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A Mixed Methods Investigation of Multidimensional Fatigue in the Wind Industry: Towards a Sustainable Workforce

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Conferences

Managing Fatigue in the Offshore Wind Industry (presentation)- Global Offshore Wind, Manchester, UK, June 2018

Towards an understanding of mental fatigue in the offshore wind industry (poster)- Physical Employment Standards, Portsmouth, UK, July 2018

Fatigue in the wind industry (presentation as part of the 'Early Researcher Showcase')- European Academy for Occupational Health Psychology (EAOHP), Lisbon, Portugal, September 2018

Human Factors and fatigue in the port industry (presentation)- International Cargo Handling Coordination Association (ICHCA) Technical Meeting, Lincoln, UK, March 2019

Building a sustainable workforce: fatigue in onshore and offshore wind technicians (poster)-European Association of Work Psychology (EAOWP), Turin, Italy, June 2019

Existing fatigue management practices in maritime and offshore industries; towards a bespoke approach (presentation)- Institute of Marine Engineering, Science and Technology (IMAREST) Maritime Industry Technical Meeting, London, UK, July 2019

Abstract

The wind industry encompasses a high hazard work environment with multiple demands unique to those working in this sector. A key risk to health, safety and productivity is operator fatigue. Poor management of operator fatigue is highly associated with unsafe behaviour as well as physical and mental health issues. Despite this, there is a lack of industry specific research on fatigue. Furthermore, wider organisational research and practice around fatigue management is highly reductionist, often simply addressing sleep-related strains. This could be attributed to the lack of agreed definition around the concept, particularly in the focussed literature on fatigue risk management. This research aimed to address these issues with a mixed methods approach to fatigue research in the wind industry.

Research initially comprised a systematic review examining research on human factors in the wind industry which identified multiple unique industry-related strains. Following this, a qualitative interview study with wind industry employees was conducted. Findings suggested that fatigue is experienced as a multidimensional state highly impacted by cumulative strain. Finally, a 4-week quantitative diary study compared fatigue and sleep between working and non-working time and two different types of operations and maintenance roles. Findings indicated that fatigue was highly influenced by multiple work-related demands and that this impact was cumulative and occurred regardless of sleep acquisition. This emphasises the need to employ a multidimensional approach when researching and managing fatigue and for workplace interventions to be implemented with a focus on both organisational design and individual behaviour.

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Chapter 1 - Introduction

1.1 The Wind Industry- Opportunities and Challenges

Wind energy has become the fastest growing renewable energy technology in the world over the last 30 years (Crabtree et al., 2015). This is especially the case in the UK, where the share of annual generation of offshore wind energy has increased from 0.8% in 2010 to 11.6% in 2020. Combined with the contribution of onshore wind (9%), wind energy accounts for 20.6% of energy production in the UK (Department of Business Energy and Industrial Strategy, 2019; Spry & Lucking, 2020). With the world's largest wind farm, Hornsea One, this is set to increase even further (Ørsted, 2019). Not only does this signal the ever-increasing move towards cleaner, renewable energy, but also a potential for local economy growth and job creation.

Despite its major contribution to the energy grid, the wind industry is still relatively young, with working practices still being established and a great amount of pressure to operate with high levels of efficiency (Linsey et al., 2016). Although wind energy itself is relatively cost effective, the logistics of running and maintaining wind farms are complex and costly. This is in part owing to their isolated and highly exposed locations (Linsey et al., 2016). This industry, alongside many others, therefore, faces the challenge of balancing sustainable working practices with productivity.

Though technology has developed considerably in recent years, the wind industry is still heavily reliant on a human workforce and likely will be for the foreseeable future. Long term maintenance of turbines is essential, as regular servicing and repairs are necessary over the course of their 20-year lifespans, which requires the effort and expertise of technicians (Linsey et al., 2016). Indeed, It is projected that the operations and maintenance (O&M) of UK offshore turbines could be worth almost 2 billion per annum by 2025, which represents an industry the size of the UK passenger aircraft service business (Linsey et al., 2016). It is critical that the operations and maintenance workforce are able to cope with the high demands of this work environment which should be ensured by wind organisations through the development of safe, healthy and sustainable work practices.

The wind industry encompasses a high hazard work environment with numerous safety and health risks for workers (Mulloy et al., 2013). This is compounded by the fact that employees are required to work long hours with intense task demands. Despite this, there is currently a lack of bespoke research and practice guidelines around how to manage these risks to employee health and safety. To ensure that this industry continues to flourish, it is of utmost importance to ensure that working conditions are safe, healthy and ultimately sustainable. A vital consideration in this area is the management of fatigue and wellbeing in employees.

1.1.1 Employee Fatigue

Fatigue is an inevitable psychobiological response to effort (Hockey, 2011; Van der Linden, 2010). It is associated with numerous safety risks often brought about by unsustainable working practices. Indeed, a number of large-scale disasters in high hazard industries have been attributed to operator fatigue, including the Chernobyl disaster, the Challenger crash and the BP refinery disaster (MacKenzie, Holmstrom, & Kaszniak, 2007; Mitler et al., 1988; Techera et al., 2016). As well as this, the poor management of work-related strain is highly associated with numerous physical and mental health issues (Bazazan et al., 2018; Heraclides et al., 2012; S. Johnson et al., 2005). Despite these known risks, fatigue continues to be misinterpreted and mismanaged in many workplaces. There is currently little research investigating fatigue risks and management in the wind industry (see Chapter 4), even though it is likely to pose a significant risk to employee safety, health and wellbeing (see Chapter 2 section 2.10.1 and Chapter 3 section 3.3.5).

This thesis focuses on gaining a comprehensive understanding of how employee fatigue is experienced in the wind industry and how it should be effectively managed. It considers three different operations and management work environments: (1) offshore wind farm employees who work far from shore and live on service operation vessels (SOVs), during their shift periods; (2) offshore wind farm personnel working closer to shore and travelling to and from turbines daily on crew transfer vessels (CTVs) ; (3) onshore wind employees. The demands and hazards associated with these three environments will now be briefly examined, first in the context of the general work demands of an operations and maintenance technician, then in an examination of the specific demands and stressors associated with each wind industry environment

1.1.2 Operations and Maintenance Technicians

The work of an O&M technician typically involves scheduled maintenance, involving major annual services and periodic inspections. Services normally consists of repetitive, process driven work with high physical demands including manual handling, working in confined spaces and exposure to extreme temperatures in a marine environment (Velasco Garrido, Mette, MacHe, et al., 2018). As well as this, there is a high amount of pressure to work quickly to ensure that the turbine does not remain de-powered for any longer than is necessary. As well as planned work, O&M employees are responsible for unscheduled repair work when turbines break down, which is unpredictable and likely mentally taxing (Linsey et al., 2016).

1.1.3 Offshore SOV

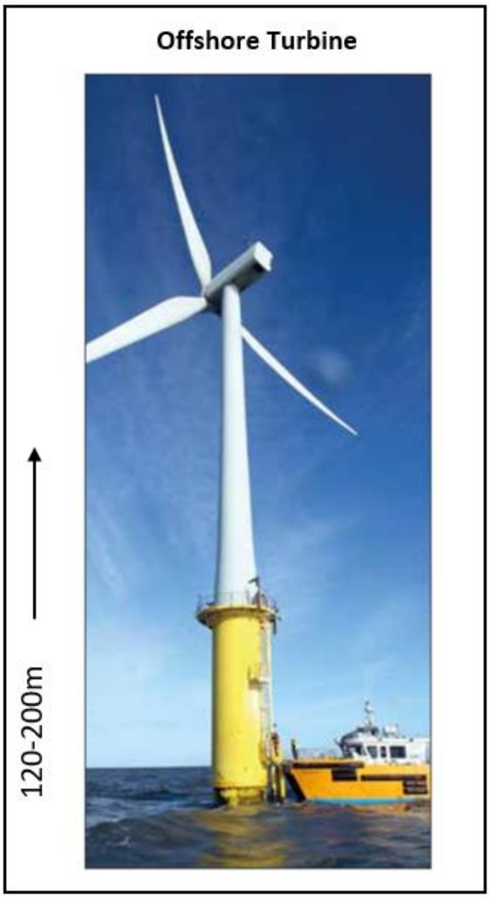
The offshore SOV context in many ways represents the future of the wind industry as most new wind farm developments are being planned and built far from shore with larger turbines (Mulloy et al., 2013). Due to the distance of these wind farms, it would not be feasible for technicians to commute there and back each day. Therefore, O&M employees are required to live offshore throughout every two week ‘on shift’ period. During this time, employees live on an SOV; a large boat with living accommodation (see Figure 1) and will undertake a short transfer to the turbine and back each day. This is in some ways like the environment of an offshore oil and gas employee, however living conditions are more confined. Offshore O&M roles include technicians who are responsible for turbine-related work and operations managers who oversee the management and logistics of this work~~,~~ as well as the management of staff welfare.

Figure 1- Service Operation Vessel (Mulloy et al., 2013)

Due to their proximity to the turbines and lack of transfer time, SOV technicians typically spend 12 hours per day undertaking turbine-related work. This means that they generally spend longer completing work related tasks than wind technicians in onshore or CTV environments as onshore technicians generally have shorter working days and CTV technicians typically spend around 3 hours of their 12-hour shifts transferring to turbines.

Underpinning all other demands is the requirement for technicians to work at height. Offshore turbines are around 120-200 metres tall (see Figure 2), which for reference, is a similar height, or taller than the London Eye (135 metres). Most work is undertaken in the nacelle, located at the top of the turbine and so has an inherent risk and exposure to all weather conditions. As well as this, there is the question of getting to the top. Ideally, SOV technicians would be able to take a service lift. However, these are often out of service due to mechanical faults (Linsey et al., 2016) or being beyond their inspection period. Therefore, it is not unusual for technicians to be required to climb to the top of turbines before they begin their work. This is undertaken with a vertical ladder climb up the centre of the turbine (see Figure 5). As well as all these risks, there is the context of the isolated locations in which employees work, meaning that the performance of rescue operations is extremely difficult.

Figure 2- Offshore Turbine



1.1.4 Offshore CTV

Employees who work on wind farms located nearer to shore often travel from home to work each day and are transported to turbines via crew transfer vessels (CTVs), which are relatively small passenger boats (see Figure 3). The most common working pattern is one week on, one week off. Work demands and risks are similar to offshore SOV workers, with 12-hour shifts being common, but the timing of their shifts is heavily influenced by tide times, port lock availability, and changing weather, which brings additional practical and psychological challenges. A further notable difference in this role is the increased transfer time, which is normally between 40 minutes and 2 hours, depending on the proximity of the windfarm to the onshore operations base. On top of this, there are personal commutes to and from work which are undertaken outside of shift time. This can be a significant additional load, as it is not unusual for technicians to live a considerable distance from the operation base. Furthermore, due to the small size of the vessels, CTV technicians are often subject to rough sea conditions and seasickness can be a prominent issue and a significant challenge for the technicians.

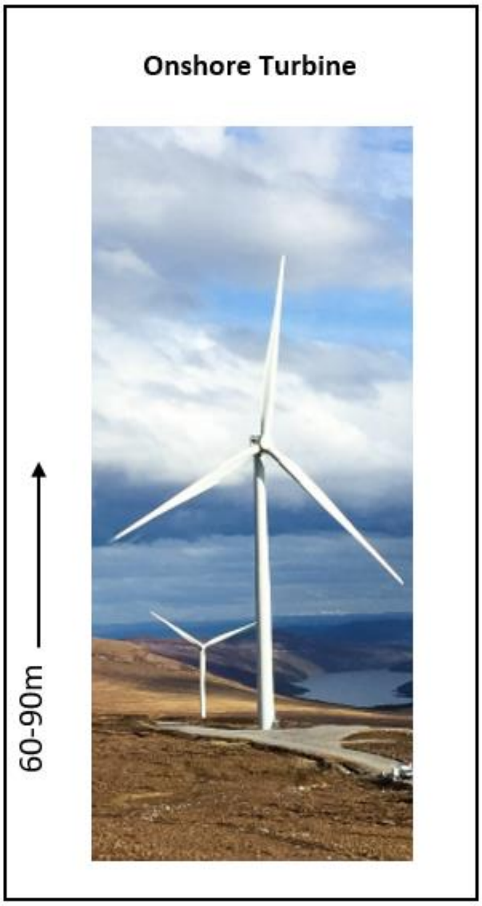
Figure 3- Crew Transfer Vessel (Sure Wind Marine)

1.1.5 Onshore

Despite a movement towards offshore wind in the UK, onshore wind still accounts for a significant proportion of wind energy production. Though onshore wind farms do not carry the risks associated with a marine environment, they are often located in isolated rural locations. Technicians normally work in small teams of two to three and have little access to welfare facilities or nearby support.

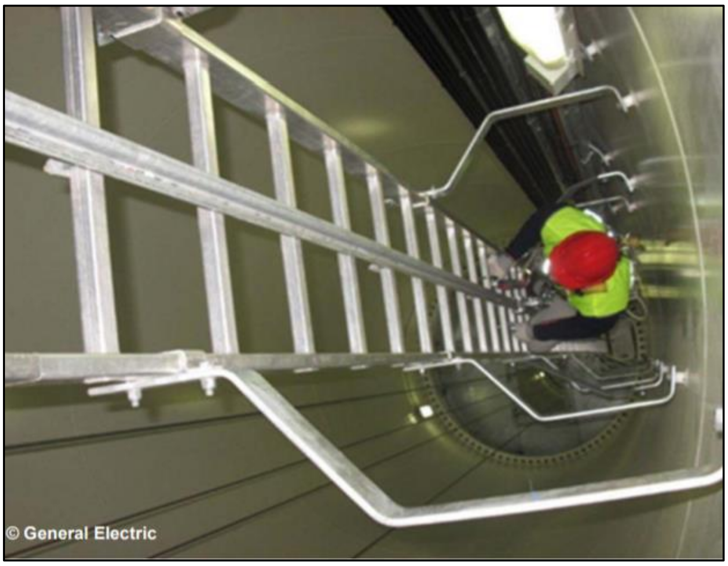
The O&M tasks in onshore work roughly follows the same requirements as in offshore work. Onshore turbines are normally significantly smaller than offshore turbines, but are still a significant height, at around 60-90 metres (for reference, Big Ben is 96 metres tall) (see Figure 4).

Figure 4- Onshore Turbine



There are inherent risks associated with the smaller size of onshore turbines. The first risk is that they often do not have enough space for the provision of a service lift, meaning that technicians are required to climb to the top of the turbine each time they are required to work on it. This climb is undertaken in confined, claustrophobic conditions (see Figure 5). The second risk is that there is less space in which to carry out service or repair work, meaning conditions are even more confined that they are in offshore work. Though this environment encompasses many risks, there is even less research about employee welfare, health, and safety relevant to this aspect of the industry, as most research to date has focused entirely on offshore environments.

Figure 5- Turbine climbing conditions (Mulloy et al., 2013)



1.2 Fatigue risks in the Wind Industry Environment

Amongst other effects, fatigue causes individuals to be less cognisant of safety risks and-more likely to engage in corner-cutting, riskier behaviour (see chapter 2 section 2.10.1 for a detailed explanation of this). This is dangerous when combined with such a high hazard environment. There is guidance available on managing fatigue in offshore environments from the health and safety executive (HSE, 2018) and an instructional paper on managing fatigue from the energy institute (The Energy Institute, 2014). However, these are not specifically designed for the wind industry and mostly focus on shift management and sleep opportunity and do not appropriately consider specific environmental factors that can influence fatigue. Thus, there is a lack of specific guidance around appropriate management of fatigue in this industry. Thus, there is a need to address this to lessen the risk for employee health and safety.

1.3 Towards Sustainable Work Practices - The Present Research

This research aims to develop an understanding of how fatigue is experienced by employees within the wind industry, how it develops, what impacts it has, and how it can be effectively and sustainably managed. This will be addressed through a detailed literature review and mixed methods primary research. The following summary will provide an overview of the thesis structure.

1.3.1 Thesis Summary

To gain a comprehensive understanding of how fatigue impacts individual employees in an applied context, it is first important to gain a theoretical understanding of the concept. Fatigue is a complex phenomenon that lacks a unanimous definition in the academic literature (Phillips, 2015). Therefore, this research will first aim to review the relevant literature and ultimately present a working definition of fatigue to be used in the project. This will be undertaken in Chapter 2.

It is important to understand current approaches to fatigue research and management in work settings to identify both good practice and existing issues that this research will aim to address. This will be undertaken in Chapter 3. Furthermore, it is vital to be aware of relevant research in this applied setting. Though the present research is unique in its specific aim of understanding employee fatigue, there is some research that addresses wider human factors related issues in the wind industry environment, therefore, Chapter 4 will contain a systematic review exploring this.

Consideration of relevant literature in Chapters 2-4 will inform the formulation of research questions addressed in the latter half of the thesis. Chapter 5 will explore the philosophical and methodological underpinnings of the present research and will culminate in the presentation of five research questions to be explored in studies one and two (see Table 8)

Following this, Chapter 6 will detail study 1, a qualitative investigation into fatigue in wind industry workers. As this is the first investigation into employee fatigue in a unique industry, it is crucial to gain a rich and nuanced understanding of the experiences of the individual employees in question. Therefore, primary research will begin with a qualitative interview investigation into wind industry employee fatigue and wellbeing, which will provide a rich basis of knowledge for study 2.

Chapter 7 will include a detailed account of study 2, a quantitative diary study tracking daily fatigue and sleep in wind industry employees. This will provide quantitative data collected from the naturalistic setting of participants' work environments and will include a unique insight into the experience of fatigue in this industry by tracking fluctuations in fatigue and sleep throughout a shift and insight into the predictive value of work related factors for fatigue outcomes.

Finally, Chapter 8 will include a discussion on the implications of findings from this research and how they link to relevant theoretical positions. Following this, attention will be given to how the present research can be used to cultivate pragmatic solutions for fatigue management in the wind industry, as well as how future research can use and improve the present research design.

Chapter 2 Psychological Fatigue

To conduct an applied study in fatigue, thought must first be given to the definition of this concept. Despite its regular study in health and industrial contexts, there remains to be debate and misunderstanding of the conceptual definition of fatigue in both academic and applied research. The present chapter will aim to address relevant definitions and debate around fatigue and ultimately reach the point where a working definition of fatigue can be presented to be used in the present research.

2.1.1 Chapter Structure

This chapter will initially consider what fatigue *is* (section 2.2). It will do this by first presenting the concept of acute psychological fatigue, distinguishing this from related concepts of chronic fatigue (section 2.2.2), physiological and mental fatigue (sections 2.2.3 & 2.2.4). Following this, section 2.3 will include an exploration of the history of research into psychological fatigue and the influences of societal and economic factors. From this understanding of historical context, three major developments in fatigue conceptualisation will be explored in section 2.4.

To gain an in depth understanding of fatigue and to aid in the quest for a scientifically accurate definition of the concept, research into the neurological underpinnings of fatigue will be examined in section 2.5. This will include an explanation of how the process of fatigue occurs in the brain based on recent research in this area.

Subsequent sections will give attention to concepts that are separate, but highly relevant to fatigue. Section 2.6 will discuss the relationship of sleep to fatigue as sleep deprivation is commonly viewed as the sole cause of fatigue (see section 2.6.9). Once a thorough understanding of sleep and its relevance to fatigue has been established, the following sections will explore key experiences in wakefulness and their interaction with fatigue. In section 2.7 consideration will be applied to effort, arousal and motivation and relation to the fatigue process. Furthermore, section 2.8 will explore control and strain and how these factors mediate the experience of fatigue, especially in a work context, which will be discussed using the highly influential demand control model (Karasek, 1979). This section will explore the conceptualisation of strain in work environments and the impact that it can have on employee fatigue.

After discussing factors that control and mediate the experience of fatigue, attention will be given to the consequences of sustained fatigue in section 2.9. This will include an explanation of compensatory control (section 2.9.1) and its after-effects (section 2.9.2). This is highly relevant to the present research as it conceptualises the negative consequences that fatigue can have in a high hazard work environment.

Finally, the knowledge accumulated from all of these sections will be synthesised into the formulation of a definition of fatigue that is relevant to the present research project in section 2.10 and this will be explained in the context of the wind industry work environment through the presentation of a causal chain of how fatigue could be attributed to a health and safety incident in section 2.10.1.

2.2 What is Fatigue?

Fatigue regularly affects every one of us. Around 25% of people report themselves to be fatigued most of the time (Müller & Apps, 2018). Despite its ubiquity, fatigue lacks a stable definition in psychological research and is often defined as a straightforward consequence of sleep deprivation (Shen, Barbera, & Shapiro, 2006). As highlighted by

Hancock, Desmond & Matthews (2012), most definitions to date have been narrow because they are each trying to measure a different part of the 'fatigue elephant'. Indeed, there is often a disparity between academic understandings of fatigue and its perception in applied settings such as in occupational research. This can lead to confusion surrounding its definition.

The concept of fatigue is significantly more complex than it first appears (e.g. simply 'feeling tired') and to investigate it in an applied setting, it is necessary to understand its theoretical underpinnings. This chapter will consider the breadth of the concept of fatigue and its associated psychological literature, with an intention of presenting a criterion in which fatigue will be discussed.

The present research is an investigation of fatigue in a unique working environment; however, to investigate this in its appropriate complexity, it is necessary to consider the breadth of the concept first. This will be attempted throughout the following sections, with the aim of presenting a working definition of fatigue for the current research project at the end of this chapter. Initially, some distinctions must be established when considering a working definition of fatigue which will be addressed in the following sections.

The first distinction refers to the chronicity of an individual's fatigue symptoms. Acute fatigue is the experience of fatigue as a situational and temporary state. Chronic fatigue is a major symptom of a condition in which an individual feels fatigued for most of the time for reasons that are not immediately clear. It is important to establish a difference between these distinctions as the factors that give rise to these differing fatigue states could vary greatly.

2.2.1 Acute Fatigue

Acute fatigue generally occurs due to mental or bodily exertion (Aaronson et al., 1999). It is commonly experienced by individuals irrespective of health and can normally be abated through appropriate rest and recovery (Aaronson et al., 1999; Shen et al., 2006; Techera, Hallowell, Stambaugh, & Littlejohn, 2016). It is experienced as a feeling of weariness, the individual will not necessarily want to sleep, but they will most likely feel an urge to desist with any effortful task that they are currently pursuing and give attention to something that they find more intrinsically enriching (Hockey, 2013).

2.2.2 Chronic Fatigue

Chronic fatigue is experienced similarly to acute fatigue in that it is felt as weariness, an urge to desist with present effortful actions and reduced concentration and memory (Fukuda et al., 1994; Jorgensen, 2008). However, it typically occurs in a sustained way and without necessary prior exertion, or with a much lower effort threshold than one would normally expect (Aaronson et al., 1999; Fukuda et al., 1994; Jorgensen, 2008). Chronic fatigue is often experienced as a symptom of severe illness (Dunn, Bhattarai, & Hughes, 2018; Jones et al., 2016) or as a side effect of medical treatment (Van Vulpen et al., 2016).

Chronic Fatigue Syndrome is a medical condition in its own right (Clayton, 2015; Fukuda et al., 1994; Naviaux et al., 2016). This long lasting and pathological disorder is characterised by extreme chronic tiredness and often bodily pain (Clayton, 2015; Radford & Chowdhury, 2016). It is estimated to affect around 17 million people worldwide (Afari & Buchwald, 2003), and there is a substantial literature investigating this from medical and alternative medical perspectives. There is still debate about the exact causes of chronic fatigue (Bested & Marshall, 2015). However, it would not be unreasonable to suggest that some cases of chronic fatigue are simply acute fatigue without its recovery phases (Lavidor et al., 2003) put simply, the unfortunate result of poor fatigue management. It would be logical to suggest that chronic fatigue can have a number of different causes, including the poor management of acute fatigue, a side effect of illness or treatment and as an illness in itself that could have origins in both lifestyle and/or medical factors.

Although there is a significant prevalence of chronic fatigue in the population, it is unlikely that an individual able to undertake the demanding tasks of a wind industry worker (WIW) will be currently suffering from chronic fatigue. The current program of research will therefore focus on acute fatigue, as this is the type most likely to occur in individuals working in the wind energy environment. If chronic fatigue is referred to, it will be expressly stated.

2.2.3 Psychological and Physiological Fatigue

Fatigue literature is notably different depending on the discipline in which it is studied. Much research in this area is either based in physiological science, generally focussed on localised muscular fatigue, or psychology, mostly categorised by mental or generalised fatigue, and each have differing associated literature. Therefore, it is important to make a distinction between muscular and psychological fatigue at this stage.

The present research focuses on the multidimensional experience of fatigue (e.g. mental, physical, emotional) and related factors (e.g. recovery, sleep propensity, anxiety and boredom) in an applied setting, therefore, this initial review will consider research that is relevant to that end. Therefore, it is appropriate to gather a broad understanding of fatigue focused on the psychological domain. Although an understanding of fatigue as a physiological experience (e.g. muscular fatigue) would be interesting, it is not within the means of the present research to gain an additional in depth understanding of this. Any attempt to do this would mean that the concept could not be viewed in its appropriate complexity within its associated domain of physiology or biology.

For the purposes of this research, a distinction can be made between psychological fatigue and muscular fatigue. Muscular fatigue is very specific - defined as a reduction in the ability to contract and exert force after a prolonged period of muscle activity. It is localised to the area in which the activity has taken place (e.g. bicep) (Al-Mulla et al., 2011). It will be 'felt' in the muscles as a physiological experience. Literature specifically associated with the biological process of muscular fatigue is generally well placed in physiology, exercise science and biology and therefore will not be expressly considered by the present research. However, for a general introduction to the topic, see Vøllestad, 1997; Westerblad, Allen, & Lännergren, 2002.

The present research focuses on an environment in which individuals are required to perform both physically and mentally meaning that fatigue associated with physical and mental demands will often occur in concert. Therefore, although this program of research will not consider physical fatigue from a biological/physiological point of view, it will consider the psychological aspects of fatigue following both mental and physical demands.

2.2.4 A Multidimensional approach- Psychological Fatigue

Another important distinction between 'types' of fatigue is more subtle. The terms 'mental fatigue' and 'psychological fatigue' are often used interchangeably in research

(Earle, 2004), yet a distinction should be made between the two. While mental fatigue refers specifically to fatigue experienced because of undertaking mental work (Murata et al., 2005), psychological fatigue is a wider definition encompassing many different factors that can affect the fatigue response including mental demands, emotional demands, sleep deprivation and physical work (Earle, 2004). The term ‘psychological fatigue’ is appropriate when considering fatigue experienced in the wind energy working environment, as WIWs encounter multiple different types of demands in their work and personal lives. Therefore, the term ‘fatigue’ in this research will refer to psychological fatigue; any other kind of fatigue will be stated as such.

The present research will focus on fatigue in a work setting. To consider this fully, it is important to examine the origins of research in this area as it will give useful context to the present research. The following sections will comprise of an examination of the history of fatigue research and linked to this, changing perception of the concept of fatigue in the altering socio-economic contexts of recent history.

2.3 A Brief History of Fatigue Research

Progression of research into fatigue has not been linear. Post-industrial Europe and America saw a surge of interest into the concept of fatigue, peaking in the 1920s and 30s, due to the new and widespread challenges of managing an industrial workforce. Consequently, in this initial phase of research, psychological fatigue was examined in a work context and a basic understanding of its existence as a barrier for productivity was developed (Hockey, 2013; Rabinbach, 1992). However, research waned as it became evident that the concept was more complex than it first appeared, and there was lack of consensus into how to investigate these complexities effectively.

Disappointingly, many of the initial challenges of understanding and predicting fatigue still exist (Hockey, 2013).

Despite the lack of progress in understanding its underpinnings, there has still been a practical need to understand fatigue in cases where its impact on quality of life is severe and undeniable. Recent years have seen a focus on fatigue in medical research, as a chronic condition in its own right, or its existence alongside other conditions (Dunn et al., 2018; Fukuda et al., 1994; Jones et al., 2016). Meanwhile, the search for an understanding of the underpinnings of acute psychological fatigue has been somewhat side lined.

The present research is an investigation of a specific aspect of fatigue in a unique work environment; however, to investigate it fully, it is necessary to consider the breadth of the concept first. This will be attempted throughout the following sections, with the aim of presenting a working definition of fatigue for the current research project.

To develop a well-founded definition of fatigue that will drive and inform the current programme of work, it is necessary to consider the origins of this concept, in both psychological research and its common understandings. The next section will comprise a brief history of fatigue, which will link to current understandings of the concept.

2.3.1 Fatigue in the Industrial Revolution

The philosopher Friedrich Nietzsche postulated a question that encapsulates western views on fatigue around the time of the industrial revolution in his famous text, The Will to Power:

‘Where does our modern world belong- to exhaustion or ascent?’

Friedrich Nietzsche, 1888 (The Will to Power, p.731)

This signifies the struggle faced in society during this time. Technology was advancing at an unprecedented rate and it seemed that the only barrier to continued progression was the inevitable exhaustion of the human workforce.

In his book, 'The Psychology of Fatigue', Hockey (2013) states:

> *'By the end of the nineteenth century, fatigue had changed from a generally benign (and rarely complained of) natural state to the negative condition we recognise today' (Hockey, 2013, p. 25).*

Indeed, there was an influx of research into fatigue between 1860 and 1948 as researchers tried to understand the issue of drops in productivity and feelings of tiredness after periods of work, (notably; Beard, 1869; Mosso, 1906; Taylor, 1911; Thorndike, 1900; Thorndike, 1912).

2.3.2 Changes in working culture and perceptions of fatigue

Shifts in perception of fatigue in western culture have likely been influenced by changes in working practices, notably in the movement towards capitalism (Hockey, 2013). With a focus shifting from individually manned land and self-regulated working, to dictated hours of work characterised by little control over work tasks or time planning in the industrial revolution. In a working culture characterised by payment depending on hours spent working (hours of service), fatigue became a barrier to productivity and therefore financial gain.

The newly industrialised, capitalist system heralded the widespread view of labour as a commodity. Because of the centralisation and industrialisation of work, people were no longer working for themselves and their families, but rather for the unquenchable thirst of the companies in which they were employed. With an average working day consisting of sixteen hours in the UK in early industrial times (Voth, 2001), many individuals were pushed to their limits to work as much as they could. It seemed that the only barrier to the labour resource was the inevitable fatigue afflicting the workers; thus, fatigue began to be known as a flaw, or even as a disease (Beard, 1869; Hockey, 2013; Rabinbach, 1992). This would make sense in a society that had newly commodified the concept of time, rendering any time away from work a loss in potential earnings.

Indeed, fatigue became known as a phenomenon that could halt the technological progress encapsulated by the industrial revolution; Rabinbach (1992) illustrates the dilemma faced by society at the time;

> *"Was not material progress undermined by the unreasonable demands that it made on the body and spirit?" Did not scientific and technological advances produce a dark underside in the physical and psychological exhaustion of modern life?"* (Rabinbach, 1992, p.20)

Thus, research searched for a way of overcoming this boundary for the unlimited progress that it craved and searched for a point of maximum productive output and minimum exhaustion (Rabinbach, 1992). Early psychologists viewed fatigue as something that could be studied, measured and eventually overcome (Rabinbach, 1992). From this, research into fatigue began in earnest.

2.4 Notable developments in fatigue research

The following section will include discussions of three notable developments in fatigue research. This will first illustrate early conceptualisations of the concept during the industrial revolution when the process of fatigue was likened to that of a thermodynamic motor 'running out of energy' in section 2.4.1. It will then explore a more recent interpretation of fatigue that is heavily based on this initial theory known as 'ego depletion' in section 2.4.2. This theory will then be discussed in the context of the opposing theory of fatigue as a motivation moderator in section 2.4.4.

2.4.1 Fatigue as an energy decrement; The Human Motor

The concept of fatigue remains synonymous with the metaphor of 'running out of energy', as though there are pools of energy resource available, and their depletion causes an individual to experience fatigue. Rabinbach (1992) suggests that a profound change in the perception of work and the working body became incorporated into a single metaphor- 'the human motor'. This description provided a clarity of understanding for the industrial age. If humans functioned in the same way as machines, then maintaining energy and preventing fatigue would be a simple question of energy in vs. energy out, allowing the complexities of the concept to be somewhat circumvented.

This dominant conception of fatigue follows a movement of using mechanical metaphors to explain human bodily functions and experience. A steam engine uses energy over time, and through use will run out of this resource. The same could be convincingly argued for absolute levels of human physical energy from a biological basis. In fact, in the latter part of the nineteenth century, workings of the human mind and body were considered to follow the same laws as that of a thermodynamic machine (Hockey, 2013).

The influential German psychiatrist Emil Kraepelin (1902) championed the theory that fatigue represented the body's falling energy while undertaking work. He maintained that this could be measured by performance decrements. This provides a logical explanation for a state which was previously (and presently) not well understood and would appear to make intuitive sense. However, there are two issues with this theory; one is that despite findings suggesting the role of glucose depletion in fatiguing activities (Gowland, 2006; Hagger et al., 2010), there is no purely biological explanation for fatigue (Inzlicht et al., 2014), although there have been attempts to claim that there is, which will be discussed in the following section. Furthermore, the experience of fatigue seems to be largely task dependent. If an individual is enjoying a task that they have chosen to undertake- they may not experience fatigue at all, in fact they may even be energised by the activity (Csikszentmihalyi, 1997).

While studying fatigue from the limiting standpoint of energy depletion gave researchers an intuitive framework for thinking about the problem, this approach caused many issues for early psychologists. In his somewhat irritated article, Henry Link (1920) discusses his opinion that the value of psychological fatigue studies to that date were nil. Indeed, other early organisational researchers Muscio (1920) and Wyatt and Weston (1920) determined through their applied industry studies, that fatigue was in fact so complex that it was impossible to isolate any lone 'fatigue factor'.

Exemplifying the frustration of investigations of this kind, Muscio (1920) recommended an elimination of the term 'fatigue' all together. In a seemingly neat circumvention of this issue, Link (1920) professes that behaviourist theories of the Gilbreths should be used as a means of understanding and eliminating fatigue. Link laments that the Gilbreths were not sufficiently recognised by psychologists, as their lack of concern with the 'theoretical problem of fatigue,' allowed them to focus on the practical steps that could be taken to overcome it.

Frank and Lillian Gilbreth (1919) subscribed to the notion of fatigue as an energy decrement. They conducted their work based on the view that all lost or unnecessary motion is a waste of energy. Link speaks of their *'beautiful technique of recording the movements which characterise individuals in certain situations, and subsequently limiting all movement which are superfluous'. (Link, 1920, p.341).* He praises the Gilbreths for their tendency not to concern themselves with the psychosocial concept of fatigue, as he professes; *'they have probably done more than anyone else to eliminate the waste motion' (Link, 1920, p.342)*.

However, despite the Gilbreths and similar works of Taylor (1911) who released a book entitled 'Scientific Management', suggesting the standardisation of procedures to reduce inefficiency of movement, fatigue in workplaces continued to be a problem. The reductionist and simplified approach of energy preservation was criticised by psychologists Munsterberg (1913) and Ioteyko (1919) who highlighted the lack of positive change established through 'scientific management' interventions and the need for the consideration of worker fulfilment and motivation, thus emphasising the difficulty in the psychological approach of examining the multifaceted nature of the fatigue issue.

Although much common understanding of fatigue still links it to an energy decrement, it is now generally established that the simple limitation of physical motion in a work environment will not do much to eliminate fatigue. Thus, as highlighted by psychologists of the time who tried and failed to devise successful fatigue management techniques following this approach, the limiting view of fatigue as an energy decrement prevents an accurate view of the phenomenon in its appropriate complexity.

2.4.2 Ego-depletion

The perception of fatigue as an energy decrement has persisted into current understandings of the concept with theories classifying fatigue as the result of the depletion of resource remaining influential in current research. However, they have developed beyond the simple model outlined above, to more advanced models, which attempt to explain the phenomenon at a cognitive level. A particularly important example of this is 'Ego depletion Theory', suggested by Baumeister and colleagues in 1998, which has significantly influenced modern conceptions of fatigue and self-control. It is important to examine this theory, as well as the discussion surrounding it, to gain an understanding of current debates dominating the discussion of fatigue and its epistemology.

Ego-depletion theory focuses on the impact of applying effort to an action over time. The activity requiring effort in Baumeister's' research was the exertion of self-control in tasks that required the suppression of behaviour or emotions. Baumeister postulates that as effort is applied to the exertion of self-control, the individual's "energy reserves" will diminish. In this line of logic, the consequence of "energy" becoming "depleted" includes the experience of fatigue (Baumeister et al., 1998;

Hagger et al., 2010). Thus, much effort-related fatigue research in this arena has been encapsulated into research on self-control.

Ego-depletion theory is underpinned by the assumption that acts of self-control draw on some limited resource, once this resource is depleted, an individual will feel fatigued and their performance will suffer during subsequent tasks. Baumeister et al seemingly supported this theory in a series of studies in which participants were asked to exert self-control in a first task (e.g. eating radishes instead of chocolate) and then to exert self-control in a second task (e.g. supressing emotion while watching an upsetting film). Their performance was compared to individuals who had not been asked to exert self-control in the first task. The findings illustrated that participants who exerted self-control on both tasks displayed decreased control on task 2 compared to participants who had only had to exert self-control on task 1 (Baumeister et al., 1998).

Baumeister, Vohs and Tice (1994) likened the process of mental depletion to that of physical exertion leading to fatigue. In this logic, just as a muscle gets tired from exertion, acts of control cause short-term impairments and just as a muscle gets stronger through exercise, regular self-control can improve willpower strength. The theory does not pertain that all performance decrements can be explained by a total depletion of energy. Baumeister again compared this phenomenon to physical strength, tired athletes can manage to summon strength at certain decisive moments. Indeed, findings from Muraven & Slessareva (2003) suggested that participants could use self-control strategically, to conserve energy if they knew that they had another task to do, or to try harder if they were offered a reward. This corresponds with Hockey's compensatory control model in which fatigue can be overcome, but with consequences (Hockey, 1997). However, Baumeister (1994) still maintained that *"at a certain point, fatigue becomes insurmountable" (Baumeister, 1994, p353).* Unlike Hockey, Baumeister maintained that the act of overcoming fatigue made further use of physical energy reserves, and once they had been depleted, fatigue would be inevitable and incurable.

2.4.3 Energy Resources

The identity of Baumeister's mysterious energy source vulnerable to depletion remains vague (Inzlicht et al., 2014). The closest that Baumeister has come to explaining this was through his studies with Galliot (2007) in which they attempted to determine a link between acts of self-control and glucose expenditure. The findings of this study were convincing; it found that acts of self-control reduced blood-glucose levels and that the ability to exert self-control was re-instated after the consumption of glucose (through sugar). These findings were supported in a meta-analysis of the Ego-depletion theory (Hagger et al, 2010) in which a significant effect of glucose on self-control was found in an analysis of 83 studies. However, there has since been much debate surrounding these findings (Beedie & Lane, 2014; Kurzban, 2010; Molden et al., 2010). The most notable argument against the "limited resource" theory is that glucose is not limited, but in fact works alongside motivational impulses to allocate energy to the performance of designated tasks.

As highlighted by Inzlicht et al (2014), if exerting self-control does not reliably reduce glucose levels, the theory of Ego-depletion is no more than a metaphor. Further supporting this assertion are studies by Job, Veronika, Dweck and Walton (2010) and Clarkson, Hirt, Jia and Alexander (2010) which found that perceptions of resource depletion affected performance more than actual 'depletion'. Dweck et al (2010) found that participants who believed that willpower was unlimited were able to maintain self-control whereas those who believed that it was limited were less likely to be able to sustain this control. In a recent paper, Baumeister, Tice and Vohs (2018) conceded; *'We now think that glucose processes are much more complicated' (p. 142).* Therefore, despite the promising findings around glucose, there is still a lack of clarity around the nature of these proposed resources.

Seemingly, ahead of his time, David Navon (1984) likened resource-based theories to 'theoretical soup stones.' By this he means a theoretical construct which seems essential to understanding the phenomenon, however it is actually unnecessary (an analogy which is taken from the folk story of 'Stone Soup' in which the stone was not needed to make the soup despite previously being thought to be necessary for this). Although the explanation has seductive qualities, it can go some way to confuse matters further (Navon, 1984).

Ego-depletion provides a convincing and intuitive explanation for fatigue experienced after periods of exerting self-control for two main reasons. One is that the subjective feelings associated with this kind of fatigue can feel as though one is 'drained' of energy and therefore a logical connection would be to associate this with the depletion of resource. The second is that this theory would fit into our collective understanding about the mechanisms and workings of the world, and ourselves, which have been held since the birth of the 'human motor' in the industrial revolution. Alas, the truth seems to be far more complex than a simple decrement of energy. An alternative theory of fatigue is that it is akin to a moderator, emotion, or internal warning system, which rather than being the by-product of depleted energy, is a signal of where energy may be best directed. The origins of this theory will be discussed in the next section.

2.4.4 Fatigue as a Motivation Moderator

A more robust theory of fatigue seems to be its existence as an emotion-like motivation moderator. To understand this approach, it is important to consider the concept of goal-directed behaviour. Dutch researchers Boksem & Tops (2008) postulate that goal directed behaviour is what motivates individuals to commit effort to action. In their paper entitled 'Mental fatigue, costs and benefits,' they explain how individuals engage in a sub-conscious cost/benefit analysis before engaging in actions. When embarking on an action, consideration will be placed in the likely reward compared to the cost of completing the action. According to this way of thinking, individuals continue to engage in this internal analysis whilst completing tasks and fatigue is a signal that the costs of continuing to engage now outweigh the expected rewards. The fatigue signal is a direction to change strategy and commit time and effort to other actions that are more intrinsically rewarding. This explanation draws on long-held theories, publicised by psychologists such as Bartley and Chute (1947) who concluded that fatigue was best considered an outcome of conflict between competing behavioural tendencies. A number of research projects, other than Boksem & Tops have delved into the complexity of the concept and gone some way to explaining its nuances (e.g. Hockey 1986; 1997; 2011; 2013 Earle, 2004; Earle, et al, 2015).

An important point to note in this approach is that although fatigue is common when engaging in tasks for a significant period, its presence is not readily experienced in all tasks (Boksem & Tops, 2008; Robert. Hockey, 2013). Fatigue is usually experienced in low control conditions when effort is applied to demanding tasks. Consider the difference between the feelings of sitting at a desk in a communal office for two hours to complete a dull piece of work due at the end of the day, to spending two hours engaging in a pleasurable, creative, self-motivated activity at home such as painting or cooking. With the more time spent, the first task is likely to evoke feelings of tiredness, frustration, boredom and loss of engagement with the task (fatigue) whereas the latter is likely to be energising, enjoyable and, if the conditions are right, put an individual into a state of 'flow' (Csikszentmihalyi,1997). This is because most personal goals have high value anticipated outcomes, with few costs (Hockey, 2013).

Conversely, the longer one spends on a low control, externally motivated task, the more expected rewards will diminish. Fatigue is a signal that allows the reconsideration of motivational priorities and directs attention to activities that offer personal rewards (Boksem & Tops, 2008; Hockey, 2013). Fatigue signals can be overcome and ignored. However, to maintain focus on the task, effort would need to be increased and feelings of strain would occur. Another option is to reduce effort and complete the task to a lower standard than expected (Hockey, 2013).

This approach to explaining fatigue can be considered from an evolutionary perspective as the balance of exploitation versus exploration (Inzlicht et al., 2014). Natural selection has favoured those who have been able to operate self-control and effort flexibly. Being able to switch from exploitation to exploration quickly aids coping with unexpected demands. Although engineering systems are designed only to fulfil one, or a very small number of outcomes, humans need to satisfy many different goals over the course of a day to survive (Hockey, 2013). Revisiting the energy depletion/resource theory, it would not have made evolutionary sense for the drive for exploration to be a result in depletion of energy, as this would leave no power to engage in necessary exploratory activity (Inzlicht et al., 2014).

Therefore, in this logic, rather than being a symptom of the depletion of energy resource, fatigue stokes a desire to engage in intrinsically rewarding, or 'want to' tasks.

To gain a more in-depth view of fatigue from a psychological standpoint, it is helpful to consider neurological research in this area. The following section will provide a brief overview of this, however as the neurological aspect of fatigue is not the focus of the present research, it will not aim to consider the wider complexities within the field. Rather, it will provide a helpful overview, allowing the definition of fatigue to be put into context with its neurological underpinnings.

2.5 Neurological underpinnings of fatigue

Recent research has gone some way to explaining the neural mechanisms involved in fatigue. Due to a development of brain scanning technology such as EEG and fMRI, the process of fatigue is able to be investigated more accurately than ever before, thus providing a deeper understanding of the neurological process that occur when an individual experiences fatigue. This section will give an overview of research into neurological underpinnings of fatigue to provide a logical companion to discussion of the theories. This will not be a portrayal of the neurology of fatigue in its full complexity, but rather a discussion aimed at providing a deeper insight into fatigue to aid the present research. (For a comprehensive introduction to this field see Moore, Key, Thelen, & Hornsby, 2017; Kuppuswamy, 2017; Van Der Linden & Eling, 2006). Research surrounding brain function associated with fatigue will initially be discussed, followed by an overview of this research in diagram form in Figure 6.

2.5.1 Local vs Global Processing

Research suggests that fatigue is more likely to affect detailed, complex thinking (local processing) rather than automatic thinking (global processing) (Van Der Linden & Eling, 2006). This means that often a fatigued individual, will still be able to function when completing single-task actions that they are used to undertaking (e.g. an experienced driver will still be able to complete their drive home from work). This is because fatigue specifically affects the pre-frontal cortex, which is responsible for tasks requiring executive control functions and is generally associated with more detailed thinking (Petruo et al., 2018; Zanto et al., 2011).

Supporting evidence for this theory comes in the fact that individuals with pre-frontal cortex damage or age-related degradation display fatigue symptoms without engaging in actions typically associated in causing fatigue in individuals with normal pre-frontal cortexes (Duncan et al., 1996; Shortz et al., 2015). Additionally, EEG and fMRI analysis has shown a diminishment of activity in frontal areas of fatigued individuals' brains (Lim et al., 2010).

