

This section was entitled "Your shift pattern" in the original questionnaire. Participants in the four police forces in the YatH region worked different shift patterns at the time of data collection. Frontline emergency response officers in North Yorkshire Police followed a nine-week shift pattern, South Yorkshire Police followed a thirteen-week shift pattern, Humberside followed a four-week shift pattern and West Yorkshire Police followed a five-week shift pattern. The shift lengths varied, from eight to ten hours, and were organised on a local basis to suit calls for service and staffing in each force area. All four patterns are variations of rotating shift patterns, where all employees work all the different shifts involved, as opposed to fixed shifts. These shift patterns are shown in Table 4.1 - Table 4.4.

The pattern followed by North Yorkshire Police was a forward rotating pattern. This always started with day shifts, moved through afternoon shifts and finished following nightshifts. This effectively reduced the time off for officers and staff following this pattern, as they would require sleep following their last night shift. In addition, at the start of the shifts, sleep duration may be shortened due to the early start, following rest days. The pattern followed by South Yorkshire Police consisted of seven consecutive shifts before rest days. This was either 7 afternoon shifts, or a combination of day shifts and night shifts, before periods of either 2, 3 or 4 rest days. In addition, the period between day shifts and nights shifts would be in excess of 24 hours. The pattern followed by Humberside Police also consisted of blocks of 7 shifts, before periods of 2 or 3 rest days. The pattern followed by West Yorkshire Police consisted of blocks of 3 or 4 day shifts moving onto 3 or 4 afternoon shifts (7 shifts in total before rest days), along with blocks of 3 or 4 night shifts. Rest days consisted of 3 days following the day and afternoon shift blocks and 4 days following the night shifts. This provided additional time for rest and recovery following night shifts.

The vast majority of participants, 91.2%, worked shifts, as opposed to regular office hours, with 98.9% having done so for the last 12 months. The shift patterns varied, depending on police force and role undertaken; however, the core shift patterns are discussed above.

Table 4.1 North Yorkshire Police shift pattern

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1	Day	Day	Afternoon	Afternoon	Night	Night	Rest day
Week 2	Rest day	Rest day	Day	Day	Afternoon	Afternoon	Night
Week 3	Night	Rest day	Rest day	Rest day	Day	Day	Afternoon
Week 4	Afternoon	Night	Night	Rest day	Rest day	Rest day	Day
Week 5	Day	Afternoon	Afternoon	Night	Night	Rest day	Rest day
Week 6	Rest day	Day	Day	Afternoon	Afternoon	Night	Night
Week 7	Rest day	Rest day	Rest day	Day	Day	Afternoon	Afternoon
Week 8	Night	Night	Rest day	Rest day	Rest day	Day	Day
Week 9	Afternoon	Afternoon	Night	Night	Rest day	Rest day	Rest day

Table 4.2 South Yorkshire Police shift pattern

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon
Week 2	Rest day	Rest day	Day	Day	Day	Day	Night
Week 3	Night	Night	Rest day	Rest day	Rest day	Rest day	Day
Week 4	Day	Day	Night	Night	Night	Night	Rest day
Week 5	Rest day	Rest day	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon
Week 6	Afternoon	Afternoon	Rest day	Rest day	Day	Day	Day
Week 7	Day	Night	Night	Night	Rest day	Rest day	Rest day
Week 8	Rest day	Day	Day	Day	Night	Night	Night
Week 9	Night	Rest day	Rest day	Rest day	Afternoon	Afternoon	Afternoon
Week 10	Afternoon	Afternoon	Afternoon	Afternoon	Rest day	Rest day	Day
Week 11	Day	Day	Day	Night	Night	Night	Rest day
Week 12	Rest day	Rest day	Rest day	Day	Day	Day	Night
Week 13	Night	Night	Night	Rest day	Rest day	Rest day	Rest day

Table 4.3 Humberside Police shift pattern

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1	Day	Day	Afternoon	Afternoon	Afternoon	Afternoon	Afternoon
Week 2	Rest day	Rest day	Day	Day	Day	Day	Day
Week 3	Afternoon	Afternoon	Rest day	Rest day	Night	Night	Night
Week 4	Night	Night	Night	Night	Rest day	Rest day	Rest day

Table 4.4 West Yorkshire Police shift pattern

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1	Day	Day	Day	Day	Afternoon	Afternoon	Afternoon
Week 2	Rest day	Rest day	Rest day	Night	Night	Night	Night
Week 3	Rest day	Rest day	Rest day	Rest day	Day	Day	Day
Week 4	Afternoon	Afternoon	Afternoon	Afternoon	Rest day	Rest day	Rest day
Week 5	Night	Night	Night	Rest day	Rest day	Rest day	Rest day

4.4.3 Commuting patterns

This section was entitled “Travelling to and from your place of work” in the original questionnaire. The overwhelming majority of 93.9% usually travelled to and from work by car, Figure 4.4 shows the modes of transport used. Participants were asked to indicate all modes of transport that they used, hence there is a degree of duplication.

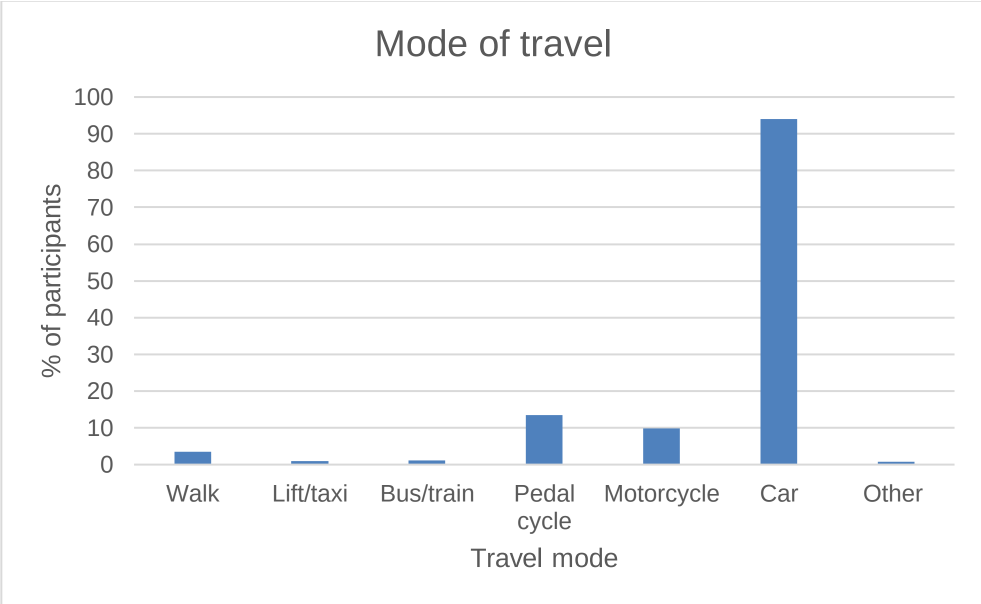

Figure 4.4 Mode of travel

In relation to times taken to commute to and from the workplace, 60.5% had a commute of less than 30 minutes each way, with 36.6% having a journey of between 30 minutes and 1 hour, and 2.9% having over an hour's travel each way. The shortest commute, in miles, was just 1 mile and the longest was 84 miles each way. Figure 4.5 illustrates the commute times, by police force area, and Figure 4.6 shows the commute time as a percentage of total participants.

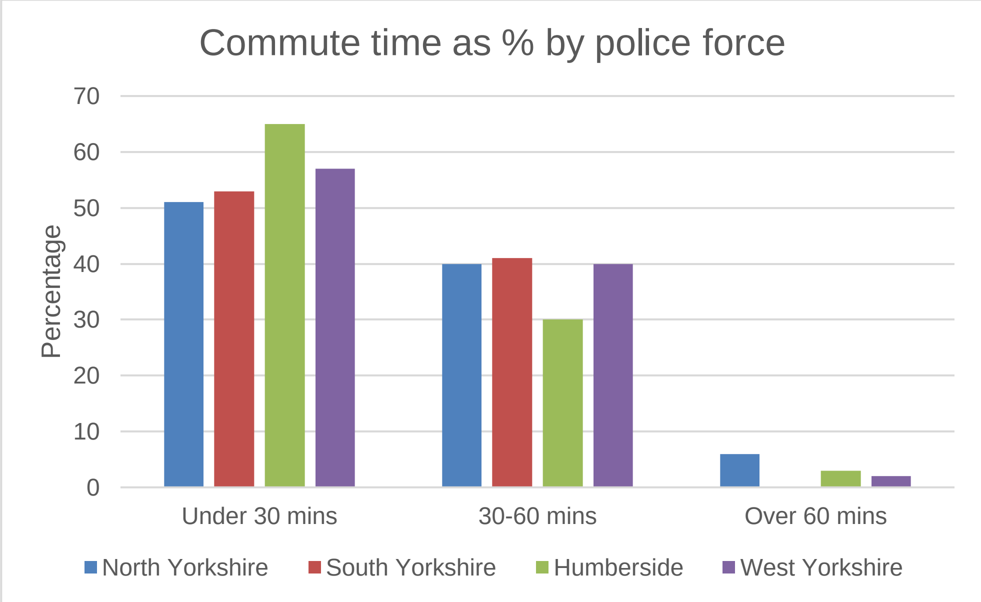

Figure 4.5 Commute time as % by force

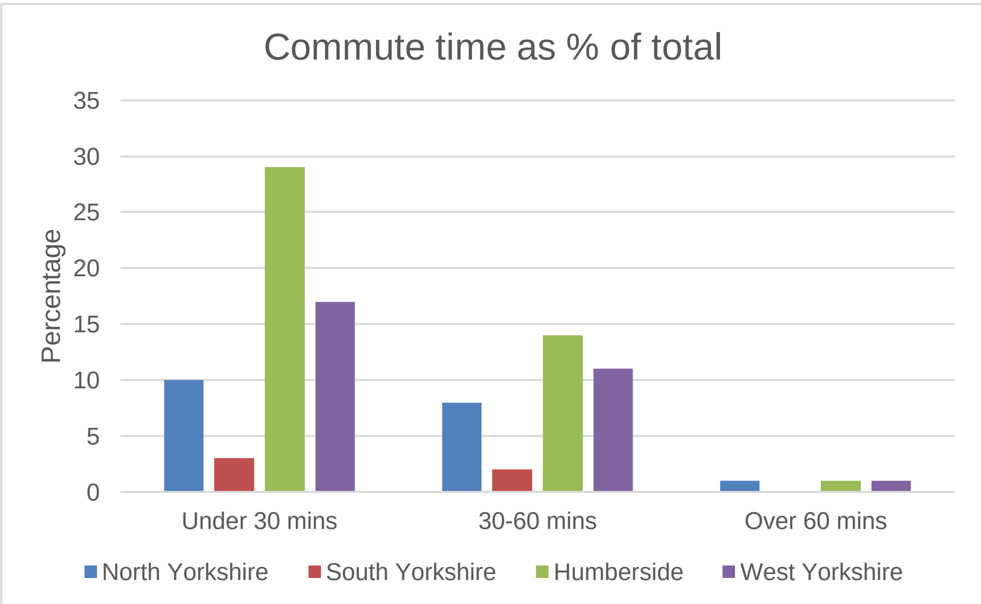

Figure 4.6 Commute time as % of total

86.5% of participants stated that they recalled feeling sleepy whilst travelling to or from work in the previous 12 months. Figure 4.7 shows the times and episodes when this has occurred. From the numbers declared, it is evident that some officers and staff feel sleepy on occasions when travelling both to and from work. 63.9% indicated that it was mainly after certain shifts, and this is illustrated in Figure 4.8. The main problems reported were following night shifts, with 67.5%

stating this, as opposed to 29.8% after a day shift, 31% after an afternoon shift and 9% of others (such as extended shifts and whilst 'on call').

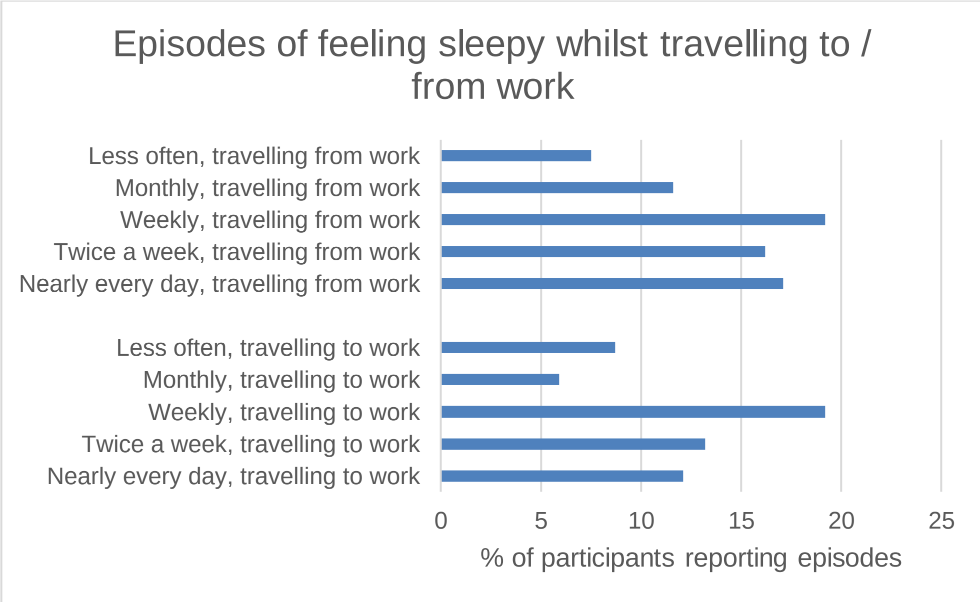

Figure 4.7 Episodes of feeling sleepy whilst travelling to / from work

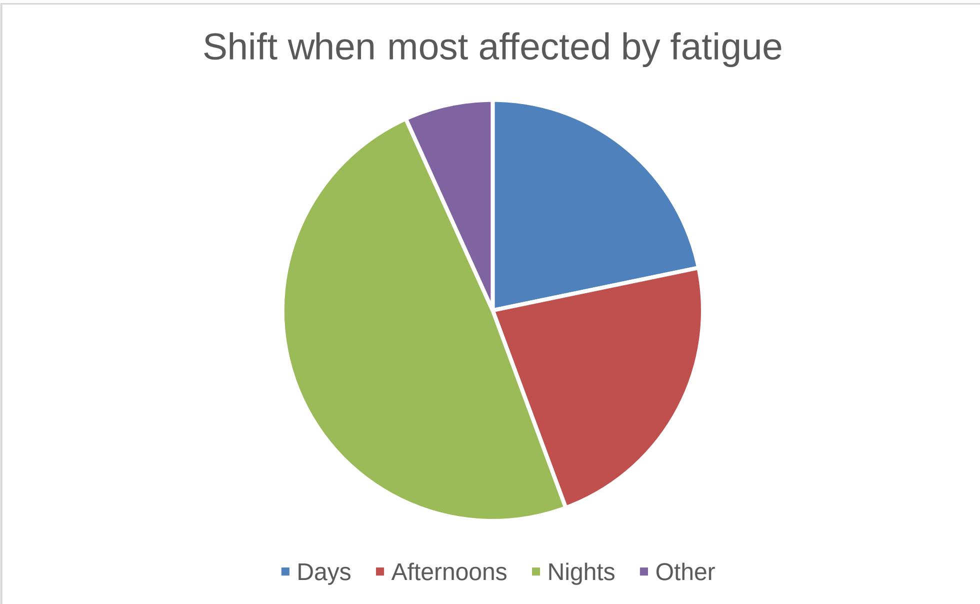

Figure 4.8 Shifts selected by participants when most affected by fatigue

Of the total number of participants, 51% answered the question in relation to the use of countermeasures, indicating that they utilised driver countermeasures. There were a number of ways in which those participants attempted to alleviate sleepiness and fatigue whilst travelling, and many of those utilised a variety of available measures as shown in Figure 4.9. Many participants used more than one type of countermeasure. Due to this, there is a degree of duplication, and the overall percentage figure does not add up to 100.

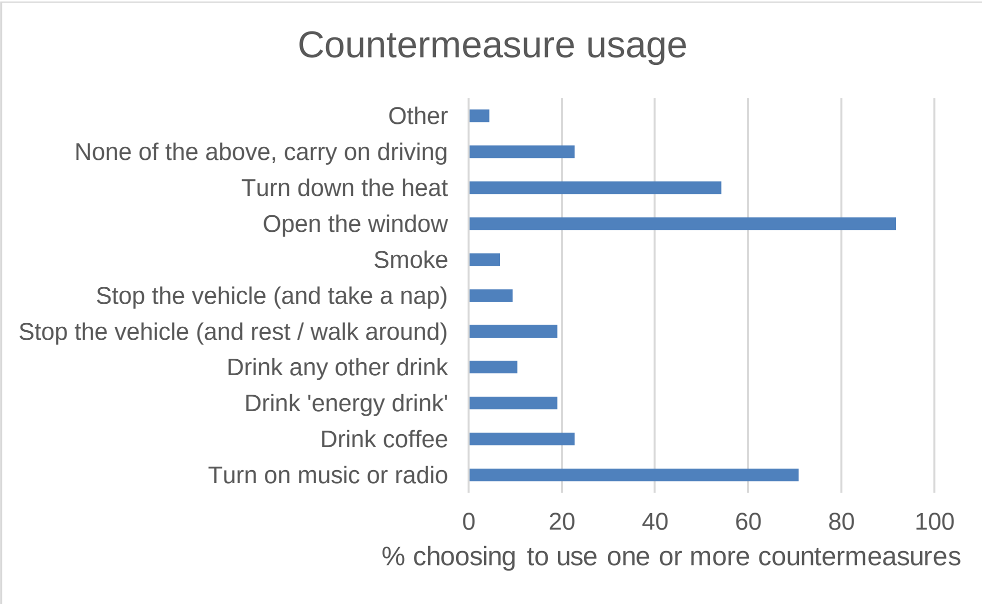

Figure 4.9 Countermeasures used by participants

When asked if there was anything that participants did on a regular basis to try to prevent fatigue on their commuting journey, the vast majority, 92%, stated they opened the window. The next most popular solution was to turn on music or the radio. When considering if any of these methods actually helped, only 3.7% stated that they found their most preferred method completely effective.

In the 12 months prior to the study, 5.8% of participants stated that they had been involved in a collision or road departure on the way to or from work. Of those, 77.4% stated the incident happened on the way home from work, and on that particular day, 15.6% had been working a day shift, 21.9% had been working an afternoon shift and 62.5% had been working a night shift. This is illustrated in Figure 4.10. In addition, the time of the incidents reported is shown in Figure 4.11. This shows 62.5% of incidents having occurred between 0601 and 1200 hours, which is in agreement with those travelling home, following a night shift.

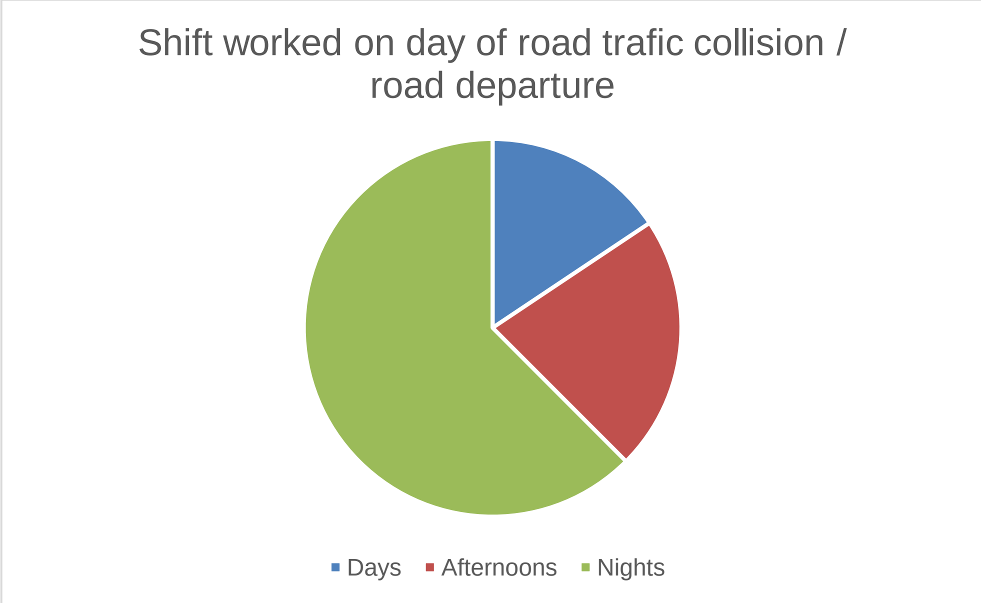

Figure 4.10 Shift worked on day of road traffic collision / road departure

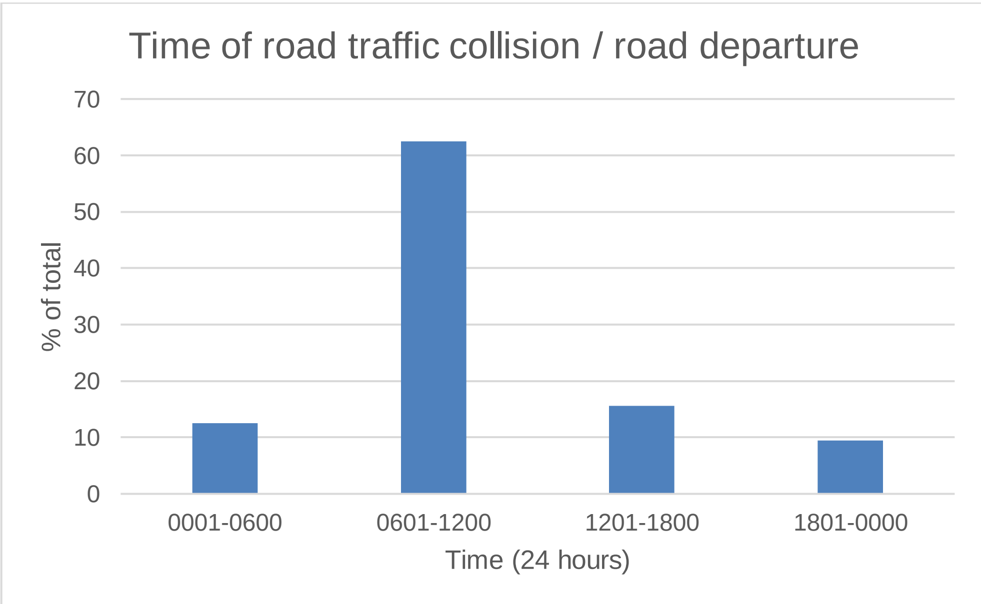

Figure 4.11 Time of road traffic collision / road departure

Of the total participants, 51.9% stated they had been involved in a ‘near miss’ incident, such as a kerb strike, lane departure or almost had a collision. Of those who stated they had been involved in a ‘near miss’, 74.9% stated this had happened more than once. 95.7% of these incidents happened on the way home from work, and 61.8% had been working a nightshift prior to the incident. Figure 4.12 illustrates the shift worked on the day of the ‘near miss’ incident.