The next sections will explore processes of fatigue through exploration of the pre-frontal and anterior cingulate cortex as well as relevant neurotransmitters as a pathway to the experience of fatigue.

2.5.2 Pre-frontal and Anterior Cingulate Cortex

The pre-frontal cortex has simultaneity constraints meaning that the amount of tasks it can undertake at one time are limited (Petruo et al., 2018). Therefore, a large 'cost' is incurred in the performance of high-level cognitive processing tasks that engage the pre-frontal cortex, e.g. learning a new language as opposed to speaking a familiar language, as they prevent the occurrence of similar tasks (Kurzban et al., 2013).

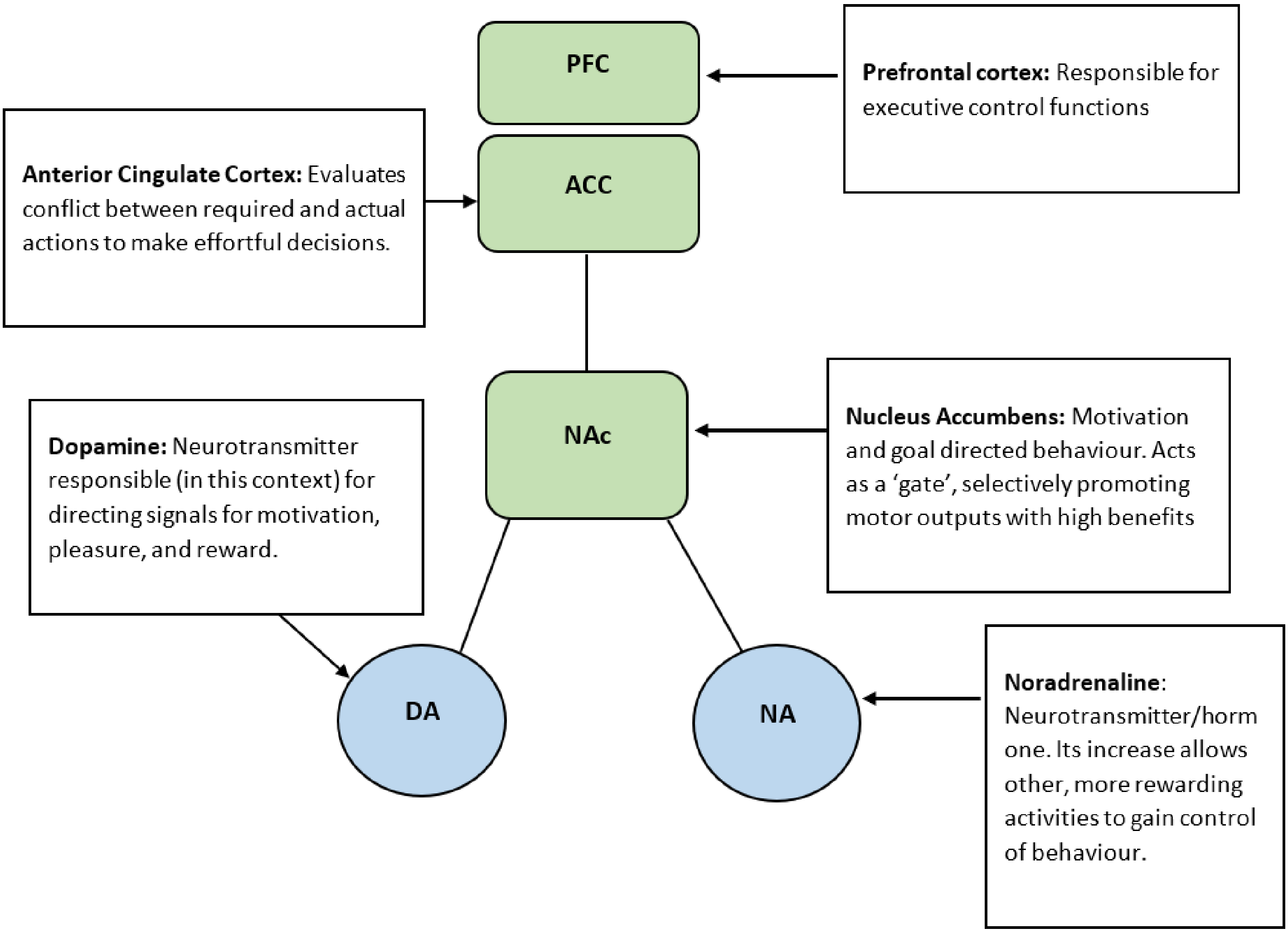
There is also evidence for the significant role of the anterior cingulate cortex (ACC) in the effort/fatigue relationship (Boksem & Tops, 2008; Robert. Hockey, 2013). The ACC's function is to evaluate conflicts between required and actual actions (Walton et al., 2006). This is consistent with the psychology-based motivational/emotional conception of fatigue and has strong neurological evidence including the fact that impairments of effortful decision-making are associated with damage to the ACC (Mingote et al., 2005; Vogt, 2009).

2.5.3 Dopamine and Noradrenaline

Neurotransmitters such as dopamine (DA) also play an important part in the fatigue process. Increased perceived effort compared to predicted rewards results in a down regulation of DA activity in the nucleus accumbens (NAc), a part of the brain associated with motivation and decision making, informally known as the 'reward circuit' (Boksem & Tops, 2008; Nestler & Carlezon, 2006). The NAc has a 'gating' function, which regulates the flow of DA activity to the PFC (Boksem & Tops, 2008; Botvinick et al., 2000). The neurotransmitter noradrenaline (NA) also plays a role. This is known as 'the stress hormone', which increases alertness and primes the body for action. NA is implicated in the interruption of ongoing activities when their utility drops below a certain level (Hockey, 2013).

Research suggests that there are optimal levels of DA activity for both goal maintenance and goal shifting. High levels encourage the maintenance and rigidity of behaviour, whereas lower levels encourage goal shifting (Schultz, 2007). NA also has 'stay and shift' modes. Quick bursts facilitate the maintenance of activities and sustained activation allows the shift to a new goal (Hockey, 2013). This supports the notion that the experience of fatigue is likely to be underpinned by the activity of neurotransmitters in the brain signalling to 'stay' or 'shift' on the activity that is currently being undertaken. Figure 6 presents an overview of this process.

Figure 6- A Broad overview of Fatigue and Effort Mechanisms in the Brain



2.5.4 Fatigue in the brain- Summary

Fatigue is the result of a subconscious cost/benefit analysis of effort vs rewards (Kurzban et al, 2013; Boksem & Tops, 2008; Hockey, 2013; Inzlicht et al., 2014). The cost/benefit analysis is performed through DA and NA activation/reduction, which passes through the 'gate' of the NAc, which then influences activity in both the ACC, which is responsible for making effortful decisions and the PFC, which controls executive function (actually 'carrying out' the tasks) (Boksem & Tops, 2008; Botvinick & Braver, 2015; Hockey, 2011). The reduction or increase of neurotransmitters in these areas of the brain either causes an individual to carry on with a task, or to experience the feeling of motivation to shift goals to other top-down activities which are more rewarding (Schultz, 2007). This experience of fatigue will often be felt through tiredness and discomfort.

This theory of fatigue is congruent with neurological, evolutional, and behavioural research and provides a more convincing explanation than ego-depletion based theories. However, as with theories based on thermodynamic machines, there is a danger of conflating the complex processes of the human brain and behaviour with current understandings of technology. The following section will examine the potential limitations of this approach framed by a discussion of Kurzban's 'computational model' of fatigue.

2.5.5 From the Human Motor to The Human Computer

In his influential theory, Kurzban et al (2013) uses a 'computational model' to explain the fatigue process. Felt sensations, Kurzban explains are the output of mechanisms designed to measure opportunity costs of engaging in the current mental task. The function of this is to direct the reallocation of computational mechanisms away from the present task and toward the task that yields greater benefits. This is an apt explanation of fatigue within this approach as it captures the multidimensional and logical nature of fatigue-related subconscious decision-making. However, it does highlight a potential danger. The computational explanation of fatigue could be an extension of the 'human motor' for the digital age. As technology becomes more advanced, so, it seems does psychological interpretation of the human mind and body. However, it is important to remember that just as imagining humans as thermodynamic motors was not entirely accurate, picturing the human brain and fatigue response as similar to a computer could lead to a lack of consideration of the concept in all of its human intricacies.

Yet, it is important to have a model on which to base our understanding of fatigue. This approach seems to be the most apt at doing so as it offers a model of fatigue that is in-line with current knowledge about its likely neurological underpinnings and evolutionary basis. However, there are still advancements to be made in the current understanding of fatigue.

An understanding of fatigue must include reference to its antecedents and related states. A common conceptualisation of fatigue is that it is wholly caused by inadequate acquisition of sleep (see section 2.6). The following section will interrogate this view and explore the relationship between fatigue and sleep as well as the concept of sleep itself and finally, an exploration of the concept of sleepiness and how this differs from fatigue.

2.6 Is it all about sleep?

The impact of sleep, and more to the point, sleep deprivation should be a major part of any applied investigation into fatigue. However, as with most facets of fatigue, the literature surrounding the relationship between sleep deprivation and fatigue is somewhat convoluted (Lavidor et al., 2003; Shen, Barbera, & Shapiro, 2006).

Much research in this area views fatigue as simply a consequence of obtaining a lack of good quality sleep. This is particularly the case with investigations into fatigue management practices in workplaces (e.g. Darwent, Dawson, Paterson, Roach, & Ferguson, 2015; Dawson & McCulloch, 2005), leading to the erroneous view that opportunity for sleep is the only thing that needs to be accounted for when considering an individual's fatigue response. Rather worryingly, anecdotal experiences suggest that this may also be the pervasive view in some industrial settings, which gives rise to concerns around comprehensive fatigue risk assessments.

A reason for this predicament could be that models of sleep and wakefulness have been highly effective at predicting levels of fatigue and wakefulness in jobs demanding shift work and extended wakefulness times (Hockey, 2012). However, these models do not consider the content of an individual's wakefulness time. According to them, fatigue endured after a highly stressful work shift with little opportunity for control would be the equal to that experienced after a day spent at leisure with friends if the individual had obtained the same amount of sleep the night before. It is clear, at least experientially, that this is not the case. Indeed, research investigating task fatigue has found that individuals are far more likely to experience fatigue symptoms when engaging in tasks which are not intrinsically motivated and encompass a lack of control (Karasek, 1979) (see section on 'fatigue as a motivation moderator').

There is a need to unite the two literatures of fatigue as a motivational construct and fatigue in relation to sleep. It would make sense, first, to consider exactly what impact sleep deprivation has on the mind and consequently fatigue. Following this, fatigue should be viewed in the context of sleep/wake drives experienced due to circadian rhythms, then an understanding of the distinction between fatigue and sleep propensity (sleepiness) should be developed, as these concepts are often erroneously used interchangeably. Finally, sleep will be discussed alongside other potential stressors related to fatigue and framed within the context of the present research.

2.6.1 What is Sleep?

Sleep is an essential function for the body and mind. All animals need sleep to varying degrees and humans are no exception to this. There has been dispute within research surrounding the exact function of sleep (Walker & Rechtschaffen, 2009). However, when considering the multitude of physical and mental processes that are improved by optimal sleep, a more pertinent question should be whether there is any process that could function properly without it (Walker & Rechtschaffen, 2009).

Much can be said about the extraordinary state of slumber and its effects on the human mind and body. However, the current account will focus on aspects that are linked to cognition, mental state and of course fatigue. This will not be a comprehensive account but will aim to provide useful background for the present applied research.

The process of sleep will first be considered, with attention placed on the utility of its effects on information processing and the impact this has on waking time. Following this, research around the consequences of sleep deprivation, both in the long and short term will be investigated and emphasis will be placed into viewing this in line with fatigue. Next, sleep/wake cycles and circadian rhythms will be considered (e.g. natural low and high points in energy throughout the day) as this is also highly relevant to fatigue. Finally, fatigue will be compared to sleepiness, a concept for which it is commonly mistaken and the question of whether there is a need for distinction between these two concepts in research will be discussed.

2.6.2 Sleep Cycles

Until recently, sleep was considered a state of complete rest in which a limited amount of brain activity took place. However, advancements in the understanding of sleep in the 1950s onwards have allowed an insight into the complex process engaged in by the sleeping brain (Aserinsky & Kleitman, 1953). From this time onwards, research highlighted the complexity and usefulness of the process of sleep.

The sleeping mind will cycle through a number of different stages of sleep in 90-minute intervals, initial and last stages of these intervals will be lighter with the individual more susceptible to being awoken due to external stimuli, however in the middle of these cycles, deeper sleep will occur. An optimal period of sleep (around 7-8 hours for an adult) (Hirshkowitz et al., 2015) will spend around half of this time with a bias towards rapid eye movement sleep (REM) and the other half will be spent with a bias towards non-rapid eye movement sleep (NREM) (Walker, 2009). During REM sleep, brain waves are very similar to those found in awake and alert individuals.

However, in NREM sleep, these brain waves slow down considerably (Walker, 2009). The reason for this cyclical activity during sleep is at least in part for effective information processing (Walker & Stickgold, 2006).

In the first half of a sleep period, there is a bias towards NREM sleep. This type of sleep allows individuals to sort through information learnt during the day and discard that which is unimportant. The second half of a sleep period generally has a bias towards REM sleep. This is when the brain consolidates information retained during the first half of the sleep period. REM sleep is usually when dreaming takes place (Walker & Robertson, 2016).

Therefore, loss of sleep at either the beginning or end of the period will mean the loss of a specific 'part' of the sleep process that plays a unique and integral role for information processing and cognitive regulation. Sleep is evidently not simply one continuous period of rest, rather is it a complex activity involving information processing and recovery.

This is particularly relevant for work environments in which sleep may be compromised, through either shift work, workload, or environmental factors. The present research considers an environment categorised by long working hours and environmental factors that may hamper sleep quality and quantity. This is a particularly pertinent issue as sleep is of critical importance due to the high-risk working environment and often-complex nature of tasks. Therefore, consideration of sleep quality and quantity is particularly important in the present research.

2.6.3 Consequences of Sleep Deprivation

The consequences of chronic sleep deprivation has been well researched. A meta-analysis of 16 studies and over 100,000 participants found that regular deprived sleep (less than 7 hours) was a predictor of early death (Cappuccio et al., 2010). There is also increasing research that links long-term sleep deprivation to Alzheimer's disease (Ju, 2013; Lim, Kowgier, Yu, 2013). Particularly relevant to the present research, the dangers of sleep deprivation have been highlighted in a number of different work environments due to its effect on cognitive processing and risk perception (Kazemi et al., 2016; Lemke et al., 2017; Saadat et al., 2016).

Sleep deprivation specifically affects complex cognitive processes (those that are also affected by fatigue, see section 2.5.1). In a recent study, Wild, Nichols, Battista, Stojanoski and Owen (2018) asked 10,000 participants to self-report the amount of sleep they had the previous night and following this, complete a complex cognitive task. It transpired that the optimal amount of sleep per night for cognitive functioning on this task was 7.02-7.91 hours. Those who slept 6.3 hours per night or less had notable impairments in overall cognition and those who slept even less than this (<4 hours) had an impairment which was equivalent to adding eight years to their age (increasing age was associated with decreased performance in all areas). Unfortunately, the participants who slept for six hours or less are representative of a large proportion of the current population, with one third of the UK only obtaining 5-6 hours of sleep per night (The Sleep Council, 2013).

The effect of sleep deprivation on mood is also notable. Research has shown that one night of sleep deprivation can cause a degradation of encoding, specifically the conversion of sensory input into neural representation (Walker & Stickgold, 2006). However, this degradation is mostly present with the encoding of positive and neutral information, with the processing of negative information remaining resilient to this encoding impairment (Walker & Stickgold, 2006). This means that a sleep-deprived individual will have a bias for encoding negative information and likely a negative outlook. Indeed, sleep deprivation has been associated with depression, burnout and anxiety (McEwen & Karatsoreos, 2015; Rosen et al., 2006).

Without accounting for any other factors, lack of sleep alone causes individuals to display fatigue-related degradation in cognitive functioning. However, it is not only lack of sleep which can cause individuals to display this decline in functioning. Factors such as time on task also have similar effects (Hopstaken, Van Der Linden, Bakker, & Kompier, 2014; Petruo et al., 2018).

Sleep deprivation combined with other stressors that give rise to fatigue will worsen fatigue symptoms and a sleep-deprived individual will take less time to become fatigued when confronted with other fatiguing factors (Ma et al., 2015). Sleep could be viewed as ‘the bare bones’ of fatigue, if adequate sleep is not obtained, managing fatigue will be significantly more difficult, however an individual who has obtained adequate sleep the previous night will still be vulnerable to fatigue from a multitude of other factors during the course of the next day. This is highly relevant to the current research, as wind industry workers are not only vulnerable to sleep deprivation, but also to many work task and environmental factors that are likely to affect fatigue.

2.6.4 Sleep/wake interaction and the Circadian Rhythm

Another important factor to consider is the process of regulation that takes place during our waking hours. Each of us has an internal body clock (circadian rhythm) which drives us to wake up, eat and sleep. This rhythm runs for around 24 hours, and is influenced by external factors such as light and dark, these factors known as 'zeitgebers' tend to regulate this process to match with the daily solar cycle (Czeisler et al., 1999).

The circadian rhythm is a strong innate driver of behaviour, and it generally takes time make to alterations to it. Consider the example of travelling between different time zones; an individual who travels from London to Singapore, which is eight hours ahead, will take three to eight days to adjust to their new sleep/wake cycle (Manfredini, Fersini, & Francesco, 1998). During this adjustment period, they will experience trouble sleeping, along with fatigue and drowsiness when awake (Arendt & Marks, 1982). A similar process will occur for shift workers who have to change working patterns, especially those working at night (Thorne et al., 2010). Circadian rhythms are yet another important factor that can affect experience of fatigue in an innate and significant way.

2.6.5 Owls and Larks

Research suggests that humans do not all operate with the same circadian rhythm. In fact, there is strong evidence to suggest that most have a slight or moderate preference towards being more alert in the mornings ('larks') or the evenings ('owls'). This innate and unique preference (known as a chronotype) can affect individuals' ability to obtain a sufficient amount of sleep if aspects of their lives demand early starts or late nights (Merikanto & Partonen, 2014). Investigations into fatigue and sleep should test this preference in individuals to determine whether it may have an influence on their sleep quality/quantity and feelings of fatigue during waking hours (Earle, 2004).

2.6.6 The Drive to Sleep

A further prominent factor in the sleep/wake relationship is a drive to sleep which starts to build as soon after waking. This is caused by the release of the hormone adenosine during our wakeful hours (Porkka-Heiskanen, 2009). As it builds, this hormone will start to cause increasing feelings of tiredness.

Research indicates that if in an individual obtains eight hours of good quality sleep, they will be able to enjoy around 16 hours of wakefulness without the strong urge to sleep. During this time their circadian rhythm will demand wakefulness and their sleep pressure will not be so severe, therefore these drives will balance one another out (Dijk & Czeisler, 1994). Wakefulness that exceeds this amount will result in a significant decline in cognitive function, especially if it is combined with wakefulness during a time when the circadian rhythm demands sleep (e.g. during a night shift) (Killgore et al., 2007).

This can also have a cumulative effect as illustrated by Van Dongen, Maislin, Mullington, & Dinges (2003) who found that when sleep was limited to 6 hours per night over a 14-day period, participants experienced similar deficits in vigilance performance than those that had been fully sleep deprived for 48 hours. Interestingly, although cognitive performance was not resistant to chronic additional wakefulness, perception of tiredness was, meaning that when sleep deprivation is chronic, subjects couldn't reliably introspect their own tiredness (Van Dongen et al., 2003). This is particularly relevant to fatigue in working environments, as it supports the notion that individuals who are chronically sleep deprived (those who obtain six hours or less of sleep per night) are unlikely to recognise the effects of this sleep deprivation.

2.6.7 Sleep-affecting Substances

Throughout history, and increasingly in modern society, humans have manipulated their natural sleep/wake drives through the ingestion of substances designed to promote wakefulness or sleep.

A prominent substance in this sphere is caffeine, with coffee being the second most commonly consumed beverage worldwide, after water (Butt & Sultan, 2011). Caffeine is present, not just in coffee, some teas and carbonated drinks, but also in many foods and medicines. Therefore, individuals are likely to ingest more caffeine than they realise. Caffeine causes individuals to feel more awake than their sleep/wake drives would normally allow through blocking the natural release of adenosine (Davis et al., 2003). Caffeine has been shown to increase subjective and performance related measures of alertness (Davis et al., 2003). However, moderate to high caffeine use is also associated with sleep difficulties (Bonnet & Arand, 1992). Therefore, investigations into fatigue and sleep should determine how much caffeine participants consume on average to account for any artificial increase in alertness or decrease in sleep quality/quantity.

Multiple other stimulants can artificially increase alertness, but in turn have a negative effect on sleep. Nicotine (Zajdel et al., 2002) and illegal drugs such as amphetamine and cocaine (Waters et al., 2003) are examples of this. Conversely, commonly consumed depressants such as alcohol can cause individuals to fall asleep more quickly, but have more disrupted sleep patterns, often waking up in the middle of their sleep cycle and struggling to get back to sleep once their effects have worn off (Roehrs & Roth, 2001). Of course, the consumption of alcohol can also cause after-effects that include fatigue in the form of a hangover (Kim et al., 2003). Sleeping pills also act as sedatives, but continued use has been shown to have a negative effect on sleep patterns (Lemmer, 2007). Therefore, investigations into fatigue should look to aggregate as much information as possible about the regularity of ingestion of substances which may affect alertness and disrupt sleep.

2.6.8 Sleep and Fatigue Summary

Knowledge of sleep, sleep deprivation, circadian rhythms and sleep drives during wakefulness is an integral basis for any applied investigation into fatigue. These factors can act as stressors for fatigue, either as independent causes, or as part of multiple causes.

Most individuals in modern working conditions will be required to work through periods when their brains are driving them to sleep or rest, thus causing feelings of fatigue or drowsiness that can impair performance and compromise safety. This may result in a reliance on caffeine and other stimulants to overcome these feelings of fatigue, thus causing issues with sleep deprivation, which they may treat with sedatives such as alcohol or sleeping pills, thus beginning a negative cycle.

An individual working in the wind industry environment is likely to experience an extreme amount of pressure to ignore their natural circadian cycle, with long shifts encompassing intense work which they have little control over. Therefore, increased wakefulness and circadian rhythm disruption is predicted to be a major stressor for fatigue in the present research.

2.6.9 Fatigue and sleep propensity (sleepiness) - are they different?

Perhaps due to the lack of agreed classification of fatigue in the literature, fatigue and sleep propensity (sleepiness) are often viewed as the same state, when they are in fact notably different (Shen, Barbera, & Shapiro, 2006). Sleepiness is a distinctive feeling categorised by heavy eyelids and the strong compulsion to sleep right away (Hockey, 2013). It is a feeling that's occurrence would ideally be reserved for a safe place and convenient time for an individual to engage in eight hours of slumber, or at least a nap. However, due to sleep and circadian rhythm disturbances (or perhaps because of illness/treatment), it can often occur at extremely inopportune times such as during driving or while completing a work task.

Fatigue on the other hand, is a feeling of general weariness. This state is not necessarily categorised by the strong urge to sleep right away. However, individuals experiencing it are likely to feel the desire to desist with the task that is currently demanding their concentration. Therefore, the two states are subjectively different; one is categorised by the strong urge to sleep right away and the other by the urge to abandon the current task and move on to something more rewarding. In an ideal world, fatigue would be experienced at the end of a working day when it is time to go home and engage in enjoyable activities, or at least before a lunch break. However, due to increased working hours, decreased control and other stressors such as decreased sleep, fatigue, like sleepiness is often experienced at inopportune or even dangerous times.

Excessive daytime sleepiness is generally caused by decrements in sleep, circadian disturbance, sleep disorders or pathological symptoms. Fatigue can also be caused or aggravated by these factors. In fact, when sleep deprivation is chronic, individuals can be more likely to report general feelings of fatigue during waking times rather than excessive sleepiness (Chervin, 2000). It is important to distinguish between these two states because their outcomes are generally different. If an individual is experiencing sleepiness, they may actually fall asleep, or engage in micro-sleeps (Boyle et al., 2008). However, if an individual feels fatigued, they are more likely to experience lapses in concentration and deviations to lower effort options (Hockey, 2013; Inzlicht et al., 2014) (see previous section on compensatory control).

While there is significant crossover between the antecedents, symptoms and impact of these two states, a distinction should nevertheless be made between them. An investigation into fatigue should examine both states separately, using separate subjective measures for sleepiness and fatigue.

Therefore, though sleep has a significant impact on fatigue, it is not the only important factor in the experience of fatigue. There are several factors associated with wakefulness that are fundamental in the occurrence of fatigue. Central to this is the application of effort, which is generally experienced as a precursor to fatigue. The following section will provide an overview of this central concept for fatigue caused by mental and physical effort.

2.7 Effort

Effort is a central point of any discussion about fatigue (Hockey, 2013; Massin, 2017). It is sustained effort that leads to the onset of fatigue. However, like fatigue, mental effort lacks a consistently accepted definition (Earle, 2004; Massin, 2017; Shenhav et al., 2017). Therefore, a working definition of effort for this research must be proposed to allow for clear research design, and appropriate interpretation of the results. This will be done separately for mental and physical effort.

2.7.1 Energetics

Hockey, Gaillard and Coles (1986) highlighted that the concept of mental effort is unfortunately positioned between the 'wet' biological and 'dry' cognitive traditions in psychology. They champion the approach of 'energetics' which aims to bridge a gap between these two schools of thought and focus on issues related to motivation, which is a useful angle for the present research, as fatigue is heavily related to motivation.

An energetics view of effort is that it is synonymous with state regulation (Hockey, Gaillard, & Coles, 1986). In activities involving executive control, there will be an actual state and a target state (e.g. the state of effort that an individual is currently working at, vs the state of effort that they would like to ideally be working at) (Mulder, 1986). Effort is the central construct involved in increasing the state of activation to optimal levels (Shenhav et al., 2017). The greater the activity required to reach an optimal state, the more effort needs to be applied to get there. An example of this is an individual working to finish a work report. They will need to work in an optimal state to finish the report for their deadline, this optimal state becomes their target state. The effort comes in the activity that they undertake to reach this target state.

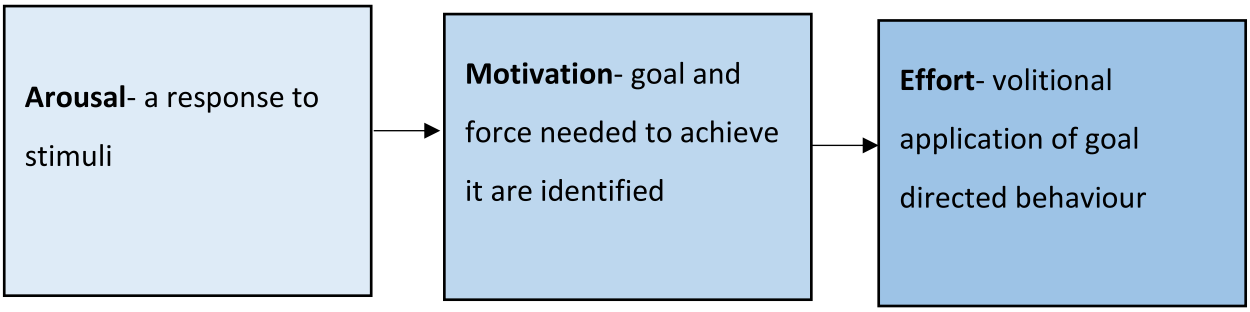
Effort is often viewed alongside the concepts of arousal and motivation, for which it can be used interchangeably. However, to gain a robust view of effort it must be separated from these related concepts as will be addressed in the following section.

2.7.2 Arousal and Motivation

Arousal and motivation are both states that occur *before* effort is committed to an action (Inzlicht et al., 2018). Arousal is specifically associated with response to a stimulus (Duffy, 1957). Whereas, following the 'energetics' theory, effort is defined in terms of the action, or force, that the individual engages in after they have initially responded to the stimulus (Kahneman, 1973; Massin, 2017). Motivation is a force that drives behaviour by determining both a direction (goal) and intensity with which the goal will be pursued. It is the thought process, occurring *before* effort.

Effort is the volitional application of this goal directed behaviour. The force that allows achievement of an identified goal. It can be defined as the subjective intensification of mental and/or physical activity to meet a goal. It is an action undertaken by an individual, rather than something that happens to them (Inzlicht et al., 2018). The relationship between effort and its related concepts; arousal and motivation are displayed in Figure 7.

Figure 7- Diagram displaying the relationship between effort and its related concepts



2.7.3 Effort and Workload

Effort is often assumed a natural consequence of *workload* (e.g. the larger or more demanding an individuals' workload is, the more effort they will apply). However, it is more accurate to think of it as an optional response to the perception and appraisal of demands (Hockey, 2011). This highlights that just because an individual has a high workload, their effort will not automatically increase sufficiently to meet that demand. Rather, the amount of effort that an individual will apply to a task will be subject to a subconscious cost/benefit analysis of costs vs rewards of completing the task. If the benefits of completing the action are deemed to outweigh the costs, effort application tends to automatically track demand and adjust to meet requirements.

However, this relationship can break down when incentives are too low, or demands too high (Inzlicht et al., 2018). Therefore, individuals have agency in whether they decide to commit action to work demands. Although much of the time, the benefits of completing work-tasks will outweigh costs (due to the overall benefits of keeping a job and getting paid, etc.), this will not always be the case.

2.7.4 Physical Effort and the Central Governor Theory

The moderation of physical and mental effort is often thought of as significantly different due to long held separation of the mind and body in research and common understanding. However, the Central Governor Theory postulates that physical effort is largely controlled by psychological process (Noakes, 2001; 2004; 2000; 2005).

This stipulates that endurance of prolonged physical exercise is managed by the brain using a model that aims for the performer to meet their goals while preventing breakdown of homeostatic systems in the body. The points of maximal exertion on this model are conservative to minimise the chance of breakdown in bodily systems. In practice, this means that an individual is unlikely to be able to meet their actual physical peak in exertion because the brain will send strong signals to stop before they are able to do so. This emphasises the importance of the mind, even in wholly physical tasks.

The central governor theory does not deny the existence of muscular fatigue, it simply states that physical effort and fatigue are controlled at the central, rather than peripheral, level (Noakes et al., 2004). This tends to prevent the muscles from performing at their absolute maximal capability as a protective mechanism. The existence of a 'central governor' in this process was disputed by Marcora (2008) who suggested that the decision to terminate exercise is taken by the conscious brain, rather than at a subconscious level. The Psychobiological model is an alternative theory and states that exercise cessation is motivated by deliberate decision making based on perceived effort (Pageaux, 2014) rather than *"complex subconscious teleanticipatory calculations made by an unknown part of the brain"* (Marcora, 2008). Both theories nevertheless highlight the integral role of psychological decision making in experiences of physical fatigue.

Thus, psychological models of effort and fatigue are relevant when considering fatigue caused by purely physical demands. This is particularly relevant for the present research as wind technicians are often required to engage in high levels of physical and mental effort.

2.7.5 The Law of Less Work

Various research has supported the 'Law of less work' (Hull, 1943). This pertains that individuals will generally pursue the option of least effort. This theory was initially applied to physical effort, however increasing research supported that this is also the case for cognitive effort, as expressed by Taylor (1981) who stated that humans are ‘cognitive misers’. This means that individuals will commit as little effort as possible to any given task. This theory has been supported more recently by Kool, Mcguire, Rosen and Botvinick (2010) who found that individuals were more likely to take low effort options on cognitive decision-making tasks.

Research such as this has led to the enduring acceptance that effort ‘costs’ us something. For a full representation of the ‘cost’ of effort, see the previous section ‘Fatigue as a motivation moderator,’ which explains the internal process of undertaking actions that require executive control, or ‘bottle neck’ activities, which can usually only be performed one at a time (Kahneman, 1973). Essentially, the ‘cost’ of effort spent on a complex mental task is that it prevents the exploration of other tasks that require the same processes.

There is also the fact that the experience of effort is often unpleasant, particularly if the task is difficult, therefore causing strain, or too easy, causing boredom. This experience of unpleasantness is exacerbated under conditions of low control and high effort as the hormones cortisol and adrenaline will be released, leading to feelings of alertness and stress (Hockey, 1997). However, effort is not always unpleasant or avoided as will be explored in the following section.

2.7.6 The paradoxical nature of effort

It seems, however that the concept of effort is perhaps more complex than the ‘Law of Less Work’ theory suggests. Inzlicht et al (2018) discusses the paradoxical nature of the effort concept. Effort has a distinct phenomenology categorised by its aversive nature. Individuals will feel tiredness and often, actual pain while applying effort to a task.

However, some research and anecdotal experience suggests that effort can be valuable and rewarding as an activity in itself (Norton et al., 2012).

It is important first, to consider the major and long held caveat of the aversive nature of effort. If effort is performed on a task, which is intrinsically rewarding, has an optimal level of challenge, with high control conditions the phenomenology of the effort its-self can be extremely pleasurable. This 'effort without distress' concept (Frankenhaeuser, 1986) corresponds with Csikszentmihalyi's 'flow' state (1990). This is a familiar experience for most, for example when cooking a new twist on a favourite recipe. This occurs when individuals have the necessary skills to perform an activity masterfully and feel a sense of timelessness when undertaking an activity that challenges them, but is not too difficult (Csikszentmihalyi, 1990). In this state, adrenaline will still be released, but often with lower levels of cortisol (Frankenhaeuser, 1986). Particularly relevant to the present research, individuals will often complete these tasks with a feeling of increased energy, rather than fatigue (Csikszentmihalyi, 1990).

However, Inzlicht et al (2018) refers to something different from the performance of flow inducing activities. They discuss the notion that individuals can often place higher value in the effort that it takes to complete a (not necessarily flow-inducing) task than the completion of the task itself. Consider the 'IKEA Effect' where individuals have been shown to pay more for furniture that they have to assemble than furniture made by a professional (Norton et al., 2012). There seems to be a cognitive dissonance with effort in which things are retrospectively assigned more value, the more effort was exerted to obtain them. This is different to the concept of 'flow' as it refers to the perception of intrinsic value in effort, even if it was not enjoyable to undertake. This serves as a counter to the 'least effort' theory.

Inzlicht et al (2018) discuss the notion of 'learned industriousness'. In real-life situations, high effort is often paired with high rewards. It would make sense to theorise that we would learn to associate high effort with high reward, just as Pavlov's bell signalled the arrival of food (Pavlov, 1927). Experiments have shown that learned associations between effort and reward can be carried over to separate and unrelated tasks (Eisenberger & Leonard, 1980). The feeling of effort could be said to signify that reward is on its way, changing this into a valuable experience. Inzlicht et al (2018) pertains that the value of effort is only realised when meaning is attached to it. When there is an obvious less effortful activity available to reach the same goal, effort becomes meaningless, similarly the 'IKEA effect' was not present in individuals who were asked to dis-assemble their furniture creations once they had built them (Norton et al., 2012).

Massin (2017) also explores this paradox in his analysis of the effort definition. He proposed the potential for effort to be 'ascetic'. This means that it has inherent moral value because it "manifests one's self-control" and "may engender some pride about one's self-mastery" (Massin, 2017, p.249). The notion that effort can create subjective value beyond its utility as a goal-reaching force has potentially interesting applications for research in applied effort and fatigue, e.g. if individuals tend to have a drive to commit effort to actions in order to experience self-mastery, work places could look to increase wellbeing and productivity through enhancing feelings of self-mastery in employees. It also highlights the multi-faceted nature of the concept, like fatigue.

2.7.7 Definition of effort for the present research

For the purposes of this research, effort will be defined as the volitional activity engaged in by individuals to achieve a goal. Distinct from that, motivation is used to determine how much effort will be needed to complete this goal and it is monitored throughout the process. Effort can be applied to a goal in different ways (e.g. physically, mentally or emotionally) and often goals require a mixture of different 'types' of applied effort. In most tasks, a combination of different 'types' of effort are required (e.g. to complete a marathon, physical, mental and emotional effort is required). The principle of applying different 'types' of effort is the same (e.g. effort is applied to reach a goal and its levels are manipulated through cost/benefit analysis). However, the actual processes required for this effort differ. Specifically, mental effort involves the application of the executive motor system, which inherently adds a 'cost' to the action as it prevents the application of any similar tasks (exploration vs exploitation) (Shenhav, Musslick, Lieder, Kool, Griffiths, 2017).

Effort can be maintained automatically, until the 'costs' of doing so outweigh the perceived benefits. Once this happens, effort will either decrease or carry on, but at the cost of strain, which is likely to cause after-effects, including fatigue. In summary, effort has a distinct phenomenology that can be felt through concentration (mental effort) and sometimes pain (physical effort); it can be recognised subjectively and by observers. In high control conditions with intrinsic rewards, effort can be pleasurable. Although individuals will often opt for less effortful options if given the choice, there may be an inherent value in the application of effortful activities due to their association with reward and feeling of achievement and their manifestation of self-control.

A potential bridge between effort and fatigue is control. The amount of control one feels that they have over the undertaking of a task, is known to mediate the amount of fatigue that one experiences while undertaking it (Karasek, 1979). It is important to gain an understanding of control and attempt to explain its relationship with fatigue. Therefore, the concept of control will be considered in the next section.

2.8 Control and Strain

A central theme throughout fatigue literature is the relationship between fatigue and control (Karasek, 1979; Park & Searcy, 2012). The importance of this relationship requires a specific discussion as it is vital to understand this, both because it is so central to the fatigue concept, and because its applications in a working environment are highly relevant.

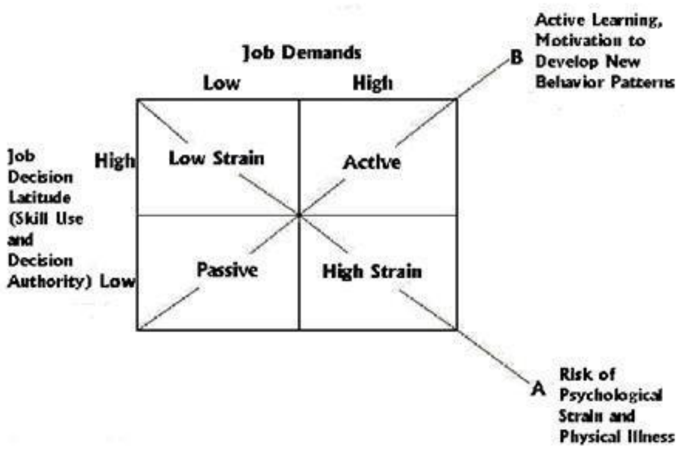
As previously mentioned, fatigue is more likely to occur in situations in which an individual has little autonomy. This highly popularised phenomenon was proposed by Karasek (1979) who introduced the demand-control model (DCM). The DCM postulates high strain working environments (those that are most likely to be fatigue inducing) are categorised by a mixture of high psychological demands and low 'decision making latitude' (control). Based on these two important work characteristics, Karasek (1979) proposed that there are four different types of working environment:

1. **High strain (high demands, low control)-** this environment is likely to cause stress, fatigue and a multiplicity of other negative states associated with this such as burnout and physical health issues.
2. **Passive (low demands, low control) -** this environment has low demands but also lacks autonomy; these environments are often dissatisfying and can lead

to skill diminishment and the experience of boredom, a related state to fatigue that will be considered in the present research.

3. **Active (high demands, high control**) **-** in this environment, high psychological demands are offset by the individual having a high amount of autonomy over their work. It was suggested by Karasek (1979) that due to high control, the demands are perceived as a challenge and the individual can manage them as they see fit, therefore developing their skills in the process.
4. **Low strain (low demands, high control) -** the individual is able to work within their comfort zone and may produce their best work; however, the opportunity for skill development and innovation is less likely to be present (De Spiegelaere et al., 2015).

Figure 8 Visual representation of the demand-control model Karasek (1979)



Karasek's model was born from a study in which national data was taken from the US and Sweden and these two factors were highlighted as most related to job satisfaction and stress. It added to the growing body of work during the 'job redesign tradition' in the 1960s and 70s and built on the work of researchers such as Hackman & Oldham

(1976) who focused on motivation through the redesign of work. Karasek and his contemporaries opposed much of the early work on work fatigue conducted by psychologists such as Taylor (1911) who suggested that work fatigue would be reduced with a more streamlined system of movements. The notion that autonomy could act as a buffer for high psychological demands was ground-breaking and continues to be a central element of modern research into work and stress.

2.8.1 Control as a Buffer

Research suggests that control protects against fatigue for two main reasons. The first is that it allows individuals to plan their own time and the second is that higher amounts of autonomy are likely to increase intrinsic motivation (Van Yperen et al., 2016). These theories will be discussed in line with their relation to fatigue, with the aim of gaining a greater understanding of the relationship between these two concepts, with a specific focus on how high control conditions can be used to manage fatigue in workplace settings.

Autonomy (or control) can be thought of in two categories (Häusser et al., 2010):

1. **Decision authority**- Level of authority in task-related decisions, e.g. timing and method control.
2. **Skill discretion**- Opportunity to use specific job skills in the working process.

2.8.2 Decision Authority

Decision authority refers to the level of control individuals have over their work time. This includes ability to manage work and rest time including the ability to incorporate appropriate recovery time into working patterns (Van Yperen & Hagedoorn, 2003).

The opportunity to manage personal needs for work and rest would seem an obvious reason as to why control can help to overcome fatigue. However, this does not always work in the way that would be expected, as individuals often have difficulty with fatigue, even if they have high autonomy over when they choose to undertake work tasks, particularly if they have a high workload. Therefore, autonomy over work time planning is an important aspect of the link between control and fatigue but is not the sole reason for this link.

2.8.3 Skill Discretion

Skill discretion is another important factor in the relationship between fatigue and control. It refers to the level of opportunity for skill development and application as part of work. If skill discretion is high, tasks are likely to be become more intrinsically motivating (Dysvik & Kuvaas, 2013). As previously discussed, when effort is expended for intrinsic motivation, individuals are more likely to experience a state of ‘flow’ and are less likely to become fatigued (Csikszentmihalyi, 1997).

With high control and demands that are high, but not overwhelming, an individual is more likely to engage in ‘effort without distress’ (Frankenhaeuser, 1986). This suggests that the application of approaches, such as Taylor’s ‘Scientific Management’ (1911) likely increased workforce fatigue and its related issues due to its reliance on increased centralised control and decreased skill discretion.

Therefore, control over work is important on two levels. The first in a practical sense of individuals having control over their work and rest time. The second in a general sense of individuals gaining ownership over work tasks and personal skill development. Full control in these areas is, of course, not possible in many workplaces (e.g. the wind industry often requires set tasks to take place in strict periods). However, decision authority and skill discretion can still be implemented where possible. For example, allowing individuals to take rest breaks wherever they deem appropriate when carrying out tasks and ensuring that they take ownership of their skill development wherever possible, e.g. emphasising opportunities for the development of valuable transferrable skills.

If control conditions are low and work demands are high, the resulting work environment will be one of 'high strain' (Karasek, 1979). The risks associated with this type of work environment will be explored in the following section.

2.8.4 High Strain Work Environments

Many work environments can include risk factors for high strain. Although in some work environments, strain is obvious and acute, such as with nursing where long hours are enforced and mistakes can cost lives (Trousselard et al., 2016; Urbanetto et al., 2013). Others are more chronic and subtle, such as in lower paid administrative roles, where workload is high, hours and breaks are enforced and there is little room for skill development (Guan et al., 2017; Ndjaboue et al., 2017).

High strain environments are repeatedly associated with increased stress (Nieuwenhuijsen et al., 2010; Trousselard et al., 2016), depression (Madsen et al., 2017), (Guan et al., 2017; Sonnentag & Zijlstra, 2008c), sleep disturbances (Halonen et al., 2017) and burnout (Bakker, Demerouti, & Euwema, 2005; Wong & Spence Laschinger, 2015). Due to the link between psychological distress and physical wellbeing, they are also linked to physical illnesses such as cardiovascular disease (Mika Kivimäki et al., 2002, 2014; Mika Kivimäki & Kawachi, 2015), stroke (Fransson et al., 2015; Huang et al., 2015) and type two diabetes (Heraclides et al., 2012; Leynen, 2003). The clear impact of high strain environments on employee health highlights the need for a movement towards lowering the strain of working environments.

Although created over thirty years ago, the DCM is still extremely relevant in current research on work fatigue management, with regular highly cited reviews of recent research in the area around every ten years (Häusser et al., 2014). Though highly influential, there are limitations to the approach. It seems that the praised simplicity of the model is also its downfall (De Jonge & Kompier, 1997). Demands and control cannot be looked at in isolation to predict work fatigue and job satisfaction as there are other factors that can worsen work fatigue, or act as 'buffers' to decrease fatigue (Van Yperen & Hagedoorn, 2003).

In 1990, Karasek and Theorell proposed that 'social support' should be added to the model because of its capability to either worsen (through lack of support), or buffer negative outcomes (through adequate support) (Karasek & Theorell, 1990). Even then, there is still a disparity in evidential support for the study between large sample survey studies and smaller interventions, suggesting that individual situations may be too complex to categorise problems into the three categories (De Jonge & Kompier, 1997).