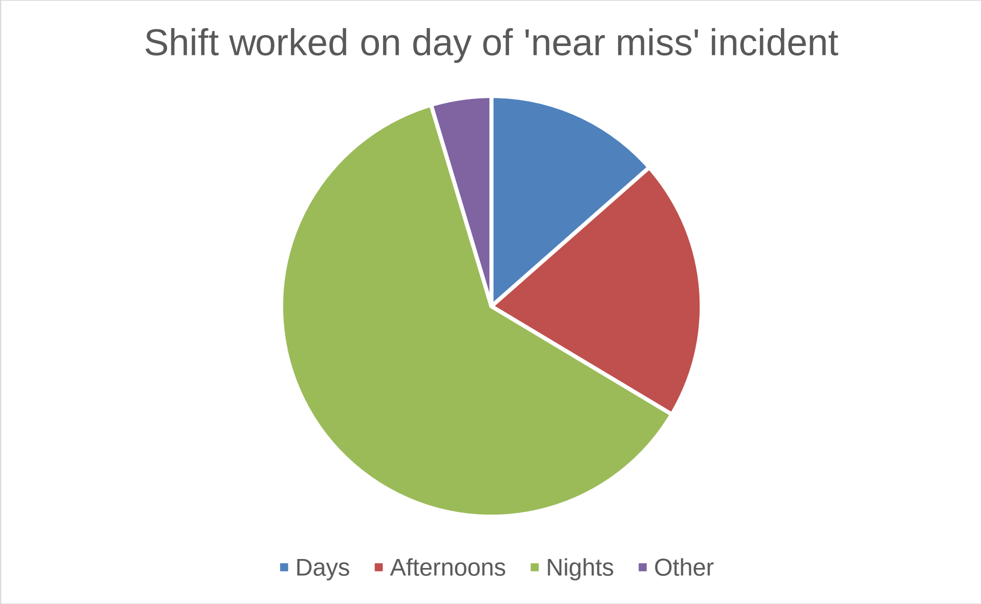

Figure 4.12 Shift worked on day of 'near miss' incident

When considering driving at other times, as opposed to specifically commuting to and from work, 74% of participants stated that they felt sleepy to the point where they felt they might actually fall asleep. 81.2% of these incidents had happened within the last 12 months. 3.4% of participants stated that whilst driving at any time, they had been involved in a collision that they would attribute to falling asleep or being fatigued and 37.5% of those were whilst on duty.

4.4.4 Health and lifestyle

This section was entitled "Lifestyle" in the original questionnaire. A number of questions were presented in relation to exercise and lifestyle in order to explore how this group differed from the general public.

In relation to exercise, 5.7% of participants indicated that they never participated in any exercise activity, 60% stated they exercise between 1 and 6 times per week and 34.3% stated they exercised 7 or more times per week. Figures produced by the National Health Service (NHS) reported that 66% of men and 58% of women in the general population in England met aerobic guidance of at least 150 minutes of moderate activity, or 75 minutes of vigorous activity per week (or a combination of both) (Scholes and Neave, 2013).

Only 6.3% of participants were current smokers, with a further 30.8% being former smokers. This is below the current prevalence of 14.4% in the general population in England (Office for National Statistics, 2018).

When it came to alcohol consumption, 2.2% stated they did not drink alcohol at all, 12.6% stated they only consumed alcohol on special occasions, 22.1% stated they consumed alcohol once or twice a month, 52.9% stated they consumed it once or twice a week and 10.2% stated they consumed it daily or almost daily. This can be seen in Figure **4.13**. Figures for the general population in England revealed that 57.4% drank alcohol in the week prior to the survey (Office for National Statistics, 2017).

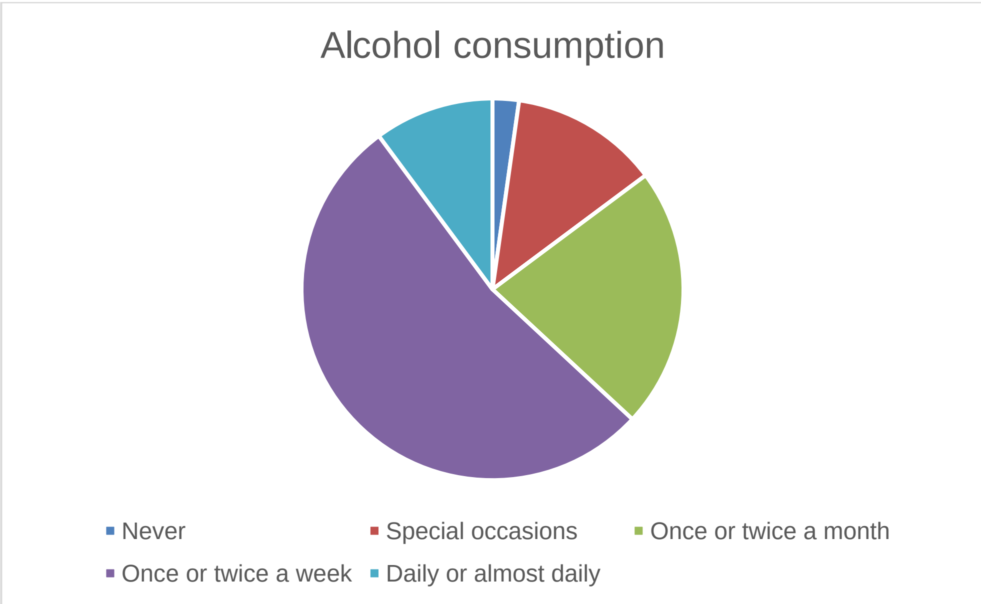

Figure 4.13 Alcohol consumption

In relation to sleep quality and duration, 50.7% stated that they did not sleep well and 96% stated they did not think they got sufficient sleep, 58.2% indicated they had difficulty falling asleep and 86.4% indicated they had problems staying asleep.

6.1% of participants indicated that they took medication, either prescribed or over the counter, that carried a warning with regard to the medication causing drowsiness whilst driving, and 3.7% stated they used sleeping pills.

4.4.5 Free text comments

A free text section for short comments was included at the end of the questionnaire in order to elicit further information from participants who wished to add anything in relation to shift patterns or fatigue that they felt was relevant to the study or to their own experiences of shift work. It was felt that this section would complement the question set, by allowing participants to share their personal thoughts and experiences; 36.9% of participants left comments in this section.

The content of the comments was analysed in order to categorise and summarise the data. Themes from the comments emerged as being related to;

- Not enough recovery time between shifts, particularly when working extended shifts
- Comparison to previous shift patterns that participants felt were better
- Health, safety and welfare
- Comparison with professional drivers such as LGV drivers who were protected by legislation in relation to working and drivers' hours

Whilst most participants accepted that shift work was an inevitable part of their vocation, there appeared to be a strong feeling that there was work to do, along with their respective organisations, in improving officer wellbeing related to shift work and shift patterns.

4.4.6 Statistical analysis

A logistic regression was performed to ascertain the likelihood of a driving incident occurring, based on police force, gender, age, whether police officer or staff, driving grade, commute time or use of countermeasures. For the purposes of this analysis, all incidents, whether collisions or near misses were considered as one and classified simply as a 'driving incident'. There was no pre-conceived hypothesis in relation to this data. Of the total number of participants (523), 25 were found to have missing data relevant to this analysis. This amounted to less than 5% of all participants and provided 498 complete data sets. The logistic regression model was statistically significant, $\chi^2(11) = 38.24$, $p < 0.001$). The model explained 10% (Nagelkerke R^2) of the variance in driving incidents and correctly classified 64.7% of cases. The Hosmer and Lemeshow test is not statistically significant (p=.090), indicating that the model is not a poor fit.

Of the seven predictor variables, only three were statistically significant. Table 4.5 presents the main regression results. Results indicated that when compared to West Yorkshire Police, as the baseline, those who worked in North Yorkshire Police were almost twice as likely to report being involved in an incident (Exp(B) 1.991); those who worked in Humberside Police were almost 1.7 times as likely to report being involved in an incident (Exp(B) 1.695). The comparison with South Yorkshire Police was not significant. When compared to those with a commute less than 30 minutes, those with a commute between 30 minutes and 1 hour were almost 1.8 times more likely to be involved in an incident (Exp(B) 1.789); those with a commute in excess of 1 hour were more than 3 times as likely to be involved in an incident (Exp(B) 3.135). When compared to those who didn’t use countermeasures, those who did were almost 1.9 times more likely to be involved in an incident (Exp(B) 1.890).

Gender, age, whether the participant was a police officer or staff member, and driving grade were found to be non-significant.

A chi-square test for association was conducted between police force and reporting of a driving incident to test how likely it was that the observed distribution was due to chance. All expected cell frequencies were greater than five. It was found that there was a statistically significant association between police forces and reporting of a driving incident, such that X^2 (3, 498) = 9.99, p = .019. The observed number of incidents was higher than expected in North Yorkshire, Humberside and South Yorkshire, and lower than expected in West Yorkshire. This is shown in Table 4.6.

Table 4.5 Logistic regression predicting likelihood of a Road Traffic Incident

Predictor	B	S.E.	Wald	df	p	Odds ratio	95% C.I.for EXP(B) Lower	Upper
Force			8.715	3	.033			
Force (NYP)	.688	.276	6.215	1	**.013**	**1.991**	1.159	3.420
Force (HUM)	.527	.225	5.497	1	**.019**	**1.695**	1.090	2.633
Force (SYP)	.783	.456	2.942	1	.086	2.188	.894	5.351
Gender (1)	-.117	.237	.244	1	.622	.890	.559	1.416
Age	-.005	.013	.120	1	.729	.996	.970	1.021
Officer / Staff (1)	.280	.501	.311	1	.577	1.323	.495	3.533
Driving Grade			3.766	2	.152			
Driving Grade (1)	-.039	.525	.006	1	.940	.961	.344	2.689
Driving Grade (2)	.358	.541	.437	1	.509	1.430	.495	4.134
Commute Time			11.559	2	.003			
Commute Time (30-60 mins)	.582	.201	8.371	1	**.004**	**1.789**	1.206	2.653
Commute Time (over 60 mins)	1.143	.537	4.531	1	**.033**	**3.135**	1.095	8.980
Countermeasures (1)	.637	.189	11.301	1	**.001**	**1.890**	1.304	2.739
Constant	-.759	.781	.943	1	.331	.468		

Table 4.6 Observed incident count in the YatH police forces

			No incident	Incident	Total
Force	North Yorkshire	Count	39	61	100
		Expected count	46.0	54.0	100.0
	South Yorkshire	Count	9	20	29
		Expected count	13.3	15.7	29.0
	Humberside	Count	101	124	225
		Expected count	103.5	121.5	225.0
	West Yorkshire	Count	80	64	144
		Expected count	66.2	77.8	144.0
Total		Count	229	269	498
		Expected count	229.0	269.0	498.0

An additional logistic regression step was performed in the same model to investigate predictors of those who regularly reported feeling sleepy whilst driving to or from work. The results are shown in Table 4.7. For the purposes of this additional analysis, the predictor variables were “Sleepy on the way to work” and “Sleepy on the way home from work”.

When compared to those who were not sleepy on the way to work, those who reported being sleepy on the way to work more than once a week were over four times as likely to be involved in an incident (Exp(B) 4.412); those who reported being sleepy on the way to work on a monthly basis were over 3 times as likely to be involved in an incident (Exp(B) 3.319). The comparisons with those who were sleepy on the way to work on a weekly basis, and less often than monthly, were not significant.

When compared to those who were not sleepy on the way home from work, those who reported being sleepy on the way home from work more than once a week were over three times as likely to be involved in an incident (Exp(B) 3.388); those who reported being sleepy on the way home from work on a weekly basis were almost 3 times as likely to be involved in an incident (Exp(B) 2.753). The comparisons of those who were sleepy on the way home from work on a monthly basis, and less often than monthly, were not significant.

Table 4.7 Logistic regression predicting likelihood of a Road Traffic Incident in those who reported feeling sleepy whilst driving

Predictor	B	S.E.	Wald	df	p	Odds ratio	95% C.I.for EXP(B) Lower	Upper
Sleepy way to work			28.979	4	.000			
Sleepy way to work (more than weekly)	1.484	.293	25.623	1	**.000**	**4.412**	2.483	7.838
Sleepy way to work (weekly)	.394	.304	1.676	1	.195	1.483	.817	2.693
Sleepy way to work (monthly)	1.200	.476	6.360	1	**.012**	**3.319**	1.306	8.432
Sleepy way to work (less often)	.280	.391	.513	1	.474	1.323	.615	2.846
Sleepy way from work			29.138	4	.000			
Sleepy way from work (more than weekly)	1.220	.275	19.619	1	**.000**	**3.388**	1.974	5.813
Sleepy way from work (weekly)	1.013	.323	9.834	1	**.002**	**2.753**	1.462	5.186
Sleepy way from work (monthly)	.220	.376	.343	1	.558	1.246	.596	2.604
Sleepy way from work (less often)	-.372	.460	.654	1	.419	.689	.280	1.699

4.4.7 Fatigue and risk indices

Fatigue and Risk Indices were calculated for each of the four shift patterns and the results are reported below.

4.4.7.1 Fatigue indices

During the 9-week shift pattern followed by North Yorkshire Police, 42 individual duty shifts were completed. During this period, the minimum fatigue score was 3.0, the mean fatigue score was 14.3 and the maximum fatigue score was 31.1. The maximum score indicates that there is a 31.1% chance that workers will be fatigued to an extent where they may struggle to stay awake on that particular shift. The fluctuation in fatigue indices throughout the shift rotation is shown in Figure 4.14.

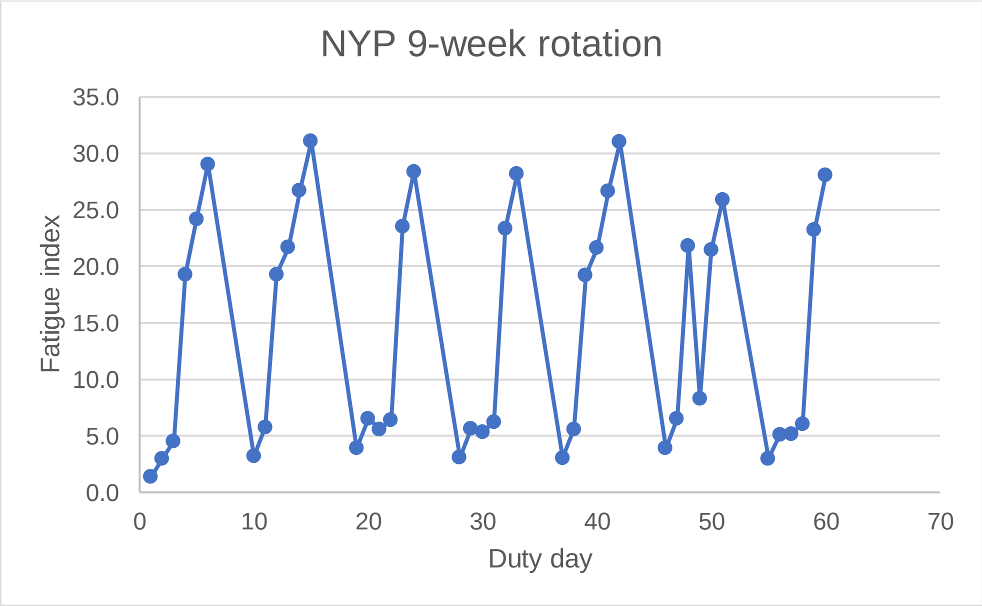

Figure 4.14 Fatigue indices for shift pattern followed by NYP

During the 13-week shift pattern followed by South Yorkshire Police, 63 individual duty shifts were completed. During this period, the minimum fatigue score was 2.2, the mean fatigue score was 13.3 and the maximum fatigue score was 34.3. The maximum score indicates that there is a 34.3% chance that workers will be fatigued to an extent where they may struggle to stay awake on that particular shift. The fluctuation in fatigue indices throughout the shift rotation is shown in Figure 4.15.

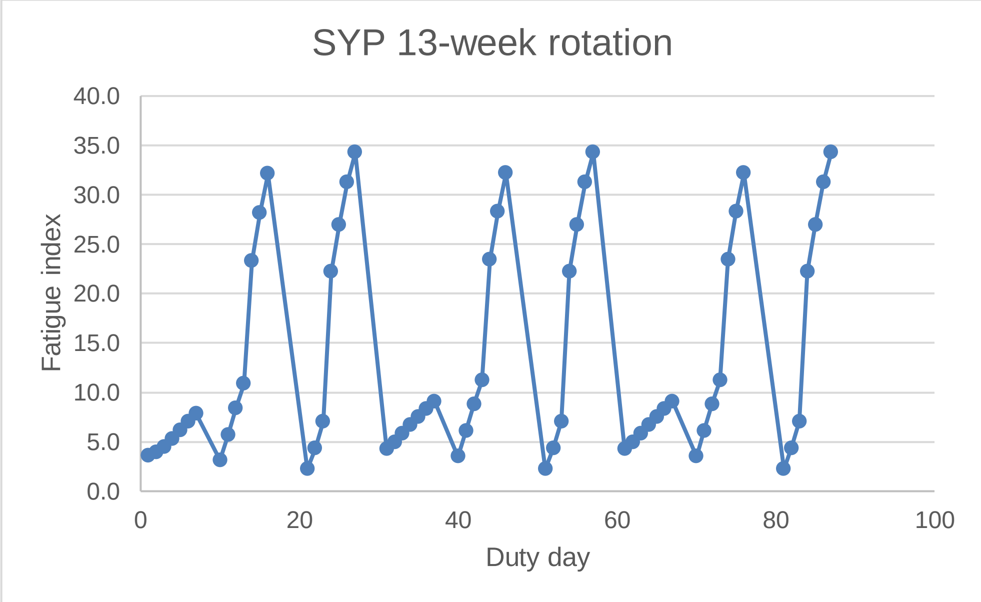

Figure 4.15 Fatigue indices for shift pattern followed by SYP

During the 4-week shift pattern followed by Humberside Police, 21 individual duty shifts were completed. During this period, the minimum fatigue score was 1.4, the mean fatigue score was 14.8 and the maximum fatigue score was 38.4. The maximum score indicates that there is a 38.4% chance that workers will be fatigued to an extent where they may struggle to stay awake on that particular shift. The fluctuation in fatigue indices throughout the shift rotation is shown in Figure 4.16.

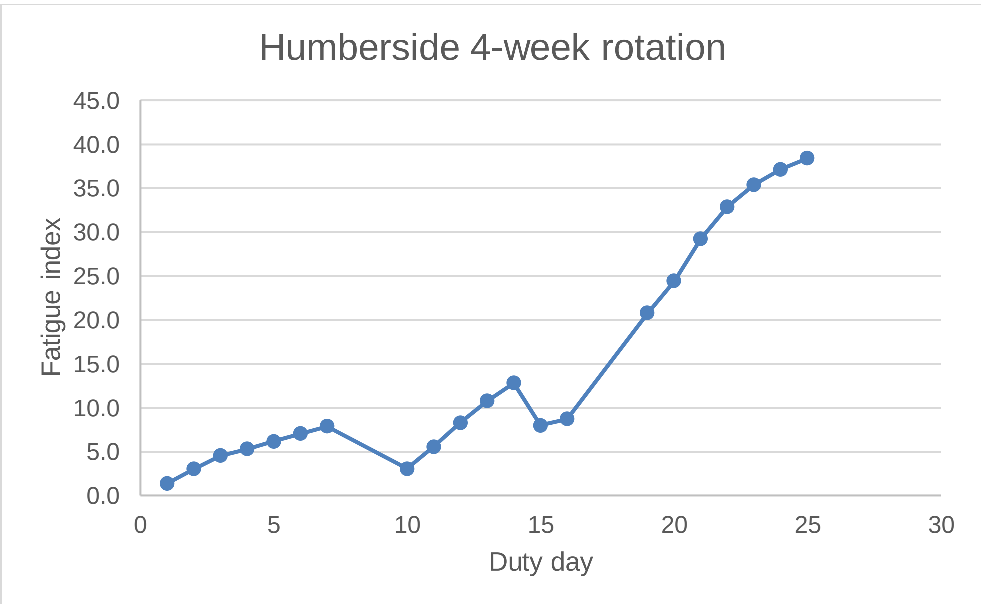

Figure 4.16 Fatigue indices for shift pattern followed by Humberside

During the 5-week shift pattern followed by West Yorkshire Police, 21 individual duty shifts were completed. During this period, the minimum fatigue score was 1.6, the mean fatigue score was 16.6 and the maximum fatigue score was 38.4. The maximum score indicates that there is a 36.6% chance that workers will be fatigued to an extent where they may struggle to stay awake on that particular shift. The fluctuation in fatigue indices throughout the shift rotation is shown in Figure 4.17.

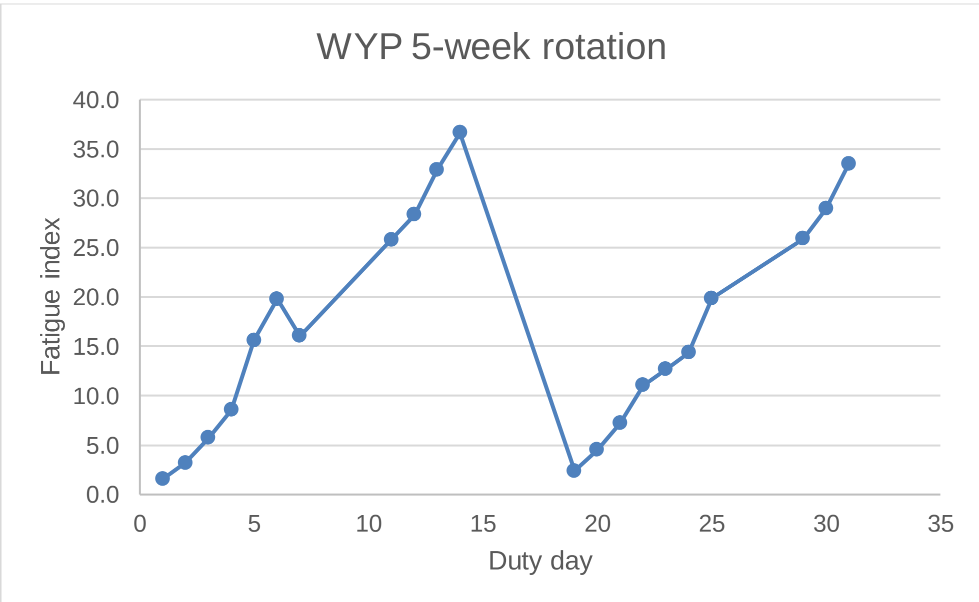

Figure 4.17 Fatigue indices for shift pattern followed by WYP

When considering Fatigue Indices alone, this therefore indicates that the shift pattern followed by Humberside Police produces the highest maximum fatigue score, whereas the pattern followed by South Yorkshire Police provides the lowest mean fatigue score. As expected, the maximum predicted peaks in the Fatigue Indices calculated, occurred at the end of the periods of night shifts. The lowest, mean and highest FI scores for each of the four forces are shown in Table 4.8.