2.8.5 Dispute around the control/fatigue buffer relationship

The presence of job control as an effective buffer for high job demands has been questioned. In a meta-analysis, Häusser, Mojzisch, Niesel, & Schulz-Hardt (2010) found a weak effect for the buffer hypothesis. Taris (2006) asked whether this was a 'zombie theory', meaning that it should have long ago died due to lack of empirical evidence, but is kept alive in theoretical debates (Taris, 2006, p.48). However, Häusser et al (2010) suggests that the lack of empirical support is likely to be due to the failure to match control to demands effectively in most studies. In one of the few experimental studies, Hockey and Earle (2006) found a significant 'buffering effect' for control and its prevention of fatigue in high demand conditions. Conversely, Elfering et al (2018) conducted a study analysing cortisol to track recovery from fatigue and found no support for control as a buffer for high demands. Further research is needed to determine whether there is indeed a buffering effect of control for high demands and whether there is a difference in its effect on immediate and perceived fatigue and fatigue recovery and this lack of consensus highlights that work environments should be considered on a case by case basis. Nevertheless, the DCM provides a useful framework in which to assess strain factors in work environments and is currently used as a basis of The Management Standards, a workplace stress assessment tool developed and used by the Health and Safety Executive in the UK (MacKay, Cousins, Kelly, Lee, 2004).

2.8.6 Application of the DCM to modern workplaces

Despite the DCM's incorporation into UK workplace stress assessment, it seems that most modern workplaces do not consider these factors in workplace design. An analysis of job satisfaction in EU countries based on the DCM found that work autonomy has declined and demands have increased in almost all EU countries since 1995 (Lopes, Lagoa, & Calapez, 2012). Unsurprisingly, the report also showed that job satisfaction significantly decreased during this time. This could be linked with the finding that in 2019 stress, depression or anxiety accounted for 44% of all work-related ill health cases and 54% of working days lost in British workplaces (Health and Safety Executive, 2019). This highlights the need for continued applied research in this area with a view of improving job design to prevent fatigue and its related effects.

It is important to gain a detailed understanding of the process that commences when an individual works at high strain in to understand the after-effects of this state. This will be considered in the following section.

2.9 Consequences of Strain and Fatigue

An important question in terms of the fatigue response to effort is *'what happens when the fatigue signal is not adhered to?'*.

There are notable examples within research of individuals performing both physically and mentally for far longer than would normally be expected. This normally occurs if they have been offered a reward to do so, or were put into a position where they felt that they could not easily stop (Poffenberger, 1928). Indeed, examples can be found in everyday life from the ordinary (consider a data input job with low skill requirements and little reward and an individual carrying out its tasks for eight hours per day) to the extreme (sleep deprived soldiers completing difficult physical and mental tasks 24 hours per day during training). The process undertaken by individuals in these situations is referred to in fatigue literature as 'compensatory control' (Hockey, 1997).

2.9.1 Compensatory Control

Compensatory control can be understood by considering the analogy of core body temperature. Teichner (1968) found that even under extreme heat and cold stress, core temperature is not usually affected. Instead, the body compensates for this through compensatory activity in sweat glands, veins, and muscles. In the same way, human minds and behaviour can compensate to persevere with a task even when highly fatigued.

The compensatory control model relies on the theory that there are two 'control loops' involved in effort maintenance (Broadbent, 1979):

1. **Lower level:** responsible for routine corrections of small discrepancies between the target and actual state. The control of this process seems to be largely automatic.
2. **Higher level:** the supervisory or executive level control used when the gap between the actual level and target level is too large for lower level control.

According to this approach, when demands are heightened, and rewards lessened there are two options available. One option is not to adjust the effort budget to a lower level. This means that the individual is less likely to become fatigued, as they are not applying as much effort, however they are likely to experience 'passive coping mode'. This is categorised by a marked increase in cortisol and a moderate increase in adrenaline, causing 'distress without effort' (Frankenhaeuser, 1986). The phenomenology of this is categorised by feelings of helplessness, anxiety, and lack of control. Indeed, anxiety is a related state to fatigue as it is an alternative response to strain and should be considered in fatigue investigations, as will be done in the present research.

A second option is to increase compensatory effort to meet the high demands. This 'strain coping mode' has emotional and physiological 'costs' (Frankenhaeuser, 1986). In this state, an individual will experience a significant increase in adrenaline and a smaller increase in cortisol. This state is most likely to cause fatigue because effort is being applied to the action, in defiance of fatigue signals.

The act of 'strain coping' will usually ensure that the primary task goals are maintained. However, degradation usually occurs in secondary tasks as aftereffects (Hockey, 1997, 2013). A classic example of how secondary task goals can suffer during strain coping is demonstrated by Sperandio (1978) who conducted an experiment investigating effect of high and low workload on air traffic controllers. The controllers' primary goal was to ensure the safety of the passengers on the planes that they were directing to land. Their secondary goal was to ensure the comfort of the passengers during these landings. When work demands were manageable, controllers used a plane-by-plane technique to carefully guide the planes to land, thus ensuring that both primary and secondary goals were fulfilled. However, when workload exceeded a comfortable level, their working behaviours changed to using a standardised procedure for all planes, ensuring that their primary goal (safety of passengers) was still fulfilled, however their secondary goal (comfort of passengers) was not accounted for. This showed that when under pressure and likely fatigued, the controllers reduced the need to involve executive systems and followed a procedure that was more automatic.

This finding was replicated by Hockey in 1998 using the cabin air management task (CAMS), which simulates the need to maintain appropriate air pressure in a closed vessel such as a submarine. This task was specifically designed to put pressure on the executive control system. The study compared a group of sleep-deprived participants to a group who had engaged in normal sleep patterns, thus exerting the stressor of sleep deprivation, meaning that the fatigue response would occur more readily. The results were subtle, but important. Participants with sleep deprivation displayed a difference in the way that they managed their tasks. Those with enough sleep engaged in *active monitoring*, a preventative strategy for any potential systems failures. However, those who were sleep deprived used a *reactive* strategy in which they relied on the system's alarms to alert them of any issues. This difference shows that fatigued participants were fulfilling the primary aim of the task, to ensure that any systems failures were dealt with, however they were not engaging in the secondary task of using preventative measures for these system failures as those with adequate sleep had.

2.9.2 Compensatory Control After-Effects

The compensatory control model also postulates that there will be after-effects associated with working in a fatigued state (Hockey, 1997; Hockey, 2013). Hockey (2013) discusses the notion that there has been comparatively little research into fatigue after-effects. This is surprising, as after-effects have been found to be far more expressive of the fatigue effect than performance decrement on primary tasks (Broadbent, 1979; Cohen, 1980; Van Cutsem et al., 2017a). The main finding from these investigations is that following a period of strain exertion, individuals will gravitate to low-effort options. This is congruent with Baumeister's 'ego depletion' theory (Baumeister et al., 1994; Baumeister & Vohs, 2007; Gailliot et al., 2007) as previously discussed (see section on 'ego depletion' page 25). As Baumeister and his colleagues discovered, participants were less likely to exert self-control in a second task if they had already done so in a first task. However, rather than this being due to a depletion of energy resource, this is more likely to be because of an unwillingness to put further strain on the executive control system through the continued use of effortful strategies (Hockey, 2013; Inzlicht et al., 2014).

This gravitation to low-effort options is not inherently negative, as it allows the facilitation of recovery. However, issues for both long and short-term health and safety are at stake when an individual gravitates to lower effort options if they are more inherently risky. For example, Dai, Milkman, Hofmann and Staats (2015) conducted a study on the hand hygiene behaviour of medical professionals over the course of their shifts. They found that hand hygiene compliance (hand washing) rates dropped by 8.7 percentage point on average from the beginning to the end of a typical twelve-hour shift. This lower effort strategy could have large implications for patient and worker health. This highlights how in longer working days, individuals automatically shift towards recovery when it is not always safe to do so.

The implications of this deviance towards lower-effort strategies can also be seen in personal health behaviour. Van Cutsem et al (2017) conducted a systematic review investigating the effect of mental fatigue on exercise behaviour. They found that after periods of intense cognitive work, individuals had lower levels of endurance when partaking in physical activity. This indicates that individuals with mentally demanding jobs likely find it more difficult to achieve the recommended exercise to maintain their physical health.

Therefore, because of the presence of compensatory control effects, any test of fatigue should look beyond the performance displayed in a primary task. Instead, measures should be concerned with secondary tasks, after-effects, and changes in task management strategies, as will be done in the present research (Earle, 2004; Hockey, 2013).

2.10 Definition of Fatigue for this Thesis

This chapter has considered the breath of relevant literature to fatigue and establishing conceptualisations of its relevant concepts such as sleep, effort, control and strain as well as examining the consequences associated with mis-managed fatigue. A reasoned definition of fatigue to be applied to the present research will now be presented which is informed by relevant theory and literature discussed in the previous sections, particularly Boksem & Tops, 2008; Earle et al., 2015; Hockey, 2013; Inzlicht et al., 2014; Kurzban et al., 2013.

For the purposes of this thesis and organisational context and based on theory and literature reviewed, fatigue is defined as a state in which individuals will feel weary and averse to further effort. Engaging in tasks that require activation of the prefrontal cortex (high amounts of concentration) and offer little control over their execution are particularly vulnerable to fatigue's effects. When completing tasks such as this, individuals are likely to experience a drive to switch to a more intrinsically appealing activity and may experience lapses in concentration. If this task is important, or the individual is unable to desist with working on it, they will continue to work, but at strain. This strain state will cause the release of stress hormones and performance on subsequent and secondary tasks will suffer, with individuals gravitating to lower effort options.

As the brain consistently engages in cost/benefit analyses, fatigue will naturally occur when the costs of completing a task start to outweigh its benefits. There are factors that cause this fatigue reaction to become significantly more prevalent such as when an individual is sleep deprived, physically exhausted, unwell, emotionally unstable or in need of vital resources (e.g. food/water). By definition, these states dictate that any action that is not solely focused on meeting their needs is inherently more costly than beneficial. Therefore, an individual who is not sleep deprived, healthy, emotionally stable and not in need of food or water will still experience fatigue at some point, however their tolerance will be higher than someone experiencing the aforementioned states.

It is now useful to consider how fatigue is likely to occur and affect individuals in the applied context of the wind industry working environment. This will be addressed in the following section.

2.10.1 Causal Chain of Fatigue in a wind industry environment

The following passage is a conceptualisation of how the experience of fatigue could impact a wind technician working on a repair task at the top of a turbine, as would be typically required in this role.

Consider the example that a repair task takes longer than expected and comprises of intricate and tiring work. The technician is likely to begin feeling fatigued and consequently will experience a drive to stop working on the task. However, as they are in a position where they would be unable to do this (e.g. low control working), they have no choice but to persist with this task, but at strain mode.

This is likely to mean that the technician will commit less attention to their secondary tasks. The technicians' primary task is to finish the repair; their secondary task could be to ensure that they tether their tools to avoid instances of dropped objects on site. If this secondary task receives less attention, it will compromise the efficiency of the task, but the primary task will still be completed. Serious issues occur if the technician views their safety, or the safety of others as a secondary task, as would be likely in this situation. This could mean that the technician meets their primary task of completing the job, however, does not meet their secondary task of ensuring that they tether their tools to avoid objects dropping on their colleagues or themselves later.

Consider the same situation, however this time, the technician only managed to obtain five hours of sleep the previous night. They will now have to not only contend with normal experiences of fatigue after time on task, but also an increased drive to sleep due to their extended wakefulness, as well as deficiencies in alertness due to sleep deprivation. Their threshold for fatigue is likely to be much lower and they will be prone to experience strain earlier than they would have done if they were not sleep deprived.

Consider again, this same sleep deprived technician and imagine that they are feeling unwell from a difficult transfer to the turbine. This will further serve to decrease their fatigue threshold. In fact, in this scenario, their 'primary task' could become the prevention of falling asleep or becoming more unwell, especially if this state has caused emotional instability. This would mean that their work task and associated safety procedures become secondary, thus making them far more vulnerable to dangerous error.

Thus, there are many factors to consider when investigating fatigue in an applied work setting, particularly when the work environment in question encompasses a multitude of potential stressors and hazards, as is the case for the present research. It is vital to enter projects such as this with a robust knowledge of the complex and multifaceted nature of fatigue as well as its close relationship with associated states such as sleepiness, anxiety and boredom so that investigations and associated recommendations are made with a full view of contextual factors in mind. As this chapter has considered the concept of fatigue in psychological literature, the following chapter will build on this knowledge and address fatigue investigations and practices in an applied context, including consideration of fatigue literature and practice in work environments.

Chapter 3- Fatigue in the Workplace

3.1 Introduction

It is important to consider applied fatigue research and practice in occupational settings before adding to this diverse research field with the present research. Chapter 2 focused on theoretical literature surrounding fatigue, ultimately presenting a working definition of the concept to be used in the present research (see section 2.10). This chapter will build on this knowledge by conducting a literature review of fatigue research and practice in industry settings.

3.1.1 Chapter Structure

Section 3.2 will focus on trends in fatigue research in occupational settings, beginning with a brief exploration of the history of fatigue research and interpretation in the modern workplace (section 3.2.1). This will consider how accelerations in understanding of fatigue gained during world war 2 impacted organisational interpretation and practice. Attention will then be given to how fatigue is understood and managed in the modern workplace in section 3.2.3 which will be explored in the context of two industries in which encompass contrasting interpretations of fatigue in relevant literature (sections 3.2.4 & 3.2.5). This will highlight that despite notable progressions in understanding, there are still major issues with the lack of consistency and reductionist approach employed in much recent workplace fatigue research and practice and an alternative multidimensional approach will be presented in section 3.2.6 as well as an exploration of emerging research that utilises this approach.

Section 3.3 will explore the risks associated with fatigue in occupational settings. This will first consider the seemingly liner relationship with fatigue safety risk and time spent at work in section 3.3.1. Following this, a deep understanding of safety risks associated with fatigue and their interpretation in modern workplace settings will be gained in section 3.3.2. Furthermore, the impact of poorly managed fatigue on health and wellbeing will be explored in section 3.3.5 and consideration of how workplace design could be improved to promote health and wellbeing will be presented in section 3.3.8. Finally, Sections 3.3.10-13 will examine research focusing on stress and burnout due to their overlap with fatigue risks in occupational research literature.

Section 3.4 will explore fatigue management practices currently used in industry and potential future directions for their development. Finally, Section 3.5 will focus on fatigue research in industries that share similarities with the wind industry in their working environments and practices.

The aim of this chapter is to gain a comprehensive insight of the state of fatigue research and perceptions in work settings. This will be discussed with a view to gaining an understanding of how the present research will contribute to the field.

3.2 Fatigue Research in Industry

Despite a lack of agreed definition of fatigue in academic literature (see Chapter 2), there is a large and growing body of research investigating workplace fatigue. It is increasingly recognised as a major workplace hazard and threat, not only to health and safety, but also to the economy. In the USA, it is estimated that $136.4 billion per year is lost in productivity and health care due to fatigue (Ricci et al., 2007). In the UK, fatigue has been implicated in 20% of accidents on major roads and is said to cost the UK £115 - £240 million per year in terms of work accidents alone (HSE, 2019). This is without addressing the less tangible impact of poorly managed work fatigue on employee wellbeing, quality of life and work satisfaction.

An exploration of the progression of academic research into fatigue was included in chapter 2 (section 2.3). To provide useful context and understanding for the content of the present chapter, it is relevant to re-visit and develop this historical focus to gain an understanding of how modern workplaces conceptualise and manage fatigue. The following section will consist of an examination of the historical context of applied fatigue research and practice.

3.2.1 A brief history of fatigue in the workplace

To contextualise current industry fatigue practices, attention should first be given to their history. A wider and more in-depth history of fatigue research was provided in chapter 1. The current section will focus on research trends in industry following their origins in the 20th century.

The focus of workplace fatigue research has somewhat changed since its origins in the 20th century. What began with a focus on increasing productivity in factories and preventing the slowing of work due to human factors (for more details see 'history of fatigue' section in chapter 1) now has a heavy basis in safety. This focus originates from a surge of research during World War II, with a strong focus aviation where many influences in modern approaches to fatigue management were born (Miller, 2017).

A series of experiments known as *'The Cambridge Cockpit Studies'* were conducted in the early 1940s (Bartlett, 1942; Drew, 1940) and their findings were extremely influential in this sphere. These studies employed an experimental cockpit and a fatigued pilot. Performance measures were taken from the pilot's abilities to conduct their normal work (e.g. maintain the various demands associated with flying the plane successfully) and subjective fatigue measurements were taken.

Results showed that when fatigued, the pilot's standards relaxed considerably and signals in the periphery of his vision were ignored (secondary tasks, see chapter 2, page 69). It was in these studies that fatigue's potential effect on safety was experimentally recognised. This development in knowledge was due to Drew and Bartlett's employment of tasks that included enough components and intricacy to observe the complex pattern of changes in the fatigue reaction.

In the decades following Drew and Bartlett's' discoveries, the impact of fatigue on safety was emphasised with several high profile and catastrophic incidents that were, amongst other factors, attributed to operator fatigue. Notable examples of this are the Chernobyl disaster and the Challenger crash (Mitler et al., 1988; Techera, Hallowell, Stambaugh, & Littlejohn, 2016).

Despite this, research suggesting changes in work policy to promote improved fatigue management was met with considerable political backlash. This is exemplified in a quotation from a US senator in response from research by George Belenky of Washington State University that controllers working night shifts should be able to take short naps; *'I think that's totally bogus, there are so many professions that have to work long hours'(p.3).* (Matthews & Hancock, 2017). This suggests that science and society do not always perceive the issue in the same way. Indeed, as previously explored in chapter 2 (section 2.3.2) fatigue management has been perceived as a barrier to productivity and innovation, particularly in capitalist societies. Thus, over and above the difficulty in understanding fatigue, there is also a potential challenge in improving fatigue management in workplaces due to cultural attitudes surrounding the issue. The following sections will consider how conceptions and management of fatigue remain to be highly influenced by culture and perception of the workplace in question.

3.2.2 Fatigue in the modern workplace

Fatigue research is not represented in all modern-day workplaces. In fact, it is still scarce in many industries, particularly when its effects are likely to be more subtle and experienced over a longer time. The most prevalent area for work-based fatigue research is conducted in industries that incorporate shift-work.

Shift work, particularly that which includes night work, poses the most immediate and palpable threat to fatigue-related incidents as individuals working said shifts are likely to be affected by both sleep-related fatigue and circadian imbalance before accounting for the actual content of their shifts (Kazemi et al., 2016; Kecklund & Axelsson, 2016). Furthermore, occupational fatigue research tends to focus on areas of work in which fatigue is likely to pose an immediate safety risk, either for the operator in question, as with the transport industry or for others, as with the medical sector.

The following section will incorporate a more detailed focus into how work-based research defines fatigue related to different outcomes, including safety, health, wellbeing and productivity.

3.2.3 Interpretation of fatigue in the modern workplace

As discussed in the previous chapter, a difficulty in addressing fatigue in workplaces is the lack of clarity of *what fatigue is.* Indeed, in literature on applied fatigue research, the definition of fatigue can often change to fit the context in which it is being discussed, e.g. in line with the workplace in question. To illustrate this point, the following sections will comprise of an examination of the contrasting ways in which fatigue is viewed in two different work environments, nursing and the transport industry.

3.2.4 Nursing and 'Compassion Fatigue'

In caring professions, such as nursing, the focus of fatigue research is on 'compassion fatigue' (Sinclair et al., 2017). This is said to be a reaction to stress and trauma resulting from time spent caring for people in difficult and often life-threatening situations. In this context, emotional work is thought to be the most important stressor. The sole consequence of exposure to this stressor is emotional strain. Compassion fatigue is thought to be experienced as the acute loss of empathy for other people, especially those with care requirements (Sinclair et al., 2017). So in caring professions, it is often assumed that fatigue is only a product of dealing with emotional demands and consequently its attempted management is often solely focused around education about compassion fatigue, encouragement of self-care and the provision of opportunities to discuss feelings with other employees or professionals (Sinclair et al., 2017; Walsh-Lyle, 2016).

Dispute about the efficacy of this approach was highlighted in a meta-analysis by Sinclair et al (2017) who postulated that compassion fatigue has been *"blindly accepted as a valid construct and clinical reality"* (Sinclair et al, 2017, p, 14). They criticised the accuracy of this term, stating that 'compassion fatigue' infers that there is something inherently tiring about compassionate feelings and behaviours. Indeed, the many other stressors associated with the working life of caring professionals such as shift work, extended working hours, work pressure and perceived autonomy seem to be somewhat neglected in many applied investigations into fatigue experienced by nurses. Although consideration of the extreme emotional demands experienced by nursing staff should be a key factor in fatigue investigations in this work environment. However, this should be viewed holistically in the context of the many other factors that might combine to cause a fatigue response, for example, long working hours, night working and time-bound, high stakes decision making.

3.2.5 Transportation and Aviation- 'It's about Sleep'

Unlike nursing, the majority of research in safety-critical work such as transportation (Arnold & Hartley, 2001; Dorrian, Baulk, & Dawson, 2011; Roach et al., 2017) and aviation (Caldwell, 2005; Lynn Caldwell, Chandler, & Hartzler, 2012) classify sleep deprivation as the most important, if not, sole cause of fatigue, which, as discussed in chapter 2 fails to account for the multidimensional nature of fatigue (see section 2.6). However, there are some notable exceptions to this trend including an investigation into airline pilots, Lee and Kim (2018) highlight some non-sleep related predictors of , such as the mental and emotional demands of navigating of cultural differences between colleagues.

Much recent fatigue research in these sectors are underpinned by an approach suggested by Dawson and McCulloch's paper (2005) entitled; *'Managing fatigue. it's about sleep'* as a major theoretical underpinning of their investigations. Dawson and McCulloch champion a progressive approach to sleep-focussed fatigue management by advocating against an approach purely focussed on hours of service and for one that accounts for actual sleep obtained. Although useful as part of a multidimensional method, this approach is still entirely focussed on sleep as a sole cause of fatigue, emphasising that if adequate sleep is obtained, fatigue will not be an issue.

These two case studies present two different industries, each with a multitude of demands including shift work as well as mental, physical and emotional challenges. However, the focus of their associated fatigue literature is notably different and tends to operate on a one-dimensional level, e.g. solely focussing on emotional demands in nursing and on sleep in transportation and aviation. The following section will consider research that uses a multidimensional approach to fatigue investigation and management in industry.

3.2.6 Towards a Multidimensional Approach

A limited body of research considers workplace fatigue with a multidimensional approach. An example of this is Techera, Hallowell, Stambaugh, & Littlejohn (2016) who conducted a meta-analysis of causes and consequences of occupational fatigue. This provides a comprehensive review of stressors that contribute to fatigue such as effort/reward imbalance and mental exertion, albeit with a major focus on sleep deprivation as a major factor in occupational fatigue.

Their review culminates in a comprehensive analysis of the various stressors that can lead to fatigue as can be seen in Figure 9. There are, however, notable limitations with this view of fatigue as there is no mention of other major fatigue-related stressors such as the relationship between fatigue and perceived control (see Chapter 2, section 2.8). This nevertheless illustrates that although literature tends to focus a one-dimensional approach, there is a present and growing understanding of the complexity of the state in applied research and practice. The present research will employ a multidimensional approach to investigating fatigue in the wind industry environment with an aim of understanding the complex nature of occupational stressors and related outcomes.

Figure 9 Diagram from Techera et al (2016) meta-analysis demonstrating causes and consequences of occupational fatigue.

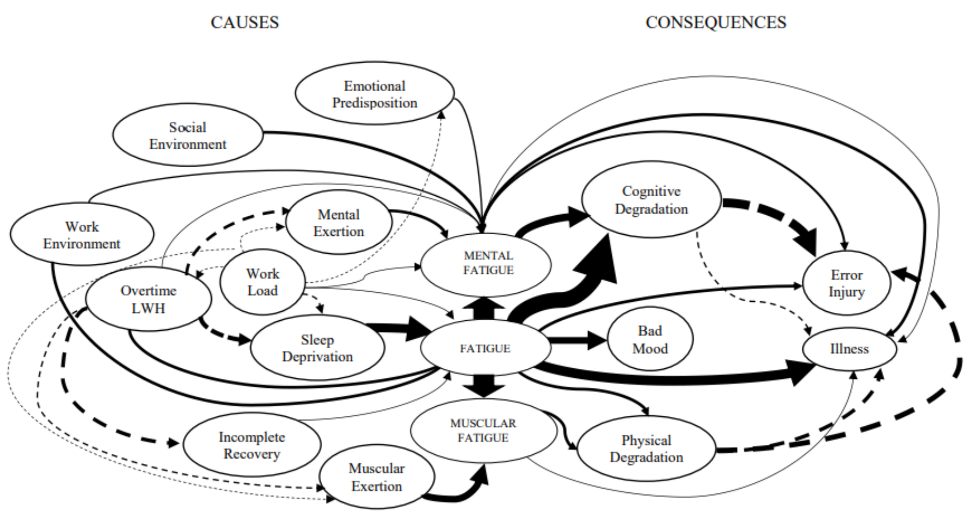


Figure 2: Systems model illustrating empirical literature on the relationships among causes and effects of fatigue.

Notation: Line thickness corresponds directly to the number of studies devoted to each relationship.
Immediate relationships between causes, fatigue, and consequences.
Inter-relationships within causes or consequences of fatigue.

To understand the progression of research to this point, it is important to consider the history of applied fatigue research. This has already been done to some extent in Chapter 2 as academic fatigue research has origins in industrial research (see Chapter 2, section 2.3.1). The following section will consider workplace fatigue research following its origins in 20th century factory-based settings with an aim of understanding how research has developed to the present day.

3.3 Fatigue Risks in Occupational Settings

The theoretical basis of why fatigue can pose a risk to individual safety and wellbeing in occupational settings was explored in Chapter 2 (see sections 2.8 & 2.10.1). It is now relevant to further explore the risks of insufficient fatigue management in employees using applied occupational research. This will first be considered in the context of time spent at work through examination of the notion that simply spending more time at work increases the risk of detrimental outcomes for employees (section 3.3.1). Following this, the risk of fatigue on safety will be discussed in section 3.3.2, with a focus on how this risk is interpreted and managed in two major industries with a large body of associated fatigue research (sections 3.3.3 & 3.3.4).

In section 3.3.5 the less tangible, but equally important risk of fatigue on health and wellbeing will be considered. After considering risks to employees, attention will be given to the organisational issue of productivity in section 3.3.9 including a discussion of the inherent conflict between productivity maintenance and sustainable fatigue management practices. After considering risks associated with fatigue, the highly related concepts of stress and burnout will be explored along with their relationship with fatigue in this context.

3.3.1 Hours of Service

An intuitive starting point to an examination into workplace fatigue is to consider the impact of time spent at work. Chapter 2 provided a historical background to the monumental impact that the widespread introduction of pay depending on hours worked, rather than output produced had on experience and perception of fatigue (see Chapter 2, section 2.3.2).

For many individuals, more time spent at work means more time spent in low control, high demand, fatigue inducing conditions (see chapter 2, section 2.8). Indeed, much research has supported the notion that the risk of fatigue-related incidents increases with the more time an individual spends at work. In a review of 10,793 job records in the US, Dembe, Erickson, Delbos, & Banks (2005) calculated that those with overtime schedules had a 61% higher injury hazard rate than those without, those with 12 hour shifts had a 37% increased hazard rate and working 60 hours per week was associated with a 23% increased hazard rate.

These increased hazard rates were calculated after accounting for exposure, meaning that their heightened occurrence was not simply because individuals were exposed to potential hazards for longer. Researchers also accounted for demographic characteristics of employees working these schedules, meaning that results were not encumbered by individuals who had pre-existing health conditions. Therefore, the conclusion was reached that long working hours indirectly lead to workplace accidents through a causal process by inducing fatigue in workers (Dembe et al., 2005).

This can be attributed to theoretical findings on compensatory control as was discussed in the previous chapter (see section 2.9.1). It can also be linked to findings from Sonnentag & Zijlstra (2008) suggesting that long working hours decrease the opportunity for recovery, causing a state of strain to be present over long periods. Therefore, wind industry workers will likely experience the initial compensatory control after-effects of working long shifts, along with decreased opportunity for recovery due to the consecutive nature of their shift patterns.

It is integral that workplace fatigue investigations consider hours of service and consecutive shifts as a key component of operator fatigue. However, this is far from the only factor that should be considered. A prevalent issue in industrial fatigue research is that investigations often consider one aspect of fatigue and pose a linear model of how it is caused and should be managed as will be considered in the following sections.

3.3.2 Safety

The impact of fatigue on safety is overwhelmingly prevalent. Although an agreed definition has not yet been reached for the concept of fatigue, its presence as a causal factor in numerous catastrophic incidents is largely undisputed (Dall'Ora et al., 2016; Fischer et al., 2017; Williamson et al., 2011). The way fatigue can lead to unsafe behaviour has already been discussed throughout the previous chapter (see sections 2.9 & 2.10) therefore, the present section will focus on the perception of fatigue as a safety risk in the workplace. This will be discussed in the frame of two case studies. The first will be in the Aviation Industry, which, as previously stated, is where much original fatigue research originated and remains to be a central focus in applied fatigue studies. The second is the healthcare sector which represents an industry in which safety-focussed fatigue research is still developing.

3.3.3 Case Study 1: The Commercial Aviation Industry

As the aviation industry was one of the first to identify fatigue as an occupational hazard, it is useful to begin this enquiry by considering their current practice in fatigue management.

The risk of fatigue on safety is well documented in aviation, especially for commercial pilots, with a considerable amount of research published in this sphere (Caldwell, 2005; Lee & Kim, 2018; Caldwell et al., 2012). A common theme in this research is the difficulty of addressing the risk of fatigue in a comprehensive manner while also keeping up with the ever-increasing demand for 24-hour service at low prices. Although it is relatively simple to aggregate answers to questions of what is and is not safe from a scientific point of view, it is often more difficult to determine where the 'line' should be in practice, especially when high demand, competition and sums of money are involved.

Numerous studies document the severe consequences of poor fatigue management in aviation. Human factors contribute to 70% of aviation accidents and pilot fatigue is recognised as one of the key determinants in improving safety (Lee & Kim, 2018). Recent air disasters such as Colgan Air, 2009 and Air India Express, 2010 were both caused by pilots failing to respond to safety issues upon landing, which has been heavily attributed to fatigue (European Cockpit Association, 2015).

In a survey of 6,000 pilots, over 90% reported having to cope with fatigue that could potentially hamper their safety behaviours while flying (Tittelbach, 2012). The survey suggested that the monotonous nature of piloting combined with long hours of service and night work appear to combine as sleep-related stressors causing 43% of pilots to report that they had experienced involuntary sleep while flying. Worse still, one third of these pilots reported occurrences of waking to find their co-pilot also asleep (Tittelbach, 2012).

It seems that there are some issues with fatigue management and reporting practices in this industry. Fatigue management often has a simplistic focus, often wholly relying on hours of service and opportunity for sleep to predict fatigue outcomes. This encourages the view that working within the prescribed guidelines will guarantee that a pilot is unaffected by fatigue, rather than viewing the issue in its appropriate complexity (Dawson & McCulloch, 2005; Lee & Kim, 2018).

As is the case in other industries, research suggests that fatigue reporting culture can be punitive and dissuade an open dialogue around its occurrence. When surveyed by the European Cockpit Association, 80% of pilots stated that they would not report a fatigue-related issue or declare themselves unfit to fly due to fatigue because they would be afraid of disciplinary action (Tittelbach, 2012).

3.3.3.1 Safety culture- towards a ‘just’ approach

There is much research dedicated to fostering an effective workplace safety culture that is highly relevant to successful fatigue management. A key movement in this area is the eschewing of *behaviourism,* an approach focusing on worker behaviours rather than systematic design or cultural attitudes. This approach to workplace safety places human error at the centre of incidents and champions a reward/punishment model around safety (Dekker, 2014).

Organisations with a behaviourist safety culture often promote a ‘vision zero’ in which a perfect safety record is strived for and expected, thus stigmatising the reporting of any incidents (Dekker, 2014). More effective in encouraging successful management of safety and fatigue is the *'Just Culture'* model. This person-centred model focuses on investigating incidents through the lens of systematic design rather than individual blame and encourages the reporting of mistakes as learning opportunities, separating them from intentional actions (Dekker, 2017).

There has been a movement towards adopting a just culture in many organisations, particularly in the western world (Liao, 2015). However, there remains to be resistance to this in some high hazard industries such as aviation and criminal charges are often pursued for the pilots of plane crashes (McCall & Pruchnicki, 2017).

The aviation industry was one of the first to highlight the inherent safety risks of operator fatigue (Bartlett, 1942; Drew, 1940). However, there is still a requirement for progress in marrying a knowledge of safety risk caused by fatigue to practical implications for fatigue management. The issues preventing effective fatigue-management faced in this industry are indicative of many other industries in which fatigue is a safety hazard, for the operator and other people, such as transport (Arnold & Hartley, 2001; Williamson, Friswell, Olivier, & Grzebieta, 2014) and the medical industry (Greig & Snow, 2017; Landrigan et al., 2004). It is likely that due to under-reporting of fatigue related incidents and near misses, fatigue related issues are more common and widespread than we are currently aware.

3.3.4 Case study 2: Healthcare

The medical sector is a work environment that has received less attention in fatigue-related safety research but is rife with fatigue-related safety issues (Greig & Snow, 2017). A combination of high-risk, intricate procedures, high stress and extremely long working hours organised into shifts make the role of a medical professional vulnerable to harmful incidents to themselves or their patients.

Multiple studies have demonstrated the risks of working long hours in a medical setting. In a survey of 1366 doctors working more than 40 hours per week, two out of five reported making errors that were related to fatigue (Gander et al., 2007). Despite this, working hours for doctors are generally extremely high, in a study conducted by Landrigan et al (2004), residents' workweeks ranged between 77 and 81 hours. Europe is known to have the most stringent working time limits for doctors in the world due to the working time directive, which states that employees should work no more than 48 hours per week (Datta & Davies, 2015). However, many reports suggest that UK doctors are regularly pressured to opt out of this directive and work longer, likely unsafe hours per week (Greig & Snow, 2017).

Indeed, reports show that although the working time directive aims to place a cap on hours worked, as many as 32% of workplaces in the UK have employees who sign out of this already high limit on working hours (Department for Business Innovation & Skills, 2014). Many studies have demonstrated that working less hours decreases the likelihood of patient-related incidents; Landrigan et al (2004) compared an average working week of medical interns to an intervention shift schedule with diminished hours and found that interns made 39.9% more serious medical errors during the traditional schedule than during the intervention schedule.

As well as an inherent threat to patient safety, fatigue in medical roles causes a great safety risk to employees, particularly when driving home after a long shift. In a survey of 3772 anaesthetists, 57% reported experiencing an accident or near miss when travelling home from a night shift (McClelland et al., 2017). This highlights the question of whether commute time should be included in working hour statistics, especially when considering theoretical evidence of compensatory control, which dictates that second tasks often suffer when an individual has worked at strain on a previous task (Hockey, 1997, see Chapter 2, section 2.9.1).

In their paper entitled ‘Are train drivers safer than doctors?’ Greig and Snow (2017) discuss the disparity between perceptions of fatigue between industries such as transport and aviation and the medical industry. In safety critical industries, greater attention is paid to the cumulative effects of fatigue and the importance of breaks (although as previously discussed, this is not always as effective as it perhaps should be). However, in the case of medical professionals, there seems to be an inherent, erroneous assumption that individuals working in this sphere are more equipped to deal with the strain caused by high-pressured work and unreasonably long hours (Greig & Snow, 2017). It is clear that a reform in perception is needed in this area, Greig and Snow (2017) postulate the likely notion that if the same logic of assessing industrial fatigue incidents were applied to clinical incidents, fatigue would ‘almost always be cited as a contributing factor’.

The medical industry presents an extreme example of fatigue in the workplace and highlights not only the disparity in perceptions of occupational fatigue research, but also the progress that still needs to be made in the field. In a paper discussing barriers to healthcare as an ‘ultrasafe workplace’, Rene Amalberti makes the following statement:

"Becoming ultrasafe may require healthcare to abandon traditions and autonomy that some professionals erroneously believe are necessary to make their work effective, profitable and pleasant" (Amalberti, Auroy, Berwick, & Barach, 2005, p.757)

This rings true, not just for healthcare, but also for many other industries where safety is compromised due to poor fatigue management. This highlights the need for all industries to place more importance in addressing the risks that fatigue has on safety.

3.3.5 Health and Wellbeing

Much as with safety, employee health and wellbeing are major issues that are in constant conflict with the drive to maintain productivity and competitive prices in a 24/7 society. However, unlike safety, the consequences of poor management of employee health and wellbeing are often less obvious and immediate. Consequently, they are often overlooked in 'health and safety' policies, even though research increasingly sheds light on issues associated with diminished health and wellbeing at work (e.g. Bliese, Edwards, & Sonnentag, 2017; Ervasti et al., 2017; Kivimäki & Kawachi, 2015; Sparks, Cooper, Fried, & Shirom, 1997).

Physical and mental health are generally treated as separate issues in workplaces and though physical health is often side-lined in the field of health and safety, mental health is done so even more. The following sections will first consider physical health research and practice in line with fatigue and then mental health and wellbeing.

3.3.6 Physical Health

The 19th and 20th centuries saw a growing realisation that certain jobs were associated with specific diseases, such as byssinosis in cotton workers (Litchfield et al., 2016). This began a movement to control exposure to hazardous substances at work. This awareness has continued during the 21st century in most western workplaces, meaning that work-related diseases such as these are largely an outdated concept. However, there remains to be significant physical health hazards associated with present day work environments.

Much research on work place physical health centres around the impact of engaging in consistent manual work (Kirkhorn et al., 2010; Macdonald & Oakman, 2015). A notable illustration of this is the 'physical activity paradox' (Holtermann et al., 2018). This refers to the notion that although physical activity is generally beneficial for health, these benefits are often only realised if it is engaged in during leisure time. Due to the monotonous nature of physical work, the lack of control that employees have over their time and tasks and lack of recovery time, manual work is likely to cause a multitude of potential health issues (Holtermann et al., 2018).

This is particularly relevant to the wind industry work environment as technicians are required to endure multiple physical demands as part of their roles.

3.3.7 Mental health

Perhaps even more worrisome is the prevalence of work-related mental health issues. Often referred to as 'invisible' illnesses (Elraz, 2018), mental health disorders are the most important cause of disability in all WHO regions (World Health Organisation, 2011) with depression alone absorbing 1% of Europe's GDP (Sobocki et al., 2006). This is likely under-estimated due to the underreporting of mental health issues by sufferers, because of the stigma surrounding them (Bharadwaj et al., 2017a). Litchfield et al (2016) discuss the notion that 'industrial injury' is a term associated with *'bodies broken by heavy machinery' (p.1)*, however present day 'injuries' are more likely to be psychological- *'minds shattered by brutish systems designed and applied carelessly'.(p.1).*

Research suggests that fatigue is a mediator for quality of life and mental health problems (Bazazan et al., 2018). This relationship is often explained as a need for recovery that is increased due to negative working conditions such as high workload, low control and excessive working hours (Karasek, 1979). As the need for recovery increases, so too does the time that it will take to fulfil this need. If this recovery need is not satisfied, the individual will continue to work at strain over a longer period, thus leading to poor fatigue management, making the individual more vulnerable to mental, and physical health issues (Sluiter, 2003; Sonnentag & Zijlstra, 2008).

3.3.8 Towards Positive Work Design

An important point to note is that work is not necessarily negative for health and wellbeing (Waddell & Burton, 2006). In fact, employment can be vastly beneficial, not only for its necessary material rewards, but also due to its importance in relation to self and social identity (Waddell & Burton, 2006). In studies investigating employment vs unemployment, working is generally shown to have the best mental and physical health outcomes (Waddell & Burton, 2006).

There are, however, there are some important provisos to these findings. One is that the financial necessity of employment cannot be discounted from these results. Individuals may be in better health when working, simply because they earn money that affords them superior food, living conditions and in some countries, healthcare. Although this is important in large-scale investigations, it can be misleading when the objective is to consider the actual content of working lives.

Another point is that unemployed individuals will often be unable to work due to disability and injury and therefore could already have diminished baseline scores of health and wellbeing. A third and potentially more challenging issue is that employment is only beneficial when it comes in the form of a 'good job' (Waddell & Burton, 2006; Litchfield et al, 2016). This is work in which harmful aspects are avoided but psychosocial benefits of purpose and social identity are retained. Positive work design should not just be protective of physical and mental health but should also strive for improved employee wellbeing.

Much research into work related wellbeing is based around Karasek's influential demand control model (DCM; Karasek, 1979). This model and its relationship with fatigue was discussed in Chapter 2 (section 2.8) and therefore, only salient points will be discussed in the current section. The DCM presents a series of workplace stressors likely to cause fatigue, high strain working and eventually health and wellbeing decline. It also includes 'buffers', factors that can mediate the effect of stressors and diminish their impact on fatigue and diminished wellbeing. As discussed in Chapter 2, UK regulatory body Health and Safety executive use the DCM as a model for their 'Management Standards' which they use to assess risk factors for work stress (UK Health and Safety Executive, 2020).

Health and wellbeing in workplaces has vastly improved since the origins of this research in the 20th century (Bliese et al., 2017). However, there is still a long way to go in ensuring that the workplaces are beneficial, rather than harmful. Perhaps most side lined in this sphere is mental health, which is an increasing issue particularly with the evolving demands of the modern workplace. More needs to be done to address this issue, which should initially begin with dispelling the stigma surrounding it (Bharadwaj et al., 2017).

Fatigue is a major factor in both physical and mental health issues at work (Bazazan et al., 2018) and improved fatigue management systems incorporating a holistic view of work-related stressors is needed to minimise its risk of damage, particularly in workplaces requiring long working hours or shift work (Kalmbach et al., 2015; Torquati et al., 2018).

Finally, workplaces should acknowledge that employment has the potential to be extremely beneficial for wellbeing and therefore should place resources into fostering an environment that provides adequate support, flexibility and opportunity for positive task engagement (Ilies et al., 2017). However, this inevitably must be balanced with the need for work to be productive and often profitable as will be explored in the following section.

3.3.9 Productivity

Workplace productivity is an interesting and complex topic. For the purposes of this research, it will be defined as the sustainable achievement of identified goals over a period. On an individual level, productivity can affect progress in careers and engagement at work. On a larger scale, productivity can dictate the success of organisations and even national economies.

In a report on productivity in Britain, Felstead, Gallie, Green and Henseke (2018) explain how productivity is decreasing in the UK, despite it having comparatively high working hours. A potential cause for this could be that work-related fatigue is hampering progress. The following section will comprise of a general overview of themes in fatigue and productivity research and will suggest potential factors influencing progress in the area.

Productivity is undoubtedly hampered by fatigue. Theoretical research repeatedly supports the notion that performance declines when fatigue is experienced (Hopstaken, van der Linden, Bakker, & Kompier, 2015). Performance decline in workplaces can be observed financially. In a study focused on the productivity of call centre agents, Collewet & Sauermann (2017) found that a 1% increase of working time led to an increase in output of only 0.9% supporting the notion that working past the point of fatigue can lead to diminished returns (Pencavel, 2014).

In a US study, Rosekind et al (2010) estimate that productivity losses from fatigue caused by sleep deprivation equal $1967 per employee annually. It seems that overtime and long working hours lead to greater fatigue and reduced productivity in the short term and are likely to lead to decreased worker health and wellbeing in the longer term, which in turn affects future productivity. This is especially the case if a worker experiences stressors that worsen fatigue, such as lack of control and lack of social support (Karasek, 1979).

Despite this the clear link between fatigue and productivity loss, the use of overtime and long working hours is high, and still increasing around the world. Indeed, the European Quality of life survey 2016 found that working hours had been increased in 28 countries and work-life-balance had decreased over the past 10 years (Eurofound, 2017).

In their article, Delmez & Vandenberghe (2018) discuss reasons for an organisational reliance on overtime rather than adequate staffing in recent years. The 2009 recession put pressure on organisations to cut costs and most of these savings were made in employment. This began a trend of using overtime to meet demands with existing workers, which remains a pervasive method to offset costs.

Although this method of working does not provide time per-cost labour savings, it is more cost effective than hiring new employees due to quasi-fixed labour costs associated with employment (e.g. training, insurance, etc.). This means that it is cheaper overall to stretch existing employees through overtime during busy periods, rather than employing a larger workforce.

It would be logical to suggest that this current model of workplace organisation is not optimal, or indeed sustainable for the health, wellbeing or productivity. Greater research is needed into the productivity costs of fatigue in workplaces and how this can be managed through work design.

Thus, fatigue is relevant for safety, health, wellbeing and productivity in workplaces. There are clear areas for improvement in each of these areas which would ultimately be achieved through systematic work design. Incorporating effective fatigue management systems is an important initial step in this process.

To gain a comprehensive view of fatigue in workplace research, it is important now to consider its related concepts. Relatively few workplace studies specifically focus on fatigue, and those that do often only view fatigue in line with sleep deprivation (Åkerstedt et al., 2002; Tucker, Dahlgren, Akerstedt, & Waterhouse, 2008). However, fatigue is often included, or alluded to in research that focuses on related topics such as stress and burnout. The following section will consider each of these topics, discuss how they are related to fatigue, how this is framed in the literature and whether they should be included as components of an investigation into workplace fatigue for the current research.

3.3.10 Stress

The first concept addressed will be stress. This state is one that is most addressed in work psychology literature. Indeed, the journal 'Work & Stress' is dedicated to this topic ("Work & Stress"). Because of its ubiquity, not only in work psychology research, but also in organisational investigations of employee health and wellbeing, it can be a term that is used to refer to a general negative state, with its actual mechanisms and experience overlooked. As well as this, the subjective experience and symptoms of stress and fatigue can be confused with one another. A description and definition of stress will be presented in the following sections, along with a discussion of how stress and fatigue inter-link.

3.3.11 Stress and Modern Work

Humans have the evolutionary disadvantage of responding to non-physical threats that categorise normal working life with a similar stress reaction to physical, life threatening threat (Hockey, 2013). For example, similar physical and psychological feelings will be experienced when receiving an unpleasant email from a boss as they would for early humans encountering a lion.

The stress reaction is characterised by allostatic regulation in the body. This means that the body will work to accommodate a change in state caused by stress to avoid internal damage and facilitate quick action. This normally would be achieved through increasing the heart rate, blood pressure, adrenaline, noradrenaline and cortisol. It is also characterised by the suspension of functions such as growth, digestion and sex

(Hockey, 2013). This reaction can be useful to overcome an immediate and short-term issue (such as running away from a hungry lion, or, performing well in a short work presentation), however it is less useful and likely detrimental when endured over a longer period.

This can often be an issue in modern work environments when various stressors such as large workloads, deadlines and work conflicts are a constant source of strain (Ilies et al., 2015). The consistent experience of stress, like fatigue, is linked to a wide variety of mental and physical health issues (Fransson et al., 2015; Kivimäki et al., 2006; Kivimäki et al., 2002). Thus, if a work environment is high in strain factors (see Chapter 2, section 2.8), it is likely to lead to long term issues with stress and fatigue for employees.

Stress and fatigue are related yet different states. Stress is *the mental and physical reaction to external stimuli that causes a change in normal homeostasis*- normally these stimuli will be in some way threatening and anxiety producing. It is helpful to view stress from an evolutionary perspective. Humans are programmed to respond to threatening stimuli by engaging in 'fight or flight' mode. We either attack (fight) the threat by dealing with it head-on causing an increase in effort, or avoid the issue (flight), causing an increase in anxiety.

As with fatigue, stress is experienced as a reaction to stimuli referred to as 'Stressors' in research. This term describes external demands or threats. In a work context, this could take the form of high or unachievable workloads or co-worker conflict.

Stress and fatigue inter-link in several ways. The first is that stress is often a precursor for fatigue (Hockey, 2013). As previously mentioned, the stress reaction implores the individual to either 'attack' or 'avoid' the stressor. If choosing to 'attack,' the individual will need to apply effort, which is likely to result in fatigue. If fatigue symptoms are ignored through a drive to overcome the stressor, the individual will work in a 'strain state'. This strain state will then lead to worsened fatigue, which requires recovery (Frankenhaeuser, 1986).

Therefore, fatigue is a state that can occur following a stress reaction and application of effort to a demand. Stress can also offset fatigue in the short term (e.g. through the production of adrenaline motivating goal focussed actions), but it is likely to worsen it in the longer term through the suspension of positive physical and mental processes, putting the individual in a compromised state before beginning a task.

3.3.12 Stressors in the Work Environment

Modern work environments often encompass multiple stressors, which can make the stress, strain, fatigue cycle more difficult to overcome. As previously mentioned, fatigue is essentially a signal that the cost of committing effort to a current goal no longer outweigh its benefits and that the individual should place energy in attending to conflicting goals (Boksem & Tops, 2008; see section 2.4.4).

In the presence of multiple stressors, the stress reaction is likely to evoke a drive to 'attack' (Frankenhaeuser, 1986). If an individual is already in the process of completing an initial goal, the other stressors will act as conflicting goals and heighten the fatigue reaction. An example of this is an individual who is working on a goal to finish a piece of work. However, they are also experiencing conflict with a colleague. These stressors will take the form of competing goals, meaning that fatigue will occur more quickly. If the second goal is ignored in favour of the first goal, the individual is likely to work at strain and experience the anxiety of having not 'attacked' a stressor. This may then cause the individual to work late to deal with both stressors. The act of working late will allow them less opportunity to recover from the stress and fatigue they have experienced, and therefore will begin a vicious cycle of poor fatigue and stress management.

Cameron (1973) suggested that fatigue could be considered as a component of the wider stress response. However, for the purposes of the current research, fatigue will be viewed as a separate, but inter-linked state to stress. Although both states occur due to external threat, their antecedents and subjective experience are different. An individual will experience stress as a response to encountering the threat, this experience will be unconscious and in many cases uncontrollable (Hockey, 2013).

Fatigue is caused by the application of effort to an action, whether this is through conscious action, such as writing an essay, or unconscious action such as remaining awake when sleep deprived (for more details on this, see Chapter 2). Stress is experienced as a state of heightened awareness and high energy, similar to anxiety, whereas fatigue is experienced as a state of low energy, similar to depression (Hockey, John Maule, Clough, & Bdzola, 2000). Stress can be a pre-cursor for fatigue or the two states can occur in concert, especially in situations with conflicting goals and low control (Hockey, 2013).

Therefore, it is important to consider both stress and fatigue as separate, but inter-linked concepts in workplace research. External factors that are linked to stress are also likely to be linked to fatigue. Despite this, workplace research has a bias towards investigations of work stress, and a lack of focus on fatigue.

Investigations that do focus on stress and fatigue tend to view fatigue in line with sleep quality and deprivation, for example Akerstedt et al's investigation on how stress influences sleep deprivation and subsequent fatigue (2009). In this study, cortisol samples and self-ratings of sleep quality were taken from individuals in periods of high stress and were compared to periods of lower stress. The study found that lower cortisol levels in the morning were related to diminished sleep quality and higher ratings of exhaustion, and higher levels of cortisol in an evening were related to stress symptoms. They also found that finishing work late contributed to a higher level of cortisol in an evening. This provides some useful information about how sleep and stress can affect one another. However, there is evidently more to the fatigue concept than sleep deprivation and a realisation of this would be beneficial for workplace psychology research.

The present research will view stress as an initial reaction to external threatening stimuli (stressors). It will consider aspects of stress alongside fatigue because of the cyclical relationship between the two states. However, it will also acknowledge that fatigue does occur without the experience of stress and will investigate fatigue as a separate state with its own antecedents and subjective experience.

Poorly managed stress and fatigue can lead to many negative health outcomes as previously discussed (see section 3.3.5). A major psychological outcome of this is a condition known as burnout. It is important to explore this topic as much occupational literature on fatigue links to this topic. The following section will discuss burnout and focus on how unmanaged fatigue can lead to this condition.

3.3.13 Burnout

Burnout is categorised by extreme fatigue and loss of idealism and passion for one's work (Maslach & Schaufeli, 2017). There has been much research in occupational psychology surrounding burnout in recent years (Maslach & Schaufeli, 2017). Fatigue is a central aspect of burnout research (Rothmann, 2008). However, there has been limited research into the exact relationship between how the experience of acute fatigue relates and potentially leads to burnout.

Burnout was initially categorised as a state synonymous with work involving caring for, or teaching others (Maslach & Schaufeli, 2017). It was thought to be uniquely associated with emotional strain (Maslach et al., 2001). This is likely owing to a major symptom of burnout described as the experience of depersonalisation when encountering individuals in their care (Schaufeli & Taris, 2005). Thus, burnout became associated with 'compassion fatigue', which was viewed as an antecedent to burnout (Maytum et al., 2004; Potter et al., 2010) and research about this state was mostly confined to studies of caring professions (Maslach & Schaufeli, 2017).

Recent research has questioned the notion that burnout should only be associated with human-facing tasks. Studies have been conducted in areas of work that do not have human facing requirements and have supported the existence of burnout in a diverse range of fields (Demerouti et al., 2002; Maslach & Schaufeli, 2017). Feelings of de-personalisation are replaced with general cynicism for the work undertaken, along with diminished self-efficacy (Bosman et al., 2005). However, the experience of fatigue is ever-present.

Although many studies focus on compassion fatigue as a precursor to burnout, there is a lack of research investigating the link between a more generalised view of acute fatigue and burnout. Notable exceptions to this are Guan et al (2017) who investigated job burnout, mental fatigue and chronic diseases among Chinese civil servants. They identified the presence of a 'viscous cycle' between job strain, fatigue and chronic disease. The relationship between mental fatigue and burnout is also supported by Demerouti et al (2002) who included 294 German employees, around half of whom worked in human services, with the other half working in industrial production. They found that results did not differ significantly between the groups. This supports the notion that burnout can occur in roles which do not require care or social demands and that emotional demands can still lead to burnout in non-human facing work environments.

Researchers Van Dam, Keijsers, Verbraak, Eling, & Becker (2015) investigated whether fatigue associated with burnout was experienced differently to fatigue linked to other conditions. They found that fatigue experienced with burnout was no higher than fatigue experienced in line with depression. However, results suggested that fatigue associated with burnout was more in line with disordered motivation, whereas fatigue associated with depression was more in line with disordered emotions. This is in line with Boksem & Tops (2008) interpretation of burnout, in which they state that reduced motivation in burnout patients is a structural condition due to physiological changes in the dopaminergic/motivational system. Thus, suggesting that burnout represents changes in the way that goals are interpreted by the individual, therefore changing and likely increasing the fatigue reaction.

The prevalence of research into burnout, a state that is so closely inter-twined with fatigue, highlights that fatigue is an important factor in work-related wellbeing. A greater emphasis in research on fatigue in workplaces would perhaps lead to an improved understanding of how to treat and prevent burnout in the future.

Now that fatigue in occupational research along with related topics have been considered, it is important to gain an understanding of how fatigue is currently managed in workplaces. This will be done in the context of occupational research and practice.

3.4 Fatigue risk management

Attention will now be given to practical means used within industry to manage fatigue. As discussed at the beginning of this chapter, occupational fatigue research often takes a one-dimensional approach, viewing fatigue as a simple 'in versus out' calculation (e.g. using sleep opportunity to predict fatigue levels). This is synonymous with early interpretations of fatigue management discussed in chapter 2 (see section 2.3.1) in which fatigue was simply seen as an outcome of 'excess movement' and highlights the lack of complexity still lacking in modern fatigue research and practice.

It is no surprise that most practical fatigue management operates in a similar vein. This is potentially linked to the fact that most industries employing fatigue management practices are those that require shift work and are therefore based in transport sectors, where plans mostly focus on sleep opportunity (see section 3.2.5), and healthcare, where interventions generally focus on building emotional resilience (see section 3.2.4). The following sections will consider how industries generally approach fatigue risk management (section 3.4.1) with consideration of how developments in this area will likely be impacted by technological innovation (sections 3.4.2 & 3.4.3). This will be underpinned by the assertion that fatigue risk management should be incorporated with a multidimensional approach if it is to be successful at managing fatigue-related risk.

3.4.1 Workplace Interventions and fatigue management planning

As previously discussed, industries concerned with fatigue management are normally those that require shift work or extended working hours and/or include safety critical work. It is important for industries in this sphere to include fatigue risk management systems (FRMS) in their health and safety planning (Lerman et al., 2012). In the UK, this is not a legal requirement, but is strongly advised by regulatory bodies who state that employers have a duty to recognise the risk of fatigue and organise work in a manner that is not harmful for employees (Spencer, Robertson & Folkard, 2006).

This topic will be discussed with the framework of primary, secondary and tertiary interventions at an organisational or individual level (Holman et al., 2018). These terms are often used in the context of workplace stress research but are also applicable to fatigue interventions. They refer to the point at which interventions are designed to target. In the context of fatigue for example, primary interventions are designed to prevent fatigue from occurring. This also refers to whether the intervention is targeted at an organisational or individual level. Using the same example, a primary intervention with an organisational design will attempt to prevent fatigue through job re-design and the removal or control of workplace stressors. Whereas at an individual level, primary interventions will attempt to prevent fatigue through selection and assessment, only employing those who appear to have a higher tolerance to fatigue.

Table 1 provides an overview of the different levels and design of workplace intervention taken from Holman et al (2018).

Table 1- Overview of Workplace Intervention Levels and Design

Intervention	Individual	Organisational
Primary	Selection and assessment, pre-employment medical examination and fitness testing.	Job redesign, working time schedules, management training and mentoring
Secondary	Mindfulness training, health promotion, skill training, resilience training.	Conflict management, peer support groups, coaching and career planning.
Tertiary	Employee assistance programmes, counselling, disability management	Vocational rehabilitation

Many workplace fatigue interventions simply target one level of intervention design (e.g. resilience training often used in the healthcare sector targets fatigue at a secondary, individual level). This can cause issues with fatigue management as there is a danger of thinking that the issue has been effectively 'dealt with,' when in fact only one small part of it has been addressed. The following section will consider this issue when analysing relevant literature in this area.

In a review of fatigue in work settings, it is vital to consider the practical manner of how fatigue management is currently approached. Most current attempts to control the risk of fatigue are based around preventing its immediate safety consequences and unsurprisingly are generally confined to transport, aviation and defence industries (Dawson et al., 2011; Peng et al., 2018).

The most common means of managing fatigue is through work time planning. There is a sizable amount of research into the organisation of shift work and its effects on fatigue (Josephine Arendt, 2010; Dall'Ora et al., 2016). A step further than this is the creation of bio-mathematical models to track and monitor the likelihood of fatigue (Dawson et al., 2011). Both of these approaches view fatigue simply as sleep deprivation and circadian imbalance, thus ignoring task-dependent aspects of fatigue (Peng et al., 2018) and the impact of other work-related stressors. However, it is important to gain a working knowledge of approaches used by the most popular methods of fatigue management, as is the aim of the following section.

3.4.2 Bio-mathematical fatigue models

In recent years, some safety critical industries have used bio-mathematical models (BMMs) to predict fatigue (Dawson et al., 2011; Van Dongen & Belenky, 2012). This approach fuses human factors with technological innovation to create predictions of fatigue in given working patterns and compare this to fatigue associated with alternative working patterns (Dawson et al., 2011). This is useful as it allows a quantitative tool to be used for fatigue management.

However, a notable detriment to this approach is that 'fatigue' is in fact only predicted by sleep/wake behaviour. This means that it cannot be viewed in the same context as the more holistic definition 'fatigue' generally discussed in this thesis so far, which classifies sleep deprivation and circadian imbalance as important stressors for fatigue, however also acknowledges that a variety of other stressors can cause or contribute to the fatigued state (for more details, see chapter 2, page 69). Thus, when discussing fatigue in-line with bio-mathematical models, this will mean fatigue caused by stressors of sleep deprivation or circadian disruption only.

There are three different classes of bio-mathematical methods generally used in industry ranging from the somewhat simplistic one-process models to the more complex three-process models.

One-process models, such as the Fatigue Audit Inter Dyne model (FAID), use estimated sleep and wake behaviour to calculate expected levels of fatigue with given work patterns. Sleep/wake behaviour is estimated based on the opportunity for sleep afforded by the work pattern in question (e.g. the amount of time off work) (Dawson et al., 2011). This is also the method suggested by the UK's health and safety regulatory body who provide a 'fatigue calculator' based on sleep opportunity and shift length. They encourage use of this with the provision that this should be taken into account alongside other job related factors such as specific work related issues and social factors (Health and Safety Executive, 2006).

There is an obvious drawback to this method in that actual sleep-related fatigue is dependent on how much sleep and restful behaviour the individual has in fact obtained. Indeed, there has been very little published data to indicate that predictions of sleep/wake based on work/rest are statistically reliable (Dawson et al., 2011).

Gaining an understanding of the amount of opportunity for sleep and rest afforded in a working pattern is useful, as measures should always be taken to ensure that there is adequate time for recovery from working. However, this type of model cannot adequately be used to predict fatigue, even in the narrow definition used by developers of the model. Therefore, this model is best used to predict whether a given shift schedule would give the operator adequate time to rest and sleep, which is a useful first step in fatigue management.

Two process models, such as System for Aircrew Fatigue Evaluation (SAFE) address the major drawback with one-step models in that they use self-reported sleep/wake behaviour, recorded from workers to predict fatigue. This allows for greater amount of accuracy in mitigating the effect of sleep deprivation (Belyavin & Spencer, 2004). However, as these systems are used to determine fitness for work, they are inevitably vulnerable to inaccurate recording due to their reliance on self-reporting. Additionally, they are likely to present issues for work planning and time constraints for organisations due to the short notice in which an individual may be declared unfit to work by the model.

Finally, three process models use a combination of actual sleep data (normally recorded through ACTi graph) and the inclusion of consideration for light exposure and sleep inertia (Jewett & Kronauer, 1999). Three-process models allow a more accurate picture to be gained of the impact that a working pattern has over sleep deprivation and circadian imbalance.

BMMs could be an example of primary or secondary interventions depending on the way they are employed. If employed at a primary organisational level, BMMs would be used in the design or re-design of working patterns as a tool to ensure that employees had appropriate time for recovery between shifts. If employed at a secondary organisational level, BMMs, particularly three process models could be used as a retrospective assessment of how much sleep an individual has obtained to decide their fitness to work on any given day. At a secondary individual level, BMMs could be used to encourage individuals to obtain enough recovery between shifts.

There are some major issues with this approach. One is that the effort and cost required to apply two and three process models would undoubtedly be high. Without regulations stipulating that effective fatigue management systems should be in place, there is little incentive for organisations to invest in them. Another is that because of the complexity of two and three process models, there would be a temptation for organisations to overlook other stressors contributing to fatigue, with the assumption that the risk is covered.

3.4.3 Fatigue Tracking Technology

Emerging research in this area focuses on the development of wearable devices to 'track' fatigue. This generally uses the method of eye tracking which either tracks pupil dilation to track arousal and motivation (Hopstaken et al., 2014) or work on the premise that as an individual becomes more fatigued, changes in gaze distribution occur. This means that gaze direction will generally stay on one point for longer and spend less time looking in their peripheral vision for potential hazards (Fang, Jiang, Zhang, & Wang, 2015). Unsurprisingly, this method is mainly designed for high hazard occupations which involve long periods of concentration, e.g. drivers, pilots and construction workers (Fang et al., 2015).

This is an example of a secondary, individual level fatigue intervention which could be useful as an alert for task-specific fatigue in high hazard industries. Indeed, although these methods are not yet widely used in industry (Zhu et al., 2017), they are likely to be attractive to organisations, particularly those based in fields such as engineering due to their use of objective measures and ability to quantify risk. However, these would only be useful when combined with both primary and tertiary organisational interventions.

Primary interventions would need to be employed to prevent employee fatigue from becoming an issue through work design. Tertiary methods would need to be used to determine appropriate treatment for those who are identified as experiencing fatigue through the tracker. Thus, fatigue management models should employ a multidimensional approach, both in their assessment of stressors and associated manifestations of fatigue (e.g. mental demands, physical demands, emotional demands) and in their level of intervention (e.g. primary, secondary, organisational and individual).

3.5 Fatigue research in similar work environments to the wind industry

It is now important to consider current practice and research in industries relevant to the present research. Though there are relevant useful findings to be taken from research based in the wind industry, due to its existence as a relatively new work environment, there is currently a lack of research specifically focussed on fatigue and its management in the wind industry as will be explored in Chapter 4. Although the wind industry work environment encompasses unique hazards and stressors, several workplace characteristics are comparable to other industries that have been in existence for sufficient time to allow for decades of research to be conducted in human factors.

The following sections will encompass a review of fatigue literature in three industries selected due to their commonalities with the wind industry. This will include an examination of fatigue guidance and applied research in the oil and gas industry (section 3.5.1). Following this an examination of fatigue in the cultural context of the maritime industry will be presented in section 3.5.2 and finally a discussion of fatigue and physical stressors in the construction industry will be explored in section 3.5.3.

3.5.1 The Oil and Gas Industry

An intuitive comparison to the wind industry is the oil and gas industry. Like the wind industry, its main function is energy production, and therefore shares some of the global market challenges. It also encompasses onshore and offshore work, along with extended working hours (Parkes, 2017). There are, however, some key differences between the two work environments, namely that oil and gas is more established in both its offshore structures and its working practices. Additionally, oil and gas employees are likely to work shifts that encompass night working, especially when offshore (Gibbs et al., 2005). It is important not to view these industries in a like-for-like fashion, but to take useful aspects of research in the oil and gas industry into consideration for the present research.

Considering the oil and gas industry allows an insight into fatigue-related research that focuses specifically in offshore work environments. This is unusual as offshore working is unique and presents challenges not often found in other work environments (Gibbs et al., 2005). Working offshore is associated with an increased risk of danger due to the hazards that are present. Indeed, in the US between 2003 and 2010, the oil and gas industry had a collective fatality rate seven times higher than for all US workers (Matthew et al., 2013). In recognition to the increased risk of danger, in 2018 the UK's Health and Safety executive commissioned specific guidance in safety management for offshore working (HSE, 2018). This guidance states that safety management systems should incorporate specific consideration of fatigue risks, which should be customised for the operation for which it is developed (HSE, 2018). They also highlight known hazards for fatigue, including early starts (before 6.00 am), overtime, beyond a 12 hour shift, tasks with low error tolerance, tasks with continuous high attention vigilance levels, tasks with high physical demands and sharing rooms with strangers.

It is interesting that this guidance goes beyond simply highlighting opportunity to sleep and potential circadian imbalance and includes recognition of the likely stressors experienced during working time. In this, a reciprocal relationship can be seen between research and policy. Health and safety (H&S) guidance was informed by research conducted in fatigue risk factors in offshore settings, specifically a series of projects undertaken by Parkes and Clark (1997).

Although H&S guidelines do incorporate recognition of work-place related stressors, most research into fatigue revolves around shift organisation and sleep opportunity. There are some interesting and relevant findings of these studies, even if they do present a somewhat reductionist view of fatigue. Gibbs et al (2005) conducted research into determining the effect of shift work on circadian rhythms and health in the offshore oil and gas (OAG) working environment. Because OOG workers are normally required to work night shifts during their time offshore, a shift pattern of 14 continuous days of 12-hour shifts was used as a baseline comparison to shifts of 14 continuous nights and swing shifts consisting of 7 days and 7 nights.

Gibb's study used several physiological measurements to determine sleep quality and hormonal metabolic responses to meals. The 14-day shift pattern was found to be more beneficial for sleep and health than shift patterns involving night work, however, sleep quality was still found to be lower in this cohort than onshore shift workers. This is interesting, as although the focus in this, and other similar studies is on the impact of night working, it also highlights the impact that an offshore shift pattern of daytime shifts has on sleep and health. Indeed, work conducted by Parkes et al (2017) highlights that most investigations into shift work are conducted on participants whose average working week is 30-40 hours, whereas offshore workers will typically work around 84 hours per week.

Recent research conducted by Riethmeister et al (2019) further supports this notion through examination of sleep-related fatigue and sleep quantity offshore oil workers. They used a diary-design to measure sleepiness pre and post-shift as well as tracking sleep using actigraphy over 14 days. Their results suggested that technicians experienced cumulative sleep loss throughout their shifts (92 minutes per night on average). Levels of post-shift sleepiness appeared to have a cumulative impact across the 2-week period which was linked to consecutive shift working and chronic sleep loss. This suggests two things; one is that offshore conditions make obtaining optimal sleep quantity more difficult and the other is that working consecutive shifts has an impact on cumulative sleepiness.

However, it seems that consecutive 12-hour shifts can be popular with technicians. A review of health and social considerations of offshore work was conducted by Ross (2009). Contrary to what might be expected, he found that workers generally had greater overall satisfaction with 12-hour shifts compared to 8-hour shifts. This is likely to be due to the ability it affords them to work condensed hours and have long periods of time in which they do not need to work. Ross cautions that greater satisfaction does not always lead to increased health and safety during periods of work. Indeed working 60 hours per week has been shown to give rise to substantially impaired performance and mood in comparison to 40 hours (Parkes & Clark, 1997). It is likely that these risks only increase with further hours worked.

Interestingly for the present research of which a component involves the comparison of onshore and offshore wind technicians, Parkes (1997) conducted a longitudinal study comparing health and wellbeing in onshore and offshore oil and gas technicians. They found that stress levels were generally higher in offshore employees and health behaviours more damaging. However, they observed a dramatic decrease in health and job satisfaction in onshore employees during the 10 years in which the study was conducted, while the offshore cohort remained the same. This change was due to a mixture of job-related factors including an increase in workload and lack of job progression. This highlights that a mixture of factors should be addressed when investigating work related stressors in both on and offshore workers.

The work environments of offshore wind technicians are comparable to that which is experienced in the maritime industry. Therefore, relevant research in this work environment will be considered in the following section.

3.5.2 The Maritime Industry

The maritime work environment encompasses time away from family, long working hours, high-risk tasks and the requirement to co-habituate with colleagues. This is like the experience of an SOV based offshore wind technician. There has been much fatigue-related research into maritime operations (e.g. Houtman et al., 2005; Jepsen, Zhao, Pekcan, Barnett, & Van Leeuwen, 2017; Thomas, Paterson, Jay, Matthews, & Ferguson, 2019; Wadsworth, Allen, McNamara, & Smith, 2008). A review on stress in seafaring highlighted some key stressors associated with the role, which are likely to be shared in offshore workers including separation from family, loneliness on board, limited time for recreation and sleep deprivation (Jepsen et al., 2017).

In their review of fatigue in the shipping industry, Houtman, Miedema, Jettinghoff, Starren, Heinrich, Gort, & Wulder (2005) discuss the notion that fatigue is a systemic issue, caused by a 'macho culture' in which employees are unlikely to admit feelings of fatigue or declined mental health due to a fear of vulnerability. Furthermore, shipping representatives often do not recognise fatigue as a significant problem progression is hampered by the industry-held perception that research will lead to more rules in an industry that is already highly governed by safety regulations. There is a danger that these attitudes could already be present in the wind industry and a need to address their potential existence.

This research suggests that there are multiple issues with fatigue in this industry yet, a pervasive culture of denial around the issues. This is interesting for the present research and highlights that fatigue investigations will need to be designed with this in mind. The following section will consider the construction industry which shares multiple characteristics with the wind industry due to the existence of high hazard, physical work along with technical tasks and the potential for long working hours.

3.5.3 The Construction Industry

There has been some research focused on fatigue and psychosocial stressors in construction workers (e.g. Aryal, Ghahramani, & Becerik-Gerber, 2017; Boschman, van der Molen, Sluiter, & Frings-Dresen, 2013; Dong, 2005).

Research of note in this cohort is a study by Fang et al (2015) that examined the effect of fatigue on construction workers' safety performance. They found that after a certain amount of time spent working, there was a linear relationship between fatigue and safety-related error rates. This time was usually at around 15:30, when workers still had at least another two hours of work to complete before they could finish.

The main fatiguing factors identified for construction workers in this study were awkward manual handling, spending prolonged amounts of time in uncomfortable positions and high workload. These experiences are likely to be shared with wind technicians, making the Fang et al's finding a cause for concern.

Research into work environments with shared characteristics to the wind industry highlight the breadth of factors that need to be considered to understand how fatigue occurs and ultimately how to manage it.

3.6 Chapter Summary and Conclusion

This chapter has consisted of an analysis of industrial fatigue research and practice. It first considered main areas of focus in sectors where fatigue research is commonly based. Through this, it was determined that there is a lack of consistency in how fatigue is designed and addressed in differing industries. Furthermore, understandings of fatigue occurrence and management commonly focused on one-dimensional models with single factors (e.g. hours of sleep opportunity) used to predict overall fatigue outcomes.

Attention was specifically applied to safety and fatigue which was explored with case studies of fatigue research and practice aviation and healthcare industries. For aviation, it was found that although much helpful fatigue research has come from work in this sector, there are still prevalent issues regarding fatigue and safe working practices. These tended to centre around the safety culture associated with fatigue reporting, which was said, in some cases, to be behavioural based and individually focussed. This prompted a discussion of the importance of addressing safety culture in fatigue management and the merits of the cultivation of a 'just culture' (Dekker, 2017). Consideration of the healthcare sector highlighted the multitude of issues that can be caused by workplace fatigue and related factors and again highlighted the lack of consistency in fatigue management approach between industries.

Fatigue and employee health were then considered and separate consideration was given to physical and mental health due to the differing way that they are addressed in research and practice. This highlighted the many issues that poorly managed fatigue can have on employee physical health including adverse musculoskeletal outcomes from consistent physical work and serious cardiovascular issues linked to consistent work fatigue. This section highlighted that health is often seen as a secondary and somewhat forgotten factor as opposed to safety which receives comparatively more research in this area. Even more side-lined is mental health which has very little fatigue-related research despite findings indicating the magnitude of mental health issues in modern workplaces.

Related concepts of stress and burnout were examined, both since much mental workplace mental health research is undertaken through the framework of these two issues and due to their related antecedents and manifestations to fatigue. Stress should be considered alongside fatigue in workplace investigations into the topic and burnout is often the unfortunate manifestation of poorly managed fatigue.

A focus was placed on the positive health outcomes that could be achieved through good work design and placed a focus on wellbeing. The relationship between wellbeing, fatigue and productivity was explored and placed this in the context of societal and economic factors, highlighting some major challenges for balancing productivity and fatigue management in workplaces.

Following this, existing fatigue management models and practices were examined in the framework of primary, secondary and tertiary interventions with an individual or organisational focus. Most currently used methods are focused on shift work design and are only commonly used in a small number of industries. This highlighted the need for wider application of fatigue management planning at all levels of intervention.

Finally, fatigue research in relevant work environments was considered which mostly highlighted the numerous fatigue related stressors and safety risks of workplaces with these characteristics and suggested that movement towards fatigue management is complex and slow moving. The following chapter will consist of a systematic review specifically considering fatigue-related research in the wind industry.

Chapter 4- Systematic Review

4.1 Introduction

After considering the wider context of fatigue literature and applied research in Chapters 2 and 3, it is now relevant to explore relevant research conducted within the wind industry. This will be undertaken in the form of a systematic review in the present chapter in which all literature deemed to be relevant to employee fatigue and related concepts will be collated and analysed.

4.1.1 Chapter Structure

First, a rationale for this review will be presented in section 4.2. Following this, a methodology for searching for and analysing relevant research will be included in section 4.3. Following this, identified literature will be discussed in section 4.4. This will be done in a thematic format including the categories of mental stressors (section 4.4.1), physical stressors (section 4.4.3), employee health (section 4.4.5) and employee safety (section 4.4.7). From this analysis, a diagrammatic interpretation and conclusion of findings and how they relate to the present research will be presented in section 4.5.

4.2 Rationale for the present research

Chapters two and three considered the concept of fatigue and its relevant research and management in occupational settings. As the present research is based in a specific work environment of the wind industry, attention should now be focused on fatigue issues and management within this work environment to inform how the present research will be conducted. However, to date there has been no specific fatigue research in this industry, though there are some investigations of human factors issues in this environment. As related research in this industry is currently a developing field, this chapter will consist of a systematic review of studies examining topics related to employee fatigue.

It will be useful to gain an understanding of the literature around fatigue-related factors in this environment, as this will provide detailed information around the environment that the present study will be investigating. This will allow any themes of fatiguing factors to be established. This will lead to a more detailed understanding about the physical and mental stressors in this environment and inform the design of research to investigate these potential stressors and associated fatigue. Finally, it will provide understanding of the current level awareness within the field around human factors and highlight any gaps in existing research that need to be filled to gain a comprehensive insight into fatigue-related factors.

Therefore, the aim of this review will be to gain a comprehensive insight into the current literature surrounding worker fatigue and human factors in the wind industry. The following sections will consist of a methodology of how literature was searched for and reviewed.

4.3 Methodology

Siddaway, Wood, & Hedges (2019) guide to completing systematic reviews in psychology was used as a framework to devise the methods for this review. Due to the relatively scarce amount of research on the wind industry environment, the inclusion criteria remained rather broad, to include all relevant literature.

4.3.1 Inclusion Criteria

The following inclusion criteria were initially decided on at the beginning of the review process.

Participants- Literature included must have a focus on workers in the offshore or onshore wind industry. It will ideally focus on operations and maintenance technicians, however, literature around all workers in this environment will be considered.

Topics- Literature included must be focused on topics around the human factors of workers in the wind industry. This could be around things that *affect* workers in this environment (e.g. factors that impact the health of workers in the wind industry), or factors *affected by* workers (e.g. productivity of workers who have worked over a certain amount of hours). Topics around factors that could influence management of fatigue in this environment will also be included, such as papers around safety hazards or work time management.

Time Periods- Due to the relatively new nature of the wind industry and the lack of prominent research in this area, the period that the literature was created will not be limited in this review. There has been one systematic review performed on a related topic in 2014 (Cooper et al., 2014), which investigated worker musculoskeletal health in the wind industry. However, this was not directly relevant to the present research topic, and therefore does not serve as a record of research that took place before this point.

Other- Although research conducted anywhere in the world will be considered, only literature written in English will be included.

4.3.2 Search methods

A literature search was conducted using the following online databases:

<u>Google Scholar</u>

An advanced search method was used, initially with terms included in Table 2.

Table 2- Included search terms in initial Google Scholar Search

With the **exact phrase**	With **at least one of** the words
"Wind industry"	Human; stress; fatigue; health; safety; strain

This yielded 13,600 results, with papers mainly focused on engineering of the turbines themselves, rather than human factors around workers. Following this, the search criteria was refined using the criteria shown in Table 3.

Table 3- Included search terms in refined Google Scholar Search

With the **exact phrase**	With **at least one of** the words	**Without** the words
"Wind industry"	Worker; human; stress; fatigue; health; safety; stress; sleep	Blade

**words in title, Only in English language, any time period*

This search yielded just eight results. Titles and abstracts were checked for relevance to the inclusion criteria and five of these were included. Google Scholar was then used again for searches specifically relating to the offshore or onshore wind environments, in case 'wind industry' had not included all relevant results. The following search terms were used for this, after adding more words that should be excluded in the search, due to the volume of papers using similar language to what would be expected from human factors papers, but which actually related to the manufacturing of wind turbines.

Table 4 Included search terms in second Google Scholar Search

With the **exact phrase**	With **at least one of** the words	**Without** the words
"Offshore wind"	Worker; human; stress; fatigue; health; safety; stress; sleep; wellbeing	Blade; jacket; structural; converter; monopole; design; gears; turbines; converters

This search yielded 187 results, which were considered for inclusion. From this, eight papers were included, with 177 not meeting the inclusion criteria and two repeated in the previous search.

The same search was then carried out with the phrase 'onshore wind' replacing 'offshore wind'. This yielded 11 results, with one meeting the inclusion criteria.

Web of Science

After experimenting with advanced search options and yielding very little results, the simple search 'offshore wind worker*' was used. This yielded 31 results, five of which were repeated from those already included from the previous search and 20 that did not meet the inclusion criteria, leaving six papers to be included.

This search was then undertaken for ‘onshore wind worker*’. Seven results were yielded. Three were repeated from those already included and three that did not meet the inclusion criteria. Therefore, one study was included.

Scopus

Scopus was searched with the following terms and key words:

Offshore OR onshore AND worker*

Key words (limit to) humans; wind; safety engineering; wind farm; occupational exposure; workplace; employee; health; offshore windfarms; work environment; working conditions; environmental conditions; ergonomics; health risk; occupational accident; offshore wind; operation and maintenance; protective clothing; risk factors; risk perception; HSE; health promotion; health risks; human activity

(Only English language)

94 results were yielded, with nine repeated from those already included and 81 not meeting the inclusion criteria. Four were included.

Science Direct

The following terms were used to search Science Direct:

Title: Onshore wind OR offshore wind Theme: worker OR technician OR workers OR technicians

190 results were yielded, with two meeting the inclusion criteria.

EBSCO

EBSCO searches (PsychInfo and PsychArticles) yielded 127 results but none met the criteria- all human factors studies that linked in some way were based in oil and gas.

Open Grey

Open Grey yielded 84 results (in English) for the search term 'wind industry'- however all of these were based around engineering, rather than human factors.

Copac (Grey Literature)

The following search terms were used: Title: wind industry Subject: Health. This yielded 24 results of which two were relevant.

4.3.3 Further analysis

Twenty papers were identified in these searches, including some grey literature. These were then read and analysed. Further literature was identified from reference lists of some of these papers and some papers were discounted at a later stage due to lack of relevance to the inclusion criteria and review aims. This resulted in sixteen peer-reviewed papers and five pieces of grey literature being included in the final review.

4.4 Discussion

None of the literature included in the present review specifically investigated fatigue in wind industry workers. However, those included all contributed to developing a picture of how fatigue is experienced in this environment. For ease of analysis, papers were grouped into the following categories:

Mental stressors

Research investigating how the environment and tasks of wind industry workers affect their psychological state.

Physical stressors

Research investigating how the physical nature of the environment and tasks of wind industry workers affect their physical state.

Employee Health

Research investigating how this working environment affects the health of workers in the long or short term.

Employee Safety

Research investigating safety hazards and systems in this environment that may be relevant to fatigue causes, consequences or management.

In total, 21 peer reviewed papers and 4 pieces of grey literature were identified and included in this review. Research will be considered separately in terms of these categories and then combined.

Overview of included literature

The following table includes a summary of literature included in the systematic review which will be discussed in subsequent sections.

Table 5- Summary of papers included in the systematic review

Title	Authors	Journal	Year	Summary of major findings
Mental Stressors				
Sleep quality of offshore wind farm workers in the German exclusive economic zone: a cross-sectional study	Velasco, Mette, Mache, Harth, Preisser	BMJ Open	2018	47.9% of workers reported their quality of sleep to be worse during offshore work and 44.1% reported no differences. Overall sleep quality in the past 4 weeks was more frequently rated to be very bad or poor among workers who were offshore or whose last offshore commitment was <1 month ago at the time of answering the questionnaire.
Living the 14/14 Schedule: Qualitative Analysis of the Challenges and Coping Strategies among Families of Offshore Wind Workers	Mette, Robelski, Kirchhofer, Harth	International Journal of Environmental Research and Public Health	2019	Being a 'single parent' for 2 weeks was seen as a major disadvantage for partners. Transition phase of 1-4 days mentioned by most partners for when the technician arrives home after their off-shift. Children often find the time before their fathers go away very difficult. The separation was perceived as more difficult for families with young children.

Linking quantitative demands to offshore wind workers' stress: do personal and job resources matter? A structural equation modelling approach	Mette, Garrido, Preisser, Harth, Mache	BMC Public Health	2019	Workers in this study showed higher levels of stress than the Danish norm sample. Quantitative demands positively related to employees' perceived stress and negatively related to psychological detachment from work but social support was a relevant job resource for the offshore workers. Psychological detachment from work partially mediated by the relationship between quantitative demands and stress- highlights the integral role of psychological detachment for offshore workers.
"It's still a great adventure"-exploring offshore employees' working conditions in a qualitative study	Mette, Garrido, Harth, Preisser, Mache	Journal of Occupational Medicine and Toxicology	2017	Physical work including climbing, working in awkward positions, working at height was considered demanding by all workers and experts. Participants described social pressure to access installations despite situations of marginal weather conditions as they didn't want to be seen as the only ones voicing reservations. Seasickness was also mentioned as a stressor.

				The job was reported to be of very high personal meaning (adventure, challenge, freedom), meaningful work through contribution to green energy. Working long hours was described as the norm- there is ‘nothing else to do there so they might as well work’. Weather days described as stressful- ‘feeling like a rat stuck in a cage’. Feelings of homesickness seen as a stressor- ‘two different everyday lives’- made worse when they have a family. Social support was described as one of the greatest resources in offshore work.
Impact of wind turbine sound on general health, sleep disturbance and annoyance of workers: a pilot- study in Manjil wind farm, Iran	Abbasi, Monazzam Akbarzadeh, Zakerian, Ebrahimi	Journal of Environmental Health Science and Engineering	2015	Noise annoyance and distance from wind turbines could significantly explain about 44.5 to 34.2% of the variance in sleep disturbance and worker’s general health, respectively. This study supports the notion

				that wind turbine noise can directly impact on annoyance, sleep and health.
2nd Reading effect of wind turbine noise on workers' sleep disorder: a case study of Manjil Wind Farm in Northern Iran	Abbasi, Monnazzam, Zakerian, Yousefzadeh	Fluctuation and Noise Letters	2015	When age is constant, sleep disorder will increase by 26% as per each 1 dB increase in equivalent sound level. In situations where equivalent sound level is constant, an increase of 17% in sleep disorder is occurred as per each year of work experience. Because of the difference in sound exposure in different occupational groups. The effect of noise in repairing group was about 6.5 times of official group and 3.4 times of the security group. Sleep disorder effect caused by wind turbine noise in the security group is almost two times more than the official group.
Assessment of noise effects of wind turbine on the general health of staff at wind farm of Manjil, Iran	Abbasi, Milad, Monazzam, Reza, Ebrahimi, Hossein, Zakerian, Seyed Abolfazl, Dehghan, Somayeh Farhang, Akbarzadeh, Arash	Journal of Low Frequency Noise, Vibration and Active Control	2016	Results showed that noise exposure significantly correlated to all sub-scales of general health, except for depression. This suggests that low-frequency noise from wind turbines can cause harmful effects on the health of workers that are too close to the turbine.
Physical Stressors				

A cross-sectional survey of physical strains among offshore wind farm workers in the German exclusive economic zone	Garrido, Mette, Mache, Harth, Preisser	BMJ Open	2017	Climbing was seen as the most prominent physical stressor with 63.8% of respondents reporting to be either always or often confronted with climbing and ascending stairs during offshore rotations. Noise was also reported to be always or often present, 55.6% of participants, vibrations reported by 52.2%. Other reported physical stressors included lifting and carrying heavy loads, transport of equipment, working in non-ergonomic positions and cramped spaces. These factors appear to be higher than that of German high-skilled manual workers
Fitness to work: a comparison of European guidelines in the offshore wind industry	Preisser, McDonough, Harth	International Maritime Health	2016	The British, Dutch, German and Norwegian offshore ‘Fitness to work’ guidelines are very similar in structure, scope and content. However most guides were developed for the Oil and Gas industry which presents some notably different workplace hazards.
The physical performance of workers on offshore wind energy platforms: is pre-employment fitness testing necessary and fair?	Preisser, McDonough, Harth	International Archives of Occupational and Environmental Health	2019	Half of workers tested did not achieve the standards set in ‘renewable UK’ guideline-21% would not have met the criteria for offshore work according to German guidelines.

Human exposure to motion during maintenance on floating offshore wind turbines	Scheu, Matha, Schwarzkopf, Kolios	Ocean Engineering	2018	Proneness to seasickness and other motion-related responses by the human body are highly subjective, whilst some technicians are able to work under highly severe conditions, others may get sick already during low sea states.
The effect of ladder climbing on forearm function	Stewart, Mitchell	Contemporary Ergonomics and Human Factors	2018	Results suggested a clear effect of ladder climbing on grip strength, not fully recovered within 15 minutes after climbing ceased.
A detailed ergonomic assessment of ladder climbing Key risks (short-and long-term) to technicians in the offshore wind industry	Milligan, Tipton	Grey literature, Presentation, Portsmouth University (paper in-press)	2018	This research compared climbing technique and endurance of experienced wind technicians to novices. Results suggested that experienced wind technicians had a more efficient climbing technique and maintained optimal movements for longer. However, for both groups climbing technique worsened with climbing fatigue and for some participants after-effects of physical fatigue were long lasting.

The effect of pitched and vertical ladder ergometer climbing on cardiorespiratory and psychophysical variables	Barron, Burgess, Cooper, Stewart	Applied Ergonomics	2018	Results indicated that climbing a vertical ladder (pitched at 90 degrees) was significantly more demanding than climbing a pitched ladder (70 degrees) as demonstrated by increases in heart rate, VO2 and rate of perceived exertion.
The physiological effect of a 'climb assist' device on vertical ladder climbing	Barron, Burgess, Cooper & Stewart	Ergonomics	2017	Levels of exertion were compared in climbing tasks with and without the use of climb-assist. Results indicated that climb-assist significantly decreased the level of physical exertion experienced as seen by reductions in heart rate, VO2 and rate of perceived exertion.
The demands of vertical ladder ergometer climbing relating to the wind energy industry.	Barron	PhD Thesis	2020	This PhD thesis explores the potentially increased demands of vertical ladder climbing experienced by wind technicians and includes further details of the above studies.
Health				

Health effects associated with working in the wind power generation industry: a comprehensive systematic review	Cooper, Kirkpatrick, Stewart	JBI Database of Systematic Reviews and Implementation Reports	2014	This review did not identify any published research with wind technicians as an occupational group and so included evidence from occupations with shared characteristics. It found that in these occupations musculoskeletal disorders were widespread. These disorders were particularly related to ladder climbing and prolonged kneeling or stooping postures.
Prevalence and its risk factors for low back pain among operation and maintenance personnel in wind farms	Jia, Ning Li, Tao, Hu, Shuangqiu, Zhu, Xinhe, Sun, Kang, Yi, Long, Zhang, Qiong, Luo, Guilian, Li, Yuzhen, Zhang, Xueyan, Gu, Yongen, Wang, Zhongxu	BMC Musculoskeletal Disorders	2016	This study included a survey of 151 operations and maintenance personnel to understand risk factors for low back pain. It found that lower back pain was present in 88.74% of respondents and risk factors included manual handling (over 10lb).
Health effects of wind turbines in working environments - a scoping review	Freiberg, Schefter, Girbig, M Murta, Seidler	Scandinavian Journal of Work Environment & Health	2018	No observational studies on health impacts among onshore wind employees were identified, only one concerning physical exposures exists. This found that noise from turbines poses an increased risk for noise annoyance, sleep disorders and lowered general health for employees.

Healthy offshore workforce? A qualitative study on offshore wind employees' occupational strain, health, and coping	Mette, Velasco Garrido, Harth, Preisser, Mache	BMC Public Health	2018	Stress reported by all employees- but specifically by those with management duties. Employees also reported difficulties detaching from work and fatigue depending on tasks, time and intensity. Long hours were also reported and were associated with fatigue, particularly if shifts included climbing and/or night shifts. Many reported a particular rise in fatigue following 1 week offshore, increasing steadily thereafter and being especially prevalent during the last few days. Some mentioned reaching a limit after 14 days offshore.
Workplace health promotion for employees working in offshore wind parks in the German exclusive economic zone: a mixed-methods study	Mette, Velasco Garrido, Preisser, Harth, Mache	BMC Public Health	2018	Only 2 out of the 21 workers interviewed were aware of health promotions at work. There was a perception that health was more invested in, in oil and gas Difficulty in being motivated to exercise after long work days was a reported factor in non-participation in health programmes. Many expressed a need for more social activities, especially in winter. Employees with a regular work schedule were more likely to use fitness facilities. Older technicians are

				likely to have a higher need for recovery after work.
Safety				
Occupational risk for an onshore wind farm	Aneziris, Papazoglou	Safety Science	2016	
A risk assessment tool for improving safety standards and emergency management in Italian onshore wind farms	Astiaso Garcia, Bruschi	Sustainable Energy Technologies and Assessments	2016	Onshore wind farms have fewer hazards, although their consequences could be greater depending on where they are located.
Why does the offshore wind industry need standardized HSE management systems? An evidence from Denmark	Ahsan, Pedersen, Nielsen, Ovesen,	Renewable Energy	2019	Individual companies create their own specific HSE systems- which is a main barrier for cross-company cooperation and knowledge sharing. There is no harmonized way to collect, store or report the "near-misses".