Table 4.8 Fatigue Index scores

	NYP	SYP	Hum	WYP
Lowest	3	2.2	1.4	1.6
Mean	14.3	13.3	14.8	16.6
Maximum	31.1	34.3	38.4	36.6

4.4.7.2 Risk indices

During the 9-week shift pattern followed by North Yorkshire Police, the minimum risk index was 0.73 the mean risk index was 0.97 and the maximum risk index was 1.22. The fluctuation in risk indices throughout the shift rotation is shown in Figure 4.18.

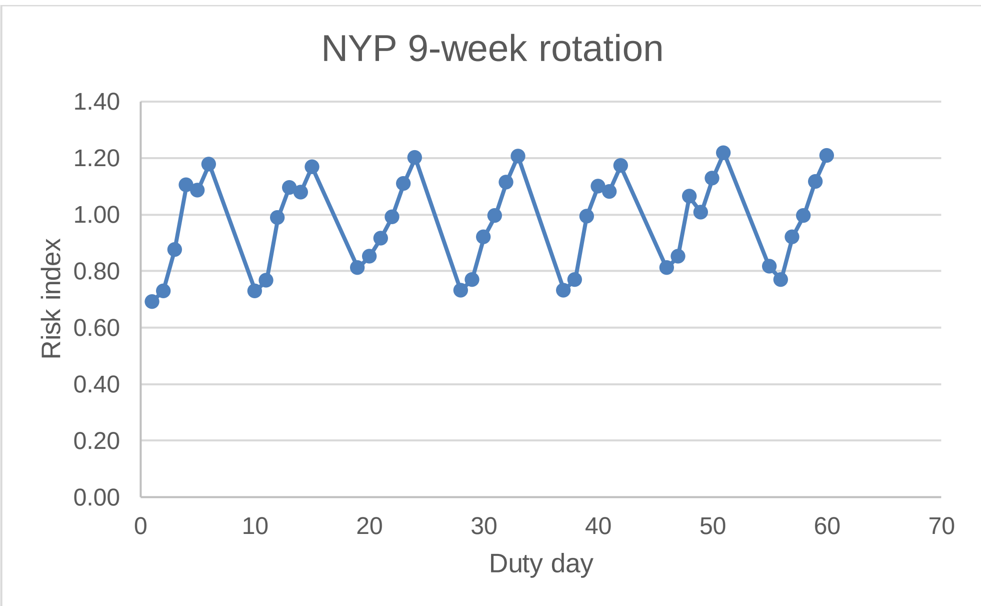

Figure 4.18 Risk indices for shift pattern followed by NYP

During the 13-week shift pattern followed by South Yorkshire Police, the minimum risk index was 0.74, the mean risk index was 1.00 and the maximum risk index was 1.30. The fluctuation in risk indices throughout the shift rotation is shown in Figure 4.19.

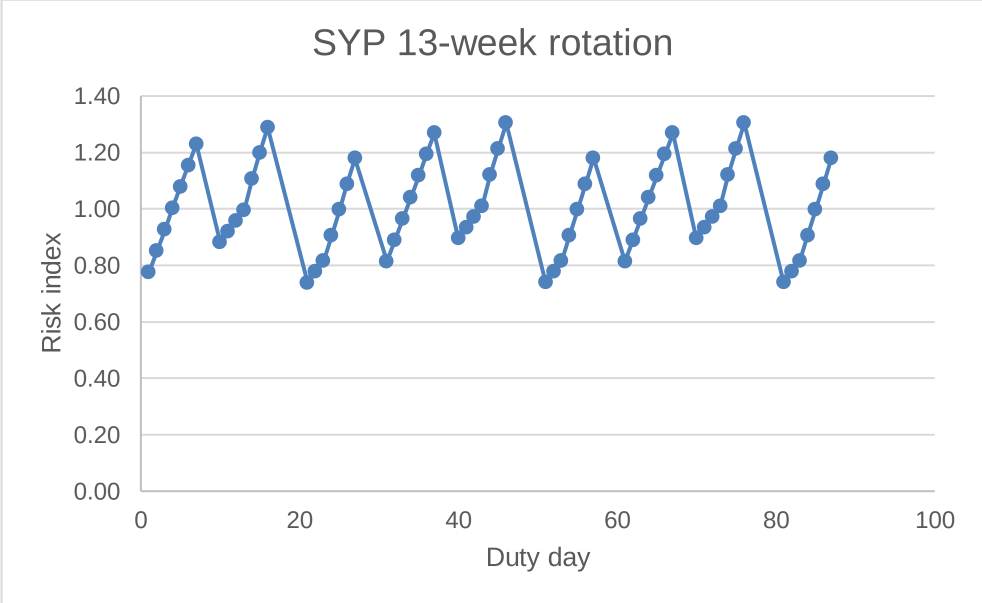

Figure 4.19 Risk indices for shift pattern followed by SYP

During the 4-week shift pattern followed by Humberside Police, the minimum risk index was 0.69, the mean risk index was 1.02 and the maximum risk index was 1.40. The fluctuation in risk indices throughout the shift rotation is shown in Figure 4.20.

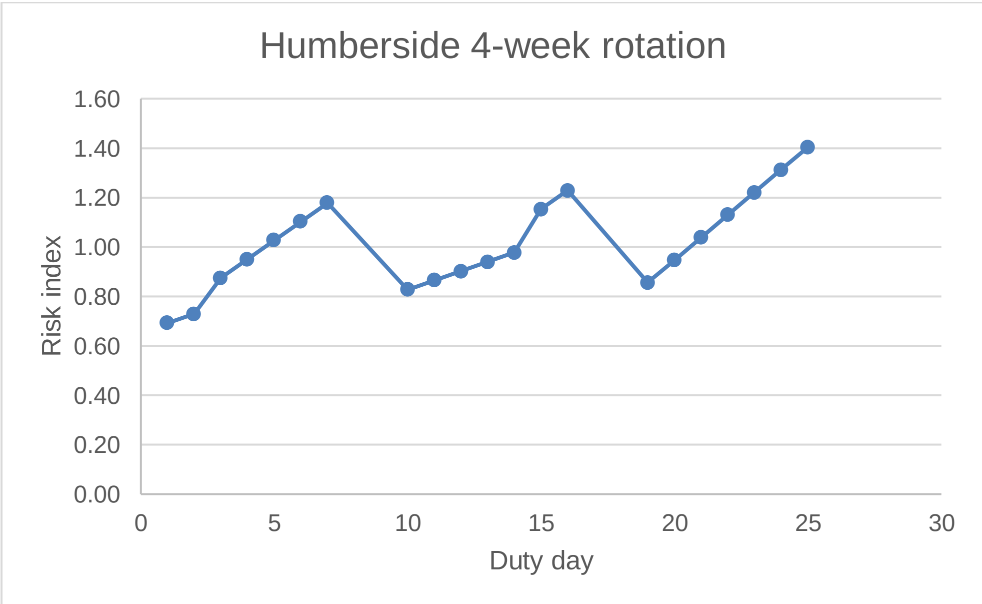

Figure 4.20 Risk indices for shift pattern followed by Humberside

During the 5-week shift pattern followed by West Yorkshire Police, the minimum risk index was 0.75, the mean risk index was 0.99 and the maximum risk index was 1.35. The fluctuation in risk indices throughout the shift rotation is shown in Figure 4.21.

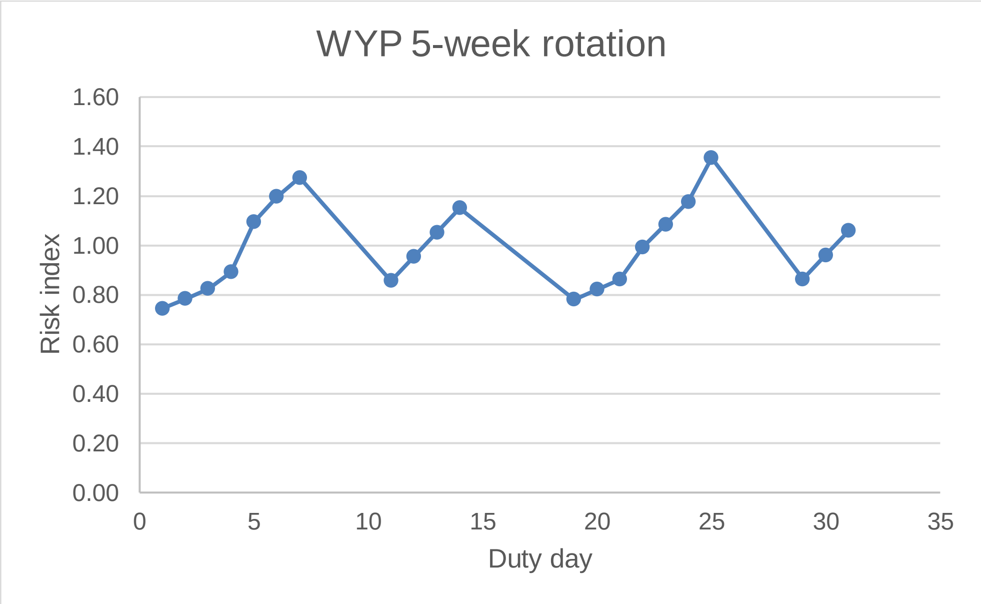

Figure 4.21 Risk indices for shift pattern followed by WYP

When considering Risk Indices alone, this therefore indicates that the shift pattern followed by North Yorkshire police produces the lowest mean risk index. In comparison with the baseline shift pattern for calculating risk indices, of a two day, two night, four off, 12 hour schedule, where shift start at 0800 or 2000 hours, this indicates that the shift patterns followed by North Yorkshire, and West Yorkshire produce slightly lower mean scores; the shift pattern followed by South Yorkshire Police provides the same score; and the shift pattern followed by Humberside Police is the only one to produce a very slightly higher mean score. When considering the maximum scores, this was again shown in the shift pattern followed by Humberside police. The lowest, mean and highest RI scores for each of the four forces are shown in Table 4.9. Humberside Police showed the greatest variability between the lowest and highest scores.

Table 4.9 Risk Index scores

	NYP	SYP	Hum	WYP
Lowest	0.73	0.74	0.69	0.75
Mean	0.97	1	1.02	0.99
Maximum	1.22	1.3	1.4	1.35

4.5 Discussion and conclusions

This study aimed to investigate shift patterns, commuting behaviour and fatigue-related road traffic incidents amongst police employees in the YatH region, by focussing on the specific research questions stated at the beginning of this chapter, which were;

RQ1: To what extent is driver fatigue identified as an issue by officers and staff in the UK police service?

RQ2: In accordance with Home Office guidelines, and Fatigue and Risk Indices, what shift pattern is deemed most acceptable amongst those followed by this particular group of shift workers?

RQ3: What is the likelihood of a driving incident occurring, depending on the shift pattern followed?

RQ4: Are driver-related countermeasures utilised and are they effective in relieving fatigue?

RQ5: How does commuting and commuting time impact on incidents reported?

This study was open to all employees of the YatH region. Nationally, the latest figures from October 2018 show that civilian police staff members make up 39% of overall police employees (Allen and Zayed, 2018). Police staff members made up only 5% of participants in this study. Police staff are not represented by the Police Federation but can be members of alternative staff unions. As the questionnaire was distributed by means of email invitation, word of mouth, and with the assistance of the Police Federation, it may not have been widely publicised amongst civilian staff colleagues, which may explain the low level of responses from that particular cohort.

In line with the first research question, one purpose of the study was to identify the extent to which police employees reported fatigue whilst commuting to and from their place of work. The results from this study indicated that 86.5% of the police officers and staff who responded to the questionnaire reported recalling feeling sleepy on occasions, whilst travelling to and from work. However, it is encouraging that they are self-identifying driver fatigue and have reported it accordingly as part of this study.

This study also revealed a high prevalence of self-reported fatigued driving and road traffic incidents related to driver fatigue. In the twelve months preceding the questionnaire date, 5.8% stated they had been involved in a collision or road departure whilst travelling to or from work and 51.9% stated they had been involved in a ‘near miss’ incident such as a kerb strike, lane departure, or had almost had a collision. Of those who stated they had a ‘near miss’, 74.9% stated this had happened more than once. 95.7% of these happened whilst travelling home from work and 61.8% had been working a nightshift prior to the incident. The vast majority of self-reported incidents happening whilst travelling home after a night shift which indicates this is the time of highest risk. However, it remains to be seen, if any of these incidents are recorded as part of any work-based recording of near miss incidents. This is unlikely as organisations do not routinely collect and record this information. In addition, staff are perhaps somewhat reluctant to report such incidents in any formal capacity, and they are not forced to do so, if the incident does not result in damage, injury, or an otherwise reportable RTC. These incidents are a safety concern for serving officers and staff. In a similar study in the USA, it was found that 50% of police officers had fallen asleep whilst driving. In addition 25% of those reported it as a regular occurrence, one to two times per month (Rajaratnam et al., 2011).

Research question 2 addressed which shift pattern was deemed most acceptable amongst the four patterns followed by those participating in the study. The only shift pattern that complied with the recommendations from the Home Office, as mentioned in Chapter 3, (Home Office, 2004; Home Office, 2010), was that followed by North Yorkshire Police, which was the 2x2x2 pattern, shown in Table 4.1. However, this pattern had slightly shorter shift duration and reduced number of rest days, of only 3, as opposed to the 4 rest days that are usually seen with this pattern. The other shift patterns did not comply with the recommendations, as they regularly had more than six consecutive days on duty. In addition, the pattern followed by Humberside police had a week of night shifts in one block. Anecdotally, the author is aware that all forces have now changed the shift patterns, since the time when this study was conducted; however, two of the forces have changed to a 12-hour shift pattern, which is still contrary to Home Office guidance on shift rostering.

In addition, using logistic regression to assist with answering research questions 2 and 3, the data obtained identified that when compared to the West Yorkshire Police baseline, those who worked in North Yorkshire Police were almost twice as likely to report being involved in a driving incident; those who worked in Humberside Police were almost 1.7 times as likely to report being involved in a driving incident. This could indicate that the shift pattern utilised with West Yorkshire Police was favourable for this cohort and for the purposes of road safety and staff wellbeing, this was a preferable shift pattern, resulting in fewer road-related incidents. Again, this pattern was not one of those recommended by the Home Office, as discussed in the previous paragraph and in Chapter 3. This illustrates the favourable shift pattern amongst those involved in the study, and also that those working in West Yorkshire were less likely to be involved in a driving incident.

The calculated Fatigue and Risk Indices also contributed to identifying where one particular shift pattern may be preferable to another. The highest mean Fatigue Index was found in the shift pattern followed by West Yorkshire police, giving a score of 16.6. The highest maximum Fatigue Index was found in the shift pattern followed by Humberside police, giving a predicted score of 38.4. This suggests that there is a 38.4% chance that workers will be fatigued to an extent that they may struggle to stay awake on the particular shift providing that score. In addition, the highest Risk Index and maximum Risk Index were both found in the shift pattern followed by Humberside police. These were 1.02 and 1.4 respectively. This is partially in agreement with the findings of the logistic regression, in that, in some respects, the pattern followed by West Yorkshire police is favourable. However, in the logistic regression model, the pattern followed by North Yorkshire police indicated those participants were twice as likely to be involved in a driving incident, when compared with West Yorkshire, but the results of the Fatigue and Risk Indices for North Yorkshire, indicated in many respects that there was less likelihood of an incident occurring. Consideration needs to be given that in all shift patterns followed in this study, the day started at 0700 hours, when compared to the 0800 hours start time for the shift pattern setting the baseline for the Fatigue and Risk Indices.

When combining results from the logistic regression and likelihood of having a driving incident, with the maximum FI and RI figures calculated, this identified that those who followed the shift pattern adopted in Humberside police were more likely to be involved in a driving incident, when compared with WYP. In addition, the shift pattern in Humberside indicated the highest maximum indices for both

FI and RI. Conversely, NYP, with the highest likelihood of a driving incident occurring, had the lowest figures for FI and RI. This is shown in Table 4.10. As mentioned above, in relation to research question number 2, at the time of this study, NYP followed a forward rotating shift pattern, shown in Table 4.1. This was unusual, in that shift duration was slightly shorter, and only 3 rest days were provided at the end of each cycle. This pattern had been altered slightly prior to the commencement of the second study, to provide 4 rest days, each cycle.

Table 4.10 Likelihood of driving incident, FI and RI

Force / shift pattern	Likelihood of driving incident (Exp(B))	Maximum FI	Maximum RI
NYP	1.991	31.1	1.22
SYP	Not significant	34.3	1.3
Humberside	**1.695**	**38.4**	**1.4**
WYP	Baseline	36.6	1.35

In relation to research question number 4, the logistical regression analysis showed that those who used behavioural technique countermeasures were almost twice as likely to be involved in an incident than those who did not. This perhaps suggests that those using countermeasures, recognised their own fatigue and were trying to mitigate this. Participants tried to mitigate this in a number of ways as previously discussed; however only 3.7% stated they found their most preferred countermeasure completely effective. This tends to suggest that use of these countermeasures was not effective and this agrees with previous findings of other researchers in laboratory studies (Horne and Reyner, 1996; Horne and Reyner, 1999). As sleep is the only efficient countermeasure to fatigue (Nguyen et al., 1998), it may well be that those who indicated that they stopped the vehicle and took a nap, were the only ones to find use of a countermeasure effective.

The duration of prior wakefulness, working during the circadian nadir (Åkerstedt and Wright Jr., 2009) and insufficient sleep during the day (Lambert and Huffcutt, 2000; Rogers et al., 2001) have been shown to increase sleepiness for night shift workers. Rogers et al. (2001) found that 12-hour night shifts and commuting times of over 35 minutes resulted in increased sleepiness and impaired driving performance. In addition, Åkerstedt et al. (2005) found that there was an increase in collisions and lane drift amongst those driving home following a night shift.

Results in the present study showed that those with longer commutes were more likely to report having been involved in an incident. This assists in answering research question number 5 and supports the previous findings, along with those of Di Milia et al. (2012), who also found that night working and long distance commuting were associated with impaired driving performance. Of course, longer commutes also extends the time awake, which has also been found to increase the risk of sleep-related vehicle crashes (Stutts et al., 2003).

No significant findings related to age, gender or police driving qualifications were found in this study.

There may be limitations in the study, such as recollection of events, when asking participants to recall events up to (and in some cases) beyond 12 months prior. Some participants may also have been wary of reporting events, despite assurances around the confidentiality and independence of the study from any particular organisation. Conversely, participants may have had a particular interest in the topic, or may have taken part due to having particular difficulties with driver fatigue themselves. No face to face interviews were conducted and all participants were in a position to remain anonymous, unless they chose to identify themselves via the additional comments section, or email to the author.

In conclusion, the results of this study support the hypothesis that participants would report difficulties with fatigue whilst commuting, particularly following night shifts or extended shifts. The study was successful in terms of answering the research questions and understanding the extent to which police employees sometimes struggle with tiredness and fatigue whilst commuting, particularly following nightshifts or extended working hours. It identified that driver fatigue was a problem for this group, particularly whilst commuting to and from work, and that there were many fatigue-related incidents that occurred, that would not ordinarily have been reported in either records held by individual police forces, or official road safety figures. It also provided evidence that drivers participating in this study were aware of their own fatigue. However, despite the awareness, and the recognition that countermeasures were not overly effective, the participants did little else to take action regarding this potential road safety issue. This is an important aspect in relation to future education and training, and improving road safety, with regard to planning journeys.

The second study, described in Chapter 5, moves on to explore sleep duration, sleeping patterns and cognitive performance in police officers and civilian staff, during a forward rotating shift pattern.

Chapter 5
Study 2: The Effects of Fatigue on Cognitive Performance in Police officers and Staff During a Forward Rotating Shift Pattern

This chapter explores differences in sleeping patterns and cognitive performance at varying stages of a forward rotating shift pattern, followed by many police forces in England and Wales.

5.1 Introduction

Disturbed sleep is perhaps the major outcome of shift work (Axelsson, 2005) and working nightshifts has been shown to reduce average sleep by around 2 hours in any 24-hour period, compared to the average sleep recorded for those working during the day (Torsvall et al., 1989).

Sleep deprivation or fragmentation, such as that found in shift workers, is also shown to affect cognitive performance (Bonnet and Arand, 2003; Goel et al., 2009) and is also thought to be associated with increased driver impairment and increased risk of collision (Jackson et al., 2013). Driving is a complex task involving divided attention, utilising a number of physical and mental processes and it has been argued that any assessments to illustrate differences in driving performance due to fatigue, need to be reliable indicators of those wakeful functions that are affected by lack of sleep (Jackson et al., 2013).

A variety of cognitive tasks have been used to demonstrate the impact a lack of sleep has on cognitive performance (Alhola and Polo-Kantola, 2007) and aspects of driving (Lamport et al., 2016), and to study the effects of fatigue. These tasks normally test the participant's working memory, visual attention, psychomotor speed, shape perception and praxis processes for conducting movements related to the control of the vehicle. Previous research has shown that performance on these tasks is noticeably susceptible to sleep loss, with some individuals more susceptible than others (Goel et al., 2009; Killgore, 2010). These cognitive domains are associated with risk of collision whilst driving, and previous research has shown a good correlation between performance on the tasks and driving performance with lower scores in the simulated tasks being associated with higher collision risk (Arnedt et al., 2005). As such, there has been an increase in demand for batteries of tests to utilise in this context as research in this field grows (Gur et al., 2010). A driver needs to be in a position to analyse what they see, process information quickly and accurately, in order to react appropriately to unfolding events; test batteries provide a safe alternative to on-road testing of fitness to drive in a variety of situations (McKenna, 1998).

As outlined in Chapter 4, a study of 523 police officers and staff, working a variety of shift patterns in the YatH region, identified feelings of fatigue to be particularly prevalent for commutes to and from work, (Taylor et al., 2014). In brief, 93.9% of participants indicated they travelled to and from work by car. In relation to collisions and 'near miss' incidents, 5.8% declared involvement in a collision or road departure, and 51.9% stated they had been involved in a 'near miss', incident. Of the total number of incident reported, 95.7% occurred during the commute home from work, and 61.8% were following a night shift. However, since this data was self-reported, a more objective study was conducted on a subset of participants, to explore this area further.

Given these numbers of reported incidents in Chapter 4, particularly following a night shift, the study reported in this chapter aimed to identify if cognitive performance and vigilance was affected at these relevant times. It was hypothesised that these aspects of performance would vary for this sample of police officers and staff, being at its worst at the end of the shift, particularly the night shift, due to reduced sleep length, circadian rhythm effects and / or poorer sleep quality associated with night shifts.

5.2 Study aims

To date, only a few studies have examined the effects of shift work on police employee performance. One such study of 29 active-duty police officers in Washington, USA was conducted by, Waggoner *et al.*, (2012). The study consisted of a simulated drive, along with psychomotor vigilance tasks, conducted in a laboratory setting. The officers participated in 2 sessions during their normal duty roster. The first, was a post-shift condition, immediately following their last of 5 consecutive night shifts, and the other was in the morning, following 3 consecutive rest days. Psychomotor vigilance and driving performance were found to be significantly degraded following the 5 consecutive night shifts, when compared with the 3 consecutive rest days. The researchers concluded that police officers were susceptible to performance degradation as a result of working night shifts.

This chapter reports on an empirical study that investigated sleep duration, and cognitive performance and vigilance at the start and end of each shift within a three-shift, forward rotating shift pattern, common in United Kingdom police forces. At the time of writing, the shift pattern studied was followed by approximately 60% of territorial police forces in England and Wales.

The study sought to address the following research questions;

RQ6: What is the difference in sleep duration following the different shifts worked in a fast, forward rotating shift pattern, common in UK policing?
RQ7: Is there a difference in cognitive performance (measured using a standardised test battery) during different shifts, for police officers and staff working a fast, forward rotating shift pattern?

Sleep duration and cognitive performance of participants at various stages of the forward rotating shift pattern were therefore studied in order to answer the research questions.

5.3 Method

5.3.1 Participants

Twenty-three police officers and staff (n=18 officers, 5 staff) aged 31 to 54 (mean age 43, 21 males, 2 females) from North Yorkshire Police participated in this study. They were all recruited by means of an internet-based appeal for expressions of interest. Some of the participants (10) had previously participated in the study reported in Chapter 4, and had expressed an interest in participating in further studies. All participants had a full UK driving licence and drove to and from work. The police staff members worked in the control room, and although they drove to and from their place of work, they were not required to drive as part of their duties, whereas the police officers were required to drive during duty times. Five of the police officers held a standard police driving qualification and 13 held an advanced police driver qualification. Twenty-six percent (26%) of participants had a commute of over 30 minutes duration, each way.

5.3.2 Shift Pattern

All participants followed a three-shift, forward rotating shift pattern as shown in Table 5.1. The shift pattern in North Yorkshire Police had changed from a '6 on, 3 off' pattern (as shown in Table 4.1), to a '6 on, 4 off' pattern, with slightly longer shift lengths, between the time of study 1 and study 2 being conducted. Shift length and start time varied by weekday, due to predicted demand for service from the public. The shift pattern consisted of;

- two day shifts, beginning at 0700 hours,
- two afternoon shifts, beginning at either 1400, 1500 or 1700 hours (depending on day of the week and particular role of participant),
- two night shifts, beginning at 2200 hours, followed by four days off.

This was a constantly repeating 10-day pattern for participants, where, following the four days off, all officers and staff returned to the same working pattern. Ordinarily, following this pattern, all shifts varied in length from 8 to 10 hours. An additional training day, beginning at 0830 hours and of 9 hours' duration, is also incorporated in the pattern, once every 10 weeks.

Table 5.1 10-week forward rotating 2x2x2 shift pattern

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1	Day	Day	Afternoon	Afternoon	Night	Night	Rest Day
Week 2	Rest Day	Rest Day	Rest Day	Day	Day	Afternoon	Afternoon
Week 3	Night	Night	Rest Day	Rest Day	Rest Day	Rest Day	Day
Week 4	Day	Afternoon	Afternoon	Night	Night	Rest Day	Rest Day
Week 5	Rest Day	Rest Day	Day	Day	Afternoon	Afternoon	Night
Week 6	Night	Rest Day	Rest Day	Rest Day	Rest Day	Day	Day
Week 7	Afternoon	Afternoon	Night	Night	Rest Day	Rest Day	Rest Day
Week 8	Rest Day	Day	Day	Afternoon	Afternoon	Night	Night
Week 9	Rest Day	Rest Day	Rest Day	Training	Day	Day	Afternoon
Week 10	Afternoon	Night	Night	Rest Day	Rest Day	Rest Day	Rest Day

5.3.3 Measures

To understand the relationship between shift pattern and its effect on fatigue, diurnal preferences (chronotype) were recorded by means of the self-assessment Horne and Ostberg Morningness-Eveningness Questionnaire (Horne and Östberg, 1976), and objective and subjective levels of sleep were measured using actigraphy and sleep diaries. Utilising both actigraphy and sleep diaries has been shown to produce more reliable data (Calogiuri et al., 2013). In addition, participants were required to complete a series of computer-based tests measuring vigilance and cognition, at designated times during their shift. Each participant was involved in the study for one complete 10-day cycle of shifts.

5.3.3.1 Chronotypes

Participants were required to complete the 19 question Morningness-Eveningness, self-assessment questionnaire (MEQ) developed by Horne and Östberg, (1976), in order to identify diurnal preferences that may indicate sleep time tendencies or performance variation on different shifts (Alward, 1988).

The MEQ was selected for use, as it is free to use, with instant results upon completion of the questionnaire. In addition, it is reportedly the most widely used measure (Adan et al., 2012), with many studies reporting on reliability (Adan and Natale, 2002).

5.3.3.2 Sleep Duration

In order to record their activity and sleep / wake patterns, participants wore an actigraphy type, iHealth (iHealth Labs Inc, n.d.) watch device, as shown in Figure 5.1, on their non-dominant wrist for the ten-day period. They were required to wear the watch for the duration of the study, with the exception of bath or shower times, or charging necessity.

Figure 5.1 iHealth watch (iHealth Labs Inc, n.d.)

The iHealth watch can be easily switched between active and sleep mode, by the touch of a button, to distinguish between time awake and when a participant has a prolonged period of inactivity. It is capable of measuring time asleep, sleep efficiency, daily activity and calories burned. This study was only concerned with time asleep. The data are downloaded to the iHealth 'app' for storage, examination and presentation, allowing data to be compared on a day-to-day basis. As outlined in section 2.3, a number of studies have been conducted utilising actigraphy. In general, the use of such devices were found to be useful in examining night-to-night variability of sleep (Ancoli-israel et al., 2003; Martin and Hakim, 2011).

5.3.3.3 Sleep Diary and Incident Report

Participants were required to complete a sleep diary and also provide other information such as alcohol and caffeine consumption or medication taken. They were also asked to note any driving incidents, including nodding at the wheel, a near miss incident or a kerb strike, that occurred during the ten-day period. The sleep diary was adapted from the American Academy of Sleep Medicine diary (American Academy of Sleep Medicine, n.d.) to suit the 10-day shift cycle. Participants were asked to keep the diary with them at all times, during both work and rest days, providing a subjective account of sleep duration, activity, stimulant, medication and alcohol consumption and any driving incidents. The adapted sleep diary is included at Appendix B.

A combination of both actigraphy and subjective methods were utilised for recording sleep and wake times. The reasons for this are as outlined in section 2.3: actigraphy is well tolerated, can be used over several days to examine variability in sleep, and is a satisfactory tool when used in conjunction with subjective measures. The subjective sleep diary and incident report allowed comparison between self-reported methods of sleep duration, with that recorded by actigraphy. It also allowed recording of any consumption of alcohol, medication and caffeine, along with any driving incidents.

In addition, polysomnography was not an option, as the researcher did not have access to a sleep lab, and this would have taken the participants away from their usual home life and work / rest habits, which was undesirable and impractical in this case.

5.3.3.4 Cognitive and Vigilance Tests

In order to explore the cognitive domains said to be utilised in the driving task and to be affected by sleep deprivation, a test battery incorporating tests analysing attention, working memory and visuomotor skills was selected for this study. These tests allowed comparison of performance on the cognitive and vigilance tasks during the different shifts. Participants completed a selection of tests, as close to the beginning and end of each working shift as possible. This was done for each of their six working shifts, during one complete 10-day shift and rest rotation. They were also required to complete the tests at the beginning of the first day shift on their return from rest days. Therefore, each participant completed the test battery on thirteen separate occasions, as shown in Figure 5.2. However, they did not complete these tests on rest days, as this study was only concerned with investigating their performance at the beginning and end of each shift worked. Conducting the tests at the beginning and end of the different shifts also ensured that they were conducted at a time as close as possible to the participant’s commute period.

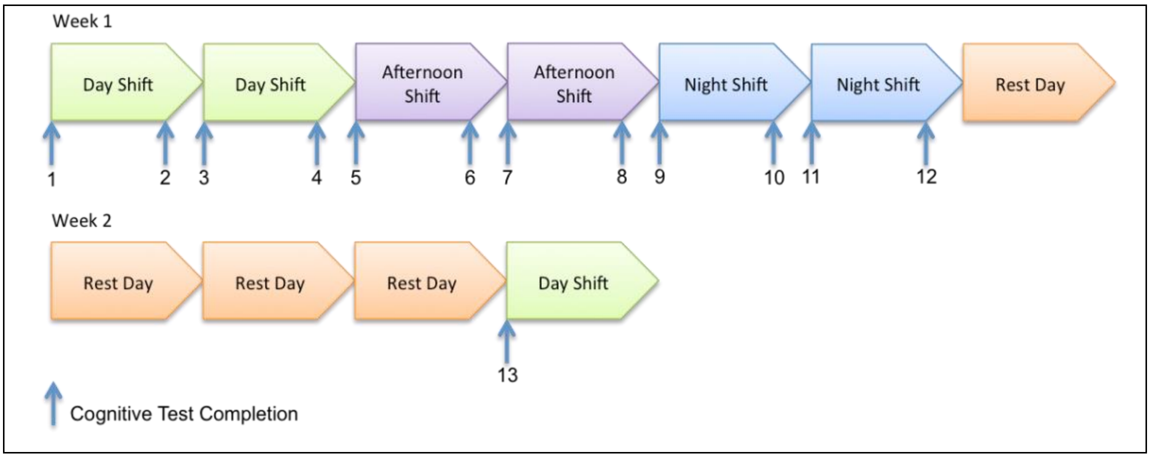

Figure 5.2 Cognitive test completion schedule (completed 13 times)

The tests were presented to participants on an iPad, using a neuro-behavioural assessment tool called Joggle Research. This programme provided the researcher with instant access to results through a secure web-based interface. A battery of five tests, all of which have previously been used to conduct research on fatigue, vigilance or cognitive impairment, as discussed below, was selected to examine reaction time as a proxy for adeptness in these tasks. The five tests utilised were as follows;

1) The Motor Praxis Task (MPT) tests psychomotor speed and visual tracking. It requires participants to quickly touch a series of blue boxes as they appear on the screen (see Figure 5.3). The boxes move around the screen and reduce in size on each occasion. A similar motor processing speed task was utilised by Gur *et al.* (2010) in their Mouse Practice task, as part of a test battery to explore individual differences in cognitive processing. The results obtained supported the use of the test battery in neurocognitive impairment research.

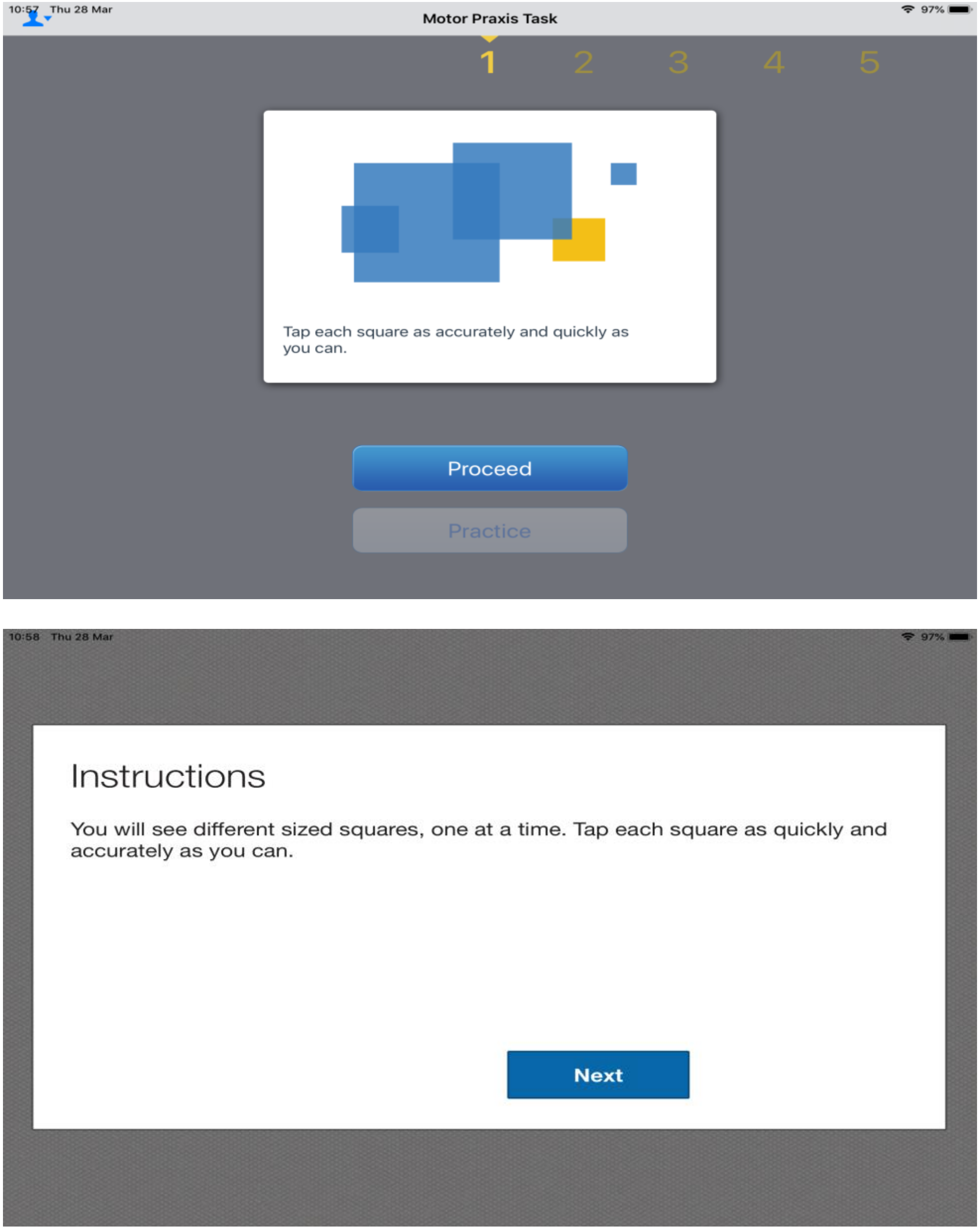

Figure 5.3 Introduction and instruction displays from the MPT

2) The Visual Object Learning Task (VOLT) tests working and visual spatial memory. It consists of a learning phase and a recall phase. The learning phase requires participants to memorise ten different sets of 3-dimensional shapes as they are displayed on the screen, one at a time. The display shapes are visible to the participant for 5 seconds each, with a 0.4 second interval between different shapes. When the recall phase begins, participants are shown twenty, 3-dimensional shapes, consisting of the 10 shapes they have seen previously and 10 alternative shapes. They are then required to recall if they have seen a particular shape before. Participants must select one of four answers during the

recall phase indicating if they have seen the shape before. The options given were 'definitely yes', 'probably yes' (seen before) and 'probably no', 'definitely no' (not seen before). The task is participant paced and they are required to respond as quickly as possible. The images do not advance until the participant has selected an answer (see Figure 5.4). McKenna *et al.* (2004) utilised a similar Shape Perception task as part of a test battery, in a study of participants with various neurological conditions, to identify those who were unsafe to drive. In their study, McKenna *et al.* (2004) concluded that these types of test can be used to inform decisions relating to driver safety.

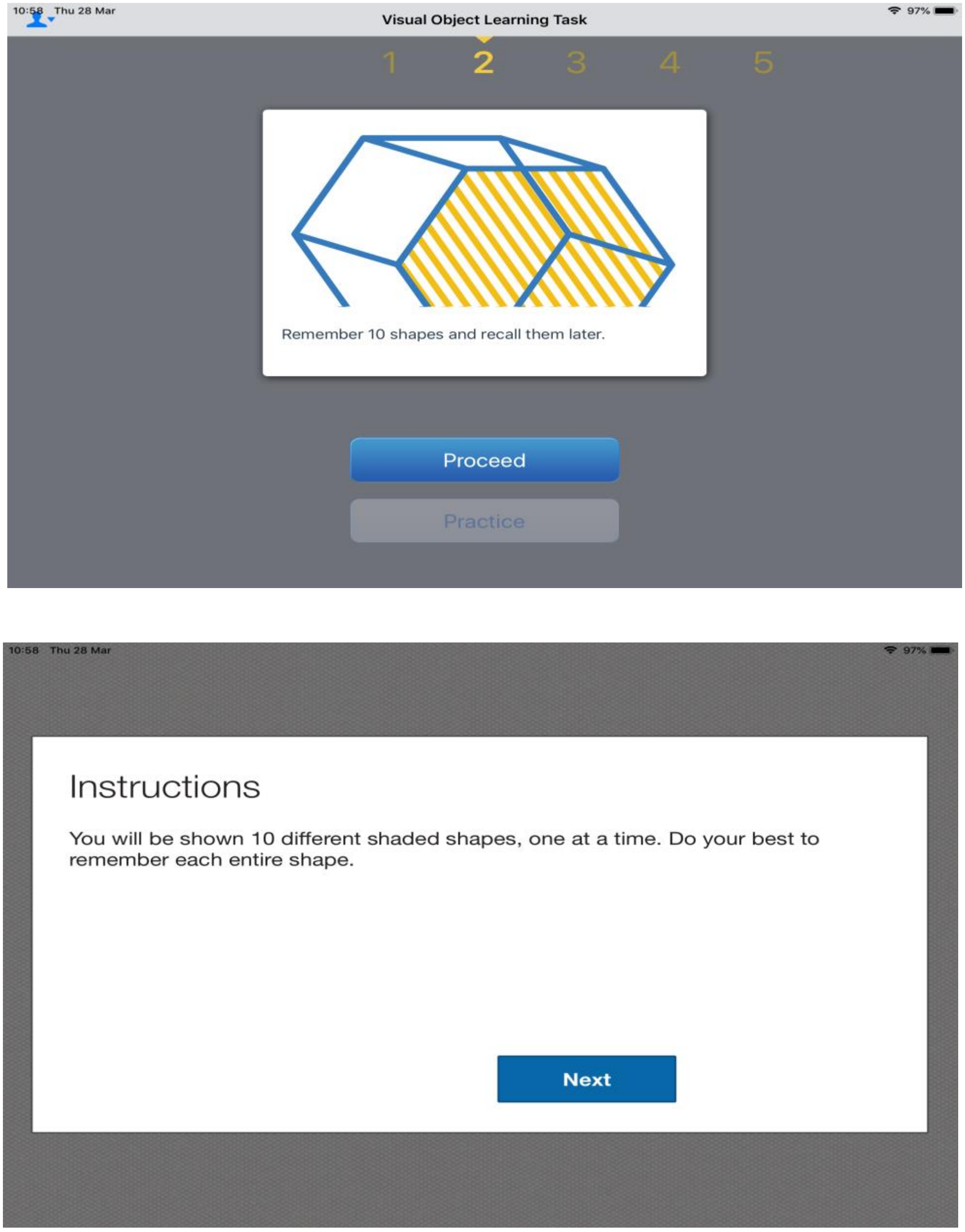

Figure 5.4 Introduction and instruction displays from the VOLT

3) The NBACK task tests attention and working memory. It takes a number of forms, where stimuli are presented as sounds or visually (digits, shapes or letters). For this test battery, it involved the presentation of one abstract image at a time that participants were required to identify ‘n’ trials ago (in this case, 2 images previous). The images proceed at a pre-defined timed sequence and continue to the completion of the task, irrespective of participant interaction. In this study, the image was displayed to the participant for 0.75 seconds with a 1 second gap between displays (see Figure 5.5). A visual NBACK task was used by Smith et al. (2002), to examine the impact of sleep loss on working memory. Healthy adult participants were moderately sleep deprived in a laboratory setting and were found to respond more slowly and make more mistakes. This becomes problematic during the driving task, when a fatigued driver may not react quickly enough, or indeed may not react at all, to events unfolding in front of them. This leaves them susceptible to causing a collision. A verbal NBACK task was used by Choo *et al.* (2005), who found that after 24 hours of sleep deprivation, performance and accuracy were negatively affected.