Evaluating wind technicians performance on safety critical rescue steps	Lawani, Hare, Cameron	Proceedings of the ICE - Management, Procurement and Law	2018	Results showed that rescue and evacuation skills decay at one and three months after the wind turbine rescue and evacuation training with 47% and 20% of technicians experiencing such decay in their skills and knowledge. However, relying only on the high knowledge proficiency gave a false sense of security in terms of overall procedural competence of the technicians. This study demonstrates to what extent new technicians struggle to sustain their competence without any form of practice.
Securing the safety of offshore wind workers	Atkinson	Grey literature, article in Renewable Energy Focus	2010	A report examining the lack of concrete health and safety regulation in the UK offshore wind industry.
Wind energy at sea: Ensuring worker safety	Robb	Grey literature, article in Renewable Energy Focus	2005	A report exploring the lack of specific understanding of safety risks in offshore environments.

4.4.1 Mental Stressors

Seven peer-reviewed papers were identified in this category and no grey research. Four of these papers were part of a recent project, 'Bestoff', which focuses on health and safety in the offshore wind industry in Germany (German Offshore Wind Energy Foundation) (see first 4 papers listed in Table 5). The project aims to address the gap in research in this work area. Researchers on this project have published a number of studies around mental stressors (Mette, Robelski, Kirchhöfer, Harth, & Mache, 2019; Mette, Velasco Garrido, Harth, Preisser, & Mache, 2017; Velasco Garrido, Mette, ,Mache, Harth, & Preisser, 2018), physical stressors (Velasco Garrido, Mette, Mache, Harth, & Preisser, 2018) and health (Mette, Velasco Garrido, Harth, Preisser, & Mache, 2018; Mette, Velasco Garrido, Preisser, Harth, & Mache, 2018) in this environment. These will be discussed in the present and subsequent sections of the review.

The second group of studies, conducted on Manjil wind farm in Iran, focus on the impact of wind turbine noise on workers' sleep and health (Abbasi, Monazzam, et al., 2015; Abbasi, Monnazzam, et al., 2015). These studies are based on a wind farm that is likely to have different working conditions to the UK. However, their inclusion in this review is potentially helpful if turbine noise is found to act as a stressor. It could highlight the need for research to be carried out in this subject on UK wind farms.

Research on mental stressors in this field seems to be in its infancy when compared to the relative wealth of research in related fields such as oil and gas (e.g. Mehta, 2017; Parkes, 2017; Saksvik et al., 2011; Sneddon, Mearns, & Flin, 2013). However, the studies identified do present some highly relevant and interesting findings for the present research, which will now be discussed.

Topics covered in the included studies are highly relevant to the experience of fatigue in offshore workers. Papers will be discussed thematically and their findings will be considered in relation to how they inform the present research and how their findings can be developed in future research. More discussion will be afforded to studies that have particular relevance to the research aims. Those that include useful information but are not wholly relevant will be discussed in less depth.

Sleep Quality in Offshore Workers

Velasco Garrido, Mette, MacHe, Harth, & Preisser (2018)'s study, which focuses on sleep quality in offshore wind technicians (WTs) is highly relevant to fatigue in this environment. Although there has been research into sleep quality in offshore oil and gas workers (e.g. Hřnborg Hansen, Hønborg Hansen, & Holmen, 2011; Parkes, 2017; Waage et al., 2012), this is the first study to investigate sleep in a wind industry environment. It is important that specific research is conducted on workers in the wind industry, rather than simply relying on research from oil and gas, as the wind industry has many unique factors that differentiate its environment from the former. These factors include smaller ships and crews, different shift patterns and notably different work tasks.

Velasco Garrido et al (2018) employed a cross-sectional survey of 268 male German offshore wind workers, with at least 28 days spent offshore per year. Most of the participants were technicians who worked a shift pattern of 14 days on, 14 days off. Participants were asked to rate their sleep quality over the past four weeks, as well as the differences in sleep quality between time spent on and offshore. The study aimed to determine whether job characteristics (e.g. shift work) and environmental factors affected sleep quality during offshore work. Sleep quality was rated with the Pittsburgh Sleep Quality Index (Smyth, 2003), demographic data was collected regarding job tasks and participants were asked to discriminate between sleep quality on and offshore by providing reasons as to why it was better or worse.

Results showed that only 8.8% of participants reported their sleep to be poor during onshore leave compared to 34.3% during offshore work. Furthermore, 26.5% reported their sleep to be 'very good' during onshore leave, compared to 12.6% during offshore work. Results generally showed a trend towards poorer sleep offshore, with 47.9% of participants reporting their sleep quality to be worse when offshore. Overall sleep quality in the past 4 weeks was more frequently rated to be very bad or poor among workers who were offshore or whose last offshore commitment was <1 month ago at the time of answering the questionnaire.

Environmental factors such as exposure to noise, vibrations and poor air quality were the most cited reasons for poor sleep offshore. The study highlighted that WTs had a higher prevalence of sleep disorders than the general German male population. This supports the notion that the wind industry environment includes risk factors for poor sleep and therefore sleep-related fatigue.

The study benefits from its large sample and thorough exploration environmental factors that may affect sleep quality in this environment. However, as surveys were retrospective over the significant period of four weeks, answers are likely to lack accuracy. The general nature of sleep assessment would make it difficult to pinpoint specific environmental factors and their impact on sleep (e.g. in comparison to a daily survey that allows aggregation of sleep quality and environmental factors). Furthermore, the study's reliance on subjective questionnaire data limits its scope as a reliable measure of sleep quality in this environment as it does not include an objective measurement.

Velasco Garrido, Mette, Mache, et al (2018) provide a useful basis for further exploration of sleep and environmental factors in this environment and highlight the need for this research to be undertaken. Future studies would benefit from a more in-depth investigation of sleep in this environment, potentially with real time mapping of sleep quality and quantity over an offshore shift period.

Challenges and Coping Strategies among Families of Offshore Wind Workers

Mette et al (2019) investigated work-family conflict in offshore wind workers. They add an interesting perspective to this by using partners of WTs as participants. Work-family conflict is a prominent emotional stressor to consider for fatigue (Rubio et al., 2015). It seems to have a reciprocal relationship, meaning that work-family conflict can cause fatigue or strain, but also that fatigue can cause work-family conflict (Nohe et al., 2014). This stressor is particularly important to consider in the wind industry work environment, where work is characterised by regular periods away from families and an intense social environment during work time.

Mette et al (2019) used a qualitative method by interviewing 14 female partners of male WTs working in Germany. This allowed an insight into factors that may affect workers, both during their time on shift and their time at home during their off shift. The study highlighted the complex and difficult impact that the WT job role has on familial relationships. Strain was reported in those who had young children, with partners stating that they felt like a single parent during the WT's offshore work. Some also highlighted that children often found it difficult when their fathers were working away. Furthermore, partners reported emotional difficulties for WTs when they missed key phases in their children's development.

A generally perceived benefit of wind industry work is the relatively long 'off shifts' in which WTs do not work. Indeed, participants in this study noted positive benefits of having their partner at home most of the time during these periods. However, interestingly from a fatigue-recovery perspective, partners also reported an adjustment period of around four days during which they felt that they and their partners needed to get used to being together again. Some also referred to a period of around three days towards the end of the off shift in which they needed to become accustomed to the notion of being apart again soon. Furthermore, partners reported a drive to 'fit everything in' to the two weeks in which WTs were at home, resulting in busy periods of events with friends and family. This indicates that rather than the off-shift being a time focussed on recovery, there is likely to be a period of around three days at the beginning and end in which the WT will need to adjust, either to being at home, or to the prospect of leaving for work. It also highlights the likelihood that the off shift will be relatively busy, with a focus on 'making up for lost time'. This is an interesting avenue for further research as recovery during off-shift is important for fatigue management.

Mette et al (2019) present an important perspective on the experiences of WTs and their families during off-shifts that is particularly relevant to fatigue in the context of work/family conflict as a mental/emotional stressor. It also provides relevant data around recovery from fatigue during off-shifts. The research benefits from its unique perspective and in-depth qualitative methodology. However, research into WT's experiences of work/family conflict and recovery during onshore periods is needed to build on this work, rather than just focusing on partners' perspectives. Furthermore, research incorporating less traditional family dynamics (rather than specifically female partners of male WTs) would be beneficial to include a more diverse subject group.

Quantitative Demands, Stress and Job Resources

Mette, Velasco Garrido, Preisser, Harth, & Mache (2018)'s research focussed on linking WT's quantitative demands to stress is highly relevant to fatigue. It essentially maps the effect of quantitative demands in this environment on workers' ability to recover from stress. It also determines whether any factors exist, that can act as 'buffers' to help workers cope with their stress. Stress is linked to fatigue and they often occur in concert (see chapter 2 section on stress). Therefore, investigations into stress are relevant to gaining an understanding of fatigue in this environment. Mette (2018) used the Job Demands-Resources model (Bakker & Demerouti, 2007; Karasek, 1979) as a format for understanding demands and resources in this environment. This model's relevance to workplace fatigue was explored in chapter 2 (see section 2.8).

This study included a survey of 250 German wind technicians. This included questions around job demands and support structures and used scales such as Sonnentag's recovery questionnaire (Sonnentag & Fritz, 2007). Findings suggested that high demands were associated with stress and lower detachment in this environment, highlighting the importance of factoring in time to detach from work in recovery from fatigue. Interestingly, the study found that control over work was not considered an important job resource by participants. This contradicts widely accepted research in this area (e.g. Karasek, 1979). Findings suggested that support from colleagues was considered an important job resource. However, it did not act as a moderator for stress or low detachment from work, suggesting that these factors would still be present regardless of social support. The study also found that WTs showed higher levels of stress than the norm sample, supporting the notion that the wind industry is a high stress environment.

This study is highly relevant to the present research and allows a greater insight into the demands, stress, recovery and job resources present in this environment. However, its use of structural equation modelling means that causal relationships between the factors cannot be ascertained through the data. Furthermore, the study suffers from similar limitations to Garrido, Mette, Mache, et al (2018) in that as a retrospective survey, it cannot provide real time data around any of these factors. Furthermore, participants were self-selected and as such, the sample could be biased towards those wanting to 'have their say'. The study provides an apt starting point for research into quantitative demands, stress and coping in this environment. Future studies would benefit from real-time data collection (e.g. 'diary studies') and a focus on aggregating predictive relationships between factors.

Mette, Velasco Garrido, Harth, Preisser, & Mache (2017) present a qualitative investigation into German wind industry workers' perceptions of demands and resources in their work environment. As with previously discussed studies, this is extremely relevant to gaining an understanding of fatigue in this environment. The qualitative nature of the study adds an element of depth to the data gained from in the quantitative investigation of job demands and resources (Mette, Velasco Garrido, Preisser, et al., 2018).

This qualitative study included 21 interviews with wind industry employees and a further 21 interviews with 'offshore experts' (e.g. health and safety specialists, occupational physicians, offshore managers). The inclusion of the perspective of 'offshore experts' adds an interesting dimension to this work, as it provides the opportunity to determine whether perceptions of working conditions at managerial level match those 'on the ground'. As with the previous study (Mette, Velasco Garrido, Preisser, Harth, & Mache, 2018), this research bases its understanding of job demands and resources on the work of Karasek (1979).

Findings in this study highlighted the intense and sometimes contradictory nature of job demands and resources in this environment. Main findings included that physical work was seen as a major demand by workers and experts, especially climbing, working in awkward positions and working at height. This highlights the high physical challenges associated with the role and suggests that fatigue from physical demands could be difficult to manage.

However participants reported that their perception of safety was a resource stating that they felt safe most of the time when working and that safety was the highest priority. Adverse or marginal weather was highlighted as a major demand, with some workers reporting that they felt social pressure to work in marginal conditions, even if they felt uncomfortable with doing so. This contradicts the statement that safety is the highest priority and suggests that there may be some issues with safety culture.

Another main resource was the high personal meaning derived from their jobs, both due to the contribution that the industry makes to green energy and the adventure and challenge that they experienced in their roles. This suggests that wind industry employees may be intrinsically motivated to fulfil the demands of their role.

A perceived demand was the long working hours experienced offshore. Some participants described a culture of working extremely long hours while away due to the perception that time away from work in this environment was not fulfilling. However, this was reported as being very taxing for workers, especially those who were older. This is interesting from a fatigue perspective as it indicates the lack of recovery and detatchment that WTs are likely to experience during offshore periods. Workers' offshore living environment was also perceived as a demand due to environmental factors such as excessive noise, poor air quality and a lack of space for leisure activities. This was seen as particularly pertinant on 'weather days', with workers reporting that they feel like 'a rat in a cage' when they were unable to leave the SOV.

Many participants reported their shift pattern to be a resource due to the relatively long off shift period. However, some mentioned that it was difficult to reconcile the two very different ways of life in their on shift and off shift (e.g. their 'home selves' and their 'work selves'). This is an example of role conflict which may be interesting to explore in further research. Participants also reported difficulties in coping with homesickness while on shift. This supports findings from Mette et al (2019), who's findings indicated that WTs and their families experienced a period of adjustment in the first few days of their off-shift as they became accustomed to the different way of life. Mette et al (2018) also found that social relations with colleagues was seen as a major resource in this environment. This is useful as it could support the need for interventions to focus on emphasising the protective benefits of social relations between WTs.

This study provides a good basis of research in stress and coping in WTs, from which, further studies can be derived. It benefits from an in-depth qualitative methodology and relatively high sample size. Future studies should investigate the highlighted factors using a quantitative methodology.

Wind Turbine Noise

Three studies undertaken in Manjil onshore wind farm in Iran investigated the impact of noise as a psychosocial stressor in wind industry workers (Abbasi et al., 2016; Abbasi, Monazzam, et al., 2015; Abbasi, Monnazzam, et al., 2015). There is a relatively long history of research conducted into the disturbant effects of wind turbine noise (e.g. Nissenbaum, Aramini, & Hanning, 2012; Pedersen & Waye, 2007; Waye & Öhrström, 2002). Reports of ear pain, vertigo and tinnitus following exposure to wind turbines have become so prominent that 'wind turbine syndrome' has become an informal classicfication of the condition (Farboud et al., 2019). However, this has been confined to investigations of members of the public who live near to wind farms, rather than individuals working on wind farms. This research is first to conduct an in-depth analysis of the effects of wind turbine noise in this population.

The research found a significant effect of wind turbine noise on the prevalence of sleep disorders and psychological issues in WTs. This effect seemed to increase with age, which is explained by the notion that wind turbines emit a low frequency sound. As age increases, the ability to hear higher frequency sounds decreases, therefore the low frequency sound of the turbine becomes less coated by other, high frequency environmental noises such as car and bird sounds, which this research found to cause less annoyance (Abbasi, Monazzam, et al., 2015).

There is debate around the factual basis of 'wind turbine syndrome', with little robust evidence to support claims around the adverse health effects of wind turbines (Farboud et al., 2019; Schmidt & Klokker, 2014). However, Abbasi et al (2015;2016) highlight the need to further investigate the impact of noise on wind technicians.

Another finding prominent finding from this research was that WTs were found to have lower scores on the general health questionnaire, higher sleepiness scores and more instances of sleep disturbances than other wind farm staff. The present research reports this to be caused by increased exposure to noise. However, this finding in its self suggests that a multitude of psychosocial stressors could be present for these workers.

The findings in this study cannot necessarily be applied to the European wind industry, due to the relatively small sample size and potential differences in working conditions between Iranian and UK wind farms. However, the potential severity of noise-related discomfort and comparative adverse health in WTs highlight the need for further investigation of turbine noise as a stressor in this environment.

4.4.2 Summary of mental stressors

The identified studies in this area provide a useful insight into the psychosocial demands of WTs, which aids understanding of mental stressors and associated fatigue in this work environment. The notable mental and emotional stressors addressed in this research were sleep disruption, work/family conflict, compromised recovery during off-shifts, physical, emotional and mental demands and environmental factors, particularly noise. Findings from a number of these studies suggest that the severity of mental stressors could be increased depending on age of the technician. Though this might not currently be an issue as the wind industry is a relatively young workforce, this will increasingly become a problem in the coming years, thus highlighting the need for improved work design at this point.

There is a need to increase and diversify investigation in this area, particularly into the psychosocial aspects of work in the onshore wind industry other than noise disturbance, as this environment encompasses different challenges to the offshore wind industry. Furthermore, there is a need for studies that focus on real-time investigation of mental stressors in both environments, so that they can be mapped to experiences of stress, fatigue and other adverse impacts.

4.4.3 Physical Stressors

Seven papers and one thesis were identified in the category of physical stressors. As with the previous category, there is a bias for research into offshore wind, rather than onshore wind. However, two of the studies, based around ladder climbing relate to both working environments. Research in this area is mostly based around pre-employment fitness testing and vertical ladder climbing. Table 5 shows the studies included in this category.

As with research discussed in the previous section, research in this area is in its early stages and more studies are needed to gain a robust picture of physical demands in this environment. As with the previous section, research will be discussed thematically with those covering the same subject area discussed together.

Physical Strains in the Offshore Wind Environment

Velasco Garrido, Mette, Mache, Harth, & Preisse (2018) is part of the previously discussed 'Best-off' project focusing on the German wind industry. It provides a useful overview of WT's perceptions of physical strains in the wind industry environment. The survey of 286 wind industry workers highlighted that their work environment encompasses high physical demands. 63.8% of participants reported that they were 'always' or 'often' confronted with climbing demands. Noise was reported to be 'always' or 'often' present by 55.6% of participants and constant vibration was reported by 52.2%.

Other physical demands reported included manual handling of heavy loads, transport of equipment, working in non-ergonomic positions, reduced visibility, odours and working with chemicals. The study highlighted that wind industry workers had higher physical demands than the general high skilled work population in Germany, thus emphasising both the multiplicity of demands present and the need for specific research in reducing the burden of these demands in this environment.

Findings from this research highlight that fatigue following physical work is a high risk in this environment. The relatively high sample size is useful in providing an overview of physical demands in this area. However, future research would benefit from analysis of the effects of physical demands over a work period (e.g. daily analysis of physical demands and experience of physical fatigue). This would allow the most detrimental physical demands to be identified and interventions to be formulated based on these findings.

<u>Pre-Employment Fitness Testing</u>

Two studies conducted by Preisser, McDonough and Harth focus on evaluating pre-employment fitness requirements in the offshore wind industry (Preisser et al., 2019; Preisser et al., 2016). The first encompasses an evaluation of requirements throughout the European wind industry (Preisser, McDonough, & Harth, 2016) and the second puts existing fitness tests into practice by testing them on wind technicians using scenarios likely to be experienced in their work environment (Preisser, McDonough, & Harth, 2019). Preisser et al (2016) will initially be discussed as it provides an interesting account of differing methods of assessing fitness to work between European countries. Following this, the later research of Preisser et al (2019) will be examined which focuses on the appropriateness of current methods of fitness testing to predict ability to cope with physical work demands.

In their point-by-point analysis of wind industry health and safety guidelines for the UK, Germany, the Netherlands and Norway, Preisser et al (2016) found that the focus on previous or existing medical conditions is similar in all of the included countries. In the UK, guidelines are based on those created for the fire service and oil and gas industry with some additional guidance for the wind industry written by Renewable UK in 2013. However, these additional guidelines are limited to medium and large wind turbines that are either onshore or 'near shore' (travel by boat less than two hours and no overnight stays). Additionally, they do not account for wind industry specific demands including vertical climbing requirements, which will be further explored in the following sections. There is a need to develop guidance for offshore wind farms that require workers to stay offshore for two weeks or more.

Preisser et al (2016) found differences between the actual fitness test used to examine physical capabilities between different European countries. German guidelines required fitness testing via cycle ergometry whereas Dutch and British guidelines used the Chester Step Test and Norway required the assessing physician to decide between the two. There is some debate about cycle ergometry vs Chester Step Test. The former is heralded as a more accurate evaluation of fitness whereas the latter is often favoured due to its ease of conducting and its ability to act as a reliable way to track fitness over a longer period of time (e.g. during re-tests) (Alexandra Marita Preisser et al., 2016).

Preisser et al (2016) highlight that the differences in use of fitness evaluations could be partly due to the differences in offshore environment in different countries with crew sizes ranging from 20 to 350 and varying physical hazards associated with each country's typical wind farm environment. Further research into this would be useful in determining whether fitness testing is designed with the specific environment in mind or if differences are simply due to lack of consistency in physical testing across the industry. This would facilitate investigation into the development of a physical test designed to match the specific strains in the environment and therefore ensure that WTs recruited were best placed to cope with these demands effectively.

Preisser et al (2019) built on this research by empirically testing physical aptitude testing for validity. They did this by testing physical strain placed on WTs while undertaking some of their most common work tasks and comparing it to strain experienced during tasks common in physical testing for this industry.

To assess physical strain, heart rate (HR) and VO2 were monitored in 23 male offshore employees during their global offshore wind (GWO) training in which they were required to perform tasks indicative of their duties while offshore. These included vertical climbing and working at height. Although this provided an accurate rendition of the types of physical tasks undertaken by wind industry workers, a notable limitation of the study is that it did not include the relevant environmental stressors that would be present in their workplace while undertaking their tasks in the field. Results illustrated two important points. The first regarding physical strain present in the wind industry work environment and the second relating to the utility of current methods of physical testing during recruitment.

Though participants were tested in a controlled training environment, away from the harsh conditions of their actual work environment, work tasks were still found to be extremely demanding. Mean HR during tasks was approximately 35% VO2 max. Relevant literature specifies that 'limit' values for acceptable strain levels at work are between 33 and 50% VO2 max for an 8 hour shift (Wilson & Corlett, 2005). For work places involving the physical strains that are present in the wind industry, even lower levels of VO2 max are suggested at approximately 30% and when taking into account that 12 hour shifts are the norm, an upper limit of 28% is recommended (Preisser et al., 2019). Higher levels of physical strain were recorded in this study during climbing activities and working at heights. Preisser et al (2019) also highlighted that when compared with similar studies in other industries characterised by physical work, physical demands in the wind industry were found to exceed those found in healthcare, metal industries and agricultural work. This suggests that physical strain experienced by WTs is likely underestimated as assessments are often based on industries with shared characteristics due to the relatively young status of the wind industry.

A greater focus should be placed in ensuring that WTs have adequate rest breaks during work to recover from the significant strain that they face. As Preisser et al (2019) investigated strain in controlled conditions of WT training with a relatively small sample size. Further research should be employed within the wind industry working environments with a larger sample of WTs. A question particularly relevant for fatigue is how regularly experiencing this physical strain affects WTs over the course of a work period (e.g. two weeks offshore work). Future studies should investigate this through daily monitoring of physical strain and health/wellbeing over the course of a shift period.

The second key result in this study is that 50% of participants did not achieve the oxygen uptake of 35 ml/kg/min required by the 'Renewable UK' guideline for offshore wind work. Additionally, 21% would not have met the German guidelines for physical requirements to work in the industry. The results of the group in general were at the lower end of the fitness level required, despite their average young age (Preisser et al., 2019).

This enforces the need for pre-employment fitness testing that more accurately reflect the physical demands of the role of a WT and perhaps the need for continuous physical testing and maintenance programmes. As previously mentioned, this study took place in a controlled training environment, rather than in the field. It is imperative for future research to investigate means in which to effectively test and support the maintenance of required fitness standards in WTs, as not meeting these standards will make WTs more vulnerable to fatigue and consequently adverse health, safety and wellbeing.

<u>Exposure to Motion on Turbines</u>

Scheu, Matha, Schwarzkopf, & Kolios (2018) present an interesting study, which highlights the need for further consideration of the impact of turbine movement on WTs. Their paper emphasises that elements of turbine movement are not properly considered during the design and work-regulation phase of wind farm development. This includes global motions experienced within the 1 hz range that are typical of wind turbines. This relatively low level of movement has a lack of research into its existence as a threat for human wellbeing. However, it is associated with motion sickness, particularly if technicians are exposed to it over a long period, as they would be during a 12-hour shift.

The paper presents a method for evaluating the impact of motion on humans in this environment and highlights that current regulations specifying limits on weather conditions and wave height in which technicians are permitted to work currently fail to account for turbine motion. Thus, this presents a physical demand that could have a more subtle, but significant effect on fatigue in this environment.

Vertical Ladder Climbing

The final four studies in this category focus on the physical impact of vertical ladder climbing in wind technicians. The relatively large focus on this particular physical demand seems appropriate when considering that climbing was highlighted as the most significant physical stressor in this environment by two relevant studies (Preisser et al., 2019; Velasco Garrido et al., 2018). Climbing demands are relevant in offshore and onshore wind environments, with technicians in onshore wind farms generally climbing smaller turbines than those working offshore, but normally having to climb more often due to the lack of available lifts in onshore turbines.

All four studies were conducted in controlled environments, which allows detailed data to be obtained on the physical effects of climbing demands. However, it prevents an ecologically valid portrayal of climbing demands in this working environment, which is likely to include other physical and psychosocial demands occurring in concert. Therefore, strain related findings are likely to be underestimated. This methodology highlights the early stage currently inhabited by this research area. The four studies employ small sample sizes and tentative methodologies that require application to a larger population to have a significant impact on practice within the field. Nevertheless, findings are useful for gaining an understanding of physical strain and fatigue caused by climbing in this environment and potential interventions to address this.

Stewart and Mitchell (2018) focus on the fact that WTs are often required to perform tasks requiring manual dexterity following a vertical climb (e.g. completing repairs with hand-tools). Their study assessed the impact of a continuous 80m climb on grip strength, hand tool dexterity, and included continuous HR monitoring. This was a pilot study, and as such included a small participant sample of 10 inexperienced climbers. The study found a clear effect of ladder climbing on grip strength, which was apparent in tests immediately following climbing and still existed in tests conducted 15 minutes post-climb. Results suggested that this effect would be present in a wider sample, but further research is required in this area.

A factor that separates the wind industry from other work environments with climbing demands is that WTs are required to undertake vertical, rather than pitched climbing. This was investigated in the PhD thesis of Barron (2020) and an associated published study (Barron, Burgess, Cooper, & Stewart, 2018) that compared the physical demands of pitched ladder climbing (75°) to vertical ladder climbing (90°). They found that vertical climbing induced significantly higher VO2, HR and rate of perceived exertion in 23 healthy, male participants indicating considerably higher physical demands. Researchers suggest that this increase in demand may be due to the increased requirement to actively maintain stability due to the position of the centre of mass being outside the base of support as well as the increased mechanical support to move vertically with every climbing cycle (Barron et al., 2018). This highlights the unique climbing demands in the wind industry and suggests the need for reform in physical standards to incorporate the specific demands of vertical climbing and highlights an imperative to consider methods of alleviating this demand.

Milligan and Tipton (2018, in press) further investigate the effects of vertical climbing. This research highlighted some important points around climbing and physical fatigue. Participants were seven WTs and ten inexperienced climbers. They completed 3X120m climbs that were separated by approximately 1.5 hours.

Results showed that experienced WTs benefitted from the experience and technique in climbing that they had acquired through their roles. Compared to novices, they were able to maintain optimal movement patterns for longer and had a wider range of movement in their hips and higher proportion of muscle activation in their upper body. However, for all participants, fatigue caused a change in climbing technique, toe clearance on the ladder was reduced and participants were seen to reach higher on the rungs of the ladder with their arms. The inclusion of sea survival suits on some of the climbs caused movement patterns to be less efficient and increased demand and heat production, thus highlighting another stressor likely to be experienced by offshore technicians in addition to climbing.

Subjective measures showed that for some participants, fatigue was still felt in their forearms for several days following climbing. This research highlights the severe and long-lasting physical demand incurred through vertical climbing. It also supports the notion that through improving climbing technique, fatigue can be somewhat delayed. Therefore, specific training in climbing technique would be beneficial for new WTs. However, as fatigue clearly still affects those with climbing experience, potentially compromising safety and long-term health, methods of reducing the burden of climbing (e.g. lifts and climb assist) should be explored and potentially utilised.

The final study, Barron, Burgess, Cooper and Stewart (2017) investigates the potential utility of climb assist as a solution to the physical strain induced by climbing in this environment. Climb assist allows individuals to climb vertical ladders with significantly less exertion than they would normally have to apply. The study tested eight participants in controlled lab conditions, comparing V02, heart rate (HR) and rate of perceived exertion (RPE) on climbs completed with and without climb assist. Results were in support of the benefits of climb assist, with a mean reduction of 22.5% V02 when using climb assist, as well as a 14.9% reduction in HR and RPE (reduced from 2.5 to 1 when using climb assist).

Results suggested that climb assist could be a solution for fatigue management through reduction of climbing demand. However, as the study used a small sample size of participants who were not WTs, the design would benefit from being repeated on a larger sample and potentially as a field experiment. Furthermore, the question of whether wind companies would be willing to invest in the provision of climb assist is a point that requires consideration. Analysis of the cost vs benefits of this would be required, along with potential trials of climb assist on smaller samples of WTs in the form of a longitudinal study, focusing on benefits realised in health, safety and productivity would be beneficial.

4.4.4 Summary of physical stressors

Research related to physical stressors in the wind industry highlights the intense physical demands associated with this work environment. There are clearly multitudes of significant stressors that require careful management to control the health and safety risk associated with fatigue from physical demands. Key findings from this research include the demands of vertical climbing, working at height, manual handling, confined spaces and motion sickness. Further research is required to assess the combined effects of these stressors on the experience of fatigue if this is to be managed effectively. Climb assist presents a compelling solution for addressing the fatigue caused by climbing (Peter James Barron et al., 2017). However, further research is needed to determine whether it is a viable solution for the industry.

An important point to note is that most participants in these studies were young, healthy males which may be indicative of the current wind technician population, however, is likely to become decreasingly so due to both an ageing workforce and efforts to improve employee diversity in the wind industry (Department of Business Energy and Industrial Strategy, 2019; McMaster, 2020). It is likely that results will be more severe for participants belonging to other demographics and there is a need for research in this area.

4.4.5 Employee Health

Employee health is a complex and multifaceted topic. It could refer to physical or mental health and short or long-term conditions or experiences. There is a clear link between health and fatigue that presents in many ways. Factors that affect health often also affect fatigue (e.g. physical strains synonymous with the long-term development of musculoskeletal disorder will cause physical fatigue in the short term). Furthermore, the ineffective management of fatigue can cause mental and physical health issues (see chapter 3 pages 89, 90and 96 for a more detailed discussion of this). Therefore, an investigation into fatigue in this work environment should consider relevant research on worker health. Table 5 shows the four studies included in this category.

Health Effects Associated the Wind Industry Work Environment

The first two studies in this category are reviews of existing literature on factors affecting WT health. Cooper et al (2014) is the earliest study included in this systematic review. Their review focused on health effects of working in the wind industry, with a specific focus on the onshore wind industry. Due to their status as a pioneering study in this area, they did not identify any existing literature conducted in the wind industry. Therefore, they included seventeen studies from industries that were found to encompass similar health demands to the wind industry. This included studies into the oil and gas industry, construction, firefighting and the military. Relevant to the previous section, they placed a focus on job roles that required the climbing of multiple vertical ladders.

Studies reviewed by Cooper et al (2014) highlighted that ladder-related injuries are common and falls are most likely to be associated with fracture in work environments. They found that rest breaks could protect workers by preserving conditions in which a fall is less likely, adding support to the notion that fatigue management is an important component of reducing the risks associated with climbing. The review also found that musculoskeletal disorders were widespread in offshore oil and gas work, accounting for 47% of work-related injuries in Norwegian offshore workers. Additionally, manual work was associated with severe low back pain and potentially knee osteoarthritis. This is due to the positions that manual workers are required to maintain for long periods while undertaking work tasks (e.g. kneeling). This adds further support to the presence of high physical demands the wind industry work environment and their adverse effects on worker health. Although the work environments included in Cooper et al (2014)'s review share characteristics with the wind industry, it is essential to collect data within this unique environment. Therefore, although Cooper et al's review is useful for gaining an impression of physical health strains likely associated with this industry, it should not be relied on as a stand-alone source of information around this topic.

Linked to Cooper et al (2014)'s study, Jia et al (2016) conducted an investigation into the prevalence of risk factors for lower back pain (LBP) in wind technicians by surveying 151 O&M WTs in 17 Chinese wind farms. They found a high-risk prevalence of LBP in this sample, which was linked to prolonged static postures, particularly related to working in the nacelle and lifting objects weighing more than 10 lb more than twice per minute for a total of 2 hours per day. They also cited climbing as a risk factor.

Interestingly, results suggested an association between LBP and mental health issues, with obsessive-compulsive disorder being the most reported condition, followed by somatisation and depression. Although there are likely to be differences in working conditions between wind farms in China and the UK, these results should be considered when investigating physical and psychosocial risks in UK wind farms. As with previously discussed survey studies, this topic would benefit from further research and particularly real time mapping to investigate relations between specific tasks LBP and negative psychological experience.

A recent review on health issues in WTs was conducted by Freiberg, Schefter, Girbig, Murta and Seidler (2018). They identified 20 studies that were relevant to worker health in the wind industry. This illustrates the recent progression of research in this area since Cooper et al (2014)'s review. However, the review could have also yielded more results due to the slightly different subject matter (health effects *of* wind turbines, rather than health effects of working in the environment) and the fact that it is a scoping review, rather than a systematic review and therefore the inclusion criteria could have been less stringent. Freiberg's review (2018) provides a comprehensive overview of research in this area, including the inclusion of some smaller studies (e.g. Abbasi, Monazzam, et al., 2015). It found that WT workers' health was likely to be affected by noise, chemical coating on turbine blades (although this was mostly in the construction phase) and musculoskeletal issues.

Occupational Strain, Health and Coping

Mette, Velasco Garrido, Harth, Preisser, & Mache (2018) conducted a qualitative study into occupational strain, health and coping as part of the previously mentioned 'Bestoff' project. This consisted of interviews with 21 WTs working in the German wind industry. This study provided a direct insight into fatigue when discussing factors that caused WTs to feel strain, as well as presenting results on other related topics. Stress-related issues were reported by all participants, but particularly ones that had management duties. Other stressful factors included unplanned changes to activities, particularly weather changes.

Interestingly for the present research, the study provided data around workers' perceptions of their consequent behaviour when they were experiencing stress, which included increased irritability, lowered team orientation and physical illness. WTs also reported difficulty in recovering from time spent at work, particularly with detachment, as they essentially remained in their work environment after they had finished work, causing them to lack the separation necessary to relax. Fatigue was reported to be an issue due to the long shift times and climbing demands and many participants reported a rise in fatigue after spending 1 week offshore and becoming particularly prevalent in the last few days. Some participants reported 'reaching a limit' after 14 days and sleep quality was generally reported to be worse offshore. The study found that recurring muscle and joint strain, respiratory infections (especially during winter), skin issues and sea sickness were the most reported physical health issues.

Factors perceived to help with coping included from support from colleagues and the presence of a medic onboard. This corresponds with findings from Mette et al (2019) who highlighted the 'buffer' effect of social support in this environment. Findings highlighted that regular contact with family at home was essential for mental wellbeing. Physical exercise was also seen as an important factor in coping with the mental and physical demands as was having access to good nutrition.

This review provides highly relevant data on factors that increase and protect against fatigue offshore. It supports findings from other studies within the 'Bestoff' group (e.g. Mette, Velasco Garrido, Preisser, et al., 2018; Velasco Garrido, Mette, MacHe, Harth, & Preisser, 2018) and acts as an appropriate basis for further research to be carried out in this area in order to develop interventions based around emphasising 'buffers' and mitigating stressors.

Workplace Health Promotion

The final study in this category is also part of the 'Bestoff' project and considers health promotion in the offshore wind environment (Mette, Velasco Garrido, Preisser, Harth, & Mache, 2018). Health promotion programmes are helpful in aiding workers to cope in challenging work environments (Mearns, Hope, & Reader, 2006). Structured programs introduced by employers to promote specific health behaviours including healthy eating (Mhurchu, Aston, & Jebb, 2010), exercise (Conn et al., 2009), and circadian adaption (Thorne et al., 2010) have shown positive results in improving health and wellbeing in employees. However, there has been little research around this in the wind industry environment. This was a mixed methods study, including interviews with 21 WTs and a survey of 303 WTs. The interviews employed in this study allowed a qualitative understanding of participants' perceptions of health programmes to be gained and surveys provided a wider understanding around views and experiences in the German offshore workforce.

Interviews showed that only two out of the 21 participants were aware of health promotions in their workplace. Those that were aware of these described interventions including counselling, group exercise and online fitness trackers. Those that were not aware of programmes generally held the perception that their employer would not be willing to spend money on introducing a programme suggesting adverse cultural aspects around health practices in the industry.

This study benefits from its mixed methods approach as results found in interviews were largely supported in survey responses. Although most WTs reported that there were no specific health programs available, most reported the provision of on-site fitness facilities, which were beneficial for overall health. However, fatigue from work was highlighted as a major factor in preventing their use. This was particularly the case for older workers, who were found to have a higher need for recovery after work. This is important from a fatigue perspective, as fatigue can cause a lack of motivation to exercise (Van Cutsem et al., 2017). However, exercise can help to recover from fatigue. Further research to investigate ways in which the wind industry environment can be organised to encourage exercise in fatigued WTs would be beneficial. Mette et al (2018) already went some way to investigating this with their finding that WTs with more regular shift patterns were more likely to report using fitness facilities.

Findings from interviews and surveys also highlighted the importance of having a medic onboard during time offshore. Medics were present for health and safety provision but were also seen to provide pastoral support. Findings in this study highlighted the potential benefits of devising structured programmes to encourage positive health behaviours, which would be likely to have particular use in improving fatigue management. When discussing the lack of health programmes provided, Mette et al (2018) suggested that due to the relatively young age of the industry, most WTs are fairly young and fit therefore, the need for programmes to address health issues has not become immediately obvious, however findings of this and other studies indicate that this will become more of an issue as the workforce becomes older and more diverse.

This study is a good basis for the formulation of health promotion-based interventions to improve working conditions for WTs. Future research should use the findings of this study to develop interventions and trial their success on groups of WTs.

4.4.6 Summary of employee health

Research around health in WTs have highlighted the multitude of health conditions associated with this work environment including musculoskeletal disorders, respiratory infections and skin complaints. They also illustrate the many disturbances regularly experienced by WTs that, if left unchecked are likely to lead to health issues including lower back pain, noise complaints and mental distress. More needs to be done in order to understand and improve health risks in this environment, particularly as the industry is faced with the likelihood of an aging workforce in the coming years.

4.4.7 Safety

Safety is the most addressed human factors issue associated with the wind industry. As with most workplaces, safety hazards present immediate threat, particularly in the wind industry when the consequences of an incident are likely to be severe due to exposure to adverse weather conditions, remote locations, marine environment (in offshore wind), working at height and working with heavy equipment. Although comparatively much has been written around safety, not all literature was deemed as relevant to the present research. Therefore, only literature that addressed safety risks or management relevant to fatigue.

Safety Risk in the Wind Industry

As has been highlighted by the previous literature, the wind industry is a high-risk environment. Fatigue reduces concentration and causes individuals to be more likely to bypass important safety procedure. The presence of hazards can also act as stressors, thus increasing the probability of fatigue. It is important to gain an understanding of the hazards in this industry that will act as stressors for WTs. It is also useful to understand the approach currently taken for risk and safety management in this industry as this will aid the incorporation of fatigue management into existing risk and safety management systems.

The Safety Risks of an Onshore Wind Farm

Two studies attempted to gain an understanding of the presence of safety risks in onshore wind farms. Aneziris, Papazoglou, and Psinias (2016) undertook a risk evaluation of a Greek onshore wind farm and compared the risks of working in different stages of wind turbine life cycles (e.g. construction, operation and maintenance). They found that risks included contact with electricity while using tools, falls from ladders and turbines, fire risks, entrapment between objects, contact with falling objects and contact with moving parts. They determined that the most important risks for O&M technicians were falling objects and falling from height, and that these types of workers have the highest risk overall of being involved in accidents.

This data was supported by Astiaso Garcia and Bruschi (2016) who aimed to develop a risk assessment tool in an Italian onshore wind farm. Additionally, they highlighted the risk of suspension trauma (damage caused by suspension from harness) in which death can occur in just 15-20 minutes. This is a high risk due to the isolated locations of most wind farms meaning that rescue teams are unlikely to be able to arrive in time to prevent fatalities from occurring from this type of injury. Findings in these two studies highlight the intrinsic safety threat that technicians experience as part of their work which is likely to act as a stressor. As these reviews were undertaken on wind farms based outside of the UK, further studies are needed to gain a more generalisable idea of safety risks associated with each part of the wind turbine maintenance life cycle. This data is useful as it provides an initial understanding of the safety risks present in the onshore wind work environment and could be used as a basis to understand safety-related stressors.

Evaluating Wind Technicians' Performance on Safety Critical Rescue Steps

Isolation and difficulty in access for medical teams are safety hazards for onshore and offshore work environments. Thus, it is vital that technicians are equipped with appropriate safety knowledge and rescue skills. Lawani, Hare and Cameron (2018) investigated the knowledge and skill retention of safety and rescue procedures of 30 new WTs three months after they completed their initial GWO safety training.

Using a situational judgement tests (SJT) and job knowledge judgement tests (JKT) to assess this, they found that skills appeared to be significantly more difficult to retain than knowledge. 47% of technicians displayed decrements in their SJT scores and 20% of WTs showed a decrease in their JKT scores. This suggests that skill-based safety procedures are an area of weakness for technicians causing potential vulnerability in the event of having to perform a rescue. Although as of yet, there is no evidence to support it, it would be logical to assume that the experience of fatigue would make this skill decay worse, as fatigue specifically affects individuals' abilities to perform tasks that they are less used to (see chapter one for a discussion around this).

This study highlights the imperative for regular skills training and practice in wind industry employees. Like Preisser et al (2019; 2016)'s studies on fitness to work, this research calls for a consistent focus on skill maintenance to be employed within the industry. Further research would benefit from assessing how skill decay can interact with other factors, such as fatigue and other environmental stressors to evaluate the impact on effective rescue skills and safety behaviours. This could help to facilitate guidance on how often practical rescue training sessions should be implemented to improve safety outcomes.

Health and Safety Management Systems

Ahsan, Pedersen, Bang Nielsen and Ovesen (2019) investigated Danish WT and managers' views of their safety management system using a mixed method approach of conducting interviews and distributing surveys. Results illustrated a lack of standardisation of safety protocol dissemination and reporting of incidents and near misses.

Reasons for this were attributed to complex stakeholder relationships between different offshore wind companies, with each company having their own HSE systems and views on how it should be operated. This not only demonstrates the potential stressor placed on WTs in the form of extra mental demands through navigating different H&S systems, but also exemplifies the potential difficulty in incorporating fatigue management aimed to be consistent across the industry.

Although this research was conducted in Denmark, and cannot be applied to UK wind farms, two articles from 'Refocus' highlight the need for development of consistent H&S systems in the UK wind industry (Atkinson, 2010a; Robb, 2005). A less complex H&S system is more likely to facilitate the cultivation of a fatigue management system within it. This is something that should be further researched and considered when developing fatigue management interventions.

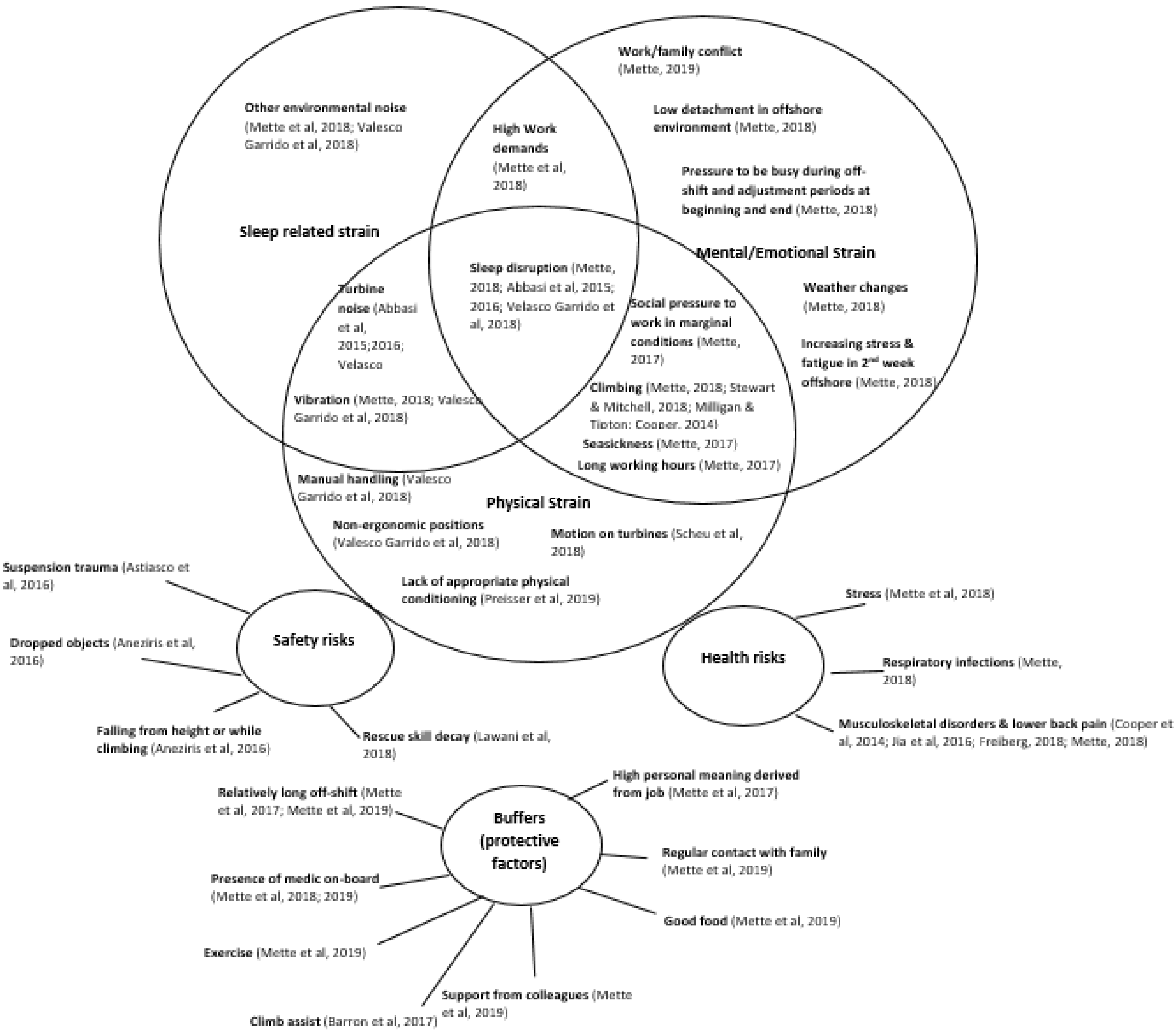
4.5 Conclusion and Venn Diagram

The aim of this review was to gain a comprehensive insight into literature related to worker fatigue and human factors in the wind industry. As previously mentioned, no research directly investigating fatigue was found, however 22 pieces of literature around factors relating to fatigue in this environment were identified (see Table 5).