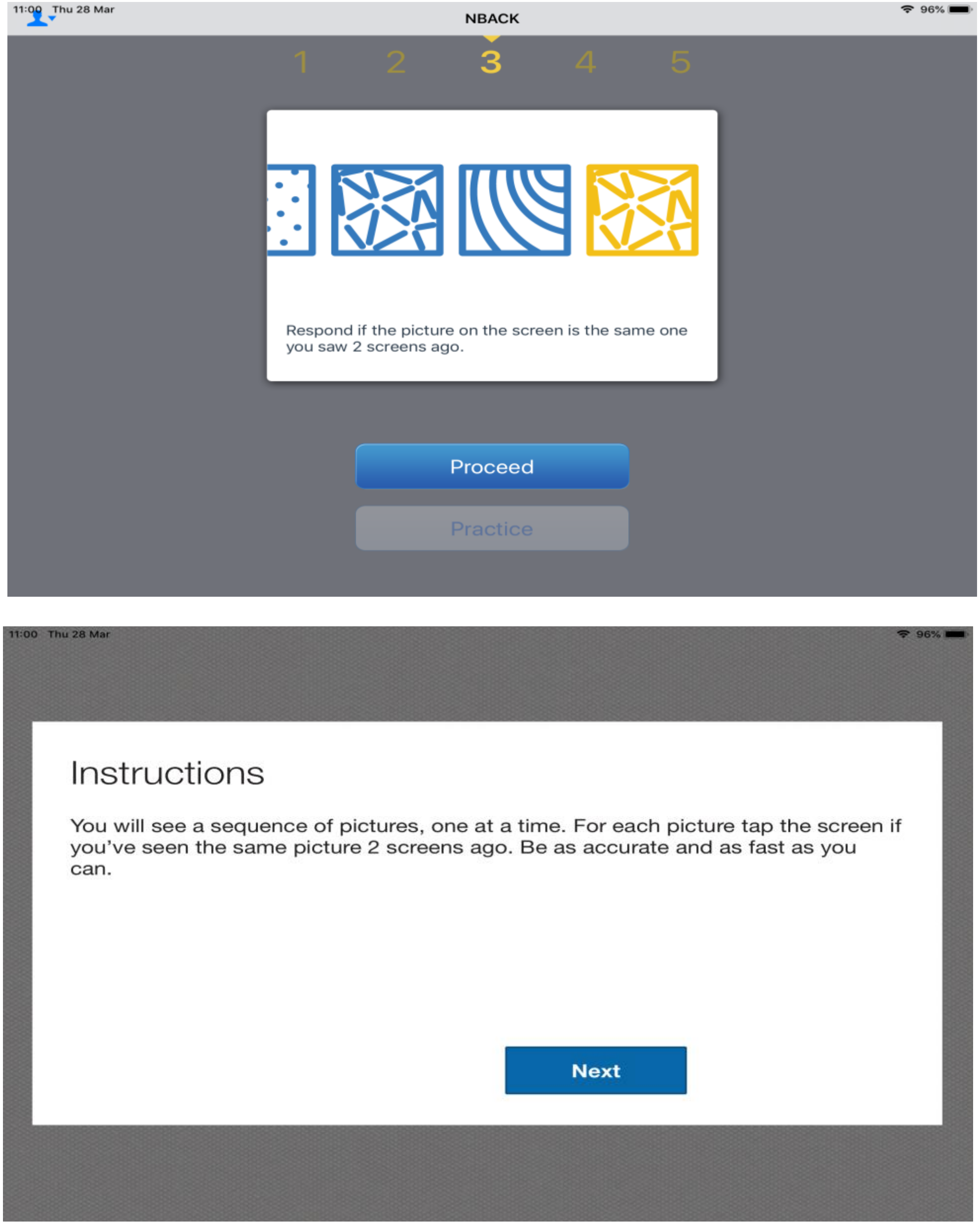

Figure 5.5 Introduction and instruction displays from the NBACK task

4) The Digital Symbol Substitution Task (DSST) tests attention, complex scanning and visual tracking. It requires participants to identify and select a symbol identical to the target symbol shown on the screen. The task has a pre-determined false start threshold of 0.1 seconds so any reaction time less than this value will not be counted as a valid response. It also has a time-out threshold of 5 seconds, whereby if a response has not been received within 5 seconds, the next stimulus is presented. The screens presented to the participants are shown in Figure 5.6.

DSST was used by Kosmadopoulos et al. (2017), in a study evaluating a number of tasks under sleep restricted conditions. The study found that performance in the task was adversely affected, and concluded that the impact of sleep loss on driving and neurobehavioural performance is more detrimental during the night.

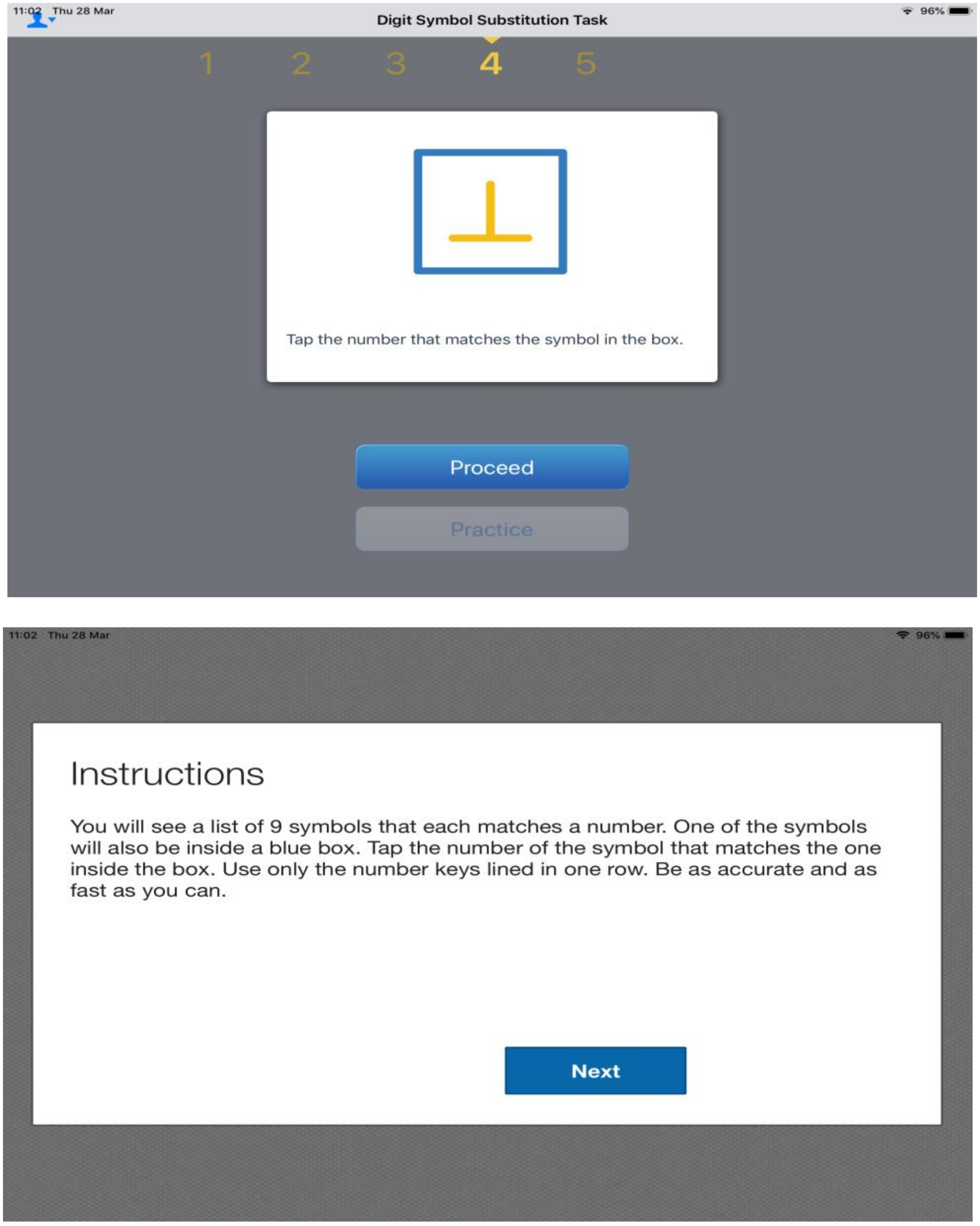

Figure 5.6 Introduction and instruction displays from the DSST

5) The Psychomotor Vigilance Test (PVT) measures psychomotor speed and vigilant attention and is among the most widely used task for alertness (Basner and Dinges, 2011). It is reportedly the most sensitive to sleep deprivation effects, is simple to perform and is the least prone to learning effects

(Transportation, 2000; Baulk et al., 2008). It requires participants to respond as quickly as possible to a visual stimulus appearing on the screen. A target box is displayed on the screen, inside which a millisecond timer appears. The participant touches anywhere on the screen as soon as possible after the stimulus appears. Their reaction time is displayed after each response. This test lasted approximately 180 seconds. Although traditionally a 10-minute task, shorter PVT tasks have been shown to provide a reasonable substitute (Roach et al., 2006; Basner et al., 2011). The screens presented to the participants are shown in Figure 5.7.

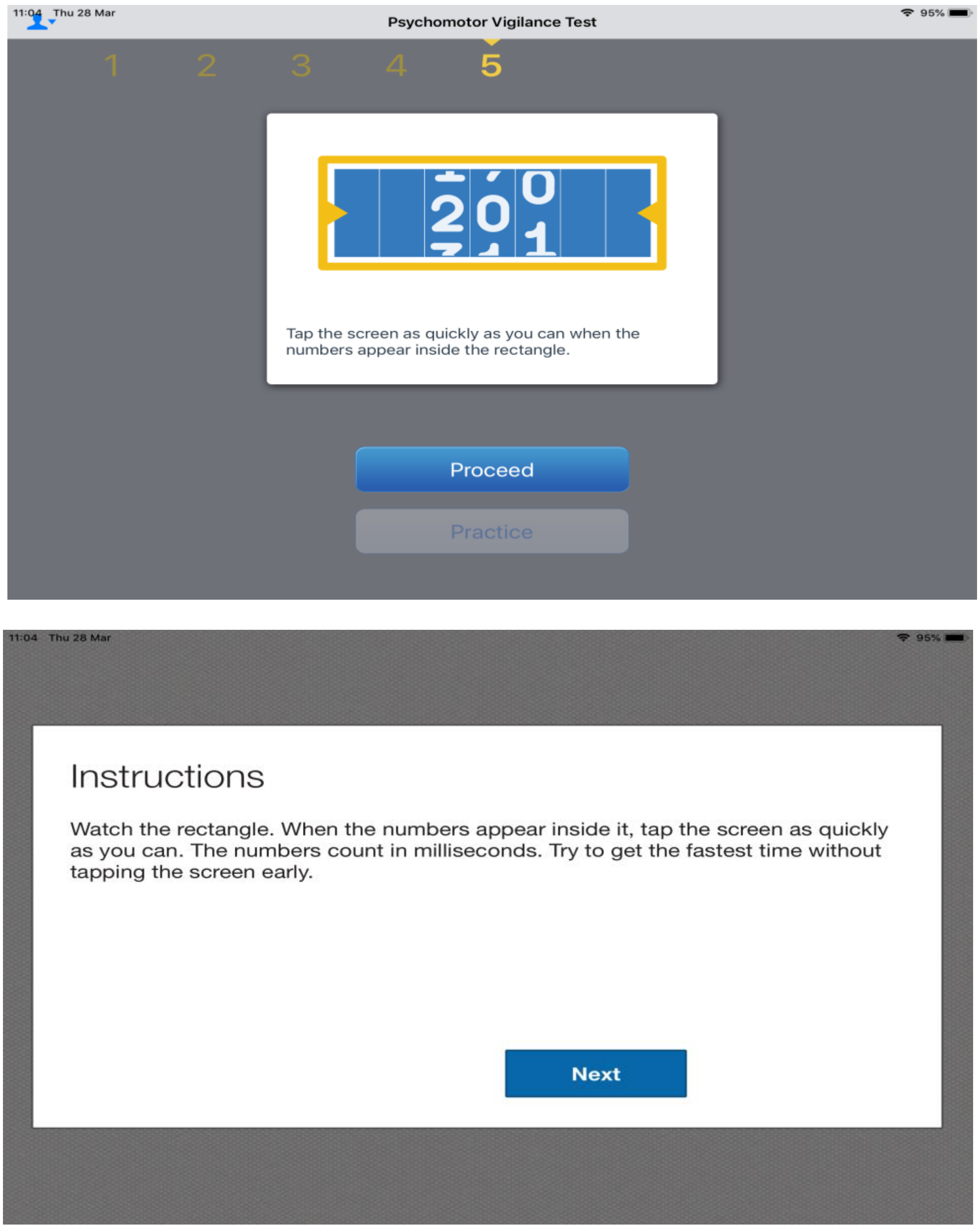

Figure 5.7 Introduction and instruction displays from the PVT

These tests, examining attention / vigilance, working memory and psychomotor skills, were chosen, as being important functions of the driving task, as described in section 2.5.

The tests were presented to the participants in the same order; however, stimuli for the Motor Praxis Task, Digital Symbol Substitution Task and Psychomotor Vigilance Test were presented in a random order. The Visual Object Learning Task and NBACK task consisted of preconfigured sequences. The complete test battery took less than 10 minutes to complete.

5.3.3.5 Fatigue and risk indices

As with the shift patterns in the previous study, Fatigue and Risk Indices were again calculated for the shift pattern followed by the participants in this study. Defaults were set to the same parameters as in Chapter 4, as follows;

Commute time: 30 minutes

Workload: moderately demanding, little spare capacity

Attention: most of the time

Breaks: every 5 hours

Length of break: 45 minutes

Longest period without a break: 6 hours

Length of break following longest period: 45 minutes

It must be remembered that there are natural variations and some of the above details can change day by day, due to the nature of the job. In addition, as previously outlined, whilst entitled to refreshment breaks, police officers do not always get regular breaks due to ongoing emergency calls and demand for service (Police Federation of England & Wales, n.d.).

5.4 Procedure

The study was conducted in the participants' own home and work environments. Each participant was first seen at their place of work at the beginning of the study, where they received a briefing and a printed information sheet providing sufficient information about the aims of the study and the procedures required. All participants were given the opportunity to practice the test battery and to familiarise themselves with the equipment. They were requested to keep to their usual routine for the duration of the study. All participants signed a consent form, agreeing to take part in the study. Participation in the study was completely voluntary and participants were free to withdraw at any stage. The study was approved by the Ethical Committee of the University of Leeds, under ethics reference AREA 14-040. Participants were again visited, for debrief purposes, at the conclusion of the study.

5.5 Design

This study used a repeated measures design. For the statistical analysis of the sleep data recorded by means of the iHealth watches, there were two Independent variables: Shift Type (with three levels: day shifts, afternoon shifts and nights shifts) and Shift Number (with two levels: shift number 1, being the first shift of each day, afternoon or night shift rotation and shift number 2, being the second such shift. The dependent variable was the total time spent asleep following each shift.

A repeated measures, within participant, design was used for the statistical analysis of the cognitive and vigilance tests, utilising the reaction time data collected during the tests. There were three independent variables: Shift Type (with three levels: day shifts, afternoon shifts and nights shifts), Shift Number (with two levels: shift number 1 and shift number 2) and Start / End (with two levels: start of shift and end of shift). The dependent variable for each test was mean reaction time of the participants for each test.

5.6 Results

5.6.1 Chronotypes

Twenty-one complete questionnaires were received. Standard scoring procedures were followed, with scores ranging from 16 to 86, where;

- 16-30 indicated a definite evening type
- 31-41 indicated a moderate evening type

- 42-58 indicated an intermediate type
- 59-69 indicated a moderate morning type
- 70-86 indicated a definite morning type

Scores of 15 participants indicated they were intermediate types and the remaining 6 participants were moderate morning types. This is not unusual amongst the general population, with Adan *et al.* (2012) stating, in their review of the literature, that 60% of the adult population are neither a distinct morning or evening type, but instead will be somewhere in the intermediate group.

5.6.2 Sleep Duration

Missing data from the iHealth watches was evident on occasions where the participant had forgotten to switch from sleep to wake mode, or vice versa, or where the battery had not been charged; however, this was minimal, amounting to 7% of overall data collected. One watch was damaged during the study, returning no data and rendering it unusable for any future studies, therefore analysis was carried out with data from 22 participants. Multiple imputation was conducted within SPSS to generate alternatives for missing values, providing a complete data set (Schafer, 1999; Alcock, 2005). The pooled output from multiple imputation estimated the results of the original data set, had that data not been missing. The only constraint set within the process was the minimum value set at zero for the imputations generated. This effectively meant that the minimum possible sleep duration was zero minutes.

Results showed that there was a main effect of Shift Type on hours slept, in the total sleep period (main sleep period, plus any nap duration), following each Shift Type, $F(2,42) = 21.740$, $p < .001$, $\eta^2 = .509$, with mean sleep times being 7.79 hours following a day shift, 7.29 hours following an afternoon shift and 5.62 hours following a night shift. There was no main effect of Shift Number, nor was there any interaction effect.

5.6.3 Sleep Diary / Incident Report

Eight of the 23 participants took advantage of ‘napping’ prior to either their first, second or both night shifts. Six of these naps were prior to the first night shift and only one participant had a nap prior to both night shifts. Two male participants (one police officer and one staff member) reported driving incidents during the study. These incidents, one each for both participants, consisted of nodding off at the wheel whilst driving. One of these incidents was between 1500 and 1600 hours on a rest day; the other incident was between 0700 and 0800 hours, during a commute home from a night shift.

There was nothing of note with regard to reported alcohol intake, medication or stimulant drinks consumed.

The mean self-reported sleep duration was 6.92 hours (SD = 1.90) whilst that recorded by the iHealth watch was 7.09 hours (SD = 2.13); a paired samples t-test confirmed there was no significant difference, $t(165) = 1.36$, $p = .175$, indicating that the objective and subjective methods of measuring sleep duration provided similar results. Furthermore, a Pearson product-moment correlation analysis showed a significant, positive relationship between self-reported sleep duration and the iHealth watch data ($r = 0.685$, $n = 166$, $p = .000$). Therefore, increases in self-reported sleep were accompanied by increases in sleep as reported by the objective measure. The mean sleep duration of participants, as recorded by the iHealth watches, across the 10-day period of one shift rotation is shown in Figure 5.8.

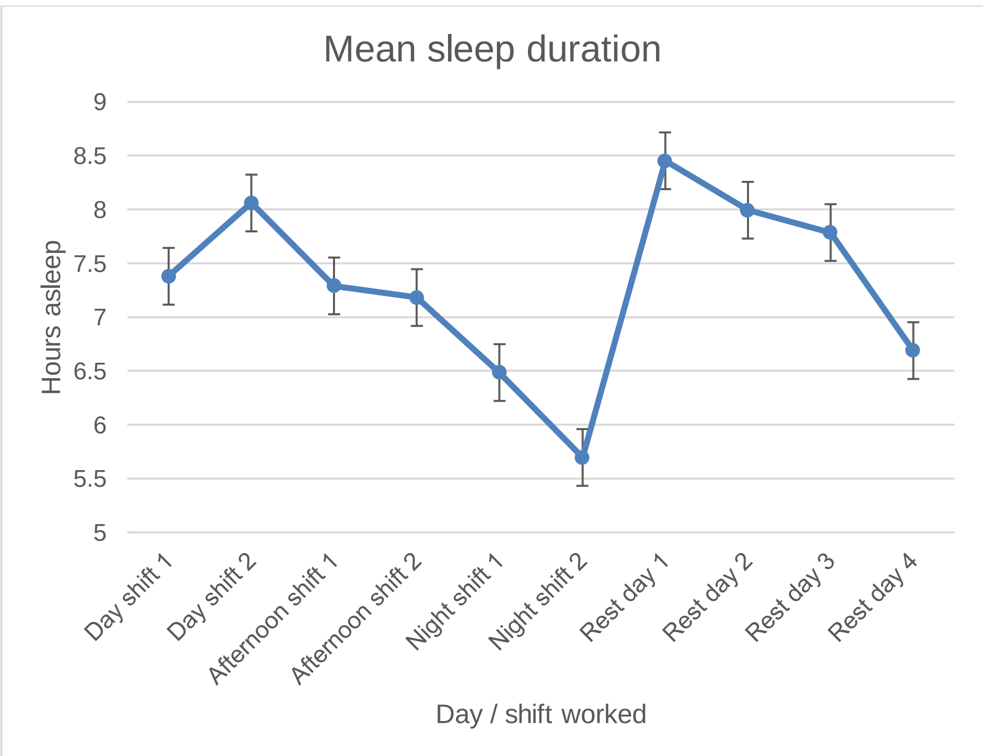

Figure 5.8 Mean sleep duration over 10-day shift cycle

5.6.4 Cognitive and Vigilance Tests

Missing data, amounting to 8% of the overall data collected, was evident in the cognitive and vigilance tests. This was due to operational reasons whereby, staff and officers, were immediately deployed to, or involved in, incidents at the beginning or end of their shifts, leaving them unable to complete the tests at the relevant times. There may also have been occasions when a participant simply forgot or otherwise omitted to complete them.

5.6.4.1 Motor Praxis Task (MPT)

There were no significant main effects of Shift Type, Shift Number or Start/End on reaction time for this task. However, there was a significant interaction between the Shift Type and the Start/End time, $F(2,44) = 7.630$, $p = .001$, $\eta^2 = .258$, this can be seen in Figure 5.9. Bonferroni post hoc comparisons showed that the mean reaction times were slower at the start of Shift Number 1 than at the end, but this was conversely so for Shift Number 2, suggesting some interaction between learning the task at the start of Shift 1 and boredom at the end of Shift 2.

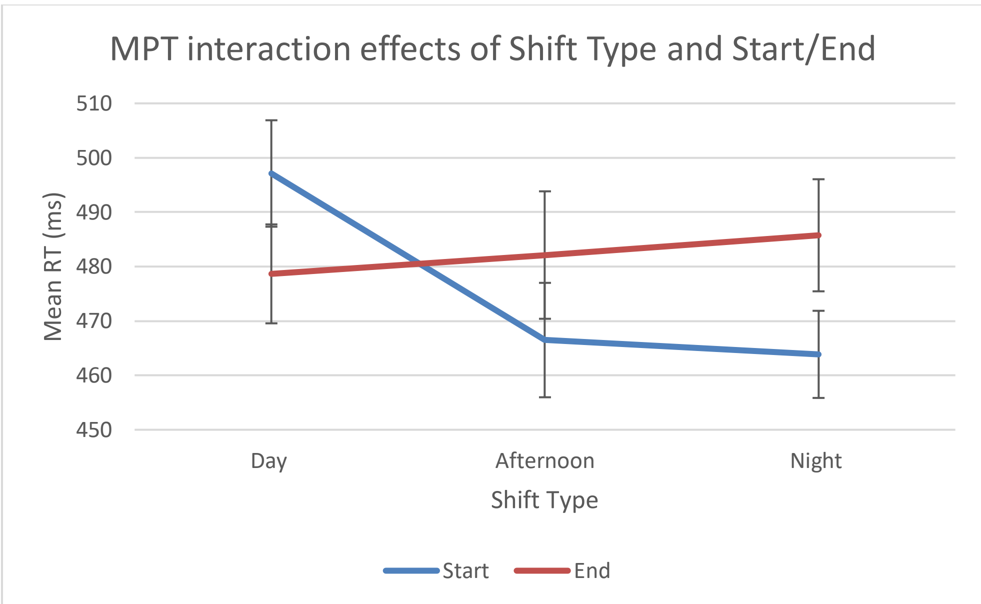

Figure 5.9 Interaction effects of Shift Type and Start/End of shift for the MPT

5.6.4.2 Visual Object Learning Task (VOLT)

Results showed that there was a main effect of Shift Type in the VOLT task, $F(2,44) = 29.907$, $p < .001$, $\eta^2 = .576$, such that reaction time was progressively faster moving from day to afternoon to night shifts. These results are perhaps counterintuitive to what was expected, with participants faster after the night shifts. There were no significant interaction effects for this task.