The literature included in this review highlights the early development stage of human factors research in the wind industry. There are a growing number of studies based around this subject, however most research is in a 'scoping stage' (e.g. reviews and surveys are used to identify issues in a broad manner using surveys, or using a 'pilot' methodology with small participant groups). There has been a notable surge of research from 2014 to 2019, with most studies included in this review having been completed during this period. This indicates that future research will build on the findings of those completed during this time to further investigate their findings, as the present research intends to do.

The identified research signals a need for the development of interventions to aid wind industry workers in coping with the significant identified demands and risk that they face in their roles. Analysis of the domains of these papers provides an overview of the major categories of demands and risks identified in the research. A visual representation of this is presented in Figure 10, a Venn diagram illustrating fatigue-related stressors in three categories (sleep-related strain, mental/emotional strain and physical strain) and how some stressors can cause a wider impact than simply mental or physical. Additionally, the diagram highlights safety and health risks associated with these stressors as well as 'buffers', factors which could lessen the impact of these stressors. These findings will be further investigated in the present research.

Figure 10- Venn Diagram depicting identified strains, risks and buffers from the literature



As well as highlighting stressors associated with this work environment, the included studies illustrate operational constraints that could cause difficulty when attempting to manage these demands. This includes inappropriate physical testing (Preisser et al., 2019; Preisser et al., 2016) and a lack of continuity in health and safety (H&S) management between companies (Atkinson, 2010; Lawani et al., 2018; Robb, 2005). Though there has been an increase of research in this area, there are some notable gaps in its current scope.

The identified research failed to reflect the breadth and diversity of different working arrangements in the wind industry. It has a bias towards the offshore wind industry, specifically offshore workers who live offshore for two weeks at a time (SOV technicians). There is no research focussed on technicians who sail to turbines daily (CTV technicians) and comparatively few studies considering workers in the onshore wind industry (see chapter 1 section 1.1 for a description of the differences in these work environments). There is a need to undertake research into these work environments, as they encompass different stressors and operational challenges to the SOV work environment that is the general focal point of current research in this area. Furthermore, field research tended to be based in countries outside of the UK, highlighting the need for research investigating human factors and fatigue based in UK wind farms as their working practices and culture are likely to be different to the majority of wind farms included in the current review.

After exploring conceptual definitions and literature surrounding fatigue in chapter 2 and considering occupational research and practice around fatigue and related factors in chapter 3, this chapter has addressed relevant research in the industry in which the present research is based. The following chapters will now place focus on primary research undertaken in this project. Chapter 5 will explain the methodological underpinnings of this primary research and will present a methodological approach which will inform this intended research.

Chapter 5- Research Philosophy and Methodology

5.1 Introduction

The previous chapters have considered existing literature on the concept of fatigue (Chapter 2), fatigue related research in industry (Chapter 3) and relevant research in the wind industry (Chapter 4). Now that a thorough insight has been gained on these topics, the formulation of primary research for the present project can be undertaken. However, before this, it is important to establish a research philosophy and methodology which will underpin the formulation of research questions and study design.

5.1.1 Chapter Structure

This chapter will focus on the formulation of a research philosophy and methodology for the present project. To establish a research philosophy, an ontological position will first be formed which can briefly be explained as the meaning of reality. Section 5.2.1 will discuss the meaning and relevance of ontology, along with the various stances that can be taken on this subject, ultimately reaching a conclusion regarding the ontological stance taken in the present research in section 5.2.6.

Following this, an epistemological position will be determined, this will encapsulate the perception of useful knowledge and how it should be extracted and will be further discussed in section 5.3. Differing epistemological stances will be discussed in sections 5.3.1 and 5.3.2 and the position of the present research will be explained in sections 5.3.3 and 5.3.4.

Once these positions have been established, it will be possible to formulate a methodological approach. Section 5.4 will discuss the methodology (the theoretical underpinning of the methods used to obtain and analyse data) and axiology (what will be defined as useful data) of the present research.

Finally, section 5.5 will present questions for the primary research to address which will be underpinned by the established research philosophy and methodology discussed in the previous sections.

5.2 Research Philosophy

The overall aim of the present research is to gain a useful understanding of stressors within the wind industry work environment and the experience of fatigue of those who work within it. Further, this research is intended to form the basis of suggestions for solutions to improve fatigue management within the industry. Before research can begin to work towards these aims, it is vital to establish an underpinning philosophy as this will provide the basis of how reality and knowledge will be viewed in the context of this research.

This will begin with the most fundamental and basic assumption, the nature of reality, ontology. The following sections will include descriptions of the main stances on ontology commonly used in psychological research, along with a discussion of how they would correspond with the aims of the present research. This will culminate in a formulation of the ontological stance of the present research. This process will be repeated for epistemology, the nature of knowledge and knowledge acquisition.

5.2.1 Ontology

Ontology is the study of 'being' and the nature of reality. It particularly refers to the question of whether *reality* is something that exists independently from human practice and understanding, or whether it is dependent on human perception (Braun & Clarke, 2013). It also poses the question of whether there is one single, objective *reality,* or whether there are multiple potential *forms of reality* depending on the perception of the individual experiencing it (Tebes, 2005).

There are multiple ontological stances, and debates can go into considerable depth (as one would expect when considering the nature of reality). However, for the purposes of the present research, an overview of the main ontological stances will be provided, along with discussion of how they would relate to the research in question. The aim of this section is to identify an ontological approach suitable to underpin the present research project.

5.2.2 Realism

Realism assumes that there is a single, external reality that exists separately to human perception. Realists view the world as concrete and external, believing that observation-based science is the best way to 'uncover' this reality (Easterby-Smith et al., 2002). Braun and Clarke (2013) provide the following analogy to illustrate this position.

"Realism would be akin to looking through a perfect glass window in your house. The information that you access through this window would correspond perfectly to what is going on outside the house…your window would have given you a way to determine

the reality that exists beyond it, a way to measure what is there" (Braun & Clarke, 2013, p.27).

Realism is associated with quantitative methods of data collection. In this, great efforts are usually taken to ensure that the researcher is as objective as possible with the data that they are observing. This is so that their presence does not affect the external shared reality they are observing (Easterby-Smith et al., 2002).

To place realism in the context of the present research; fatigue would be viewed as an objective concept, which is experienced in the same way by everybody regardless of potentially influential external factors. Levels of fatigue could be accurately predicted based on 'formulas' of antecedents that would cause a 'fatigue reaction' in individuals affected (e.g. hours of sleep predict levels of fatigue). The most effective means of investigating fatigue would be to employ empirical methods to 'test' fatigue-generating conditions. In this stance, it would be important for the researcher to be objective and detached from the research process so as not to disrupt the reality that they are observing.

5.2.3 Relativism

The opposing position to realism is *'relativism',* which encompasses the view that reality depends on human interpretation and knowledge. This can be further explained with another analogy from Braun & Clarke (2013):

"Relativism is better captured by the idea of prisoners looking at a view from their prison cells. Prisoners housed in different cells see different views of the world outside the prison, but there is no way of prioritising one prisoner's view as more real than

another's. Moreover, the views appear real, but could be a projection or hologram. A prisoner has no way to ascertain the truth of the information they have about what is outside the prison" (p.27).

Thus, relativism does not assume the presence of one objective 'truth' or 'reality', but postulates that reality is subjective and based on individuals' experiences and views; reality is 'in the eye of the beholder'. This does not mean that relativism denies the existence of reality, but rather it assumes the existence of multiple realities and does not place one version of reality over another.

Relativism is commonly associated with qualitative research methods. This is because collecting rich, detailed and subjective accounts allow researchers to glimpse an individuals' unique perception of their own reality. Differing from realism, qualitative research generally acknowledges the role of the researcher in data collection and highlights how his or her own personal perception of reality will affect how data is collected and interpreted (Braun & Clarke, 2013).

In the context of the present research, fatigue would be viewed as a subjective concept that individuals experience in their own unique way. Levels of fatigue would be unpredictable in a general sense, but insight could be gained into an individuals' personal experience of fatigue and its antecedents. This would need to be done through gathering rich qualitative data (e.g. through interviews) and the researchers' place in the process of this would need to be recognised and reflected upon, as it would be impossible for them not to affect the results of the investigation.

5.2.4 The Ontological Debate

There is often debate between these two opposing views of reality, as realism was originally used to interpret the natural world around us in subjects such as physics (Easterby-Smith et al., 2002). In psychology, its use in interpreting the human experience is sometimes questioned, due to the unpredictable and sometimes illogical nature of human behaviour, emotions and consciousness (Easton, 2010; Maul et al., 2016). Furthermore, even the merits of a reliance on realism in natural sciences such as physics has been questioned, not only by the study of quantum physics (Panagiotatou, 2017; Saatsi, 2017), but also by the general assertion that accepted scientific findings are heavily tied to the reputations and careers of the scientists who research them (Latour & Woolgar, 1979). Therefore, there is question of whether there is one objective reality, especially when dealing with human subjects.

Conversely, relativism is often seen as an extreme position, in which everything can be questioned (Tebes, 2005). This leaves little to draw from when creating a research narrative. Additionally, the merits of a relativist approach can be brought into question when considering their usefulness, particularly in research with a practical aim.

It seems that neither of the extreme ontological positions would be wholly suitable for the research in question. Therefore, a stance that recognises the existence of reality as largely influenced by individual perception and circumstance, but also allows for practical solutions to be formulated from retrieved data is needed.

5.2.5 Critical Realism

The ontological position of Critical realism falls between realism and relativism. It assumes that there is a real and knowable world, but that it sits behind subjective structures created by society and individuals (Madill et al., 2000). To re-visit Braun and Clarke's metaphor:

'Critical realism would be like looking at a view through a prism, so what is seen is nuanced by the shape of the prism (the prism is culture, history, etc.). If you could just get rid of that prism, you'd be able to see what lies behind it (the truth), but you can never get beyond it'. (Braun & Clarke, 2017, p.28).

This position is compatible with a mixed methods approach, as it allows for multiple methods to be used to investigate the research questions. Qualitative methods allow for an in-depth investigation into the culture, social structures and perceptions affecting participants and quantitative methods allow for empirical investigation into the concept in question.

A critical realist standpoint can be used to help understand the changeable way that the concept of fatigue is defined and measured (see literature review chapters 2 and 3). The meaning of 'fatigue' has altered to fit in with its surrounding social context (see section on 'the history of the fatigue concept' in chapter 2). However, all the presented definitions in the literature still relate to an underlying construct of fatigue, which although alters slightly, still broadly refers to the same experience. Table 6 presents an overview of the discussed ontological positions.

Table 6- Summary of Ontological Positions

Ontology	**Definition**
Realism	• Reality is entirely separate from human ways of knowing about it (Tebes, 2005).

	• Science only progresses through observations that have a direct correspondence to phenomena being investigated.
Relativism	• Reality entirely depends on human interpretation and knowledge. • There are multiple constructed realities. • What is 'real' and 'true' differs across time and context. • Objectivity is not possible.
Critical Realism	• The world is constructed through our individual standpoints and perception (Creswell, 2004). • While there may be multiple perspectives on a single event or object, there are realities that cannot be known. • Theories can only be impartial representations of reality. • The goal is to measure and verify underlying structures. • Objectivity can only be approximated.

5.2.6 Ontological Position of the Present Research

The present research will adopt a critical realist ontology, meaning that fatigue will be viewed as an objective experience, but one that is heavily influenced by the context in which it is experienced. Therefore, the 'real experience' of fatigue sits behind a 'prism' of social context, work environment and personal perceptions of fatigue. There is a level of shared reality, however, each individual will have a nuanced perspective of this reality based on his or her personal 'prisms'. Therefore, data collection should first focus on gaining an insight into the 'prism' of social context and fatigue perception before it can look to obtain an approximate understanding of the shared reality through empirical methods. This would lend itself to a mixed methods approach, with qualitative research first used to gain a nuanced understanding of social context and quantitative methods can be used to gain an approximate understanding of factors within that shared reality.

Attention will now be given to a discussion of epistemology, the nature and collection of knowledge and how this will be viewed in the present research.

5.3 Epistemology

Epistemology refers to knowledge- how it should be extracted and what 'type' of knowledge should be considered meaningful (Braun & Clarke, 2013; Snape & Spencer, 2003).

Epistemology is linked to ontology, as it determines how the ontologically defined reality should be studied to extract appropriate knowledge. Ontological and epistemological stances normally correspond to one another, e.g. an ontological position stating that there are multiple, subjective realities will require an epistemological position that recognises this and views appropriate knowledge as detailed insights into these subjective realities.

Though they are linked, it is useful to discuss ontology and epistemology separately as they relate to different aspects of methodology. Ontology, reality itself, is the foundation and epistemology moves toward the more practical question of how a researcher should extract what they need to know from this reality.

The following sections will consist of discussions of major epistemological stances, along with examples of how these positions would be applied within the current research. Finally, it will arrive at a description of the epistemological stance that the current research will employ.

5.3.1 Positivism and Post-positivism

Positivism corresponds with realism in that it views reality as something that objectively exists apart from human perception (Snape & Spencer, 2003). Therefore, knowledge acquisition should be objective and value-free. It specifies that valid knowledge can only be obtained with use of the scientific method and after being subjected to rigorous checks for validity and reliability (Braun & Clarke, 2013).

Positivism operates with the assumption that through the correct application of scientific rigour, the 'truth' will be uncovered. However, a divergence from the somewhat reductionist views of positivism was largely influenced by Popper (1959), who championed the idea of 'approximate truth'. This led to the popularity of Post-positivism in which appropriate knowledge is thought to largely represent the 'objective reality' but is unavoidably coloured by its context.

Most modern researchers do not openly adhere to pure positivism (Braun & Clarke, 2013; Easterby-Smith et al., 2002). However, the methods championed by post-positivism remain similar to what would be used in its pure form. Although post-positivism recognises contextual influence, it seeks to eliminate it as much as possible. Therefore, research aims to remove all subjective influences on knowledge production and values knowledge that can be verified through repetition of existing methods in different contexts (Braun & Clarke, 2013).

To place post-positivism in the context of the present research, research questions would be factual and have a quantitative basis, e.g. "on which day in the shift pattern of an offshore wind technician does the risk of fatigue become unsafe?" Data collection would be experimental, and conditions would be controlled as much as possible. Only knowledge deemed statistically reliable would be accepted as appropriate. There would also be an emphasis on the repeatable value of the data collected.

5.3.2 Constructionism

Constructionism corresponds to the ontological position of relativism (see related section). Just as relativism recognises multiple realities, constructionism assumes numerous different types of knowledge (Braun & Clarke, 2013).

In constructionism, each type of knowledge is seen as a ‘social artefact’ that allows the researcher to gain an insight into aspects of a subjective reality (Braun & Clarke, 2013). Constructionism is opposed to the traditional positivist/post-positivist notions of truth, objectivity and reason. It does not deny the value of research, but rather places emphasis on gaining an understanding of some kind, rejecting the view of ‘one objective truth’ and objective data gathering.

For the current research, a constructionist approach would mean that data collection would focus on gaining detailed, first-hand perspectives from participants. Research questions would aim to explore personal experience and surrounding influences of perspectives, e.g. “How do wind technicians perceive and manage their own fatigue?” Knowledge deemed as detailed and revealing would be accepted as appropriate.

5.3.3 Towards Epistemological Balance

As with the ontological approaches of realism and relativism, post-positivism and constructionism each have strengths and limitations when considering the aims and stance of the current research.

Post-positivism offers the possibility to discover some approximation of an 'objective truth' around fatigue in this environment and allows for the potential introduction of statistical models to 'predict fatigue', which could be useful for the overall aim of helping to improve fatigue management in this environment (see review on fatigue models in Chapter 3).

However, issues with this method come when attempting to 'divorce' the concept and experience of fatigue from its surrounding context. The post-positive method relies on a basis in objective truth. Therefore, research into how fatigue is influenced by nuanced concepts such as perception and stigma would be limited. This would be detrimental to the aim of gaining an overall understanding of the experience of fatigue in wind technicians, as discussed in terms of the critical realist ontology, this understanding would need to include the 'prism' of social context.

However, reliance on a constructionist epistemology would limit scope for suggesting practical solutions for fatigue management, due to its divergence from accepting a 'shared reality'. The most apt epistemology to adopt in the present research would be one that recognises the value of objective reality, as well as the context in which it exists.

5.3.4 Contextualism

Contextualism is similar to critical realism in that it acknowledges that a truth is 'out there', but maintains that this 'truth' must be viewed in context with its surrounding circumstances (Tebes, 2005).

An assumption of contextualism is that 'all propositions are true' in most contexts, just as 'all propositions are false' in most contexts. This stance views appropriate knowledge to be that which helps to determine which propositions are true in which contexts (Edmonds, 2001). As with critical realism, contextualism does not tend to rely on a single method of inquiry, but instead favours pluralistic methods on the basis that a combination of methods is likely to yield more knowledge than either alone (Tebes, 2005).

The present research will be underpinned with a contextualist epistemology, in that it will view the experience of fatigue as a 'reality that is coloured by its context'. Therefore, knowledge useful for furthering understanding about both the reality, and the influential context will be deemed as appropriate and useful. This epistemology favours the use of multiple methods to gain an understanding of the investigated concepts. Therefore, a combination of qualitative and quantitative approaches will be employed.

Table 7- Summary of Epistemology and relating Ontology

Epistemology	**Definition**	**Related Ontology**
Positivism/ Post-positivism	• Meaningful realities already reside in objects awaiting discovery. • Objective, value-free research is possible. • Methods of natural science are appropriate for the study of social phenomena.	Realism
Constructionism	• There is no 'one truth' that research allows us access to. • There are 'knowledges' which are constructed through social and political lenses.	Relativism

	• The task of the social scientist is to appreciate the different constructions and meanings that people place upon their experience.	
Contextualism	• Human activity is situated within a socio-historical and cultural context of meanings and relationships. • Retains an interest in understanding the truth, hence has a realist dimension.	Critical Realism

5.4 Methodology and Axiology

The subsequent sections will discuss the underlying paradigm that will act as the basis for the methodology of the present research. It will also consider axiology, meaning what will be considered as valuable. These two concepts will be discussed within the same line of reasoning, as they have a shared underpinning paradigm.

As established in sections 5.2.6 and 5.3.2 the ontology and epistemology of the present research call for pluralistic methods to gain an understanding of truth and context. Therefore, the projects' methodology must facilitate this. Additionally, this research ultimately aims to understand a 'problem' and help to produce workable solutions. Therefore, a practical methodology will be needed to fulfil these aims. The following sections will discuss the methodological and axiological position of Pragmatism in the context of the present research.

5.4.1 Pragmatism

Pragmatism has been defined as a 'leading contender for the philosophical champion of the mixed methods arena' (Greene, 2008). To put it simply, pragmatism concerns its-self with “doing what works” to answer research questions, and ultimately creating practical action to solve wider problems. It emerged from the early writings of Peirce, James, Dewey and Mead in the 1870s (Johnson & Onwuegbuzie, 2007) and is commonly used in mixed methods research, particularly in research that involves intervening into the world, rather than merely observing it (Goldkuhl, 2012).

Pragmatism is often used as a paradigm to underpin both philosophical and methodological underpinnings of research projects. However, there is debate surrounding its utility as an ontological and epistemological paradigm, due to its overarching focus on ‘what practically works’, and lack of specificity regarding assumptions on reality and knowledge (Lincoln, 2010).

For the present research, it was important to formulate robust ontological and epistemological stances to highlight the emphasis that will be placed upon truth and context. Therefore, pragmatism will be used to guide methodology and axiology, but not ontology and epistemology. It is not anticipated that this will cause an issue, as the philosophical assumptions underpinning pragmatism are in-line with critical realism and contextualism, albeit less specific (Goldkuhl, 2012).

5.4.2 Pragmatism Methodology

Pragmatism is an appropriate paradigm on which to base the methodology of the present research due to its foundational imperative of creating knowledge to facilitate controlled change in a chosen environment (Goldkuhl, 2012). Indeed, this is exactly what the current research aims to do.

Therefore, the methodology of the current research will employ a pragmatic focus of considering each stage of research in terms of its potential utility to engineer positive change. For example, if conducting interviews, emphasis will be placed on their ability to identify the key situational stressors associated with fatigue, so that this can later be addressed in a practical intervention designed to improve fatigue management.

5.4.3 Pragmatism Axiology

Axiology refers to what is considered as 'valuable' in a research project. For the purposes of the current project, value will be placed in data that has potential practical implications in the overall aim of engineering change. For example, gaining data on times in the shift period when participants tend to experience the higher levels of fatigue is valuable, as it means that interventions can be designed to develop preventative measures to alleviate fatigue during these times. Throughout the research process, the question of whether research methods and data collected can be used to make positive change will be postulated, and this will guide the research design process.

5.4.4 Research Philosophy and Methodology Summary

This research project will be guided by the ontological underpinning of critical realism, meaning that reality will be viewed as 'out there', but heavily nuanced by social context and personal perception. It will employ the epistemological stance of contextualism, meaning that appropriate knowledge will be viewed as that which gives a greater understanding of both the context, and the underlying reality of a situation. Therefore, research methods will focus on understanding the contextual factors surrounding the experience of fatigue in the wind industry environment, with the assumption that this will be vital for investigating the underlying shared reality of fatigue.

The present research will employ a methodology and axiology based on the paradigm of pragmatism, which essentially means "doing what works" to engineer positive change in an environment. A mixed methods approach will be used with the aim of creating useful interventions to improve the management of fatigue in this environment.

These philosophical and methodological stances will underpin the present research and guide design of research questions, data collection methods and analysis. The following section will consider research questions that the present research will aim to address.

5.5 Research questions

Research questions for the present project will now be presented and discussed in the context of the philosophical and methodological underpinnings as well as the applied environmental setting of the present research. As previously stated, the aim of the present research is:

"To gain a useful understanding of stressors within the wind industry work environment and the experience of fatigue of those who work within it. Further, this research is intended to form the basis of suggestions for solutions to improve fatigue management within the industry and areas for further research."

As previously established, research in fatigue often takes a one-dimensional approach, therefore the aim of the present project presents a novel approach to applied fatigue research (see Chapters 2 and 3). Additionally, research based in the Wind Industry has has not previously addressed fatigue directly (see Chapter 4), therefore the present research will also serve the purpose of addressing a gap in existing research. The following section will further examine the aims of the present research, splitting the above statement into workable components to be individually examined.

5.5.1 What will constitute as 'useful'?

The statement "*To gain a useful understanding of stressors within the wind industry work environment and the experience of fatigue of those who work within it."* is rather broad. However, an understanding of the research philosophies underpinning the project make the decision of 'what will be useful' more straightforward.

Ontological and epistemological stances of the project state that it is essential, not just to investigate 'objective reality', but also to gain an understanding of the context in which this reality exists. Therefore, a 'useful understanding' in this project will incorporate both.

This means that contextual factors will need to be initially addressed including perception of fatigue and environmental stressors.

5.5.2 Contextual Factors

As previously discussed, contextual factors such as societal perception of work (see Chapter 2, section 2.3) and factors associated with a type of workplace (see Chapter 3 section 3.2.3) can have a significant impact fatigue experience and management. Therefore, research questions one and two will focus on these factors. From a pragmatic stance, it is important to ensure that these questions are both linked to a practical output (e.g. the design of impactful interventions) and can be addressed in a relatively straightforward manner.

Therefore, questions will be addressed through gaining a 'consensus' in answers from several individuals. This will be achieved through the collection of qualitative data from several participants and identifying themes in answers to related questions through the use of thematic analysis (Clarke & Braun, 2017). It will then be important to gain insight into how these factors impact on experience of fatigue during a period of work. This will be done using a quantitative field study method.

5.5.3 Perception of fatigue

The first question to address in the present research is:

'*How is fatigue perceived by technicians and their managers?'*

Perception of fatigue is particularly important because fatigue is a concept that is not generally well understood and often misinterpreted. Perception of fatigue will affect the way that it is reported, managed and experienced. Individuals will have a unique perception of fatigue based on their own experiences, and likely influenced by the views of those around them.

Organisational perceptions of fatigue are also relevant to this question. It is likely they will impact employees' experience of fatigue (e.g. if an organisation views fatigue as an excuse for not working hard, individuals are likely to be less mindful of their own fatigue). Therefore, there is an imperative to understand individuals' perceptions of their own experience of fatigue and their perception of how their organisation views fatigue in its employees.

This will be addressed through qualitative interviews with technicians and their direct managers. These interviews will aim to gain a holistic picture of perceptions of fatigue through semi-structured, probing questions. The data will be thematically analysed to gain a cohesive picture of answers. Data will have pragmatic value for its use in identifying potentially unhelpful perceptions of fatigue and gaining insight into how this may affect its management and experience.

5.5.4 Multidimensional fatigue experience during data collection

Fatigue is a multidimensional concept experienced in response to demands and effort (see chapter 2 section 2.7). It is often experienced alongside the related but separate concepts of sleepiness, anxiety and boredom. These concepts will be assessed alongside fatigue in the present research using a multidimensional scale (Earle, 2004). This will not only provide insight into alternative response to environmental demands (e.g. through boredom or anxiety), it will also add an element of wellbeing assessment to the present research. When subsequently referring to 'fatigue', this will be in relation to fatigue and these related factors.

The second research question will be:

'How does the experience of fatigue change during working and non-working time and throughout on shifts?'

It will be valuable to gain an impression of how the experience fatigue compares between working days (on shift) and time off (off shift). Considering fatigue during the off shift will allow a 'baseline' to be established of how participants experience fatigue when away from their work environment. This can be compared to data collected during their on-shift time to determine the effect of their work on fatigue.

Examination of fatigue during off shifts will also provide interesting information around the adequacy of off shifts for facilitating fatigue recovery (e.g. do fatigue levels stay high for the first few days of the off shift?). Therefore, the utility of this component of the research question is two-fold- 1. It allows for a baseline measurement of fatigue and 2. It allows an insight into recovery during time off.

It will also be useful to determine how fatigue changes over a period of working time. This is particularly relevant in the wind industry, as work is often characterised by shift periods. However, these shift periods vary depending on the working environment (e.g. SOV technicians often work for 2 weeks and have 2 weeks off and CTV technicians often work for one week and have one week off).

Additionally, insight into how fatigue develops and changes during a shift period will allow key information to be obtained around 'high fatigue points' and the likely determinants of this. Interventions could then be designed around work task planning and boundary setting, to help prevent these high fatigue points and to plan around them so that safety critical work is avoided during these times. It will also allow interesting comparisons to be made around the differing shift patterns used in wind industry environments.

This research question will first be addressed during qualitative interviews. Following this, quantitative data will be collected through twice-daily fatigue and wellbeing measurements over a period of four weeks, including on shifts and off shifts.

5.5.5 Recovery and Sleep

The third research question will be:

'How does recovery and sleep change during working and non-working time and throughout on shifts?'

Sleep is an extremely important element of fatigue recovery. This has been discussed at length in previous chapters (see chapter 2 sections 2.6 and 2.6.1). As it is essential to understand sleep when assessing fatigue, sleep will be a focus in qualitative interviews and will be further investigated in quantitative data collection. This will be done through subjective questions around sleep quantity and quality as well as objective measurements of this recorded using ACTI graphs.

Sleep is an objective reality (e.g. a person either obtained 6 or 8 hours of sleep) and there are objective truths about its impact on health and functioning (see chapter 2 section 2.6.3). However, sleep is heavily affected by contextual factors and the experience of sleep deprivation and its associated impact is likely to manifest differently depending on individual differences, environmental factors and perception. Therefore, a mixture of qualitative, subjective and objective measures will be employed to understand sleep in this work environment.

Non-sleep recovery is also essential for overcoming fatigue, with its length and content needed dependent on the severity of the fatigue experienced (Geurts & Sonnentag, 2006; Sonnentag & Kühnel, 2016; Sonnentag & Niessen, 2008). Sonnentag and Fritz (2007) Devised a model of recovery incorporating detachment (feelings of being separate from work), relaxation (feeling that no further demands are required in the immediate future), challenge (experience of enjoyment through employment and development of leisure related skills) and control (feeling agency over actions and schedule) which will be employed in the present research.

Recovery is an objective reality, as it involves practices that are either ‘done’ or ‘not done’ and the quality of recovery can be measured through psychological assessment (e.g. Sonnentag & Fritz, 2007). However, recovery is a contextual factor affecting the experience of fatigue and can be influenced by perception and environmental factors. It can also be impacted by psychological state (e.g. a person can undertake 'recovery activities' but not experience recovery due to feeling anxious or stressed).

It is important to understand recovery on these two levels. The first relates to practices employed by individuals during their designated 'recovery time' (time off work and breaks). The second is the quality of this recovery time and whether it is adequate to help individuals overcome fatigue. Knowledge of these factors will allow interventions to be designed to incorporate improvement in recovery practices to help alleviate fatigue.

Recovery will first be investigated through qualitative interviews, with questions based around behaviours during recovery times (e.g. 'what do you tend to do in an evening after work?'). Quality of recovery will be assessed in a quantitative study in which participants will be required to fill in measures to assess their feelings of recovery after periods in which they have not been at work, e.g. in an evening.

5.5.6 Work Related Stressors and Buffers

The fourth research question will be:

'What are the key factors affecting employees' experience of fatigue in this work environment?'

As discussed in chapters 2 and 3, everybody experiences fatigue. However, there are factors present in each environment that can either cause fatigue to occur more readily and worsen the experience of fatigue when it does occur (stressors) (see chapter 1 section). There are also factors that can delay the onset of fatigue and aid recovery (buffers).

This Question focuses on aggregating stressors and buffers in this work environment and determining their impact on individuals' experiences of fatigue.

Factors will first be identified through qualitative interviews. As with perception of fatigue, answers will be thematically analysed to gain an understanding of the most salient stressors for a representative sample of participants.

Qualitative data will be used to inform the design of study 2, a quantitative field study aiming to gain an understanding of how these stressors interact with fatigue daily over a period of working time. This will be done through identifying themes in qualitative data around factors affecting fatigue and highlighting them as specific areas to focus on in study 2. This will be of practical use, as it will allow interventions to be designed around work time planning.

5.5.7 Comparison of three different Wind Industry Environments

The fifth research question will be:

"How does the experience of fatigue and its antecedents compare in three different wind industry environments?"

The wind industry encompasses several different working environments, which each have unique challenges and stressors (see chapter 1 pages 1.1.34, 6 & 7). To gain insight into fatigue in operations and maintenance technicians, it is important to consider how different environments within this industry may affect fatigue differently. Therefore, this research will include participants from three different environments.

1. Onshore wind technicians
2. Offshore SOV-based wind technicians
3. Offshore CTV-based wind technicians

It will be useful to assess the similarities and differences of the factors affecting fatigue in these three environments. It will provide greater insight into the contextual factors that give rise to fatigue. It will also allow bespoke interventions to be suggested depending on the unique challenges in that environment.

This will be assessed by including a group of participants three different wind industry environments and comparing their results during data analysis.

5.5.8 Summary of Research Questions

Table 8 summarises the research questions, along with how they link to the theoretical and methodological imperatives of the research project.

Table 8 Research Questions

Question/ Component	**Intended measurement**	**Ontology & Epistemology**	**Methodology & Axiology**
Question 1- How is fatigue perceived by technicians and their managers?	Qualitative interviews	Fatigue is an objective reality (aspects of its experience are universal). Fatigue perception is contextual and heavily influenced by external factors.	Fatigue perceptions could be based on unfounded knowledge (e.g. fatigue stigma). Interventions can address this. This will also help to

			interpret results of the studies.
Question 2- How does the experience of fatigue change during working and non-working time and throughout on shifts?	Quantitative field study (study 2)	The experience of fatigue is an objective reality; however it is influenced by contextual factors.	This will allow for a greater understanding of how fatigue is experienced in these environments and work and time planning interventions can be formed based on this data.
Question 3- How does recovery and sleep change during working and non-working time and throughout on shifts?	Initially identified in qualitative interviews- deeper understanding through quantitative field study	Quality of recovery is an objective reality but can only be assessed through subjective means and is heavily influenced by contextual factors. It has a contextual impact on fatigue.	This will provide insight into the causes of fatigue- e.g. if it is a consequence of lack of recovery or sleep.

Question 4- What are the key factors affecting employees' experience of fatigue and related factors in this working environment?	Initially identified in qualitative interviews- deeper understanding through quantitative field study	The existence of external factors that affect fatigue (positively or negatively) is an objective reality. However, their impact on fatigue in this environment is contextual.	Identification of these factors will allow an understanding of how fatigue is affected in this environment and will help towards the formulation of interventions which mitigate the impact of stressors and enhance the positive effect of factors that protect against fatigue.
Question 5- How does the experience of fatigue and its antecedents compare in three different wind industry environments?	Initially identified in qualitative interviews- deeper understanding through quantitative field study	There will be contextual similarities and differences in each environment that have an impact on fatigue.	This will provide greater insight into the contextual factors that give rise to fatigue. It will also allow bespoke interventions to be suggested depending on the unique challenges in that environment.

Chapter 6 - Study 1 Qualitative Investigation into Fatigue in the Wind Industry

6.1 Introduction

This chapter will focus on data collection and analysis of the first study in this research project- a qualitative investigation of fatigue in wind industry workers. The method of data collection will initially be considered, followed by a discussion of how data was analysed.

As discussed in Chapter 5, a qualitative approach was determined to be an effective method for study 1. This is because the qualitative method allows for the collection of rich data about personal experiences (Braun & Clarke, 2013). Although recent studies have investigated experiences of WIWs (e.g. Mette, Velasco Garrido, Harth, Preisser, & Mache, 2017; Velasco Garrido, Mette, Mache, Harth, & Preisser, 2018, for further details, see chapter 4), this is still an emerging area, which has mostly been limited to offshore SOV based technicians and there is currently no specific research surrounding fatigue in this setting.

Research conducted in the wind industry environment, and similar working environments, suggests that there are many factors that impact the experience and management of fatigue. However, without specific research in this area, 'how' in and 'in what way' these factors influence fatigue cannot be known. It is therefore useful to gain a first-hand perspective from wind industry workers about their personal experiences.

Interviews were selected as the most appropriate method of data collection as they are best suited to exploring understandings, perception and constructions of things that participants have some kind of personal stake in (Braun & Clarke, 2013). Also, as data collection would cover potentially sensitive questions around experience of fatigue, stress, workplace incidents and physical/mental health issues, it was decided that one-on-one interviews would be the most appropriate method of obtaining rich and accurate data.

6.1.1 Chapter Structure

Part 1 of this chapter will focus on the methodology and design of study 1 (section 6.2). This will include a discussion of the aims and objectives of this research in section 6.2.1 and the presentation of research questions in section 6.2.2. Section 6.2.3 will consider the methodological underpinnings of the present study linking to the philosophical discussion in Chapter 5. Following this, section 6.2.4 will outline the ethical considerations addressed in the design of this study and how data collection met relevant ethical standards. In line with qualitative research practice, a reflexivity section written from the first-person perspective of the researchers is included in section 6.2.5 which considers the role of the researcher in data collection. Section 6.2.6 considers participants and recruitment. Finally, section 6.2.8 describes the design of interview structures.

After considering the design and method of data collection, Part 2 (section 6.3) will focus on the analysis of this data. This will include a discussion of the method of qualitative analysis (section 6.3.1) and a description in the analysis process used in the present study (section 6.3.2).

Part 3 will consist of an exploration of results and a discussion of their links to relevant theory and applied research findings (section 6.4). This will also be placed in the context of their applications for practice in the wind industry. The structure of this section will be explained in section 6.4.1 as results will be presented in three groups in a thematic structure. Finally, a conclusion will be presented in section 6.8 which will provide a holistic discussion of results and their implications for further research and practice.

6.2 Part 1- Methodology and Study Design

The following section will consider how this study will be designed and executed in line with the methodological underpinnings outlined in chapter 5. Attention will then be given to the method in which data was collected including ethical considerations, participant recruitment and interview practice.

6.2.1 Aims and objectives

Study 1 will use a qualitative approach which involves interviewing technicians and health and safety managers from three different wind industry working environments. This method will enable the development of an in-depth understanding of how individuals interact with this work environment and provide insight into perception of fatigue and environmental stressors. The inclusion of health and safety managers will add another layer of perspective to this research, as managers will likely have an overview of operational constraints and motivations on workload, health and safety.

A key aim of study 1 is to inform the design of study 2, a quantitative field study. This will be done through identifying salient themes in the data linked to the research questions and highlighting them as factors for further examination in study 2. An example of this would be if manual handling demands were highlighted in study 1 to be a prominent factor affecting fatigue in this environment, a question in study 2 could be "how high were your manual handling demands today?". This will mean that the present research is informed by those with first-hand experience of the wind industry environment throughout the process, which is particularly important given that such little research has been conducted in this area to date. The following section will consider research questions relevant to the present study and present a rationale of how they will be addressed in the study design.

6.2.2 Research questions

Chapter 5 provided an overview of the research questions for this project (see chapter 5 section 5.5.8). These questions will be addressed across the two studies encapsulated in the present research project, some will be wholly addressed in study 1 and others will be investigated in both studies. Question one will be solely addressed in study 1 as it focuses on perceptions, which is an inherently subjective concept and therefore best addressed using qualitative methods. For other questions, this study will aim to provide an initial understanding which will then be built upon in study 2. Table 9 provides an overview of the research questions that this study will aim to address and reasoning for this.

Table 9- Study 1 Research Questions

Question/ Component	**Reasoning**
Question 1- How is fatigue perceived by technicians and their managers?	It is important to investigate perception of fatigue, as this can have significant effect on how fatigue is experienced and managed.
Question 2- What are the key factors affecting employees' experience of fatigue and related	As previously discussed, research indicates that there are many factors present in this environment that can affect the experience of fatigue. This study will aim to gain an

factors in this working environment?	understanding of what factors are specifically associated with this and why.
Question 3- How well do participants tend to recover from fatigue in this environment and what factors affect this?	Appropriate recovery is essential for fatigue management and understanding how this is currently experienced is important.
Question 5- How does the experience of fatigue compare in three different wind industry environments?	It is important to include this question, not only to place emphasis on the unique aspects of each wind industry working environment, but also to highlight the influence of each working environment on the experience and management of fatigue. Conversely, it will be useful to establish any similarities that there may be in these working environments.

6.2.3 Methodological Underpinnings

As discussed in Chapter 5, the present research will be underpinned by the ontology of critical realism and the epistemology of contextualism (see chapter 5 page 175). For study 1, this will mean that an objective truth will be considered as ‘out there’, but heavily nuanced by social context and personal perception. It also means that knowledge considered as useful will be that which provides a greater understanding of context and the underlying reality of the situation. Study 1 will therefore aim to gain an impression of each participants’ ‘truth’ and will endeavour to gain an understanding of the shared aspects of these truths. This will have two beneficial outcomes. One will be that contextual elements that can affect the ‘external reality’ will be investigated and the other will be that a greater understanding of this ‘external reality’ will be reached through comparison of shared characteristics in interview responses.

As was also discussed in chapter 5, the present research will be informed by the methodological and axiological approach of pragmatism (see chapter 5 section 5.4.2). This means that results of study 1 will need to be considered in terms of their 'usefulness' to the overall objectives of the research. The first way in which this study will be useful is that it will help to gain an understanding of perceptions around fatigue. Gaining a qualitative understanding of perception of fatigue is an important first step in the process of understanding how fatigue is experienced within this environment. In terms of 'critical realism', it will provide insight into the nuance affecting the 'reality' of fatigue (for a more thorough discussion of this, see chapter 5). The second aspect of this is that data gained in study 1 will help to inform the design of study 2, a quantitative investigation into fatigue in this environment. Ultimately, it will provide the basis of interventions aimed at improving the management of fatigue in this environment.

6.2.4 Ethical Considerations

Ethical approval was sought and received from the University of Hull Business School as this was the Faculty Ethics committee responsible for Risk Institute projects, under which the present research was commissioned. As this study involved the investigation of three different work environments, data was collected from employees in three separate organisations. Ethical approval was sought separately for each of these organisations (see Appendix 1 for approval letters).

Although this study received ethical approval from the Business School, it was also a psychology project and therefore followed the ethical process outlined by the British Psychological Society (2014, 2017, 2018).

There were inherent risks for appropriate ethical practice since participants were employees and data collection included asking for potentially sensitive information that would not normally be made available to an employer (British Psychological Society 2014, 2017, 2018). Therefore, care needed to be taken to ensure that practices facilitated the appropriate protection of participants in these circumstances. The following sections will focus on relevant areas of ethical consideration and contain descriptions of how these were approached in the present study.

Informed consent

Informed consent is an individuals' right to choose to participate based on the best information presented in the most appropriate way (British Psychological Society, 2018). The BPS advises that psychologists should be aware of the complexities of obtaining informed consent due to the perceived power, status and authority of the professional psychologist (BPS, 2018). In this study, authority did not just come from the presence of the psychologists, but also from employers who were involved in the process of participant recruitment. A potential risk was that individuals could have felt that they were in some way obligated to participate in the study.

To ensure that all participants were able to give informed consent, they were provided with a consent form that outlined the process and aims of the study, as well as how data would be presented to their employer (see Appendix 2 for consent form). This was also explained verbally by the researcher before the interviews began. Researchers emphasised that their decision to participate would have no effect on their employment or relationship with their employer and individuals were given time to consider whether they would like to participate, as well as the knowledge that they could withdraw from the study at any point. All participants signed their consent forms and agreed that they were happy for their data to be used in the study.

Confidentiality and Disclosure of Information

Confidentiality was of primary importance in this research and it was ensured that only the primary researchers had access to any identifying data. As the study involved working with participants' employers, this process needed to be managed carefully. The BPS advise that in research involving employers, researchers should only provide employers with what they 'need to know' (BPS, 2018). Therefore, it was agreed with organisations at the beginning of the study that results would be presented in a cohesive form which highlighted general findings but did not in any way identify individual participants.

Debriefing

Although no deception was used in this study, it was still important to have a thorough debrief procedure (BPS, 2014). This was to ensure that participants understood that they could choose to withdraw their data after they had participated in the study. It was also to offer support in case participants had been affected by the content of the interviews. Participants were issued with written debrief forms after interviews had been completed (see Appendix 3 for debrief form). They were also verbally debriefed by the interviewers.

As interviews could involve some discussion of negative incidents and mental health related issues, it was important to have a procedure for any participants impacted by their experience of the interviews. Due to the relatively small number of participants, they were advised to contact the researchers in this instance, who could then direct them to relevant support networks if necessary. Depending on the impact this had on the participant, this could be in the form of organisational-based mental health support, through their GP or public helplines.

Data Management

All five interviews were recorded on university owned Dictaphones and transferred into University of Hull password protected 'box' folders and were only accessible to the research team. Transcriptions of interviews were created in Microsoft Word and analysed in NVivo and both files were stored in the same way as recordings. Handwritten notes taken during interviews were kept in a locked cabinet at the researchers' home and will be securely destroyed in five years in line with the Data Protection Act (2018).

6.2.5 Reflexivity

Reflexivity is an essential part of qualitative research which views the researcher as taking an active role in shaping the research process (Braun & Clarke, 2013). During this study, the main researcher kept a record of reflections throughout the research process and regularly discussed these with the supervisory team. Relevant reflections in this area will now be discussed from a first-person perspective as is customary in qualitative research.

Researcher Reflections (first person perspective)

I am a 25-year-old female PhD researcher with an undergraduate degree in psychology with history and a background of working as a national minimum wage investigator for the civil service. Unlike the participants in this study, I have not spent time working in a physically challenging or dangerous working environment and my experience of working so far has been based in academic or professional working environments.

I was aware that a lack of experience in these work environments may act as a barrier to being able to empathise with the participants. I attempted to address this by engaging with the working environment as much as possible. I completed a week of offshore health and safety training, including working at heights and sea survival, which allowed me to engage with the risks and physical challenges regularly experienced by WTs in their work environments. I also sought out the opportunity to travel to an onshore wind farm and climb to the top of a wind turbine. This helped me to appreciate the magnitude and challenge of this task.

I engaged with the industry regularly throughout the research process and sought guidance on aspects of the research design that I thought would be difficult for me to effectively carry out independently. This research was supported by a wider team of two other researchers who had experience of conducting research projects in the offshore wind industry and so their knowledge and experience was drawn on throughout the research process.

I am aware that researchers' personal views on subjects related to the research can impact their style and method of research. Therefore, it was important to approach this process with self-awareness and to openly recognise any personal views related to the project that may affect my judgement. I believe that organisations have a responsibility to understand and control the potential risks that working environments may pose not just to their safety, but also to their mental and physical health and wellbeing. I also believe that factors around mental health and other psychological aspects of the workplace are not currently considered as much as they should be and that workplaces generally should do more to ensure that their employees' health and mental wellbeing are cared for. These beliefs could mean that I am more attuned to aspects of conversations that focus on these points than others.