5.6.4.3 Number Back (NBACK)

There was a main effect of Shift Type in the NBACK task, $F(2,44) = 10.973$, $p < .001$, $\eta^2 = .333$, with faster responses seen following the afternoon shifts than the day shifts. This then slowed again for night shifts, but was still found to be faster on night shifts than it was on day shifts. Bonferroni post hoc comparisons showed that the significant differences were between the day shifts and afternoon shifts, and also between the day shifts and night shifts.

There was a significant interaction between Shift Type and Shift Number, $F(2,44) = 5.379$, $p = .008$, $\eta^2 = .196$. Bonferroni post hoc comparisons showed that significant effects were evident between both the day and night shift interaction, with Shift Number and the afternoon and night shift interaction with Shift Number. This interaction effect can be seen in Figure 5.10.

There was also a significant interaction between Shift Number and Start/End, $F(1,22) = 9.812$, $p = .005$, $\eta^2 = .308$, such that reaction time tended to become quicker between the start and end of the first shift and slower between the start and end of the second shift. This can be seen in Figure 5.11

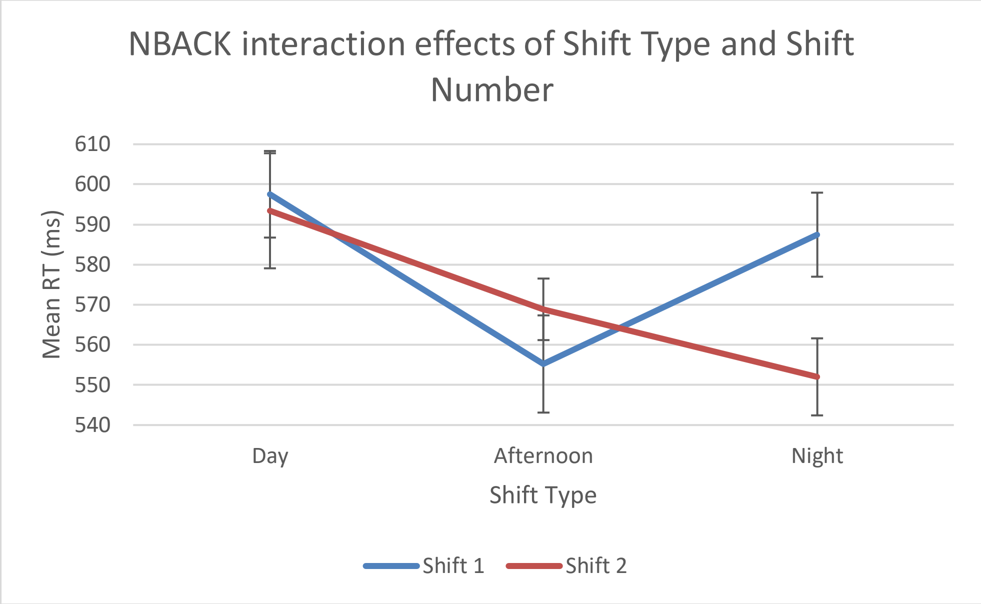

Figure 5.10 Interaction effects of Shift Type and Shift Number for the NBACK task

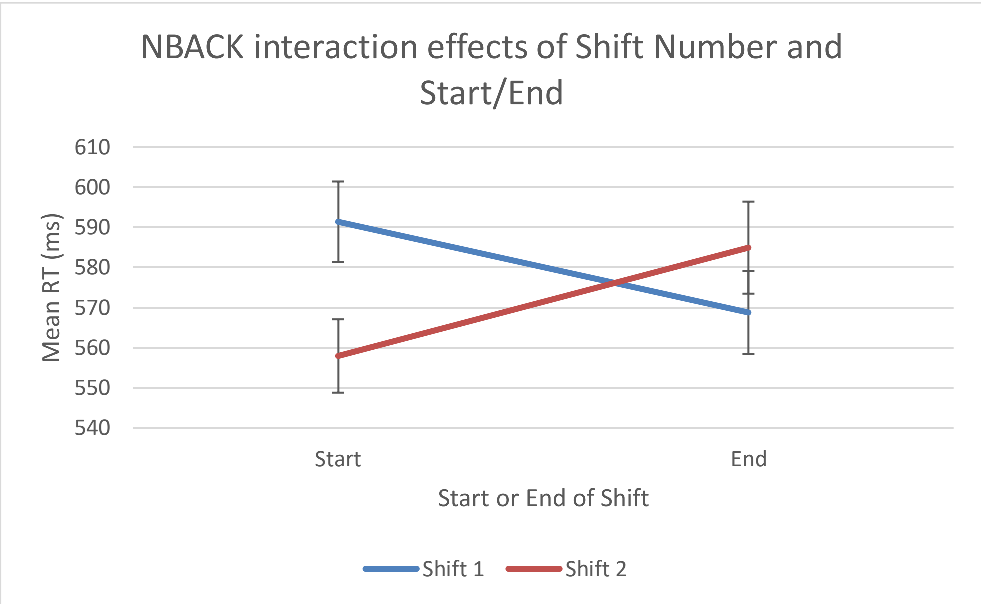

Figure 5.11 Interaction effects of Shift Number and Start/End of shift for the NBACK task

5.6.4.4 Digital Symbol Substitution Task (DSST)

There was a significant main effect of Start/End, $F(1,22) = 4.430$, $p = .047$, $\eta^2 = .168$, such that reaction time was significantly faster at the start of the shift, compared with the end of the shift.

There was a significant interaction between Shift Type and Start/End, $F(2,44) = 6.127$, $p = .004$, $\eta^2 = .218$. Bonferroni post hoc comparisons show that the significant differences were between the day shifts and night shifts. This interaction effect can be seen in Figure 5.12.

There was a significant interaction between Shift Type, Shift Number and Start/End, $F(2,44) = 4.930$, $p = .012$, $\eta^2 = .183$. Post hoc comparisons showed the significant differences were between the day shifts and night shifts, and also between the afternoon shifts and night shifts.

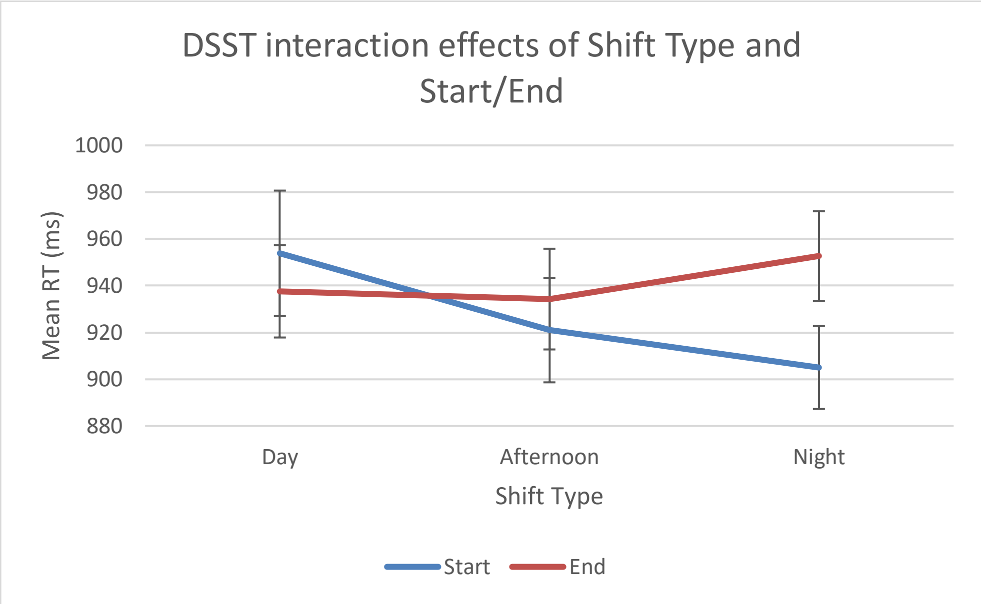

Figure 5.12 Interactions effects of Shift Type and Start/End of shift for the DSST

5.6.4.5 Psychomotor Vigilance Test (PVT)

The results for the mean reaction time (RT) for PVT indicated there were no significant effects for any of the main effects or interactions. However, further analysis was also conducted for the mean reciprocal RT (MRRT), mean of reciprocal of fastest 10% RT (MFRRT), median RT (MEDRT) and lapses (RT greater than 355 ms). Lopez et al., (2012) suggest that these additional RT measures are more normally distributed than mean RT. In addition, these additional measures are frequently reported in PVT outcomes (Basner and Dinges, 2011).

There was a significant main effect of Shift Type for MRRT, $F(2,44) = 5.091$, $p = .010$, $\eta^2 = .188$. Bonferroni post hoc comparisons show that the significant differences were between the day shifts and night shifts, such that reaction time was faster on nightshifts.

There was a significant main effect of Shift Type for MFRRT, $F(2,44) = 7.820$, $p = .001$, $\eta^2 = .262$. Bonferroni post hoc comparisons show that the significant differences were between the day shifts and night shifts, and also between the afternoon shifts and night shifts, such that reaction time was faster on day shifts than afternoon shifts, which in turn was faster than nightshifts.

There was a significant main effect of Shift Type for MEDRT, $F(2,44) = 5.792$, $p = .006$, $\eta^2 = .208$. Bonferroni post hoc comparisons show that the significant differences were between the day shifts and night shifts, such that reaction time was faster on day shifts than it was on night shifts. In addition, there was a significant main effect of Shift Number for MEDRT, $F(1,22) = 4.497$, $p = .045$, $\eta^2 = .170$.

There was a significant main effect of Shift Type for PVT lapses, $F(2,44) = 4.781$, $p = .013$, $\eta^2 = .179$. Bonferroni post hoc comparisons show that the significant differences were between the day shifts and night shifts, such that lapses were greater on night shifts.

A summary of PVT results is shown in Table 5.2.

Table 5.2 Summary of PVT results

Outcome	**Result**
Mean RT	Not significant
Mean 1/RT (MRRT)	Significant main effect of Shift Type
Fastest 10% of 1/RT (MFRRT)	Significant main effect of Shift Type
Median (MEDRT)	Significant main effects of Shift Type and Shift Number
Lapses	Significant main effect of Shift Type

5.6.5 Performance in relation to sleep duration

Consideration was also given to performance of all cognitive tests in relation to sleep duration, rather than shift worked. Analysis was conducted, taking into account recommended hours of sleep duration (7-9 hours), and less than recommended sleep duration (less than 7 hours). There were no instances of exceeding the recommended period of sleep, for the duration of the study.

No significant results were found, indicating that sleep duration did not significantly affect test performance.

5.6.6 Learning Effects

Participants completed the test schedule on thirteen separate occasions, as shown in Figure 2. It was hypothesised that the performance on occasions one and thirteen should be the same, as at both these times, participants completed the tasks after a 4-day rest period. In order to consider the effects of learning, results were compared from these two occasions and hypothesised that if learning effects were present, then reaction time on occasion thirteen would be quicker than that on occasion one. Results showed a significant difference for MPT, $F(1,22) = 7.748$, $p = .011$, $\eta^2 = .260$, VOLT, $F(1,22) = 23.626$, $p < .001$, $\eta^2 = .518$ and DSST, $F(1,22) = 12.655$, $p = .002$, $\eta^2 = .365$, with reaction time becoming faster, indicating that learning effects may have been present for these tasks. This was not observed for NBACK or PVT.

5.6.7 Fatigue and risk indices

Fatigue and Risk Indices were calculated for the shift pattern reported in this study. The results are shown below.

5.6.7.1 Fatigue indices

During the 10-week shift pattern followed by North Yorkshire Police, at the time of this study, 43 individual duty shifts were completed. During this period, the minimum fatigue score was 1.5, the mean fatigue score was 13.1 and the maximum fatigue score was 33.1. The maximum score indicates that there is a 33.1% chance that workers will be fatigued to an extent where they may struggle to stay awake on that particular shift. The fluctuation in fatigue indices throughout the shift rotation is shown in Figure 5.13.

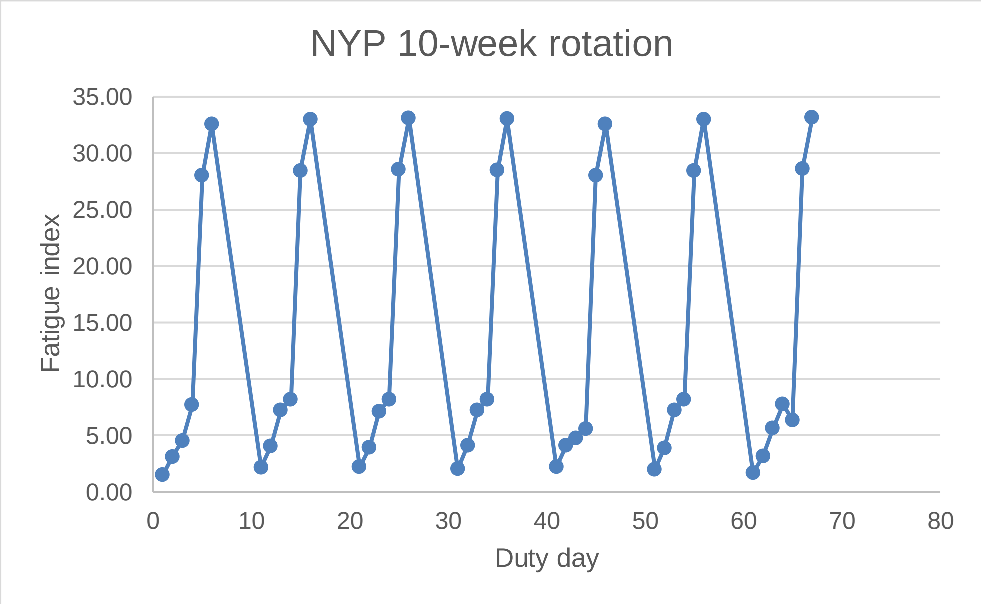

Figure 5.13 Fatigue indices for shift pattern followed by NYP

5.6.7.2 Risk indices

During the 10-week shift pattern followed by North Yorkshire Police, at the time of this study, the minimum risk index was 0.72 the mean risk index was 0.98 and the maximum risk index was 1.27. The fluctuation in risk indices throughout the shift rotation is shown in Figure 5.14

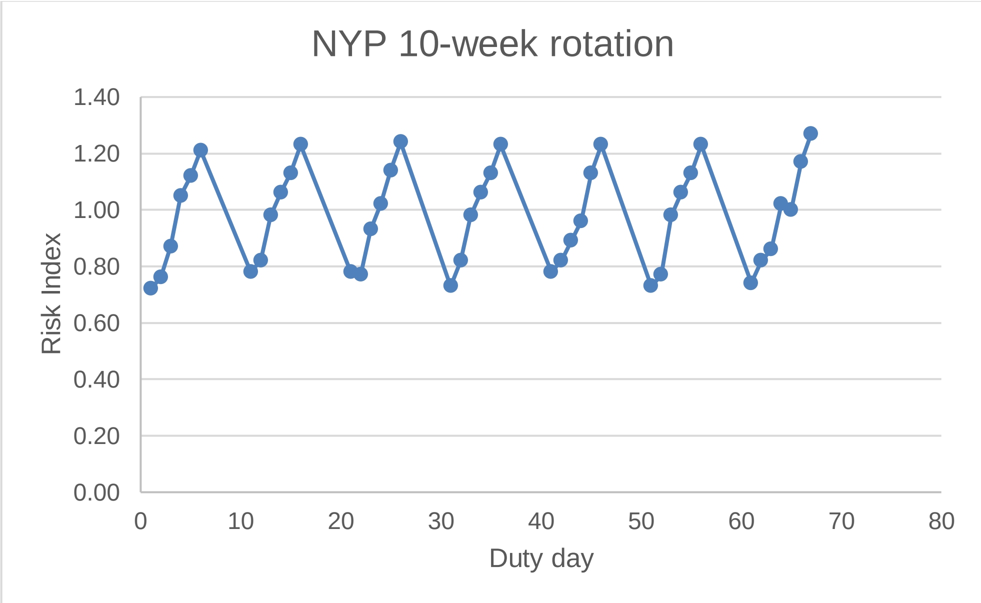

Figure 5.14 Risk indices for shift pattern followed by NYP

Fatigue and Risk Indices expectations were both shown to increase during the working shifts, being highest following the last night shift of each rotation, and dropping again during rest days. This does not ultimately concur with the cognitive test conducted in all cases, as cognitive test results were mixed with some demonstrating that RT was faster following night shifts.

5.7 Discussion and conclusions

This study sought to investigate how variations in sleep during a forward rotating shift pattern affect performance on a number of cognitive and vigilance tasks, completed by 23 police service employees. Data collection was conducted in the participants' regular workplace and at home, utilising a combination of sleep and incident diaries, actigraphy and a cognitive test battery. Participants were serving police officers and staff who were working their normal duty shifts. The main aim of the study was to establish how sleep pattern and shift type affected participants' performance on the test battery during their working hours and commute journeys.

The research questions specified at the beginning of the chapter were;

RQ6: What is the difference in sleep duration following the different shifts worked in a fast, forward rotating shift pattern, common in UK policing?

RQ7: Is there a difference in cognitive performance (measured using a standardised test battery) during different shifts, for police officers and staff working a fast, forward rotating shift pattern?

The participants' self-reported data correlated with the objective watch data, regarding length of sleep, supporting the correspondence between both sources of measurement. Results showed that sleep duration was significantly reduced, by around 2 hours, whilst working night shifts, which answered the first research question presented. These findings are in agreement with a study by Torsvall *et al.*, (1989), which also found that working a night shift reduced sleep duration in participants by around 2 hours. The implications of these findings are worth noting, since they suggest that participants driving immediately after their night shift are likely to be more sleep-deprived than recommended. The impact of this sleep-deprivation and the risk to their own and others' safety on the road must be considered.

A debrief was held with both participants who reported driving incidents. Both were male and were shift workers of many years. The participant who had the incident during the day, on a rest day, was caring for an elderly relative at the same time as working full time shift work. This had placed additional, temporary demand on his daily routine by way of additional driving and potentially reduced sleep duration or a disturbed sleeping pattern. He stopped his vehicle as soon as safe to do so and took a break. The participant who reported the driving incident whilst commuting home following his first nightshift, had not had a nap prior to that shift. His commute was in excess of one hour in duration. In addition, this participant had recently been moved to work in a different area of the force, doubling his daily commute. He advised that since his move, he regularly stopped at a service station to have a 30-minute nap whilst commuting home from a night shift. Following discussion, he was receptive to having a nap prior to his nightshifts to pre-emptively reduce the possibility of future incidents.

The selected cognitive and vigilance tests utilised in this study explored different aspects relevant to the driving task, such as; sensory motor speed, visual attention, spatial working memory, complex scanning, visual tracking and vigilant attention. The results discussed in the following paragraphs have answered the second of the research questions presented in this chapter, and ultimately demonstrate that cognitive performance does differ across the different shifts worked in this particular shift pattern.

The test battery was completed by each participant on 13 separate occasions. With the exception of PVT, repeated use of cognitive tests can lead to learning and 'practice effects' (Falleti et al., 2006). Results showed that, despite the randomised nature of the cognitive tests and the varying test batteries used, learning effects may have been present for the MPT, VOLT and DSST tests. This was not evident for NBACK and PVT.

The results for MPT, VOLT, NBACK and DSST all supported the hypothesis, to a certain extent, that there was a difference in cognitive performance at different times during the forward rotating shift pattern. However, these were not entirely as expected, with results tending to indicate that reaction time was faster following night shifts, where these were predicted to illustrate the worst performance, due to shorter sleep periods following night shifts.

A number of measures for PVT were analysed. These included mean RT, MRRT, MFRRT, MEDRT and lapses, which are all frequently utilised measures for PVT (Basner and Dinges, 2011; Lopez et al., 2012). The results obtained here supported the hypothesis that there would be a difference in performance, and indicated significant main effects for Shift Type. The results for PVT were mixed, with some measures indicating slower mean reaction times following night shifts, and some indicating faster mean reaction times. Basner and Dinges (2011) reported that MRRT and lapses should be the primary outcome metric for PVT analysis. If discounting other measures and only considering MRRT and lapses on this occasion, then again, mixed results were obtained. MRRT indicated reaction time was faster on night shifts (indicating better performance) and lapses indicated more lapses on night shifts (indicating poorer performance).

The particular PVT used in this study had a duration of approximately 180 seconds. Although the standard PVT is of 10-minute duration, Roach et al. (2006) and Basner et al. (2011) identified that a shorter PVT provided comparable results, when compared to the standard test. The PVT is reported to be sensitive to sleep loss and is a widely used task in sleep-related studies (Alhola and Polo-Kantola, 2007; Basner and Dinges, 2011). Balkin *et al.* (2011) reported that PVT was subject to the least learning effects when compared with other cognitive tests; this is supported by the findings in this study. On the other hand, Basner and Dinges (2012) suggest, that a short PVT may be too short to detect changes in performance in participants who may only be moderately impaired and who's performance may suffer from 'time on task' in the standard 10-minute PVT. This was not the case in this study, and use of the shorter, 3 minute PVT, is supported.

Härmä *et al.* (2006) suggest that a fast, forward rotating shift pattern does not adversely affect alertness amongst participants. In addition, participants may have partly adjusted to their shift work pattern and are able to perform some cognitive tests to a satisfactory standard at any time during their shift schedule (Harma, 1993; Tamagawa et al., 2007).

A study by Philip *et al.* (1999), that compared young (aged under 30 years) and older subjects (30 years and over), demonstrated that the older driver group had a greater tolerance to driving-related fatigue. The participants in the present study were all aged between 31 and 54 years (mean age 43), hence the results could tend towards greater tolerance to shift work and fatigue in these circumstances, and support the suggestion that they were only moderately fatigued.