I reflected on my personal role in the research process throughout this study and It became clear when listening back to the interviews that my previous role as a national minimum wage compliance investigator and position as an early career researcher influenced my style of interviewing. In this previous role, I was often required to interview employers and employees regarding working practices. Those interviews would generally be detailed and focus on gaining an impression of the structure and organisation of the company, working hours and practices. I noticed that during interviews in this study, I had the tendency to 'slip into that mode', which was not always the best method of obtaining how participants *experienced* their work environments. This was something that I became particularly mindful of when comparing my interview style to Dr Earle's, who tended to ask more personal and probing questions, which tended to elucidate deeper answers.

Another reflection was the impact that the setting of the interview had on the tone of the conversation and quality of information obtained. When designing the study, I thought it would be best to conduct interviews in private rooms in company offices, due to familiarity, comfort and convenience for participants. Additionally, I endeavoured to conduct all interviews face to face as to effectively build rapport. However, in hindsight, the two most successful interviews were those that were conducted either over the phone, or away from the participants' work environment. Upon reflection, this made sense as participants were away from their workplaces and colleagues, meaning that they likely felt that they could speak more freely. Additionally, particularly for the interview that I conducted over the phone, I felt more able to ask deeper, more probing questions as I was not intimidated by being face to face with a participant who may not feel comfortable with this. This is something that I would apply deeper consideration to in future qualitative field work to ensure that the setting of the interview was the most apt at encouraging open and free-flowing dialogue.

Another factor that could affect the data collection was the difference between my own characteristics and the participants'. As a 25-year-old woman, most of the participants were male and older. It is important to consider how participant characteristics and differences between the researcher and participant can be understood and managed to ensure that the participant feels comfortable and the study is able to achieve its aims. This will be done in the context of relevant literature in the following section.

Interviewing across difference

In light of the reflection that differences in researcher and participant characteristics may impact the quality of elucidated data, I consulted Schwalbe and Wolkomir's guide to interviewing men (2003). They highlight the notion that although men are often viewed as the 'generic participant', the performative aspects of how men 'do gender' can often have a significant impact on the interview.

A key aspect of this is the cultural expectation for men to appear 'masculine' by not expressing emotions such as fear, insecurity and anxiety. This can cause them to experience these exact emotions when being prompted to discuss them in interviews

(Schwalbe & Wolkomir, 2003). This is particularly relevant to the present study in which participants are asked to discuss times when they may have felt exhausted, stressed or unstable in their work environment. Schwalbe and Wolkomir state; *"an interview situation is both an opportunity for signifying masculinity and a peculiar type of encounter in which masculinity is threatened"* (Schwalbe & Wolkomir, 2003, p.206). This means that male interview subjects may display behaviours that disrupt the aims of the interview, such as the non-disclosure, or very limited disclosure of emotions.

According to Schwalbe and Wolkomir, these issues can be further complicated when the interviewer is female, they state; *'Women are a dangerous audience…even while they may help to sustain the masculine self, women, as witnesses to men's weaknesses and failures, know just how much of an illusion it is"* (Schwalbe & Wolkomir, 2003, p.206). They highlight that this is particularly the case when questions call for answers that put control, autonomy or rationality in doubt. Therefore, questions needed to be worded sensitively with these factors in mind.

Schwalbe and Wolkomir advise that rather than regarding these issues as a barrier to obtaining relevant data, their occurrence should be considered as useful and informative data. This is relevant for the present study, as an unwillingness to display emotions and difficulties is likely to have a significant impact on the experience and management of fatigue. Therefore, it is important to keep relevant reflections about participant behaviour in this area.

Schwalbe and Wolkomir also discusses techniques that can be used to address this potential lack of emotional disclosure. These were considered when devising the interview guides and during practice. Techniques included phrasing questions as though asking for anecdotes or hypothetical answers, (e.g. *'Imagine a day at work when you feel very tired, what would generally be the factors surrounding this?').* Another was to 'circle back' to questions that were initially met with 'minimised' answers (those that do not go into appropriate depth). This method was also utilised while conducting interviews.

6.2.6 Participants and Recruitment

To fulfil research question 5, *(How does the experience of fatigue compare in three different wind industry environments?)* participants were recruited from three different wind industry working environments:

1. Onshore wind
2. Offshore wind SOV
3. Offshore wind CTV

These three environments represent the range of work situations inhabited by wind industry operations and maintenance technicians. As explored in chapter 4, although there is an increasing amount of research conducted into offshore SOV environments (e.g. Mette, Velasco Garrido, Harth, Preisser, & Mache, 2017; Mette, Velasco Garrido, Preisser, Harth, & Mache, 2018; Velasco Garrido, Mette, MacHe, Harth, & Preisser, 2018), there is a lack of data investigating other wind industry environments, particularly qualitative investigations. This study will consider how the unique aspects of each wind industry environment affect perceptions and experience of fatigue in their employees. Table 10 presents inclusion criteria used for participant recruitment in this study.

Table 10- Inclusion criteria used for this study

Inclusion Criteria	Rationale
Individuals who work or have recently (in the last 5 years) worked as an operations and maintenance technician in the wind industry.	This project focuses on operations and maintenance technicians, and therefore requires participants with recent experience of working in this role.
Individuals who currently or have recently worked as managers of operations and maintenance technicians in the wind industry. Their roles must also include aspects of managing health and safety.	It will be useful to gain an insight of fatigue from the perspective of people who have the responsibility of managing technicians' health and safety.
Fluent English speaking and listening skills.	Questions in a foreign language may not be directly comparable or understood similarly to questions in English.

6.2.7 Recruitment Methods and Participant Groups

Contact was made with health and safety managers from three different wind industry companies. All three health and safety managers agreed to take part in the interviews and ask for volunteer technicians within their companies to also take part, with the permission of head office.

Opportunity sampling was used to recruit participants in all groups as it was important for interviews not to be too disruptive to organisational work practices. This was done through contact with the health and safety managers who selected technicians fitting the criteria outlined by researchers (see previous section) based on their availability to devote their time to the interviews (around 1 hour per interview).

The first round of interviews took place in October/November 2018 with onshore technicians. The experience of interviewing participants in this group was used to determine an appropriate sample size to collect from each group, as it was decided that having equal sample sizes would facilitate effective comparison between the groups. After conducting a total of five interviews (four technicians and one health and safety manager), it was decided that data collected was sufficient to gain an understanding of the subject matter in-line with the research questions, and this group size was decided to be appropriate to replicate for the other two groups.

As part of the project scope, it was agreed with two of the companies that a report outlining key findings would be produced and presented to them. This was so that findings from the research could provide them with an understanding of employee fatigue and wellbeing in their organisation. As participants in the third company only included three participants (two technicians and one manager) and a report would not have been particularly relevant to them. Data in the two reports was presented in a general manner that did not identify any of the participants (see appendices…for reports). The following sections will include descriptions of each of the participant groups including their demographics, relevant information about their work environment and tasks and interview details.

<u>Group 1- Offshore SOV</u>

'Offshore SOV' refers to a working environment in which technicians work offshore and live on a 'service operation vessel' (SOV, a relatively large boat) for around two weeks at a time. This group consisted of 4 offshore SOV operations and maintenance wind technicians (WTs) (3 males, 1 female) and their operational manager (male), who oversaw health and safety as well as day to day operations for this team when offshore. Participants were aged between 26 and 48 and all worked for the same offshore wind company.

Living conditions on SOVs can vary between organisations. In this organisation, they were at a fairly high standard and all employees had their own rooms and had all meals provided to them by on-board cooks during their time spent offshore.

During an on-shift (2-week period spent offshore), the SOV would house a team of 8-12 technicians, 3-5 managers and a ship crew. Technicians' time spent offshore was generally categorised by continuous 12-hour working days, where they would either have a short transfer to the turbine that they were going to be working on by boat (either a CTV, or a smaller 'daughter craft'), or 'walk to work' using an extendible platform from the SOV. Their work duties generally consisted of servicing or troubleshooting depending on the day's tasks and their level of training. There were no scheduled rest days during the on shift time. However, their duties could be called off due to bad weather. This would happen more often during the winter months when 'weather days' are common. On 'weather days', technicians could either be given SOV-based duties (e.g. preparing equipment, safety training, etc.), or have the day off, but would have to remain on the SOV. Technicians would generally be required to climb turbines about 50% of the time that they spent working on them due to faults with turbine lifts. As turbines generally reached about 120 metres, this would be a large physical undertaking. Technicians generally worked in teams of 5-7 on the same turbine while performing duties.

The operational manager included in this group was based offshore when working and lived on the same vessel as the participants during his on-shift period. He worked in an office located on the vessel and did not work on turbines with the technicians. While offshore, he was responsible for health, safety, welfare and operational concerns. Other participants in this group all worked as operations and maintenance technicians. One of the participants held a more senior role (WT4) which included some management responsibilities as well as technician work and another participant was off work at the time of the interview due to a knee operation.

All interviews apart from two took place in the company's onshore offices. These interviews were conducted on 'change-over days'- either when participants were due to be returning home after their two-week shift or before they were due to be sailing out to begin their two-week shift. Interviews were conducted in a private meeting room with only the researcher and participant present. One interview was conducted over the phone as the technician was off work with an injury and another was conducted in a private office at the University of Hull.

Interviews took a mean time of 01:22. The manager interview time was not included in this mean time calculation as this interview was significantly longer than the time taken for the technician interviews (03:09). This was due to the fact that both his experience of fatigue as a manager and his perception of his team members' experiences were discussed as both perspectives were determined to be relevant for the study due to his close working relationship with the technicians and the likelihood that improving management of his fatigue would have a positive impact on the team overall.

Participant group 2.1- Offshore CTV, Company 1

‘Offshore CTV’ refers to a working environment in which technicians work offshore and travel to turbines on a ‘crew transfer vessel’ (CTV) every working day. Discussion on participants in this category are split into two parts because they were recruited from two different organisations that included different environmental factors and work practices.

The first group of participants were recruited from a company who employ and supply contract workers to offshore wind companies. Recruitment was done through contact with the health and safety manager who selected participants on an availability basis. Due to operational constraints, only three participants could be recruited from this company and the decision was made to recruit a further two participants from another offshore wind company so that sufficient data could be gained and that equal numbers of participants were recruited from the three different working environments.

Participants in this group consisted of a health and safety manager (female) and two males who had around eight years of experience of working as technicians (both male). They were aged between 28 and 54.

Participants with technician experience had worked as contractors in CTV based roles. This meant that they worked for wind industry organisations on a contractual, sometimes short term, basis. Their working days were generally 12 hours in total, but included time spent sailing to turbines and back. Their shift patterns generally consisted of 5 days spent on shift with weekends off work, however their working patterns depended on that of the site that they were working on and could be changeable. As contractors, these technicians often worked far away from home and therefore would generally stay in a hotel near to the wind farm and would drive home for weekends, returning to their accommodation near the wind farms on Sunday evenings. As with offshore SOV technicians, they would have no planned rest days within their working periods, however their work was subject to weather conditions and if weather was deemed to be too bad to transfer to the turbine, work would be called off as a 'weather day'.

The health and safety manager was office based and managed the health and safety of the wind technicians remotely, but with regular site visits to wind farms. The other two participants both had around 8 years of experience as CTV operations and maintenance technicians. However, at the time of the interviews they were working as wind technician trainers.

All participants were interviewed in the company's offices and took a mean time of 01:09.

Participant group 2.2- Offshore CTV, Company 2

Both participants in this group were male and senior wind technicians which meant that as well as their technician roles, they had management responsibilities. They were aged between 35 and 40.

In this group, WTs worked on offshore wind farms and their working days were generally 12 hours. However, as with the other CTV group, their working days included boat transfers to the turbines (usually between 40 and 90 minutes each way). Unlike technicians in the other CTV group, these WTs were permanent employees and not contractors. Their working periods would consist of one week spent working offshore and one week off work. When working, they would commute from their homes and back each day. As with offshore SOV technicians, they would have no planned rest days within their working periods, however their work was subject to weather conditions and work could be called off as a ‘weather day’. On these days, WTs would either be expected to work in the onshore offices, be put on helicopter standby (they would fly out to the windfarm to fix a broken turbine if called out) or would be allowed to have a day off at home.

Interviews were conducted by two different researchers- Stefi McMaster (lead researcher on this project) and Dr Fiona Earle (PhD supervisor). Dr Earle was asked to conduct the second interview in this group for two reasons. The first was that it was deemed to be more time-effective and considerate to the participants to conduct both interviews at the same time, rather than asking one of the participants to wait while the researcher completed their interview of the first participant. The other was that the lead researcher thought that it would be a beneficial learning experience to reflect on Dr Earle’s style of interviewing, as she is more experienced in conducting interviews of this kind, and to determine whether there were any notable differences in the information generated from this interview to other interviews in the study. Dr Earle used the same interview structure that had been used in the other interviews to refer to. As she was already part of the wider research team on this project, and a Chartered Occupational Psychologist her role as an interviewer did not impact on the ethics of the study. Interviews were conducted in private meeting rooms and took a mean time of 01:03.

<u>Group 3- Onshore</u>

This group included four male onshore wind technicians (WTs) and one health and safety manager (also male) aged between 37 and 52.

Technicians in this group worked on onshore wind turbines, usually located in large fields in remote areas of the country. Their duties involved servicing and fixing turbines and due to the relatively small size of onshore turbines (around 60 metres tall), compared to offshore turbines (around 80-120 metres tall), they were almost always required to manually climb turbines in order to perform their duties.

They generally worked in teams of two or three and would normally drive to the wind farm together and work on the same turbine throughout their working days. They tended to work five days per week (Monday to Friday) starting at around 8 am and finishing at around 5 pm. However, they spent around 30-50% of their time working away, which involved staying in a hotel for between one to five nights at a time. Time spent working away often involved working longer hours, which would be paid as overtime. They generally had weekends off work but were required to spend one in four weekends on-call, which meant that they could be called out between the hours of 9 am and 4 pm on a Saturday or Sunday.

The health and safety manager was office-based and responsible for overseeing working practices of the technicians to ensure that they met health and safety standards of the company. He initially spent six months working as a WT before becoming a health and safety manager. All other participants in this group were working as wind technicians at the time of their interviews. One participant was partly office based as their job consisted of spending around half their time writing technical guides for wind technicians to use while fixing turbines and another was office based at the time of the interview due to a back injury which prevented him from working on the turbines.

All interviews took place at the company's offices in a private meeting room with just the researcher and participant present and took a mean time of 01:05.

6.2.8 Interview Design

Attention will now be given to the design of interview structures and how this was determined in line with philosophical and methodological assumptions of the research and best practice in qualitative research.

Interview structures were designed by the lead researcher in collaboration with supervisors. A semi-structured interview style was used, as this was deemed to be in-line with the methodological underpinnings of the study. A semi-structured design allows for a structure of questions to guide the interview and ensure that salient information for the overall project aims is obtained. However, it also leaves room for the interview to be guided by participant answers and conversational flow. As stated by Rubin (1995, p42), the ideal qualitative interview is 'on target while still hanging loose'. This meant that interview structures were able to fulfil the pragmatic methodology of obtaining relevant information for the overall study aims and fulfil the critical realist/constructivist underpinnings by collecting information about individuals' circumstances which nuance their perception and experience of fatigue.

In their guide to qualitative research, Braun and Clarke (2013) advise that interview structures can be informed by, or adapted from previous research. As the research team had experience of conducting interviews with WTs for past projects, they were able to draw on examples of interview guides that had been successfully used in past research (Earle et al., 2020). These guides were used as a loose basis for the interview structures used in the present study, but heavily adapted for the present research.

Following the guidance of Kvale and Brinkmann (2009), interview structures were designed with 'lighter' questions towards the beginning intended to establish a rapport with the participants, as well as collecting useful data about their personal and professional lives. They then progressed to deeper, more technical questions in the middle of the interview (e.g. 'how do your feelings of fatigue tend to change throughout a working day?'), to provide an in-depth understanding of the subject. At the end of the interview structure, 'clean up questions' were included to summarise findings and to address anything that hadn't been addressed before that point (e.g. 'to sum up, what do you think are the three biggest things that affect your experience of fatigue while on-shift' or 'Is there anything else you would like to add that hasn't been covered yet?'). As well as questions, probes were included in interview schedules to be used depending on participant answers (Braun & Clarke, 2013).

Final interview structures

Six different interview schedules were designed (see list below). Interview structures were broadly similar in content but amended depending on the type of participant. See Appendix 4 for an example of interview structures.

1. Onshore SOV technician
2. Onshore SOV H&S manager
3. Offshore SOV technician
4. Offshore SOV Operations manager
5. Offshore CTV technician
6. Offshore CTV H&S manager

Though interview structures were intended as a guide, interviews were constructed in a semi-structured manner meaning that participants could steer the interview in any direction they felt was relevant.

Once interviews had been completed, data was transcribed and analysed. The process of this will be discussed in the following sections.

6.3 Part 2 - Transcription and Analysis

All interviews were transcribed by the lead researcher from audio recordings. Initially, interviews were transcribed with the researchers' questions abbreviated. However, after further research into the process of transcribing for qualitative research, it was decided that a more thorough approach should be taken, and subsequent transcription included the researchers' questions in full. Interviews were transcribed using Microsoft word and then were put into NVivo for analysis.

6.3.1 Method of Qualitative Analysis

The method of thematic analysis (TA) was chosen for this study (Braun & Clarke, 2013). Thematic analysis is a flexible method in terms of theoretical framework, research questions, data collection and sample size (Braun & Clarke, 2012). Unlike other qualitative methods (e.g. Grounded Theory), it does not provide a *methodology* for the entire qualitative study, including data collection, ontological and epistemological positions, but rather focuses only on data analysis (Braun & Clarke, 2013).

This has caused the approach to receive some criticism due to the potential for research utilising this methodology to be 'unrooted' in terms of methodology or philosophical positioning (Braun & Clarke, 2013; Holloway & Todres, 2003; Nowell, Norris, White, & Moules, 2017). However, the present research already has a clear methodology (see chapter 5) and TA corresponds with both its critical realist/constructionist philosophical underpinnings and pragmatic methodology and axiology. This is because TA offers the opportunity to gain an insight into participants' contextual and practical experience of fatigue in a straight-forward and practical manner. Another reason why TA was determined as the most appropriate method for this study was that one of the aims of the research was to compare data from three different groups of participants. TA offered the most effective way of doing this, as themes could be generated and then compared for similarities and differences between the groups.

TA is a method of systematically identifying commonalities in the way a topic is discussed and making sense of these cohesions. This is done through identifying 'themes' within the data. Themes are subjects that have been 'important' within the data, either due to the frequency in which they are spoken about, or the significance that participants appear to attach to them. It is imperative that these themes are relevant to the research questions (Braun & Clarke, 2012). In their paper on thematic analysis, Braun and Clarke (2012) suggest a 6-stage approach to thematic analysis, which was followed in the present research and will be outlined in the following section.

6.3.2 Analysis Process

Stage 1- Data Familiarisation

Braun and Clarke (2012) describe this stage as 'immersing one's self in the data'. Interviews were transcribed word-for-word from their recordings by the researcher. This rigorous method of transcription allowed the researcher to become immersed in the data. Following this, transcriptions were read through several times, and notes were taken around initial impressions of the data, focusing on general questions such as 'how does this participant make sense of their experiences?' and 'what assumptions do they make in interpreting their experience?' (Braun & Clarke, 2012).

Stage 2- Generating Codes

Braun and Clarke (2012) describe codes as 'the building blocks of analysis'. They provide a pithy summary of a potentially relevant portion of data. In the present research, coding was undertaken in six phases following the guidance of Saldaña (2013) in his coding manual for qualitative researchers. The following headings provide a description of each phase of coding.

1. **Structural Coding**

   Initially, 'structural coding' was used, meaning that interviews were split into main areas based on the topic that was discussed (e.g. all times that participants spoke about the physical demands of their roles were grouped together) (Saldaña, 2013). This allowed for discussions in different interviews on the same subject area to be compared to one another. For example, instances in which physical demands were discussed could be compared between the different interviews to gain a view of how participants tended to experience physical demands in their roles and how participant answers were similar or different from one another.

2. **Descriptive Coding**

   After interviews had been coded structurally, a second round of coding was undertaken. This time, a more detailed, descriptive method was used, and data was placed into categories that best described their contents. For example, if a participant said "I find climbing physically hard"- this could be coded as 'physical demands' and/or 'climbing'. If necessary, simultaneous coding was used, meaning that quotations were sometimes coded twice under different categories (Hashimov, 2015). This method gave an indication of what topics regularly 'came up' during interviews and what potential themes could be drawn from the data. It generated many different categories of coding due to the detailed nature in which each interview was coded.

3. **Pattern Coding**

   The third phase of coding involved examining the coding areas identified in phase 1 and considering how they could be placed into wider theme. For this, 'pattern coding' was used. This is a method designed to pull together codes from structural and descriptive coding to form more meaningful descriptions of groups of data. For example, if data had been coded as 'Stress due to conflict with colleagues' and 'difficulty coping with close living arrangements', this could be pattern coded as 'colleague relations stressor'.

4. **Latent Coding**

   This phase involved examining data at a latent level, meaning that psychological insight was sought from data, rather than just directly observable information (Braun & Clarke, 2013). For example, if a participant had said 'I like that I have freedom to plan when to have my breaks'- rather than considering this to just be about 'taking own breaks', this could be viewed as 'control over work' and viewed in line with theories of fatigue and control (e.g. Karasek, 1979).

Stage 3- Generating Themes

Stage 3 involved the process of using identified codes to construct themes. A theme is something that "captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the dataset" (Braun & Clarke, 2006, p.82).

Braun and Clarke describe this process as active, meaning that themes are generated or constructed, rather than discovered (Braun & Clarke, 2012). To generate themes and sub-themes (subcomponents of themes), codes were grouped together, along with relevant interview extracts and checked for relevance to the research questions and entire dataset.

Braun and Clarke (2012) state that there should be between 2-6 themes per 10,000-word report. However, as there was a practical need to gain an impression of multiple factors impacting participants' perceptions and experience of fatigue in this environment, a relatively large number of themes and sub-themes were constructed. To mitigate the potential negative effect of this, results were split into three parts, each addressing a different research question (e.g. part 1 focuses on perceptions of fatigue).

Stage 4- Reviewing Potential Themes

In this stage, themes were reviewed in relation to the research questions and entire dataset and their usefulness in line with these were considered based on the following criteria:

1. Whether the themes were representative of the dataset.

2. Whether the themes contributed significant understanding to participants' perception and experience of fatigue.
3. Whether the theme sufficiently highlighted a fatigue-related environmental factor that could either be addressed using this data, or that could be further addressed in study 2.

As this study included three different groups of participants, data was arranged into themes shared between two or more groups and those that were unique to the group in question, addressing research question 4.

Stage 5- Defining and Naming Themes

This stage involved creating a narrative around themes so that they can be used to communicate results in a clear and compelling manner (Braun & Clarke, 2012). As well as naming the themes, this stage involved selecting data extracts to be analysed within the report that would communicate the core meaning of the theme and fit into a wider analysis of the data.

A mixture of participant quotations and latent-analysis titles were used for theme names as this was deemed the most appropriate way to both provide an insight into participant's experiential understanding with an added layer of psychological analysis. Sub-themes were included to build levels of deeper understanding on wider themes.

Stage 6- Producing the Report

Themes were explored and placed into context with relevant literature in a report which will now be presented.

6.4 Part 3- Study 1 Results and Discussion

This section will include a discussion of study 1 findings, a qualitative investigation of wind industry employees' experiences of fatigue in their workplace. Findings will be split into three parts in line with research questions (see section 6.2.2).

6.4.1 Results and Discussion Guide

Results Group 1 (section 6.5) will consider perception of fatigue to address research question 1 *"How is fatigue perceived by technicians and their managers?".* This will first be addressed through an exploration of participants' mental model of fatigue. Following this, consideration of participants' attitude around fatigue will allow for reflection on how this may affect their experience of fatigue and their behaviour around its management.

After gaining an understanding of perception of fatigue, Results Group 2 will focus research question 2 *"what are the key factors that affecting employees' experience of fatigue in this working environment?".* Themes will be split into physical and mental/emotional for ease of understanding.

Finally, part 3 will explore recovery from fatigue, addressing research question 3, *"How well do participants tend to recover from fatigue in this environment and what factors affect this?".* Themes and discussion will be split into leisure time recovery and sleep.

Throughout the discussion, findings from the three different groups will be compared to one another, providing insight into research question 5, "*How does the experience of fatigue compare in three different wind industry environments?".*

To facilitate comparison between the three groups (in line with research question 5), themes that were found to be present in all groups will be discussed together and themes that were found to be unique to any of the groups will be discussed separately. The following presents a structure outline for each section and can be used as a reference point:

- Overview of shared and unique themes for each group
- Results and discussion of themes shared between all 3 groups
- Results and discussion of themes shared between 2 groups
- Results and discussion of themes unique to group 1
- Results and discussion of themes unique to group 2
- Results and discussion of themes unique to group 3

The following sections will consist of results and discussion of this study.

6.5 Results and discussion group 1- Fatigue Perception

Part 1 will focus on participants' perception of fatigue, what they think it 'is' and their attitude towards it. This will be split into two sections: 'mental model' of fatigue and attitude towards fatigue.

6.5.1 Mental Model of Fatigue

It is initially useful to consider participants' 'mental model' of fatigue. This refers to their they definition of fatigue and their interpretation of the process of becoming fatigued. This is important, both from a philosophical and experiential perspective. The present research is underpinned by the ontology of 'critical realism' meaning that 'reality' is heavily obscured by context and personal beliefs (see Chapter 5, section

5.2.6). Therefore, gaining insight into participants' perception of what fatigue 'is' helps to gain an impression of this nuance.

Additionally, as explored in previous chapters, fatigue is a generally ill-defined concept (see Chapter 2 for a wider discussion around this) thus, it is useful to gain an impression of how it is generally defined by participants before investigating the more practical factors surrounding its management. Finally, the way that fatigue is defined in working environments is often heavily dependent on environmental factors surrounding it (see Chapter 3 for a wider discussion of this), therefore an exploration of how each group defines fatigue will provide useful understanding of how fatigue is experienced within the working environments.

During interviews, participants were encouraged to share their interpretation of fatigue meant to them. At the beginning of each interview, participants were asked to explain how they would define fatigue before the researcher shared the definition used in the present research. This was done to gain an initial insight into participants' perceptions of what fatigue 'is' before it was influenced by the provision of any other definitions.

6.5.2 Overview of Shared and Unique Themes

Table 11- Fatigue Mental Model Themes

Theme/Sub-theme	**SOV**	**CTV**	**Onshore**
Theme 1- Fatigue is multidimensional and task dependent	**X**	**X**	**X**
Theme 2- Cumulative effect of fatigue- 'fatigue builds'	**X**	**X**	**X**
Sub-theme 1- Second week fatigue	**X**		

6.5.3 Theme 1- Fatigue is Multidimensional and Task-dependent

A notable finding surrounding fatigue perception in all groups was that participants emphasised the multifaceted nature of fatigue, both in its antecedents and experience.

In terms of experience, participants in all groups highlighted that fatigue was something experienced both mentally and physically as highlighted in the following quotation.

> *"mentally and physically drained...yeah that's my interpretation of it" [CTV participant].*

This suggests that participants' definition of fatigue is a holistic experience and not confined to the body or mind. This is consistent with the definition of psychological fatigue presented in Chapter 2 (see section 2.10) stating that fatigue is a state that can be influenced by a variety of factors including mental, physical or sleep-related stressors.

In terms of antecedents, participants in all groups highlighted the variable nature of fatigue, which is heavily influenced by the combination of demands experienced during that day, or the days leading up to their experience of fatigue as exemplified below in a quotation from a participant in group 1.

> *"yeah when I come off shift, I usually find I'm quite tired, depending on the shift, depending on the weather, depending on how much work we've done, it's variable" [SOV participant]*

The above quotation lists some of the many stressors that could combine to give rise to fatigue in this environment, ranging from the content of work tasks to the influence of the weather. This suggests that fatigue is highly dependent on environmental and task-related factors in this setting.

This notion is further supported by findings from a participant, who at the time of the interview was working in the office due to an injury. He compared fatigue experienced during days spent in the office to days working in the field, as illustrated in the following quotation.

> *"when I'm pottering around the office…it is quite 'energy sucking'… I'm not doing anything and the time goes so slow, I feel more tired when I'm in the office…But if I was doing a full week of climbing, I would be knackered doing that." [Onshore participant]*

This highlights the sometimes counter-intuitive nature of fatigue in that the participant expressed that he could be 'not doing anything' but still feel just as fatigued as he did after working in the field. This adds support to theories that view fatigue as a motivation moderator discussed in Chapter 2 (e.g. Boksem & Tops, 2008, see chapter 2 section 2.4.4). These theories rely on the assumption that fatigue is the result of a sub-conscious cost/benefit analysis favouring activities with higher intrinsic benefits. In this logic, fatigue would not necessarily be the direct consequence of high physical effort, but rather be highly associated with activities demanding allocation of cognitive or physical resource preventing an individual from pursuing activities with perceived intrinsic benefit. Therefore, the scenario described by this participant is an apt example of how the fatigue process would occur as it demands the allocation of cognitive effort and offers little control over allocation of activities.

Findings encapsulated in this theme suggest that fatigue is a holistic experience that can be caused and impacted by a diverse range of environmental factors. They highlight that these factors are not just those that obviously cause high strain, but could also be those that cause generalised, low-level feelings of low control or discomfort (e.g. repetitive office work), supporting motivational (e.g. Boksem & Tops, 2008; Robert. Hockey, 2013) and multidimensional (e.g. Hockey 1986; 1997; 2011; 2013 Earle, 2004; Earle, et al, 2015) conceptualisations of fatigue.

6.5.4 Theme 2- Cumulative Effect of Fatigue- 'Fatigue Builds'

A notable theme in from all groups was participants' descriptions of the cumulative effect of fatigue. This refers to the notion that fatigue is impacted by activities and demands over a longer period than just the immediately preceding day. Fatigue can be built over multiple days, weeks and months. This is highlighted in the following quotation.

> *"its sort of a build-up of, you know if you're doing like physical stuff day after day after day and you're shattered from it" [SOV participant]*

The cumulative nature of fatigue was addressed in Chapter 3 when discussing the impact of long working hours on fatigue (see Chapter 3, section 3.3.1). This discussion focused on the notion that longer working hours are likely to result in the experience of higher strain, thus causing compensatory control after-effects (Broadbent, 1979; Cohen, 1980; Hockey, 2013). It also highlighted that working consecutive shifts can cause a cumulative effect of fatigue as the individual is unable to recover from strain and therefore recovery its self becomes more difficult and requires longer rest time (Sonnentag & Zijlstra, 2008).

Findings from the present study indicate that it is not just working hours that cause the accumulation of fatigue, but the intensity of tasks undertaken throughout that day. Indeed, Sonnentag & Zijlstra (2008) highlight that the more intense a working day has been, the longer it will take to recover afterwards. Therefore, working periods consisting of intense tasks, high demands and long working hours both increase the need for longer periods of recovery and long working hours decrease the opportunity to obtain adequate recovery.

Findings from the present research highlight that participants categorised fatigue as a sense of tiredness that is often still present after a period of recovery. This is further illustrated by the following quotation from a CTV participant discussing their difficulty to obtain adequate recovery after an intensive work period.

> *"eventually you get to a point where your body just starts to get tired and fatigued anyway it doesn't matter how much sleep you have" [CTV participant]*

This indicates that as a work period progresses, available time for recovery becomes less adequate for overcoming fatigue. This is supported by research into the cumulative effect of working 12-hour shifts conducted by Brennan and Thompson (2019). Their study compared performance on cognitive and physical tasks in nurses after one 12-hour shift to performance after three 12-hour shifts. They found a significant decrease in performance on cognitive tasks after three shifts compared to just one shift, thus highlighting the cumulative effect of fatigue exacerbated by long working hours and is particularly pertinent due to its findings around decreased cognitive performance, indicating that performance and safety could be compromised with consecutive days spent on shift.

This also challenges the notion that fatigue can be managed through adequate sleep-time provision alone (see chapter 2, section 2.6) and suggests that other factors would need to be considered to manage fatigue effectively in this environment.

6.5.5 Sub-theme 1- Second Week Fatigue (Unique for Group 1, Offshore SOV)

Participants in group 1 tended to associate fatigue with the second week of their on-shift time. The second week was described as a time when things *"start to go downhill"* due to the accumulation of fatigue during the shift and experience of living offshore. This was said to manifest in raising tensions between technicians as illustrated in the following quotation.

> *"so you see it sort of… heads down-hill towards the end, that's when people are tired and that's usually when you get a little bit of someone rubbing up the wrong way" [SOV participant]*

Research conducted in the oil and gas industry with technicians who, like this group, live offshore for two weeks at a time supports the notion that fatigue is particularly prevalent in the second week of the shift. Riethmeister et al (2019) conducted a study with 42 technicians consisting of twice daily 'fatigue' assessments and sleep analysis over a two-week shift period and found that by day ten, more than a third of participants reported 'high risk' levels of fatigue. They postulated that as the shift progressed, participants' ability to cope with the demands of their work decreased, due to increasing chronic sleep deprivation.

Although highly relevant, Riethmeister et al's study relies on a definition of fatigue that is focused almost solely on sleep and does not investigate the impact of intensity and difficulty of work tasks and other environmental factors. Accumulation of fatigue is explained by the fact that participants tended to experience shorter periods of sleep as their shift progressed, losing an average of 92 minutes per night, resulting in an average sleep time of 6 hours 28 minutes compared to 8 hours 14 minutes prior to beginning their shift.

Their measure of subjective 'fatigue' was the Karolinska sleepiness scale (Torbjörn Åkerstedt & Gillberg, 1990). As discussed in chapter 2, the present research defines fatigue and sleepiness as separate, but related states (see section chapter 2, section 2.6.9). Therefore, like many industry-based investigations of fatigue, Riethmeister et al's definition of fatigue is not attuned to the present research. Their study is nevertheless useful as it demonstrates how offshore employees are likely to be vulnerable to sleep related fatigue in the second week of their shift.

This sub-theme indicates that SOV technicians could be particularly vulnerable to the cumulative effects of fatigue discussed in theme 2. This is potentially due to their longer shift periods (compared to the other groups) that include consecutive 12-hour shifts, the requirement to live offshore and the intense social demands in this environment (this will be discussed in section 6.6.10). It is important to further investigate the impact of these unique factors on fatigue and wellbeing in this environment.

6.5.6 Attitude towards Fatigue

After considering how participants define fatigue (what it 'is'), it is important to investigate their attitude towards this experience (how they feel about it). Personal attitudes around fatigue can have a significant impact on how it is experienced and managed.

This notion is supported by Ajzen's influential Theory of Planned Behaviour (TPB) (1991). This model purports that performance of a behaviour is the joint function of attitude (belief that behaviour will have a positive or negative outcome), subjective norms (how an individual feels their behaviour will be perceived by those around them) and perceived behavioural control (how easy or hard it is to display a behaviour or act in a certain way). This theory has been supported as an apt way to explain motivations behind behavioural trends in a variety of situations (Armitage & Conner, 2001). Particularly relevant are investigations into how the TBP can explain safety behaviour. In their investigation into risk taking behaviour in drivers Rowe et al (2016) found that The TPB explained between 41% and 69% of the variance in intentions to perform these behaviours.

Especially relevant is research that uses the TBP to investigate why individuals continue to drive while fatigued. In their study on 214 drivers, Jiang et al (2017) found that subjective norms were the most significant predictor of fatigued driving behaviour. This supports the notion that individuals' perceptions of how others will react if they display certain behaviours may impact fatigue related perception and behaviour.

As well as being congruent with relevant safety behaviour theories, investigating attitudes and subjective norms corresponds with the critical realist philosophy of the present research, as it aims to gain insight into the ‘prism’ obscuring experiences fatigue. It also supports the pragmatic methodology as negative perceptions around fatigue management can be addressed through interventions.

6.5.7 Overview of Shared and Unique Themes

<u>Table 12- Fatigue Perception Themes</u>

Theme/Sub-theme	SOV	CTV	Onshore
Theme 3- ‘You just get on with it’- Fatigue Stigma	X	X	X
Sub-theme 2- ‘I don’t want that discussing’ Stigma around Mental Health	X	X	X
Sub-theme 3- Suffering in Silence- ‘It’s not macho to say that you’re tired’	X	X	X
Sub-theme 4- ‘Never Say Die’- Military Norms, Culture and Values	X		

6.5.8 Theme 3- ‘You just get on with it’- Stigma around Fatigue (all groups)

Findings from all three groups suggested that a central attitude towards fatigue was the imperative to *‘just get on with it’*. The tone and phrasing around this indicated that a stoic mentality was perceived as necessary to cope with the demands of their roles. Findings around this were consistent across the groups as illustrated in the following quotations.

> *“You just get into that mentality of getting on with it and you get used to it, it becomes the norm” [SOV participant]*

"There were days when I had a cold and I could have done with the day in bed, but I think that's me personally...I'll just get on with it" [CTV participant]

"I don't think anyone turns around and says 'I'm not feeling great, I need a break' or anything like that…it's difficult" [Onshore participant]

This finding is echoed in other qualitative studies investigating perceptions of fatigue in workplaces. In their investigation into fatigue in medical students, Taylor, Raynard and Lingard (2019) found that despite the knowledge that fatigue threatened their personal health and safety of their patients, medical students highlighted the pervasive culture of stoicism around fatigue. They discussed the perception that fatigue was an immutable reality of their experience, but openly experiencing it was nevertheless seen as a threat to their professionality. Qualitative studies in this area have mostly focused on individuals working in medical settings, such as doctors and nurses. This is perhaps due to the prevalent culture of excessive working hours in the medical sector, particularly for junior members of staff (Greig & Snow, 2017) (see chapter 3 section 3.2.4 for a wider discussion around this). However, findings from the present research indicate that a culture of non-admittance of fatigue is also evident in the present sample.

During interviews, it became apparent that participants experienced stigma around 'admitting' to feeling fatigued, as is illustrated in the below quotation.

"there seems to be a stigma attached to it (ok) even though it's never stated, it's something I think you make up in your own head, 'I don't want to be the first person to say I'm tired' even though you might know your whole team are all

absolutely shattered, nobody wants to be that first person (yes) the whole sort of group mentality thing isn't it?" [SOV participant]

Stigma is *"a mark or sign of disgrace usually eliciting negative attitudes to its bearer"* (Thornicroft, Rose, Kassam, & Sartorius, 2007, p.192). A key reason for existence of stigma is lack of knowledge around the stigmatised issue leading to misconception (Thornicroft et al., 2007). The present results indicate that this could be an important causational factor for the stigma around fatigue in the present sample. This lack of knowledge was demonstrated particularly well by an SOV participant as is highlighted in the following quote.

> *"but it's not always the easiest, you know, to see, particularly, I haven't particularly had any fatigue training as such... this project's sort of trying to obviously bring it into the industry and so it's looked at… I don't think there's any policy for *company name* in place" [SOV participant]*

Reasons for the existence of this stigma were further explored with participants. A prominent factor in these discussions was fear of being branded as 'lazy' by colleagues. This illustrates a misconception likely born from a lack of education and knowledge around fatigue. This is illustrated in the following quotation which shows a participants' response when they were asked why they thought people in their workplace were reluctant to openly discuss fatigue.

> *"because people don't want to seem like they're lazy, people want to get the job done, if someone thinks I should be able to do something, I'd like to prove them right and say 'yeah I can do that" [SOV participant]*

Fatigue stigma has been explored in other qualitative studies of workplace fatigue. Findings from Steege and Rainbow (2017) presented the model of 'Supernurse' based on findings from their qualitative investigation into fatigue experience by nurses. This centred on the belief that participants needed to operate with superhuman resilience to fatigue. A particularly relevant aspect of the 'Supernurse' model is the 'cloak of invulnerability', described by Steege and Rainbow as *"a sense of pride in working long hours and not resting or sleeping, despite the awareness of multiple health, safety and wellbeing issues caused by work related fatigue" (p.24)*.

This is congruent with findings in this theme and presents an issue for fatigue management, both individually and at an operational level. The stigma around 'admitting to fatigue' is likely to result in individuals delaying fatigue reporting until it is past the point that it can be managed through simple interventions. Rather, the present findings suggest that individuals are likely to wait until their experience of fatigue becomes unbearable. By this point, the safety and health risks of working in such a state will have already been present for a significant amount of time and interventions to address fatigue are likely to involve more time and resources.

Multiple studies have supported the notion that stigma can be reduced through the use of educational interventions (e.g. Gronholm, Henderson, Deb, & Thornicroft, 2017; Hanisch et al., 2016; Kosyluk et al., 2016). This indicates that educational training in fatigue and related human factors may help to reduce stigma in this work environment.

6.5.9 Sub-theme 2- 'I don't want that discussing' Stigma around Mental Health (all groups)

When discussing stigma around fatigue, a wider stigma around the discussion of mental health (MH) was often highlighted by participants. There were similarities in perception of these two concepts as neither can be obviously seen and both are synonymous with a lack of understanding. This stigma was described by an SOV participant and is illustrated in the following quotation.

> *"people want to be managed properly and respectfully and with dignity…but at the same time they've still got the stigma against mental health" [SOV participant]*

The above quotation is taken from a discussion around technicians taking time off work due to mental health issues and the negative attitudes about this within the team.

Participants highlighted that this work environment is particularly risky for those experiencing mental health issues due to isolated working and living arrangements (in the case of SOV participants) and the presence of safety hazards. However, many described a culture of avoiding the discussion of openly discussing mental health issues and some highlighted that they felt ill-equipped to respond appropriately when faced with colleagues' mental health issues.

The following quotation is from a CTV participant who discussed the impact of a lack mental health knowledge or training when faced with colleagues experiencing MH difficulties in their work environment.

> *"I've been on turbines with people who look ok, but they're going through divorces or their child's not very well and they might not say anything to anyone, but the next minute, they're breaking down in front of you…and you have to deal with that and you haven't got any training, you haven't got a clue what to do, and it's alright when people are saying 'you'll know what to do', you don't…I suppose you just be a human being…but…" [CTV participant]*

The statement *"I suppose you just be a human being"* is particularly pertinent as it suggests that supportive behaviour is often perceived as intuitive. However, this often is not the case in this environment.

There is growing awareness around the prevalence of mental health issues in workplaces. In 2019, the HSE reported that stress, depression or anxiety accounted for 44% of all work-related ill health cases and 54% of all working days lost to ill-health (Health and Safety Executive, 2019). It is likely that these figures are under-reported due to the wide-spread stigma surrounding mental health, as highlighted by Bharadwaj, Pai and Suziedelyte (2017). They demonstrated this through a comparison of self-reported mental-health conditions and medical records in over 250,000 individuals where they found that mental health ailments were significantly more likely to be under-reported than physical health conditions. Perhaps unsurprisingly in light of the stigma previously described findings from the present study highlight that mental health issues are likely to be under reported in this work environment, as illustrated in the below quotation.

> *"I think people would use that [physical injury] as an excuse to stay off work if they have mental health issues…I don't know…they'd use that as a 'get out of*

jail' thing rather than admitting to mental health issues…they'll probably use that instead" [Onshore participant]

In this extract, a participant describes using a fictitious injury as a *"get out of jail thing"*. This implies an expectation that the consequences of reporting mental illness would be negative. The notion of *'admitting'* to mental health issues also suggests shame and stigma. As with fatigue, a risk is that employees fail to report MH issues until they become unbearable, this puts them into a uniquely dangerous position due to the high hazard environment. This risk was highlighted by discussions of instances where technicians had taken or attempted to take their own lives while at work. In the extract below, an onshore participant discusses the ease and speed at which an individual could do this.

> *"it's very easy- it's easy to hurt yourself or kill yourself in a turbine y'know. You've got thousands of volts, and you're 80 metres up. It's a dangerous place to work" [Onshore participant]*

Indeed, research has supported the notion that male-dominated, high risk working environments such as this are synonymous with higher rates of suicide (Klingelschmidt et al., 2018; Milner et al., 2017; Turner et al., 2017). A combination of cultural stigma around MH and access to immediate means to end one's life (e.g. working at height) are cited as major reasons for this. This highlights the importance of interventions focused on challenging the stigma around MH and related issues in the wind industry environment as well as training aimed at equipping employees to effectively support themselves and one another when experiencing mental health issues.

Fatigue and mental ill-health were perceived to be linked concepts, and both were treated with similar attitudes of danger and stigma. This is likely due to the unseen nature and vulnerability associated with these states worsened by the lack of knowledge and education surrounding both concepts. These factors are likely exacerbated by participants' demographics that make them particularly vulnerable to the stigmatisation of mental ill-health and other related issues as discussed in the following sub-theme.

6.5.10 Sub-theme 3- Suffering in Silence- 'It's not macho to say that you're tired' (all groups)

The wind industry is male dominated, with women only making up 21% of its employees (Renewable Energy Agency, 2019). Women are likely to be even less represented in technician roles due to the extreme environment and lack of flexibility. The participant sample in the present study is representative of this, as male participants outnumbered females at a ratio of 2:13. Many participants equated the stigma around fatigue and mental health to the male-dominated nature of their working environment, as illustrated in the quotations below from participants in all three groups.

> *"I think it's the tail end of that generational thing where men aren't allowed to feel things" [CTV participant]*

> *"you've kind of got that macho image, you know, if someone says 'just get on it got on with it will you? stop whingeing' sort of attitude it's hard to break" [SOV participant]*

“it's a very macho industry. And it often gets sort of, swept under the rug and the "I'm tough", y'know the tough guys, and there's a very military attitude. Yeah, it's 'they're tough and they get on with it'” [Onshore participant]

A notable theme in discussions was that participants described a pressure to fit into a stereotypically masculine environment and that openly discussing perceived weaknesses such as fatigue would threaten this. It was highlighted that this could manifest in technicians becoming competitive about how much demand they could withstand. This was illustrated by an SOV participant in a discussion around the reporting of a fatigue risk.