Shift work involves many different factors, such as differences in 'body clock' and personal demands of home life and work / life balance that may affect a person's pre-disposition to adjusting to shift work (Alhola and Polo-Kantola, 2007; Roenneberg and Merrow, 2007). Tamagawa et al. (2007), also suggest that police officers, in general, are extremely tolerant when faced with psychological challenges. It is possible that inter-participant rivalry, producing a degree of competition and motivation (Alhola and Polo-Kantola, 2007), existed to obtain the 'best scores' and indeed this factor was discussed with the researcher during the debrief on a number of occasions.

Finally, it is possible that at the end of the shifts, participants were sufficiently alert and ready for the reward of going home, and that the demand placed on them temporarily whilst conducting the tests, provided a stimulating effect that raised their overall vigilance and alertness to mask any signs of fatigue (Grandjean, 1979; Knutsson, 2004).

The study was limited by the time-consuming nature of the tasks and the repeated measures conducted with each participant over a ten-day period, thus leading to the small sample size.

The tests utilised were conducted as close as possible to the beginning and end of each shift, in order to consider the commuting times, and not at typical times of circadian lows. There is therefore scope for further studies involving additional tests at these times, considering tests that may more readily identify those who are moderately fatigued, or utilising a larger sample size or individual workload during the period of the study and alternative shift patterns. A simulator or on-road study of the drive home after work would also be an interesting future possibility in order to study what happens with participants when they have left the workplace and during their commute, as increased adverse driving events have been reported during this time (Ftouni et al., 2013).

The results from the FRI indicated that maximum FI was 33.1. This indicates that there was a 33.1% chance that participants may struggle to stay awake on that particular shift. This maximum was obtained on a night shift. The maximum RI was 1.27. This is the relative risk of an incident occurring and again, this was found on a night shift. These models are designed to predict average group figures, and do not take into account any individual factors or the nature of the work being undertaken (Gander et al., 2011).

The FI and RI of this shift pattern were considered alongside those of the previous shift pattern in use in North Yorkshire Police, at the time of the study reported in Chapter 4. Both patterns were similar, in that they were a forward rotating pattern, with 2 day shifts, followed by 2 afternoon shifts, followed by 2 nights shifts. The difference was in the length of each individual shift and the quantity of rest days. The former shift pattern had marginally shorter shift duration, also allowing 8-hour night shifts as recommended to be better for health and welfare (Totterdell and Smith, 1992). This pattern allowed only 3 rest days. The latter, therefore had longer shift duration to allow for 4 rest days each cycle. The comparative FI are shown in Table 5.3, and RI are shown in Table 5.4. It is known personally to the author that the “6 on, 4 off” pattern was much preferred by officers, who anecdotally reported feeling better rested on this pattern, due to the additional rest day and longer recovery period from night shifts. It can be seen that although the minimum and mean FI were less for the “6 on, 4 off” pattern, the maximum FI was slightly higher. It can be seen in Figure 5.13 that the minimum FI scores are always obtained at the end of rest days. The lower score on the “6 on, 4 off” pattern is likely as a result of the additional rest day and corroborates the feelings of officers reporting being better rested. The maximum FI scores are always obtained following night shifts. The higher maximum score of the 6"6 on, 4 off" pattern is likely due to the longer duration of the nightshifts (Totterdell and Smith, 1992). However, despite this higher score, it has to be considered that less nightshifts are worked over a longer period of time on this pattern, which ultimately reduces the repeated exposure to participants. This is similarly seen in the RI comparisons, as shown in Table 5.4

Table 5.3 Fatigue Indices of the shift patterns in North Yorkshire Police

FI	NYP (6 on, 3 off)	NYP (6 on, 4 off)
Lowest	3	1.5
Mean	14.3	13.1
Maximum	31.1	33.1

Table 5.4 Risk Indices of the shift patterns in North Yorkshire Police

RI	NYP (6 on, 3 off)	NYP (6 on, 4 off)
Lowest	0.73	0.72
Mean	0.97	0.98
Maximum	1.22	1.27

In summary, the findings of this study may be relevant to those in other populations, working rotating shift patterns. The limitations are discussed above. However, the particular shift pattern followed by participants in this study is common in United Kingdom police forces. The results indicate that participants coped well with the shift pattern, without being overly fatigued, and despite the significant reduction of sleep whilst working night shifts. This is positive feedback for those police forces already following this pattern and can be considered by others as part of their regular reviews into current shift patterns adopted throughout England and Wales.

Chapter 6
Discussion, conclusions and recommendations

In this final, concluding chapter, the thesis is summarised and the significance of the findings for policing, and other similar shift working organisations, is outlined. The chapter begins with a brief summary of the findings from the full programme of research, and results are discussed in relation to the research questions outlined in Chapter 3. The implications of the research, as well as limitations of the studies are also discussed, and recommendations made regarding the direction of future research. The final section will discuss policy recommendations, along with suggested methods and strategies to assist with educating and managing driver fatigue, in shift-working personnel.

6.1 Summary of key findings

This thesis is concerned with the impact on road safety, of shift workers who may be driving whilst fatigued. The research presented in this thesis is explored in the context of policing in the UK. The chapters within this document have addressed the research questions presented and guided the thesis towards the findings and conclusions now discussed here. The research studies were conducted with police service employees, with a particular emphasis on commuting journeys (to and from work); however, the findings may also have relevance in other industries operating shift work systems.

Background research identified that there was a need for further research on driver fatigue within the UK, particularly with respect to work-related collisions and commuting journeys (Jackson et al., 2011). In addition, Jackson *et al.*, (2011) suggested that there should be a focus on education around driver fatigue, along with targeting key risk groups, such as shift workers. Examination of the literature found it to be lacking in the areas stipulated by Jackson *et al.* (2011). This was particularly evident for UK policing research.

Examination of The Police Roll of Honour data identified that although the number of deaths of in-service police officers were decreasing, the percentage of those related to Road Traffic Collisions (RTCs) was increasing. In addition, a substantial percentage of those road-related deaths were attributed to commuting, particularly commuting home from duty (37% of those fatalities were whilst commuting home from work, for the 10 year period between 2010 and 2019).

Following a number of Freedom of Information Act (FOIA) requests to police forces within England and Wales, it became clear that there was insufficient information recorded (or information was not recorded in an easily retrievable format) in relation to the involvement of police service employees in RTCs. In addition, driver fatigue training and fatigue management measures were found to be rarely considered amongst police force policies and procedures, despite previous recommendations (Pertile, 2006; Pertile and Blain, 2008). The Health and Safety at Work Act (1974) and, specifically for policing, the Police (Health and Safety) Act 1997, impose a duty of care on employers in respect of many aspects of employee physical and mental health and safety, including working times and practices, staffing levels and supervision, and training. The Act also specifies the need for employers to consult with employees regarding the introduction of measures likely to affect health and safety, such as, for example, a change in shift patterns. As such, it seems prudent that employee awareness, and fatigue management measures should be moved to the forefront of training and awareness within organisations, by means such as Fatigue Risk Management Systems (FRMS).

Seven specific research questions were posed for investigation, as documented in Chapter 1, which then guided the studies reported in this thesis.

The primary aims of the first study were to explore driver fatigue in UK police employees, and to establish if this was a problem for a sample representing this demographic, whilst commuting. As such, the five specific research questions investigated in Chapter 4 were;

RQ1: To what extent is driver fatigue identified as an issue by officers and staff in the UK police service?

RQ2: In accordance with Home Office guidelines, and Fatigue and Risk Indices, what shift pattern is deemed most acceptable amongst those followed by this particular group of shift workers?

RQ3: What is the likelihood of a driving incident occurring, depending on the shift pattern followed?

RQ4: Are driver-related countermeasures utilised and are they effective in relieving fatigue?

RQ5: How does commuting and commuting time impact on incidents reported?

For this purpose, a questionnaire was developed, that is described in the main body of Chapter 4, and included in Appendix A. Overall, results of this study showed that 86.5% of those responding to the questionnaire, reported fatigue as a problem whilst commuting to and from their place of work. In addition, 67.45% indicated fatigue was a particular problem following night shifts.

As outlined in Chapters 2 and 3, there are a wide variety of shift patterns available to suit differing organisations, and policing is no different. Indeed, from the four police forces from whom participants were drawn for the study in Chapter 4, each force utilised a different shift pattern for their frontline officers at that time. In addition, there are also variations within other departments, within the same force. For example, a roads policing team may work different shifts to a standard, uniform response team. Some patterns adopted by police forces are in line with those considered 'best practice' by the Home Office, and some are not (Home Office, 2004; Home Office, 2010). The reasons for this variation across forces are unknown, with the decision made by the individual chief officer teams in each force area. In relation to the four police forces chosen for the study outlined in Chapter 4, the only pattern that complied with Home Office guidance at the time, was that followed by North Yorkshire Police, which followed the forward rotating, 2x2x2 pattern. However, it incorporated a slightly shorter shift duration and only provided 3 rest days, on each rotation, instead of the 4 rest days usually seen with this pattern. It is known personally to the author that all four police forces have now changed their shifts patterns. However, at the time of writing, two of the forces (Humberside and North Yorkshire) are now known to be utilising a 12-hour shift pattern, which is contrary to current Home Office guidance. South Yorkshire and West Yorkshire currently operate the 2x2x2 pattern, with four rest days, for frontline officers.

The findings from the questionnaire study indicated a prevalence of sleep-related collisions or road departures (**5.8%**) amongst the population surveyed, as well as **51.9%** reporting a 'near miss' incident in the previous 12 months. To the author's knowledge, this has not been explored in previous research, in the policing environment (**RQ1**).

In a survey of the general driving population in Australia, 68% reported driving whilst fatigued, and 2.4% reported being involved in a fatigue-related collision (Armstrong et al., 2013). These figures are lower than the findings of this thesis. This is likely due to the specific shift working, occupational group of participants in the study described in this thesis. In a separate questionnaire study by Rogers et al. (2001), distributed to both shift workers and non-shift workers, indications were that subjective sleepiness was higher for the shift workers in the study, which supports this suggestion.

Overall, when compared with the baseline shift pattern followed by **West** Yorkshire Police, this study found that those working the shift pattern followed by **North** Yorkshire Police, were almost twice as likely to report being involved in a driving incident; those who worked the shift pattern followed by **Humberside** Police were almost 1.7 times as likely to report being involved in an incident, when compared with the baseline shift pattern. The comparison of **South** Yorkshire Police, with the baseline shift pattern was not significant. From the basis of the Fatigue and Risk Index (FRI), the shift pattern followed by Humberside police, provided the greatest maximum Fatigue Index and Risk Index. This, combined with the likelihood of reporting a driving incident, perhaps indicates that the Humberside Police shift pattern was less favourable, and that the pattern followed by West Yorkshire Police was more favourable, despite not being one of those recommended by the Home Office (**RQ2** and **RQ3**).

Driver-related countermeasures, such as drinking coffee, opening the window or turning on the radio, were utilised by 51% of respondents, and the most popular method was to open a window. However, only 3.7% reported that any countermeasures were effective. Those who utilised countermeasures were found to be almost **1.9** times more likely to be involved in a driving incident. From the drivers own self-reported data, and from statistical analysis, it can be seen that drivers perhaps identified their own fatigue. However, utilising the driver countermeasures specified in the study outlined in chapter 4 appeared not to be effective for this group (**RQ4**).

When considering the commuting time of the participants, those with a commute between 30 minutes and 1 hour were almost **1.8** times more likely to be involved in an incident, and those with a commute in excess of 1 hour were more than **3** times as likely to be involved in an incident, when compared with those with a commute under 30 minutes. This indicates that those with a longer commute were more likely to report a driving incident (**RQ5**).

The results from this study supported the hypothesis that participants would disclose difficulties with fatigue whilst employed in shift work, and in particular would disclose driver fatigue whilst commuting to and from work.

Due to the potential uncertainty regarding the reliability of self-reported results (O'donnell et al., 2009; Chan, 2009), a more objective methodological approach was implemented for the second study.

The primary aims of the second study were to investigate sleep duration, along with cognitive performance and vigilance at the beginning and end of each shift worked in a three-shift, forward rotating shift pattern, with a view to identifying if performance varied according to the different shift worked. As such, two specific research questions were investigated in Chapter 5;

RQ6: What is the difference in sleep duration following the different shifts worked in a fast, forward rotating shift pattern, common in UK policing?

RQ7: Is there a difference in cognitive performance (measured using a standardised test battery) during different shifts, for police officers and staff working a fast, forward rotating shift pattern?

The study described in Chapter 5 investigated these questions, within the participants normal work and home environment. Chronotype questionnaires were fully completed by 21 of the participants in this study. This demonstrated that 71% of participants were neither a distinct morning or evening chronotype, but were considered intermediate. Amongst the general population, this has previously been found to be 60% of the adult population (Adan et al., 2012), so is not unusual.

The particular shift pattern followed by participants in this study is shown in Table 5.1, in Chapter 5, and was a 6 on, 4 off (2x2x2) forward rotating pattern, incorporating 2 day shifts, followed by 2 afternoon shifts, followed by 2 night shifts, and then 4 rest days. This pattern is one of those recommended for efficiency and effectiveness in the Home Office, (2004, 2010) reports, and at the time of writing was followed by approximately 60% of territorial police forces in England and Wales.

Sleep duration was examined by utilising both self-report data, and actigraphy. Participants self-reported data correlated with actigraphy data. Results showed that sleep duration following night shifts was significantly reduced, by around 2 hours (**RQ6**). This was in agreement with findings in the Torsvall *et al.* (1989) study, that also identified that night shift work reduced sleep duration by approximately 2 hours. However, the study by Torsvall *et al.* (1989), was conducted with 25 papermill employees, working a 3-shift system rotating between periods of morning, afternoon or night shift work. Each working 'block' of shifts was between 2 and 4 days in duration. The impact of this reduction in sleep duration, is likely to indicate that participants were sleep deprived whilst working night shifts, and is an important consideration regarding road safety implications.

The results for most of the cognitive and vigilance tasks (excluding PVT), indicated, that there was generally a difference in cognitive performance at different times of the day (**RQ7**). The results were not entirely as hypothesised, and the potential reasons for this are discussed in Chapter 5. In brief, this could be for a number of reasons. A number of tests were selected for this study, in order to research different aspects of the driving task. There has previously been differences in the findings for these tests. However, the one with most agreement is PVT. This was utilised in this study, albeit a shortened version, which has previously been found to be acceptable in applied field settings (Basner et al., 2011). Due to the mixed findings, particularly for the favoured PVT, it is possible that participants only had a moderate level of impairment, or that this particular shift pattern does not adversely affect overall alertness, or participants have adjusted sufficiently to the shift pattern, in order to perform these cognitive tests to a satisfactory standard at any time during the shift pattern (Harma, 1993; Tamagawa et al., 2007). In addition, the timing of the tasks towards the end of the shifts may have instigated a temporary stimulating effect sufficient to hide fatigue, as the participants were busy with washing vehicles, putting equipment away and handing over to colleagues (Grandjean, 1979; Knutsson, 2004).

6.2 Contribution to the field

Investigating the effect of shift work and fatigue on driving skills is a complex challenge, particularly when it involves conducting empirical studies with operational police employees.

The research presented in this thesis has contributed to the field of road safety by adding to the previously identified lack of UK specific research in driver fatigue, particularly amongst shift workers and commuting journeys (Jackson et al., 2011). In addition, a lack of research in this context, linked to policing in the UK has been identified.

This thesis has assisted with adding to the understanding of shift work in the policing environment. The research has identified that police employees struggle with driver fatigue to the extent that those involved in the first study, outlined in Chapter 4, reported a large number of driving incidents and collisions that they attributed to fatigue. Self-report data on a scale such as this, within policing, has not been obtained and explored before, despite suggestions that fatigue may have contributed to road deaths whilst commuting. The study illustrated that those involved in the study were aware of their own fatigue, but also self-reported driving incidents that they related to fatigue, particularly whilst commuting home from work after a nightshift. The study identified a favourable shift pattern, from the four identified in the different police force areas, on the basis of driving incidents and the Fatigue and Risk Indices.

In addition, the study reported in Chapter 5 was the first such study to be conducted with UK police employees. It has provided an indication that despite a difference in performance in cognitive and vigilance tasks, the fast-forward rotating shift pattern may be a good choice of shift pattern for this group of shift workers.

6.3 Limitations of the research

The FOIA process was challenging in this project, in that in some cases, it proved difficult to obtain relevant, timely information from police forces. The FOIA process, giving provision for disclosure of information, is summarised in section 3.2. In a number of cases, police forces did not respond at all, cited exemption under cost limits to decline providing information or advised relevant information was not held. There are significant differences between organisations in how costs are calculated. In addition, it has been argued that “excessive cost” given as a reason for not providing information is a metric for institutional limitations in data recording and management (Kingston et al., 2019). As an insider, previously on the receiving end of occasional FOIA requests directed from disclosure units, it may also be the case that the person who has initially reviewed the FOIA request, does not know who may be best placed to answer the query. In such circumstances, having been directed to different departments who may deduce they cannot answer the question, the response to the researcher / requester would be that no information is held in relation to their request.

For the first study conducted in this research programme, 523 participants were recruited. Although this is a healthy sample size, this was from a potential pool of over 20,000 employees in the Yorkshire and the Humber (YatH) police forces. The vast majority of participants, (95%), were police officers, and the remainder civilian police staff. Nationally, police staff make up 39% of overall police employees (Allen and Zayed, 2018). From figures provided in Chapter 4, police staff made up 47% of overall staffing in the YatH region at the time the study was conducted. The imbalance in police officer or police staff respondents is likely due to the questionnaire mainly being distributed via the Police Federation branches, who represent police officers, and not police staff members. However, due to the nature and different types of roles fulfilled by officers and staff, it is also likely that a lesser percentage of civilian police staff members work 24 hour shift patterns. As such, this provided a smaller number of potential participants in this group.

The participants self-selected to take part in the research, so there is a possibility that those who responded to the survey were those who identified that they had individual difficulties with shift work and fatigue, or potentially were unhappy with any recent changes to their shift working arrangements. Participants were given an opportunity for short, free text comments, as part of the questionnaire, and these were themes that emerged from those comments.

The second study, described in Chapter 5, was an empirical study, conducted in the participants’ usual work and home environments. This provided logistical challenges with data collection, as the researcher attended at various different police stations to brief each participant, prior to them beginning the study, and also at the conclusion of data collection, to debrief participants, and to collect and redistribute equipment to the next participant. The study was very time consuming, and the researcher had to trust participants to complete the study to the best of their ability, without supervision. The reasons for the study being time consuming was down to the study design, and logistics of distributing equipment and briefing staff at different police stations, in a large rural police force. The participants repeated the cognitive and vigilance tasks on 13 separate occasions, due to the shift pattern.

Missing data (7%) from the iHealth watches were evident on occasions, where the participant had forgotten to switch between sleep and wake mode, or where the battery had not been charged. With regard to completing the sleep diaries, participants were requested to do this regularly and as soon as possible after wakening. It is recognised that there may have been delays in completion of this task, which could have led to inaccuracies regarding recall. However, the recorded data did correlate with the actigraphy findings.

More importantly, participants were operational and on duty when completing the cognitive and vigilance tasks. Due to the unpredictable nature of policing, interference was unavoidable in this environment. On occasions, participants had to respond to real time emergencies at the very beginning or end of their shift. Understandably, this caused delay in completing some of the tasks, or prevented them from being completed at all, leading to a degree of missing data (8%). As such, there were instances where full data sets could not be collected. In addition, sometimes short notice duty changes are required in policing, or there are operational reasons why shift duration is forcibly extended beyond the scheduled finishing times, both of which affected data collection for this part of the study.

The difficulties experienced in this study perhaps point towards why this type of research is not often attempted, and the laboratory environment is usually preferable in order to better control variables. However, this highlights some of the unpredictable nature of policing, and why this manner of collating data is so important and unusual. Therefore, I am grateful that my position as a full time police officer allowed for this data collection to take place, with relative ease.

6.4 Future research and dissemination

The current research provides an insight into police employees and how they are affected by fatigue, due to their shift work. This contributed to the area of literature around shift work and driver fatigue in UK policing. At the same time, it has generated a number of questions that warrant further investigation to assist in furthering the contribution to this field. There are three relevant areas for further research, which have arisen as a result of these studies.

The first point of note relates to the background research conducted and included in Chapters 2 and 3. It was identified that a number of organisations successfully utilise Fatigue Risk Management Systems (FRMS) in order to manage and reduce employee fatigue. As such, future research regarding the introduction of FRMS in policing in England and Wales is suggested. Further recommendations in relation to this are covered in the next section.

In relation to the outcome of the first study, reported in Chapter 4, it would be beneficial if this study is repeated and updated, with a wider range of police forces, in order to incorporate different shift patterns. This would increase the participant pool and allow examination and comparison of self-reported incidents, by shift pattern and by region. In addition, it would lend support, or otherwise, to the various shifts currently recommended for policing. In addition, a further study in relation to employee commuting distance and duration would be beneficial in respect of identifying those who may be at heightened risk of a driving incident whilst commuting. This could also assist in shaping best practice when it comes to station postings.

The second study, reported in Chapter 5, was extremely time consuming, both from the point of view of the researcher and the participants. The reasons for this were outlined in the Chapter itself, and in the limitations section above. Due to this, and the shift pattern followed, they required the equipment for a period of at least 11 days. As equipment was limited, it was not possible for multiple participants to be involved concurrently. This restricted the number of participants, and extended the duration of the study. If additional equipment could be funded, the study could be conducted with a greater number of participants. Furthermore, as with the recommendations relating to the first study, additional shift patterns should be incorporated into future studies, in order to explore any differences in performance encountered. In addition, with a greater numbers of participants, a comparison of individual differences, such as age, sex and chronotype can be explored. This will enable policing to understand more fully, the impact of different shift patterns. This particular research project was concerned with commuting, hence the tests in this study were conducted as close as possible to the beginning and end of duty. It may also be beneficial to conduct the tests at typical times of circadian lows. This would allow for further exploration of potential danger when finishing afternoon shifts, or extended shifts in the early hours of the morning.

In respect of sleepiness scales, the KSS measures subjective levels of sleepiness at particular times of day, as set by the researcher. It has been utilised successfully in studies with shift workers, as well as investigating driver ability (Shahid et al., 2011). It would be beneficial to include this in a study such as that conducted and described in Chapter 5, to further explore self-reported sleepiness at times when the cognitive tasks are completed. However, in this case, the author was cognisant of requesting too much from participants at the end of their duty shifts.

It is now my intention to further disseminate these research findings to UK police forces. Interest has now been raised in the subject of driver fatigue, with the College of Policing and National Police Wellbeing Service. It is hoped this can now be progressed further, with their assistance, and with the support of strategic leaders for wellbeing within policing. I have already had initial discussions with those who can assist with dissemination, as well as academic researchers, with a view to future collaboration.

6.5 Policy recommendations

Fatigue has been shown to be a critical problem across many studies in the USA and Canada (James et al., 2018), yet it is not something that has been widely considered within UK policing to date, despite the need for officers and staff to work round-the-clock shifts. As such, there is currently a lack of guidance on how to manage and mitigate workplace fatigue. UK policing needs to accept that shift-work and long working hours, often in high pressure environments, cause, or contribute to overall fatigue, which can increase the likelihood of workplace accidents, injury, RTCs or general ill-health (Dawson et al., 2011; James et al., 2018; Ramey et al., 2019).

As outlined in Chapter 3, a duty of care sits with employers in respect of employee physical and mental health, safety and welfare, including working practices and working hours (Health and Safety at Work Act 1974; Police (Health and Safety) Act 1997). In addition, in more recent times, the Common Goal for Police Wellbeing (Home Office, 2018) outlined that every member of the police service would feel confident that their welfare and wellbeing was actively supported by their police force, throughout their career. The plan to achieve this stipulated that there would be a focus on embedding clear, consistent, evidence-based standards to welfare and wellbeing, including through occupational health, line management and relevant signposting to other partners. Chief Constables ultimately hold the statutory responsibility to manage the welfare of officers and staff. Sleep and fatigue management clearly fit into this, in terms of working practices and working hours arrangements.

A full review of police shift patterns in the UK has not been conducted since 2004 (Home Office, 2004). At that time, it was identified that four core patterns were being followed. These were Variable Shift Arrangements (VSA), regulation 8-hour shift patterns, standard 2x2x2 (6 on, 4 off), and 12-hour shift patterns. The review specifically discouraged 12-hour shift arrangements, and favoured either the standard 2x2x2 or VSA. This was further supported in a supplemental report in 2010 (Home Office, 2010). These two shift patterns were found to offer the most suitable supply and demand match, in addition to maximising officer and staff welfare considerations (Home Office, 2004; Home Office, 2010). Forces have reportedly conducted their own shift reviews, citing individual force peculiarities made this necessary. However this was found not to be the case (Home Office, 2004). The Home Office guidance should be reinforced and supported by Chief Officer Teams. A timely, national review of shift patterns, as it stands, is recommended in order to ensure shifts are safe, healthy, legal and efficient.

The Working Time Regulations (WTR) were introduced in 1998. The regulations are outlined in section 3.3. However, the purpose of these was to regulate and monitor the working hours of employees in order to provide safe and healthy working environments (The Working Time Regulations, 1998). Although there are partial exemptions to WTR in policing (Wardman and Mason, 1999), compliance with the WTR should be explored and reinforced to ensure officer and staff wellbeing.

In addition, the WTR require organisations to offer a Night Workers Health Assessment to employees before they begin and at regular intervals thereafter (The Working Time Regulations, 1998). Policing organisations need to be reminded of this and ensure that this is offered, as stipulated, to employees. This should be incorporated into a FRMS where responsibility is shared between organisations and employees (Schutte, 2010).

FRMS are an umbrella for evidenced based guidelines and policies for fatigue risk management, based on systematic reviews, where responsibility is shared between. They have been successfully utilised in many other industries, such as aviation, rail or nuclear power settings (Patterson et al., 2018). Despite previous recommendations that such measures should be introduced in policing, (Pertile, 2006), based on responses to the FOIA request relating to this subject, there is limited evidence to suggest that meaningful FRMS training has been adopted by any police force in England and Wales.

There is a need to introduce FRMS in UK policing, with open and honest policies, raising awareness related to organisational responsibilities, along with individual responsibilities. FRMS for policing should include;

- A training programme including an introduction to sleep and shift-work, when employees join the organisation, along with an ongoing fatigue management training at strategic intervals, such as when attending driving courses. This has the potential to increase overall satisfaction with sleep, working arrangements, physical and mental health (James et al., 2018).
- A fatigue management policy, including fatigue reporting systems and driver fatigue strategy. This should include what the organisation's responsibilities are, what line manager responsibilities are, and what employee responsibilities are. These could include; Force / organisational responsibilities – such as supporting the introduction of guidance relevant to fatigue and driver fatigue, along with headline messages on force intranet pages. Line manager responsibilities – such as considering practical alternatives where an

individual reports they feel unable to drive, ensure familiarity with policies, procedures or guidance. There needs to be clear guidance for line managers regarding their options if an employee approaches them with an issues related to driver fatigue. This will give line managers options and will support their decision making regarding employee wellbeing and team management. Individual Responsibilities – such as informing a line manager if feeling unfit to drive, considering fitness to drive home at the end of a shift, prioritising rest prior to duty, taking account of commuting time when considering moving home, reporting any medical conditions or use of prescribed medication that may cause impairment, reporting any wellbeing issues to a line manager, planning journeys and utilising alternative means of transport where possible.

- Consideration to employee station postings with regard to their home address and possible commuting distance or time duration, which could ultimately extend their time awake to unsafe times and increase their risk of an RTC (Stutts et al., 2003). In addition, consideration should be given to drivers hours, single or double crewing policy during night shift hours, in order to maximise driver safety.
- Sleep disorder investigation and management, to allow early diagnosis and treatment of such disorders that may increase the risk of an employee to accident or injury.
- Improved incident reporting and investigation, along with improved recording of fatigue related incidents, in order to allow future interrogation of police systems for research purposes and to direct learning and best-practice.

The above policies and procedures will allow a pro-active learning culture to develop, where safety management is a joint approach between the organisation and employees.

6.6 Overall conclusions

Understanding that the role of the researcher is to identify and introduce new and original contributions to the knowledge in the field, this study of shift work and driver fatigue in the police service has met the original research aims and objectives in full.

Revisiting the broader aims of this research, which were set out in Chapter 1, it is clear that fatigue is a problem for the participants in the study included in Chapter 4 of this thesis. This work has identified that police employees recognise and have self-reported difficulties in relation to driver fatigue, and are experiencing driving incidents as a result of fatigue. Chapter 5 concludes that participants coped well with the forward rotating, 6 on, 4 off shift pattern, common in UK police forces.

It has been highlighted that there is still a lack of understanding in relation to fatigue and the effects of shift working in policing, and how this may impact on road safety. In response to one of the FOIA requests discussed in Chapter 3, that specifically requested information regarding police employee Road Traffic Collisions (RTCs), one force in England responded with the following;

> *"Whilst all police vehicle collisions are fully investigated, the issue of fatigue is not specifically addressed in terms of on-duty collisions as the driver would not be fit for duty if such was the case. The element of fatigue is not a recorded factor when the police vehicle collision is recorded or finalised".*

This lack of understanding perhaps goes some way to also explaining why police forces do not routinely record information regarding RTCs in an easily retrievable format. In addition, it was identified that police forces do not routinely have policies, procedures, guidance or training in relation to driver fatigue and how to manage it. It has been highlighted that police force employees, at all levels would benefit from the introduction of FRMS, and in particular, some form of training or awareness input in relation to understanding and managing fatigue. These have been shown to be successful in other industries and have recently been introduced with the Royal Canadian Mounted Police (RCMP), realising positive sleep health benefits for those participants (James et al., 2018).

The policy recommendations outlined above should be introduced in UK policing, in order to help the entire workforce better understand the difficulties associated with shift work, along with relevant suggestions for mitigating the negative effects, and an effective means of reporting of incidents and intervention, prior to incidents occurring. This will provide an overall healthier, happier workforce, contributing to the common goal for police wellbeing (Home Office, 2018).

Academic publications and conference papers

Below is a list of academic publications, conference presentations and conference posters that were published or presented during the completion of this PhD. In addition, there have been numerous, further presentations at non-academic proceedings.

Academic conference presentations

Taylor, Y., Merat, N. and Jamson, S. 2013. Shift Work and Driver Fatigue Poster Presentation. *Human Factors and Ergonomics Society, Europe Chapter, Annual Meeting, "Human Factors: Sustainable Life and Mobility", 16th-18th October 2013, Turin, Italy.*

Taylor, Y., Merat, N. and Jamson, S. 2014. Shift work and driver fatigue *In*: *Proceedings of AHFE 5th international conference on applied human factors and ergonomics, Jagiellonian University, Krakow, 19-23 July*. Krakow, Poland.

Published journal articles

Taylor, Y., Merat, N. and Jamson, S. 2019. The Effects of Fatigue on Cognitive Performance in Police Officers and Staff During a Forward Rotating Shift Pattern. *Safety and Health at Work*. **10**(1), pp.67–74.

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Appendices

Appendix A
Fatigue and shift work related road traffic collisions questionnaire administered to participants in study 1, contained in Chapter 4

A1 – Online questionnaire, including informed consent

Appendix A1: Online questionnaire, including informed consent

UNIVERSITY OF LEEDS

I am a Roads Policing Officer with North Yorkshire Police. I am studying for a PhD on a part time basis with the Institute for Transport Studies at the University of Leeds. My research concerns fatigue amongst Police Officers, Police Staff and other shift workers. I would be very grateful if you could spare a few minutes to answer some questions. Your answers are completely confidential and will not be given to your employer or anyone else, they will be used purely for my research purposes and will help me to understand and manage fatigue better amongst shift workers. Taking part is completely voluntary but would greatly assist my research. The questionnaire will take only 5-10 minutes to complete. Please contact me at yvonne@collisionresearch.co.uk if there is anything that is not clear or if you would like further information. Thank You.

<u>About you</u>

***1. What Police Force do you work for?**

South Yorkshire

Humberside

North Yorkshire

West Yorkshire

***2. Are you male or female?**

Male

Female

***3. How old are you?**

***4. Are you a Police Officer or a member of Police Staff?**

Police Officer

Police Staff

***5. How long have you been employed as a Police Officer or member of Police Staff, in years?**

***6. What is your current post / specialism?**

***7. What is your Police driving classification?**

Advanced

Standard

N/A

Other (please specify)

***8. How long have you been in your current post / specialism, in years?**

9. In the last 12 months, what do you estimate your annual mileage to be? (Please enter numbers only, without any commas, etc)

Private

Police vehicles

<u>Your shift pattern</u>

***10. Do you work shifts?**

Yes

No

11. Have you worked shifts for the last 12 months?

Yes

No

12. What shift pattern do you follow?

8 hours

Variable Shift Arrangement

Other

13. Please briefly describe your shift pattern

Travelling to and from your place of work

***14. How long, on average, does it take you to get to / from work?**

Under 30 minutes each way

30 minutes to 1 hour each way

Over 1 hour each way

***15. How do you usually travel to / from work?**

If you use more than one mode, please select all that apply, e.g. part cycle, part train

Walk

Lift / Taxi

Bus / Train

Pedal Cycle

Motorcycle

Car

Other (please specify)

***16. What distance do you travel to work, in miles?**

***17. Do you recall feeling sleepy whilst travelling to / from work in the last 12 months?**

Yes

No

18. How frequently do you recall feeling sleepy whilst travelling to / from work in the last 12 months?

Nearly every day, travelling to work

Twice a week, travelling to work

Weekly, travelling to work

Monthly, travelling to work

Less often, travelling to work

Nearly every day, travelling home from work

Twice a week, travelling home from work

Weekly, travelling home from work

Monthly, travelling home from work

Less often, travelling home from work

19. Is it only before / after certain shifts?

Yes

No

Other (please specify)

20. If it is only after a certain shift, please specify below;

Earlies

Lates

Nights

Other (please specify)

21. If you feel sleepy whilst driving, do you do any of the following? Please select all that apply, listing in order of preference, starting with 1 (as most preferred) and continuing whilst you have a preference

Turn on music or radio

Drink coffee

Drink 'energy drink'

Drink any other drink

Stop the vehicle (and rest / walk around)

Stop the vehicle and take a nap

Smoke

Open the window

Turn down the heat

None of the above, carry on driving

Other

22. Thinking of your most preferred method from the previous question, how effective do you find this? Please rate 1 - 5, where 1 is completely ineffective and 5 is completely effective.

1

2

3

4

5

***23. Before you go home from work, do you do any of the following on a regular basis to prevent sleepiness on your journey?**

Drink coffee

Drink 'energy drink'

Shower

Sleep / nap

Rest

None of the above

Other (please specify)

***24. In the last 12 months, have you been involved in a collision, or road departure, on the way to or from work (either as the driver or passenger)?**

Yes

No

25. Would you attribute this collision or road departure to falling asleep or nearly falling asleep whilst in control of the vehicle (either yourself as the driver or another as the driver)?

Yes

No

26. Were you the driver?

Yes

No

27. Was it on the way to or from work?

To

From

28. What shift were you working that day?

Earlies

Lates

Nights

Other (please specify)

29. What time of day was it?

(Please enter your answer in the format, e.g. 0700, 1315, 2205, etc without any other characters)

30. In the last 12 months, have you been involved in a 'near miss' incident (such as kerb strike, lane departure, almost having a collision, etc) on the way to or from work that you would attribute to fatigue (either as the driver or passenger)?

Yes

No

31. Has this type of 'near miss' happened more than once?

Yes

No

32. Thinking of the most recent incident, was it on the way to or from work?

To

From

33. Were you the driver?

Yes

No

34. What shift were you working that day?

Earlies

Lates

Nights

Other (please specify)

35. What time of day was it?

(Please enter your answer in the format, e.g. 0700, 1315, 2205, etc without any other characters)

***36. While driving at any time, have you felt sleepy to the point where you thought you may fall asleep?**

Yes

No

37. If yes, when was the most recent incident?

In the last 12 months

1 - 2 years ago

2 - 5 years ago

More than 5 years ago

***38. While driving at any time, have you had a collision that you would attribute to falling asleep or being drowsy?**

Yes

No

39. Was this in duty time?

Yes

No

40. Please briefly explain what happened

<u>Lifestyle</u>

***41. How many times a week do you engage in physical activity?**

***42. Do you smoke?**

Yes

No

***43. If not a current smoker, have you smoked in the past?**

Yes

No

***44. How often do you drink alcohol?**

Daily or almost daily

Once or twice a week

Once or twice a month

Special occasions only

Never

***45. Do you feel that you sleep well?**

Yes

No

46. Do you have difficulty falling asleep?

Yes

No

47. Do you have problems staying asleep?

Yes

No

48. Do you feel you get enough sleep?

Yes

No

***49. Do you regularly take any medication either prescribed or non-prescribed that carries a warning with regard to drowsiness and driving?**

Yes

No

Don't know

***50. Do you currently take sleeping pills?**

Yes

No

51. Would you be willing to be contacted again to assist further research in this area (further questionnaire, interview, driving simulator studies, etc)?

Yes

No

If yes, please leave contact email address, or if you would prefer, contact me direct at yvonne@collisionresearch.co.uk

52. Please add any other short comments you feel are relevant to shift patterns or sleepiness

Appendix B

Fatigue and cognitive performance participant Information and consent form used in study 2, contained in Chapter 5

B1 – Letter to the participant and informed consent

B2 – Morningness / Eveningness Questionnaire

B3 – Sleep diary

Appendix B1: Letter to participants and informed consent

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University of Leeds - Institute for Transport Studies

Participant Information and Consent Form

Study: The Effects of Fatigue and Rotating Shift Work on Police Officer / Police Staff Performance

Researcher:

Yvonne Taylor

Researcher's Statement:

Thank you for agreeing to participate in a research study. This study will further explore driver fatigue amongst Police Officer/Police Staff shift workers. The purpose of this form is to give you the information you require to make an informed decision regarding whether or not to take part in this study. Please read the form carefully. You are entitled to ask questions regarding the research and your own participation in the study, the purpose of it, what I will ask you to do and anything else that you feel is not clear. You will then be in a position to make your informed decision on participation. Participation is completely voluntary. You will be provided with a copy of this form on request.

Purpose and Procedure:

Prior to undertaking the study, you will be asked to complete a questionnaire that will help to identify if your peak alertness is expected to be in the morning, evening or somewhere in between.

You have been selected for this study due to the fact that you are currently working a 10 day rotating shift pattern, consisting of two early / day shifts, two late / afternoon shifts and two night shifts, followed by four days off. Your participation in the study is required across the entire ten-day period. If you do not believe, before you begin, that you can commit to the study for the full ten days, please inform the researcher.

During the ten days, you will be expected to;

- Complete a daily sleep / activity diary.
- Wear a watch type device that must be worn on your non-dominant wrist. This device records sleep / rest / activity. The watch cannot be worn in the bath or shower, but you will be expected to wear it at all other times, during the ten-day period. You will have to manually switch between wake and sleep modes, and it may require charging during the ten-day period. It must not be left on charge whilst you are asleep, as this is the most important data that it is expected to capture. Other than that, it will require very little attention.
- Participate in short, iPad based vigilance / reaction time tasks at the beginning and end of every working shift (you will not be expected to do this on your days off).

Full verbal instructions will be given by the researcher (or representative) prior to commencing the study and you will be provided with a contact telephone number in the event of any problems. Please inform the researcher in the event of possible loss or damage to equipment. Do not worry if you forget to complete any of the tasks at the relevant time or if you forget to switch the watch between sleep / wake mode, just make a note of it and carry on as normal, do not try to 'make up' any results!

At the conclusion of the study, you will be provided with your own data, should you so require it.

Using the information gained, I hope to grasp a better understanding of cognitive function, fatigue and recovery of Police Officers and Police Staff who work rotating shift patterns. All responses will be stored securely without identifying any individuals. All gathered data is purely for the purpose of this study and individual data will not be shared with anyone or any other organisation. Data will be securely stored, and password protected. No publication of results will identify any individual participant. The experimental design has been approved by the ethical committee at the University of Leeds.

Selection of Participants:

You have been invited to participate in this study as you have previously expressed an interest in participating in further studies of this type and / or you are presently working a 10 day rotating shift pattern and have volunteered to participate.

Withdrawal:

You are free to withdraw your consent and stop participation in this study at any time by indicating your desire to withdraw to the researcher.

Participant's Consent:

The study has been explained to me and I volunteer to participate in this research. I have had the chance to ask questions.

Signature:

Name:

Date:

Appendix B2: Morningness / Eveningness Questionnaire

Horne JA and Östberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms.

International Journal of Chronobiology, 1976: 4, 97-100.

Self-Assessment Version (MEQ-SA)1

Name: ______________________ Date: __________________

For each question, please select the answer that best describes you by circling the point value 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 (05:00–06:30 h)

   [4] 6:30 AM–7:45 AM (06:30–07:45 h)

   [3] 7:45 AM–9:45 AM (07:45–09:45 h)

   [2] 9:45 AM–11:00 AM (09:45–11:00 h)

   [1] 11:00 AM–12 noon (11:00–12:00 h)

2. Approximately what time would you go to bed if you were entirely free to plan your evening?
   [5] 8:00 PM–9:00 PM (20:00–21:00 h)

   [4] 9:00 PM–10:15 PM (21:00–22:15 h)

   [3] 10:15 PM–12:30 AM (22:15–00:30 h)

   [2] 12:30 AM–1:45 AM (00:30–01:45 h)

   [1] 1:45 AM–3:00 AM (01:45–03:00 h)

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 at all

[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 up?

   [1] Not at all hungry

   [2] Slightly 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?
   [4] Seldom or never later
   [3] Less that 1 hour later
   [2] 1-2 hours later
   [1] 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 (07-08 h). 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 (20:00–21:00 h)
    [4] 9:00 PM–10:15 PM (21:00–22:15 h)
    [3] 10:15 PM–12:45 AM (22:15–00:45 h)
    [2] 12:45 AM–2:00 AM (00:45–02:00 h)
    [1] 2:00 AM–3:00 AM (02:00–03:00 h)

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 entirely 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 (08–10 h)

[4] 11 AM–1 PM (11–13 h)

[2] 3 PM–5 PM (15–17 h)

[0] 7 PM–9 PM (19–21 h)

12. If you got into bed at 11 PM (23 h), how tired would you be?

    [0] Not at all tired

    [2] 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 (04-06 h) 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–10 AM (08–10 h)

[3] 11 AM–1 PM (11–13 h)

[2] 3 PM–5 PM (15–17 h)

[1] 7 PM–9 PM (19–21 h)

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 (22-23 h). 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 4–8 AM (05–08 h)

[4] 5 hours starting between 8–9 AM (08–09 h)

[3] 5 hours starting between 9 AM–2 PM (09–14 h)

[2] 5 hours starting between 2–5 PM (14–17 h)

[1] 5 hours starting between 5 PM–4 AM (17–04 h)

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

[5] 5–8 AM (05–08 h)

[4] 8–10 AM (08–10 h)

[3] 10 AM–5 PM (10–17 h)

[2] 5–10 PM (17–22 h)

[1] 10 PM–5 AM (22–05 h)

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 than a morning type

    [1] Definitely an evening type

_____ Total points for all 19 questions

INTERPRETING AND USING YOUR MORNINGNESS-EVENINGNESS SCORE

This questionnaire has 19 questions, each with a number of points. First, add up the points you circled and enter your total morningness-eveningness score here:

Scores can range from 16-86. Scores of 41 and below indicate "evening types." Scores of 59 and above indicate "morning types." Scores between 42-58 indicate "intermediate types."

16-30	31-41	42-58	59-69	70-86
Definite evening	Moderate evening	intermediate	Moderate morning	Definite morning

Appendix B3: Sleep diary

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10-DAY SLEEP DIARY

INSTRUCTIONS:

1. Write the date, day of the week and type of day: Work or Rest Day
2. Put the letter ‘S’ in the box when you have a stimulant, such as coffee, cola, tea, caffeine tablets or caffeinated drink
3. Put the letter ‘M’ in the box when you take any form of sedative or sleeping tablet
4. Put the letter ‘A’ in the box when you drink alcohol
5. Put the letter ‘E’ in the box when you exercise
6. Put the letter ‘D’ in the box to indicate any ‘driving incident’ such as nodding at the wheel, a near miss incident, kerb strike, etc
7. Put a line (l) in the box to show when you go to bed
8. Shade in all the boxes that show when you are asleep
9. Leave boxes un-shaded to show when you wake up during the night and when you are awake during the day

SAMPLE ENTRY BELOW: On a Monday, I was at work. I had a coffee at 0700 hours, another at 0800 hours and another at 1200 hours. I exercised at 1900 hours, had two alcoholic drinks between 2000 and 2200 hours. I then took a sleeping tablet and went to bed at 2200 hours, falling asleep at 2300 hours. I slept until 0500 hours, when I got up to go back to work on the Tuesday. Whilst travelling home from work I struck a kerb to the nearside of the road.

Today's Date	Day of the week	Work Or Rest Day	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06
sample	Mon	Work	S	S				S					D		E	A	A	M I								