“the other team absolutely kicked off about that and they said "we've done more than you and we're not complaining about fatigue" [SOV participant]

This suggests negative cultural aspects present in this work environment that must be addressed for effective fatigue management. Perhaps because of this negative culture, there was a pervasive view that male employees felt the need to *“suffer in silence”,* as illustrated below.

“I don’t want to sound sexist but they’re mainly men on there, so I think men suffer just as much as women do, but women are more likely to talk about it than men” [SOV participant]

Indeed, research indicates that men are particularly affected by mental health stigma (Bharadwaj, Pai, & Suziedelyte, 2017; Clement et al., 2015). Although statistics show that around half as many men experience depression compared to women (Baker, 2018), the rate of suicide for men is significantly higher than for women. In 2018, the male suicide rate was 17.2 in every 100,000 compared to 5.4 for women (Office for

National Statistics, 2019). This indicates that men are less likely to seek effective support for MH issues and are more likely to live with MH issues until they become unbearable. Research suggests that men are more likely to have lower levels of mental health literacy than women (Hadjimina & Furnham, 2017). This indicates that men are more likely to have trouble in recognising signs of mental ill-health in themselves and struggle to communicate about it to others, thus supporting findings in the present study.

Research conducted in male-dominated work-places such as farming (Alston & Kent, 2008) and the military (Finnegan et al., 2010) have highlighted their increased levels of MH stigma. In their review of masculinity and occupational health and safety in high hazard working environments, Stergiou-Kita et al (2015) discuss how findings often indicate that men feel the need to stifle pain in order to 'prove' their worth and masculinity. This often not only manifests in decreased reporting of MH issues, but also in the normalisation of risk-taking behaviours in the workplace (Stergiou-Kita et al., 2015).

In the SOV group, discussions around risk taking often centred around the presence of two female technicians within the team. This was attributed to a declination of risk-taking behaviours as illustrated in the following quotation.

> *"I think it's [having female members] had a calming influence on the team, I think we've got a more thoughtful team, they want to know why they're doing something, the other shifts tend to be more like "let's just go and do it, we want to do a Max of 10 services today, well let's do 12! Whereas our shift would be*

more like "10? ok that's quite difficult if you're going to do it in this context ok... what if we did 9? how would you feel if we did 9?" [SOV participant]

Interestingly, the wind industry have recently engaged in efforts to promote greater representation of women in the field (Department of Business Energy and Industrial Strategy, 2019; McMaster, 2020). It would be useful to examine the impact of this on fatigue and mental health reporting as well as risk taking behaviour in further research.

6.5.11 Sub-theme 4- 'Never Say Die'- Military Norms, Culture and Values (SOV Group)

In the SOV group the fact that many technicians had military backgrounds was often discussed in relation to fatigue. In this group, most participants (4 out of 5) had a background of working in the military. A large proportion of participants in the other groups also had military backgrounds and often mentioned their time spent in the forces during interviews. However, this was not found to be as prominent when linking discussions to their perception of fatigue as it was in the SOV group. This is perhaps because SOV participants are required to work away from home in conditions comparable to what they would have experienced in the military, as illustrated below.

"its quite similar in the erm the sort of work that I do, I suppose the work's a little more physical than I was doing in the RAF, but erm the environments slightly different, but even then I was working in all sorts of extreme environments as well, except more deserts and less sea I suppose"

Ex-military personnel are likely to make up a large proportion of employees in the wider wind industry, as many companies offer initiatives to encourage those leaving the armed forces to transition into technician roles (Energy & Utility Skills, 2018). When discussing their attitudes towards fatigue and mental health, many participants mentioned that they had been highly influenced by their time spent in the military. Some linked this to the development of a dismissive attitude towards fatigue and MH in themselves and others, as is demonstrated below.

> *"I think my background in the forces as probably has a negative effect on that [mental health] because you've kind of got that macho image … I've seen people that are struggling and I just 'ah just get on with it will you, stop whinging' that sort of attitude... and then I think 'maybe I shouldn't have been like that'"*

They also described a 'never say die' mentality that they had developed during their time in the forces, which often meant that completing a task would take priority over their own wellbeing.

> *"I think the biggest thing is about a work ethic, you're just so used to getting on with it, it doesn't matter how difficult the task is, you never throw the towel in, you'll find a way to do the job"*

When asked how they felt this attitude impacted their fatigue and wellbeing, some reflected that it is likely to add to their experience of fatigue. However, this was underscored with a perception that it was nevertheless their responsibility to go 'above and beyond', as illustrated in the below quotation.

> *"(how do you think that impacts on fatigue?) That does impact in that we take more on, rather than shedding it....we take it on... probably less likely to say no… so erm I think we are probably adding to it and we probably know we're adding to it but we kind of look at it as our responsibility to take it on"*

This demonstrates an issue in that participants are likely to take on more work than sensible, inducing higher levels of fatigue, but are unlikely to discuss and acknowledge fatigue when it does occur. This issue has been demonstrated in wider research which has supported the notion that military culture is categorised by the ideation of 'toughness' and the ability to withstand pain with little complaint or support (Paskell et al., 2019; Tanielian et al., 2008). This is unsurprising when considering the demands regularly faced by military personnel including Intense physical exertion, sleep deprivation, caloric deprivation and frequent dietary changes, not to mention the stress of life-and-death decisions (Weeks et al., 2010).

Multiple studies have indicated that members of the armed forces are particularly vulnerable to mental health stigma (Langston et al., 2007; Rona et al., 2007; Sharp et al., 2015). This is often attributed to a high emphasis placed on stereotypically masculine behaviours such as and self-reliance causing military personnel to avoid seeking help for psychological issues such as stress and PTSD (Greenberg et al., 2003). Often when surveyed, soldiers cite a fear of losing their jobs if they were to seek help for psychological distress (Cawkill, 2004). This suggests that the present group of participants are particularly vulnerable to the potential effects of the 'macho' military culture on their likelihood to manage and report fatigue and MH issues even though they are no longer in a military work environment.

Some participants held the belief that they had a higher resilience to fatigue because of time spent in the military. Upon further exploration, this belief hinged on two components. One was that the demands of their current role were perceived to be lower than previous military roles. Therefore, they held the belief that their ability to deal with the comparatively smaller demands in their current role was higher, as illustrated in the below quotation.

> *"in the Navy when I was away I don't have a phone signal the internet was like, pretty much non-existent you struggle to get emails on that internet so yeah in contrast to the navy and past jobs it's really good"*

Experience of past adversity may provide ex-military participants with a belief that they have a higher ability to endure present challenges. This sense of belief is likely to contribute to an attitude of perseverance in their current roles. Though good for short term productivity, this could add to a culture of ignoring fatigue and adverse health issues thus causing issues in the longer term. The second component was a belief that they had developed an ability to rest and recover in uncomfortable settings, as illustrated below.

> *"I'm a typical soldier, so I can sleep anywhere, I can sleep on a washing line"*

Anecdotally, there is a common belief that soldiers find it easier to sleep in small pockets of time and uncomfortable settings. This makes logical sense when considering that their work environment is synonymous with sleep deprivation (Williams et al., 2014) making them more likely to find it easy to sleep whenever they have the opportunity to do so. However, there is a question of whether this becomes a learned ability that they can employ in times when they are not as sleep deprived in their post-military lives. This would be an interesting avenue of research to explore further and has the potential to be particularly beneficial when considering recruitment for working environments that may make sleep more difficult.

It makes sense when considering these factors that the wind industry would favour the recruitment of ex-military personnel, particularly in the SOV-based environment. However, the present results highlight that the need for training and support is perhaps even more important with this demographic. An unfaltering work ethic and ability to withstand discomfort are important in military work environments and to an extent, the present work environment. However, unlike soldiers, wind industry employees are not required to face extreme life or death situations where food, rest and comfort are scarce. It is important to be able to face mental, physical and emotional challenges in their current roles, but to do this with a focus on long-term stability and a careful attitude towards their need for rest and recovery if their roles are to be sustainable in the long term. There is a danger that a person with 'military values' and high belief in their own resilience to fatigue will eventually 'burn out'. Therefore, education around human factors and a supportive culture are even more important for ex-military employees.

6.5.12 Results Group 1 Summary

Group 1 investigated perception and attitude around fatigue. Findings around fatigue perception demonstrated that participants in all three groups experienced fatigue as something that is task dependent and multidimensional. This indicates that their experience of fatigue is varied and complex and can build over a significant period as their need for recovery increases and is not appropriately fulfilled.

When exploring attitude towards fatigue and related factors, it became clear that there was a pervasive stigma surrounding fatigue in all three groups. This was often discussed alongside mental health which was regarded with similar attitudes of stigma. Reasons for this stigma were explored and included the male dominated nature of this work environment and an expectation to display typically masculine behaviour resulting in a perceived need 'suffer in silence' and take higher safety risks.

As well as the obvious impact of taking higher safety risks, attitudes such as this could lead to issues being ignored until they become severe and more difficult to address. More specifically for SOV participants, a focus on military norms, culture and values was highlighted as a reason for 'pushing through' fatigue due to a higher level of perceived resilience and a need to 'go above and beyond'. Though good for short term productivity, this is likely to cause issues for fatigue and wellbeing management in the longer term.

Findings emphasised that fatigue was a difficult and emotive subject for participants in all three groups and highlighted the need for further research, training and support in fatigue and mental health awareness.

6.6 Results Group 2- Environmental Demands

Results Group 2 will focus on environmental demands. This will address research question 2 and will provide a basis of knowledge for study 2 (a quantitative analysis of fatigue and environmental demands) by providing participant-led data about the most prominent environmental demands in this work environment.

Part 2 will be split into two sections, each investigating a different 'type' of demand (physical, mental/emotional). However, it is important to note that demands affecting individuals in one way normally have further impact in other ways (e.g. physical demands can add to the experience of mental fatigue). Therefore, it is not organised in this way to imply that physical stressors will not have an impact on mental or emotional fatigue, but rather demands have been split in this way for ease of reading and understanding.

6.6.1 Section 1- Physical Demands- Overview of Shared and Unique Theme

Table 13- Overview of Physical Strains Themes

Theme/Sub-theme	SOV	CTV	Onshore
Theme 4- Climbing- 'It's Lung Busting'	X	X	X
Theme 5- 'Strenuous, repetitive work'- Servicing	X	X	X
Sub-theme 5- Lifting and Shifting	X	X	X
Theme 6- 'Getting Bashed about on the Boat'		X	

6.6.2 Theme 4- Climbing – 'It's Lung Busting'

Climbing was the most mentioned physical demand by participants in all three groups. This supports research using larger sample sizes (Garrido, Mette, Mache, Harth, & Preisser, 2018, see chapter 4 for more detials) and is unsurprising given the magnitude of this physical task which involves climbing a vertical ladder for between 60 to 120 metres. Technicians in all three groups described the intense physical effort associated with this task, as illustrated below.

> *"It's lung-busting, to be honest. We range from 40 meters on an external tower to 85 meters internally. Y'know, you're harnessed up, you've got safety equipment on, helmets on and it's a very physical activity, that even the lads in their twenties don't like doing it… it's the worst part of the job. "[Onshore participant]*

“(how do you find climbing?) tough, tough, it never gets easier, fitter you get, the quicker you climb… it sort of never gets easy” [SOV participant]

“It’s the physical exertion…catching your breath at the top is quite hard to do” [CTV participant]

Climbing demands were different between onshore and offshore technicians. Onshore technicians described climbing as a constant and unavoidable task. Due to the smaller size of the turbines they worked on, hardly any were fitted with lifts and so they would normally be required to climb at least one turbine per working day meaning that this demand was constant and relentless.

Offshore participants encountered this demand less often as most larger turbines were fitted with lifts. However due to mechanical faults and safety concerns, lifts were often disabled forcing technicians to climb around 50% of the time. Offshore technicians would therefore climb less often but would have to climb higher turbines meaning that this demand was significant and often occurred when technicians were less used to experiencing it.

Undertaking long vertical climbs in this kind of regularity is something that is in many ways unique to the wind industry working environment. Because of this, much of the limited human factors research in this industry has focussed on vertical climbing (Barron, Burgess, Cooper, & Stewart, 2018; Barron, Burgess, Cooper, & Stewart, 2017; Milligan & Tipton, 2018; Stewart & Mitchell, 2018). This research is, however, in early stages as most studies are conducted in experimental conditions with small sample sizes as discussed in chapter 4 (see section 4.4.3). There remains to be a lack of understanding about the demands of vertical ladder climbing in operational practice with physical fitness tests based on industries with pitched ladder climbing which is less physically demanding (Barron, 2020; Preisser, McDonough, & Harth, 2019).

When describing the effects of this demand, participants in all three groups described an initial surge of adrenaline post-climbing followed by a full range of fatigue-related after-effects including physical, mental, emotional fatigue and sleepiness as is illustrated by the following quotations.

Physical fatigue

> *"by the end of the week it was…it hurt just going up the stairs at home, it takes a while for your legs to recover" [CTV participant]*

Mental fatigue

> *"If you go to a turbine with a lift you're like 'right, sweet, that's it let's go' and you get straight up, whereas if you've got a ladder, you'll wait about a bit and you're like "ooh no, I don't want to do this, I can't be bothered"[Onshore participant]*

Emotional distress and fatigue

> *"I don't really get stressed to be fair…I get down…(what makes you feel like this?) If I'm having to climb all the time." [Onshore participant]*

Sleepiness

> *"the amount of times I've climbed a turbine and laid there [in the nacelle] and nodded off" [Onshore participant]*

As well as this, many participants highlighted that consistent climbing had an extremely detrimental impact on physical injury. It was emphasised that climbing caused and worsened injuries and meant that a small injury could become debilitating to their work, as illustrated below.

> *“It's demanding, it's really demanding you know. There are injuries, you know. We have a lot of bad backs, I've got a bad back personally, and it might not be through this specifically, but it doesn't help, and it's the physical nature of the job.” [Onshore participant]*

It is important to emphasise that even without climbing, technicians’ roles would still include a multitude of physical demands, therefore climbing is a demand that considerably adds to this physical load rather than being the only physical demand that technicians are required to endure.

This impacts on both personal wellbeing and the ability of technicians to perform in tasks associated with their roles. This was demonstrated on a physiological level by Stewart and Mitchell (2018) who investigated the impact of vertical climbing on grip-strength in typical tasks required in technician roles. They found that climbing had a significant negative impact on grip strength. This highlights that although climbing is required simply to ‘get’ to their area of work, it is likely to have a significant impact on technicians’ ability to undertake work tasks.

There are approaches that could be taken to reduce climbing demand. Namely, the employment of ‘climb assist’ (a device that is able to bear the weight of an individual while climbing) has been shown to drastically reduce its physical demand (Barron et al., 2017). The potential benefits of climb assist were mentioned by multiple onshore participants, who highlighted that it would drastically increase their motivation at work.

However, the employment of climb assist devices is associated with significant costs and logistical difficulties. Organisations are unlikely to invest in this without clear and undisputable evidence in their support. Therefore, there is an imperative to employ large scale research in this area to investigate their benefits more thoroughly.

Although some participants emphasised that climbing *'never gets easier'*, others highlighted the adoption of good climbing technique significantly reduced the exertion and fatigue associated with this task, as illustrated below.

> *"its about technique if you pick up a good technique it's easier. I think you'll find a lot at the start they'll be all climbing with their arms…you need to trust your kit, lean back, arms on the ladder but not holding the weight and it's literally all in your legs" [Onshore participant]*

This indicates that delivering training on optimal climbing technique early in technicians' job roles could be a relatively low-cost intervention to improve fatigue management around climbing demands.

Climbing demands in this industry are large and unprecedented. Although research has begun to address this, larger scale studies are required to foster change in organisational practice. Findings from the present study and wider research in this area indicate that interventions should focus on the potential employment of climb assist, work planning, re-addressing physical standards and focussed training initiatives.

6.6.3 Theme 5- 'Strenuous, repetitive work' Servicing (All Groups)

Participants in all three groups highlighted the intense physical demands associated with servicing wind turbines. Servicing is a major aspect of 'scheduled maintenance' and is normally carried out annually for each turbine (Hassan, 2013). Servicing is a regular task for wind technicians, particularly during the summer months when most scheduled maintenance takes place (Hassan, 2013). A service will normally take around 12 hours to complete meaning that technicians will spend their whole working day on the turbine undertaking this task.

Due to the formulaic nature of this work, most participants described this task as a physical demand rather than a mental one, as exemplified below.

> *"I think servicing is very, very physical whereas the troubleshooting is something that could just be switching a switch on or replacing a fuse" [SOV participant]*

Offshore participants explained that as they usually work in teams of 7-9 on large turbines, it is often most efficient for each technician to undertake one specific task (e.g. replacing bolts) throughout the duration of the service, meaning that tasks were often repetitive and lacked variety. Participants in these groups emphasised the intense physical burden of the repetitive nature of these tasks, an example of which is tightening bolts with a heavy tool in the cramped environment of the turbines' generator as illustrated below.

> *"you're in the generator which is very cramped and small and you've got to like tighten bolts as you go you're up hauling round this big tool…and like I say, that's quite tiring" [SOV participant]*

Indeed, research suggests that repetitive activities cause significant physical fatigue due to their consistent use of the same muscle groups (Nordander et al., 2009; Tse et al., 2016). Perhaps in part because of this, research focusing on wind technicians has found that they are more at risk of musculoskeletal issues than the rest of the population (Jia et al., 2016).

Participants in all groups described how consecutive services eroded their stamina and ability to deal with physical strain due to aching muscles and minor injuries sustained during previous days' services as highlighted in a quotation from an SOV participant.

> *"waking up in the morning and having all these aches and pains and scrapes and bruises, you know, I know full well that they're going to be there for the day and just feeling less physically able to do the things that I did the day before and the day before that…just having less stamina" [SOV participant]*

Participants also highlighted the physical demands of working in turbines due to confined spaces and extreme temperatures which was explained particularly well by an onshore participant.

> *"Well they're like ovens in the summer and they're like freezers in the winter. They're the two extremes, and they're wet and cold and they're not nice places to work to be fair." [Onshore participant]*

Interestingly, when asked how many consecutive services they could undertake without fatigue becoming a major issue, participants in all groups indicated that five services would be their limit. An SOV participant explained the dangerous consequences of undertaking consecutive services beyond this limit with an anecdote about a cognitive lapse that they experienced leading to a serious safety issue, as illustrated below.

> *"I went to get on the crew transfer vessel and I hadn't even put my lifejacket on, I thought I'd put it on earlier and someone said to me 'you haven't got your life jacket on' and I was like 'yeah I have' and I'd not put it on because I was…my mind, my body was sort of tired, fatigued from the previous 5 days so I just, yeah I just, it slipped my mind" [SOV participant]*

This participant went on to explain that he reported the issue and his team integrated a work planning procedure around servicing in response to this meaning that wherever possible technicians would not be asked to undertake more than five services in a row.

It is encouraging that this team responded in a pro-active manner. However, this also highlights the lack of widespread guidance around management of this intensely physical activity within the industry. It would be beneficial for the impact of this task to be researched and for research-based guidance to inform fatigue management plans within the industry on a wider scale.

6.6.4 Sub-theme 6- 'Lifting and Shifting' (All Groups)

Participants in all groups emphasised that manual handling caused significant physical strain. Although they do have access to cranes and other lifting aids, participants described these demands as being unavoidable when completing tasks in the turbines due to the intricate nature of tasks and cramped conditions within the turbines preventing the employment of lifting aids. The nature of these demands could come in the form of having to consistently handle and use heavy tools, as discussed in the previous theme and further emphasised in the quotation below.

"stretching blades can be quite tiring because you're on your knees all day and the pumps and the machinery that you need, you have to move in and out all day and its quite heavy, it's like 30 kilograms" [SOV participant]

The above quotation highlights the magnitude of the regular manual handling demands experienced by technicians in this environment. Manual handling tasks could also come in the form of having to 'shift' or manoeuvre heavy parts and equipment, as illustrated below.

"I think the hardest thing we do is moving the gearboxes, they're 70-80 kilos, lugging those around up there is hard work…I think that's the biggest cause of injury, twisting while lifting…there's instances where there's no way around it, we do what we can but sometimes we've got to man-handle it" [Onshore participant]

The above quotation empathises the risk of injury when performing these tasks due to cramped conditions within the turbine. Indeed, fatigue caused by other demands in this working environment could make the risk of a manual handling injury even higher when considering that fatigued individuals are more likely to take shortcuts in their work in pursuit of their main objective (see chapter 2 section 2.10.1for a more detailed description of this). If this occurs during a manual handling task, it could result in significant injury. Therefore, manual handling both causes fatigue and increases the risk of injury from undertaking it while in a fatigued state.

The risks of manual handling in physical workplaces such as this are well known (Antwi-Afari et al., 2017; Klussmann et al., 2017) and wind technicians receive specific training on manual handling (GWO, 2019). However, the impact of manual handling in the confined working environment of turbines has not been studied. Therefore, this remains an under-investigated demand that is likely to significantly contribute to fatigue and potentially cause serious injury.

6.6.5 Theme 6- 'Getting Bashed about on the Boat' Rough Transfers and Seasickness (CTV Group)

CTV Participants highlighted rough transfers as major source of fatigue. It is logical that this finding would be more prevalent for CTV than SOV participants, as they are required to undertake much longer transfers, usually taking between one and three hours.

Long transfers were described to have an interesting and varied impact on fatigue that was heavily dependent on weather and sea conditions. Participants conveyed that during times of good weather and calm seas, transfers were an opportunity for rest and recovery.

> *"it was good working offshore because you knew that after about half an hour you can be back on the boat and get your head down a bit and go to sleep"*

However, in temperamental sea states, participants described experiencing a variety of negative symptoms, particularly fatigue. These descriptions were conveyed with a sense of confusion, as participants struggled to understand how they could have felt so fatigued without having undertaken any physical task, as illustrated below in an exert of a conversation in which a participant was asked to describe a day when they would feel most fatigued.

"if I felt tired, it would be because it was a rough day or getting bashed about on the boat... it's weird you're doing nothing but it's just really tiring"

Increased vessel motion can give rise to motion sickness (MacLachlan, 2017). Motion sickness has a complex symptomology, but some well documented effects include dizziness, headaches, nausea and Sopite Syndrome, which refers to profound fatigue and drowsiness (Cheung, 2008; Lackner, 2014; Matsangas & McCauley, 2014).

Therefore, rough transfers are likely to impact fatigue in a multitude of ways. Firstly, through the loss of opportunity for rest and recovery. Secondly through the physical exertion of forced movement through vessel motion. Thirdly through the demand of feeling unwell due to motion sickness and finally as a direct symptom of Sopite Syndrome.

Multiple studies demonstrate the strong link between vessel motion and fatigue in marine working environments (e.g. Abaei, Abbassi, Garaniya, Arzaghi, & Bahoo Toroody, 2019; Hystad & Eid, 2016; Islam, Khan, Abbassi, & Garaniya, 2018). Specifically for the present research, findings are supported by two studies which found that bad weather and seasickness were amongst the highest rated environmental strains in this environment (Mette et al., 2017; Mette, Velasco Garrido, Harth, et al., 2018a).

Some participants emphasised that specific wave conditions gave rise to worse motion sickness symptoms and were able to describe this in detail, as illustrated below.

"if it's really rough but the boat is going with it, it's ok but when that turns round and it's really rough and you're hitting the waves… so it depends on the

swell direction (yes) I tend to feel worse if we can't transfer and we're waiting around, so there's a lazy swell"

A recent multi-disciplinary study conducted in the offshore wind environment investigated the psychological effects of seasickness during CTV transfers and the specific sea-state conditions more likely to give rise to it (Earle, Huddlestone, & Williams, 2020). This research was conducted to aid the development of accurate decision making of whether to sail. Preliminary findings of the study suggest that both the direction of vessel motion and the condition of technicians prior to sailing, particularly the amount of sleep they obtained the previous evening, are important predictors of seasickness and fatigue.

Findings relating to specific sea conditions likely to give rise to motion sickness should be used to inform decision making processes on whether it is appropriate to sail. In the meantime, it would be beneficial to have a robust reporting procedure for motion sickness prior to technicians beginning to work in a potentially dangerous state. The importance of technician state prior to sailing was also highlighted in this study and highlight the importance of a wider fatigue management system and positive reporting culture.

6.6.6 Physical Demands Summary

This section has outlined themes around physical demands. These were climbing, servicing, manual handling and vessel motion during CTV transfers. Each of these demands are extreme and when experienced in concert, as they often will be in this environment, they will likely give rise to fatigue.

Participants discussed three notable outcomes from endurance of these demands. The first was the experience of physical aches and pains. This is a logical outcome of physically demanding work can cause multiple issues including difficulty in distinguishing between muscle soreness and lasting injury and pain when having to continue with physical tasks.

The second was the impact of physical demands on motivation to exercise outside of work. This is known as the 'physical activity paradox' (Holtermann et al., 2018) and was discussed in chapter 3 (see section 3.3.5). This means that individuals with physically challenging jobs are less likely to exercise outside of work and are more likely to engage in unhealthy behaviours, meaning that although they engage in exercise at work, they are often more unhealthy than those with sedentary jobs who engage in leisure time exercise. This was illustrated particularly well by one participant who quipped; *"one five-minute climb isn't going to turn you into an iron man".* As well as decreasing health and wellbeing and making physical injury more likely, this can cause issues with safety as it makes technicians less likely to maintain their physical fitness in line with work standards, which research has already suggested are inadequate for the high physical demands in this workplace (Preisser et al., 2019).

The third perceived outcome of physical demands was a lack of longevity of the technician role. Participants highlighted that older technicians seemed less able to cope with the physical demands of the role and often sought out office-based jobs once they passed the age of around 40. This suggests a lack of sustainability within the wind industry workforce and indicates that issues around an ageing workforce will occur as the industry matures.

It is positive that several studies aimed at investigating the high and unprecedented physical demands in this workplace are emerging and it is important to use their findings to incorporate evidence-based interventions to industry practice to improve the wellbeing, safety and sustainability of the workforce.

6.6.7 Section 2- Mental and Emotional Demands

Table 14- Summary of Mental and Emotional Themes

Theme/Sub-theme	SOV	CTV	Onshore
Theme 7- Team Leader role- 'Too much to think about'	X	X	X
Theme 9- Work-Family Conflict	X	X	
Theme 8- Relations with colleagues- 'Pressure cooker environment'	X		X

6.6.8 Theme 7- Team Leader Role – 'Too Much to Think About' (All Groups)

For all three groups, technicians qualified to a certain level could act as team leader, meaning they would be responsible for completion of tasks and team safety for that day. This is normally done on a rotational basis with qualified technicians taking it in turns to lead the day's tasks. Participants highlighted the high mental demands associated with this role. Discussions around this tended to focus on two main points.

The first was a sense of responsibility, both for productivity and for the safety of the team. SOV and CTV participants described this as a procedural responsibility in that team leaders were required to follow a complex process to ensure that safety-related tasks such as isolations could be carried out before the rest of the team began work. Research suggests that undertaking multiple competing tasks typically results in the experience of stress (Hockey, 1997) and the earlier occurrence of fatigue (Hockey, 2011). Participants in these groups highlighted that the highest demands in the team leader role occurred when completing services, rather than troubleshoots due to the multiplicity of tasks and the long working hours they required. Participants described how the complexity of these processes often resulted in an experience of confusion, as illustrated below.

> *“there’s so many things to think of, to keep track of, to make sure that you’ve done, and if you’ve had a couple of days where you’ve been real busy and you haven’t slept well you sort of… get confused about ‘have I done that, or am I remembering that from yesterday?’” [SOV participant]*

This type of confusion has the propensity to become dangerous, especially when considering the immense responsibility held by team leaders with regards to their own and their teammates’ safety.

Onshore participants experienced the team leader role differently owing to their smaller team sizes (normally 2-3). They highlighted that they often felt the need to take responsibility for most of the work and all the safety tasks, particularly if their colleague was inexperienced.

The team leader role therefore was categorised by mental demands of an increased feeling of responsibility and the undertaking of several different cognitive tasks for all three groups. However SOV and CTV participants described feelings of responsibility for larger teams and onshore participants described a sense of isolation and a lack of support often resulting in a perceived need to take on more than their fair share of tasks due to an inability to rely on small, sometimes inexperienced teams.

The second point mentioned by all three groups was the increase in administration requirement. This resulted in an added mental demand on top of the normal demands associated with their roles. It also had the potential to impinge on recovery time, particularly for SOV participants who did not have time during their transfer back from the turbine to in which to complete administrative work.

Therefore, the team leader role is akin to undertaking two roles at once. Participants described how this resulted in the experience of extreme mental fatigue, especially if acting as team leader for consecutive days. One participant described observing a colleague who had led services for five days in a row.

> *"Last summer, I think we did 5 or 6 services on the bounce I think probably more or less the same team (mmm) and there was erm, the guy who was in charge, I think he was in charge for sort of 5 days, and you could tell on the end of it, he was, his brain was absolutely fried" [SOV participant]*

It is interesting that this participant was able to recognise this level of fatigue in their colleague through observing their behaviour and demeanour. This suggests that encouraging peer-support around fatigue management may be beneficial in this environment. This finding also highlights that the high mental demands associated with the team leader role are a key risk for operator fatigue. This seems to be particularly severe when the role is undertaken on consecutive days.

6.6.9 Theme 8- Work-Family Conflict (SOV and CTV Groups)

SOV and CTV participants emphasised the strain their jobs could place on their family lives, causing them to feel stressed and fatigued at work. Offshore work provides challenges in this area due to time spent away from home (for SOV participants) and its long working days (for CTV participants).

To understand this area of strain, it is useful to consider participants' explanations for deciding to enter this area of work. Most participants who previously had military careers explained that they now had young families and wanted to be present in their lives. Their wind industry roles offered the potential of a greater work/life balance with shorter periods of working away than they previously had in the military. This expectation of greater balance, both for individuals and their partners could lead to greater feelings of strain in situations when they felt that this balance was not being met.

SOV Participants described their shift pattern (two weeks offshore, two weeks at home) as a blessing and a curse. Although they had two weeks to spend at home with their families, they also experienced the relentlessness of the burden of going offshore for the same amount of time, as illustrated in the below quotation.

> *"working away for 2 weeks, it can…erm put…it can put pressure on your home/work balance, I know 2 on, 2 off sounds like a dream, but I don't, when you're away from home for 2 weeks, it can get a bit much sometimes" [SOV participant]*

This finding is supported by another qualitative study conducted in this area by Mette et al (2019). They found that working away could cause strain for technicians, particularly those who had young children. They also investigated experiences of technicians' partners, finding that the responsibility of being fully in charge of childcare while their partners were away was difficult for them. This issue was also discussed by participants in the present study, as illustrated below.

> *"(wife found it) difficult at times…she's openly admitted at times that she's felt like a single mum with me being away" [SOV participant]*

This theme was also present in the CTV group, but discussed slightly differently. In this group, participants described extremely long working days during their on-shifts and a strong desire to arrive home to be present for their families, as highlighted in the following quotation.

> *"my goal in a day is to be on a boat as early as possible so that I can get home and put the kids to bed" [CTV participant]*

This could result in a feeling of being present due to the ability to return home each night, but not being able to play an active role in family life during their working periods, thus causing role conflict between work and home.

Work-family conflict (WFC) is an inter-role conflict where some responsibilities from the work and family domains are not compatible (Greenhaus & Beutell, 1985). This can include time-based conflicts in which there are competing time requirements across work and family roles. It can also include strain-based pressures in one role impairing performance in the second. Finally, it can include behaviour-based incompatibility where the behaviours required for work and family roles are different and cause difficulty in adaptation. The present findings suggest that conflicts in these groups are time-based in that participants were required to live away or spend long days working away from their families and therefore felt that they were unable to fulfil their family roles effectively.

Research suggests an interesting and complex relationship between work-family conflict and fatigue. While some studies support the notion that WFC simply causes emotional fatigue (Rubio et al., 2015), others suggest that WFC and fatigue have a reciprocal relationship in that an individual who is already fatigued is more likely to experience WFC (Nohe et al., 2014). Both findings highlight the importance of WFC as a demand in this environment and emphasise the need to support employees in this area.

6.6.10 Theme 9- Relations with Colleagues- 'Pressure Cooker Environment' (SOV and Onshore Groups)

Emotional demands associated with team relations was a major theme for SOV and onshore participants. Team dynamics and the impact of colleague support is an important consideration for most work environments (Schaufeli & Bakker, 2004; Wu et al., 2018). However, this is even more prominent for the wind industry work environment as teams spend intense periods of time together and have a high reliance on one another for safety. This is supported by research conducted in similar work environments including construction (Boschman et al., 2013b) and offshore oil and gas (Mearns & Reader, 2008). More specifically, a recent study conducted with wind technicians highlighted the importance of social support as a coping mechanism for work strain (Mette et al., 2017; Mette, Velasco Garrido, Harth, et al., 2018). In the present research, this subject was framed differently for SOV and onshore participants which was reflective of their differing work characteristics and shift patterns. However, there was notable crossover in in their narratives. Similarities between groups will be first discussed before considering points of difference.

Participants in both groups described the complex impact that team dynamics had on their wellbeing. Positive colleague relations were described a source of strength and support. This is demonstrated in a quotation from an onshore participant describing the atmosphere in their team which seems to be at odds with the typically 'macho' environment described by participants when discussing other topics (see section 6.5.10).

> *"for some strange reason we're all quite huggy here…they dish out quite a lot of hugs… [manager] will give you a hug in the morning…then we'll come in and he might be stressed because he's had loads of work on so we'll have him a shoulder massage and he'll be like "aww you guys are the best" (laughs)." [Onshore participant]*

Due to the unique closeness in their work environments, many highlighted the familial nature of their relations with colleagues, as illustrated in the extract below where an onshore participant describes their relationship with a colleague.

> *"He's like my best mate, we go on holiday and everything, we go skiing. If I was here with people I didn't get on with, it wouldn't be that good." [Onshore participant]*

Participants in both groups described how their teams often used 'banter' to communicate and support one another through difficult experiences in their personal lives. This is illustrated in an extract below where a participant discusses how support from his colleagues helped him to cope with his divorce.

> *"I'm quite happy to make jokes about it…and because I'm quite happy to do that erm, like the guys I work with feel that, and they'll make the odd joke*

about it, knowing that it will make me laugh and I don't mind them doing that and its…its funny, it cheers me up and it makes light of a negative situation and if I'm able to make light of it….it doesn't really affect me" [SOV participant]

This participant also described that his team would emphasise with him and adopt a serious disposition if necessary.

"the guys totally latch onto that and notice the change in my voice, if it kind of, changed when I was talking about it, they would give me whatever advice they thought was best, and give me the sort of advice where we wouldn't be making jokes" [SOV participant]

This demonstrates the complex social behaviour needed to strike appropriate balance between jovial and supportive in this environment. The 'buffering' impact of colleague support is supported by influential research (Karasek & Theorell, 1990). However, the negative impact of adverse colleague relations was also highlighted by participants who stated that this would cause major issues with fatigue and related factors. Therefore, colleague relations could be protective when positive, but straining when negative.

This presents an interesting scenario in terms of fatigue, as decreased communication ability and increased irritability were cited as major consequences of fatigue by participants. Therefore, when, experiencing fatigue, individuals are less likely to successfully navigate the complex social behaviour described above which is necessary to appropriately support their colleagues and prevent tension. Thus, fatigue compromises the buffering effect of social support. This then causes a reciprocal effect in which existing fatigue negatively impacts colleague relations which then acts as an emotional stressor, likely causing further fatigue.

Indeed, Conflict with colleagues was described by many to have the most prominent negative impact on wellbeing. This was mostly attributed to the intensity and isolation of their work environments. For SOV participants, the SOV itself was described as a 'pressure cooker' by one participant as small irritants became larger due to an inability to remove themselves from this environment. This major difference between the SOV and CTV environments was illustrated particularly well by an SOV participant.

> *"what was a small problem that would have been drowned out in the music of the car going home, it's being discussed and people are saying "you need to say something about that" [SOV participant]*

This quotation highlights the lack of space and distance from work gained by the SOV participants at the end of each day, thus causing tensions to rise.

As well as conflict deeply affecting individuals directly involved, it was also described to have significant impact on the wider team. This was exemplified by one participant who described an instance of conflict between two technicians.

> *"this argument you're having which stays there for 2 weeks which can then impact on all of the other work you're doing, you know you should be focusing on the job, staying safe in the job, making sure everything's done correctly and safely instead of worrying about how your colleagues feel about you, or whether your colleagues are talking about you behind your back, so that's a really big thing" [SOV participant]*

Participants cited the fact that they were unable to leave the SOV during their non-working time as the reason for this extreme impact of team dynamics on their wellbeing.

Onshore Participants only worked away from home some of the time and did so in less intense conditions. However, small teams and isolated working conditions presented a similarly intense social environment. Discussions around team dynamics in the onshore team tended to focus on the notion that negativity from one technician could quickly spread with a participant using the phrase *'it only takes one rotten apple to spoil the barrel'.* This was further demonstrated by a participant who described the effect of a negative colleague on their mood.

> *"if someone starts moaning to you, you could be the most positive person and then you start moaning and you're like hang on…why am I moaning?" [Onshore participant]*

This theme highlights the complex impact of colleague relations, both as a demand and an area of support. It would be beneficial for further research to address the impact of this with an aim of cultivating interventions that can help to maximise the buffering effect of colleague support and minimise the stressor of relationship dysfunction in these socially intense working environments.

6.6.11 Mental and Emotional Demands Summary

Three major mental/emotional demands were identified from participant interviews which were the team leader role, work-family conflict, and colleague relations. Interestingly, most of these themes centred on emotional stressors which highlights the emotionally challenging nature of this work environment. These demands could be exacerbated by the pressure to display stoicism as explored in the previous themes (see sections 6.5.8, 6.5.9 & 6.5.10). This pressure could mean that emotional stress is not discussed openly and therefore becomes more difficult to manage. Findings indicate that it would be beneficial for technicians to receive training on emotional intelligence and sessions aimed at cultivating positive team working dynamics in this environment.

6.7 Results Group 3- Fatigue Recovery

Table 15- Summary of Recovery and Sleep Themes

Theme/Sub-theme	SOV	CTV	Onshore
Theme 10- 'I ain't got time for hobbies'	**X**	**X**	**X**
Sub- theme 6- Exercise aids recovery	**X**	**X**	**X**
Theme 11- Owls and Larks, Impact of Chronotype on Sleep	**X**	**X**	**X**

Results Group 3 will present themes relevant to fatigue recovery during waking time and sleep. Appropriate recovery during non-working time is essential for fatigue management. The most obvious aspect of recovery is sleep however, recovery in waking time is also important and often less acknowledged in fatigue management practices. There has been much academic research into recovery with a particularly large body of work undertaken by Sonnentag (e.g. Geurts & Sonnentag, 2006; 2001; Sonnentag, Kuttler, & Fritz, 2010; Sonnentag & Zijlstra, 2008).

Recovery can be defined as 'the opposite of the strain process' and refers to a mechanism in which negative experiences (e.g. job stressors) in one domain are offset by positive experiences in another domain (e.g. relaxation and pleasure) (Craig & Cooper, 1992). Sonnentag presented a model for recovery focusing on three core experiences linked to effective recovery including detachment (feeling separated from work demands), relaxation (feeling that there are unlikely to be demands in the near future), mastery (engaging in challenging experiences and learning opportunities) and control (a feeling of being able to choose one's own activities)(Sonnentag & Fritz, 2007). The following sections will explore themes directly relating to participants' recovery experiences during their non-working time and will be discussed in the context of Sonnentag's recovery theory.

Sleep is essential for fatigue recovery. If individuals do not obtain appropriate amounts of sleep, they will be more vulnerable to acute fatigue and likely to experience drowsiness which is particularly dangerous in high risk working environments (Dawson et al., 2011). Sleep and its relation to fatigue management in workplaces was discussed more widely in Chapter 2 (see pages 37, 46 & 47). In the present study, one sleep-related theme was identified which will be discussed in the final section.

6.7.1 Theme 10 – "I ain't got time for hobbies"

Participants in all three groups highlighted that their time away from work was usually busy and filled with social and familial obligations. This is understandable when considering that many participants chose their present careers due to the promise of a good work/life balance as discussed in the work-family conflict theme (see section 6.6.9).

Although participants in the three groups had different shift patterns, their descriptions of the impact of looking after young children on recovery from work was remarkably similar. This centred around the notion that they had a lack of time to pursue their own hobbies and interests during time off due to their current stage of life in which they had young children and were also often taking on large projects such as house renovations, as highlighted in the following quotation.

> *"I'm knackered and then I'm going home to two young kids with a kitchen to do [chuckles] I'll get on with it though, sometimes that's the mentality innit?" [SOV participant]*

Although participants are likely to experience some benefits from busy homelives including a greater sense of detachment from work-related demands, they are also likely to miss out on other key recovery experiences such as relaxation, mastery and control (Sonnentag & Fritz, 2015).

There were some key differences in the way that recovery was discussed between the groups owing to their differences in shift patterns and work environments. SOV Participants described a pressure to 'make up for lost time' during off shifts. Those with partners and young families felt the need to compensate for their partner's experience of taking on all household demands and childcare while they were away. This finding supports research conducted by Mette, et al (2019) which highlighted a sense of pressure around technicians' offshore time them with relatively little time for self-directed leisure.

CTV participants described a similar experience, however this was lessened by the ability for most to return home on nights during their on-shifts. Although they were not able to enjoy quality time with their families during this time, their presence in the home was still felt. However, this in turn was described as having its drawbacks in that participants in this group described pressure to engage in childcare during on shifts in the little time that they did spend at home. They also highlighted that their sleep was often affected by the presence of young children. This illustrates a sleep-related stressor that is not present for SOV participants.

Onshore participants described the relentlessness of their shift pattern and how they were unable to find any time for hobbies due to beginning work at 8 am and being busy with family during weekends and evenings. For some participants, this led to an ideation of the offshore shift pattern (working longer hours, but having longer periods off) as they felt that this would provide them with a better chance of engaging in quality recovery time, as highlighted below.

> *"alright you've got 4 long days, but then you've got 4 days of rest, it's completely recharging you. People wouldn't be bothered about working the long days because they know they'll have the time off". [Onshore participant]*

It is important to further research how shift patterns and work demands affect wind industry workers' experiences of recovery with the understanding that each scenario will have positives and drawbacks in this area. Fatigue management plans should be designed with this in mind, and the importance of self-directed recovery behaviours should be highlighted to employees.

6.7.2 Sub-theme 6- Exercise Aids Recovery

Participants in all groups emphasised that engaging in leisure time exercise was one of the most effective ways for them to recover from the demands of their work. Indeed, vast amounts of research supports the physical (e.g. Ruegsegger & Booth, 2018; Wilson, Ellison, & Cable, 2016) and mental (e.g. Chekroud et al., 2018; Mikkelsen, Stojanovska, Polenakovic, Bosevski, & Apostolopoulos, 2017) benefits of exercise. Indeed, multiple studies have shown that employees feel more recovered from work if they exercise during time off (Feuerhahn, Sonnentag, & Woll, 2014; Sonnentag, 2001). More specifically, a recent study undertaken in the offshore wind industry found that exercise was an important method of coping with the physical demands in this environment (Garrido, Mette, Mache, Harth, & Preisser, 2018).

Not only is exercise important for recovery, but it is also essential for technicians to maintain their physical fitness for safety reasons. If they do not remain within recommended physical fitness for their roles, they may struggle to escape and help colleagues in emergency situations (Alexandra Marita Preisser et al., 2016). Therefore, it is essential for organisations to encourage exercise to maintain a safe and sustainable workforce.

Despite this, many participants in the present study highlighted that they had a lack of time to engage in regular exercise due to long working hours and fatigue, as highlighted in the following quotation.

> *"when I get home, I'm like…don't really fancy going to the gym now…it takes 10-20 minutes to go and then an hour there, then I get back and its 9.00 pm, then I go to bed and go to work again and I don't really like that." [Onshore Participant]*

Onshore and SOV participants stated that their employer had made provisions to help them exercise during work periods including discounted gym memberships and the provision of a gym on the SOV. Mette et al (2018) found that this was also deemed useful in a wider sample of wind industry employees. However, in the present research, participants in these groups highlighted that the provision of gyms was not enough when faced with high work demands and long hours.

Exercise and recovery research suggests that simply encouraging employees to engage in exercise on top of long working hours is not beneficial. Exercise only aids recovery if individuals have engaged in sufficient sleep before exercising (Sonnentag et al., 2013) and if motivation to exercise is intrinsic rather than extrinsic (Ten Brummelhuis & Trougakos, 2014). Therefore, methods to promote exercise for recovery should be done in line with consideration of its impact on other important recovery factors such as sleep.

6.7.3 Theme 11- Owls and Larks, Impact of Chronotype on Sleep (All Groups)

Participants in all groups highlighted that their circadian type impacted their ability to obtain an optimal sleep time. Differences in circadian type means that some individuals are more likely to perform better earlier in the day (morning types/ Larks) or naturally wake up later and perform better later in the day (evening types/ Owls) (Taillard et al., 2003). This is known as a 'chronotype' and was explored in more detail in chapter 2 (see section 2.6.5) (Fárková et al., 2019).

'Evening types' described a struggle with obtaining enough sleep during on shifts and struggling with drowsiness earlier on in the day, as illustrated in the quotations below.

> *"(what aspect of the job do you feel has the biggest effect on your wellbeing?) erm…I'd say for me I'm not very good at falling asleep, so it's the early mornings*

that really do it for me, so I sort of, I can be absolutely shattered and not fully awake for those first few hours of the day" [SOV Participant]

"(would you say you get enough sleep in the week?) no, definitely not…I'll be groggy and tired all day, a bit low and de-motivated" [Onshore participant]

Many studies suggest that evening types are disadvantaged within society. They are more likely to suffer from sleep disorders (Fárková et al., 2019; Merikanto et al., 2012) as well as mental and physical health issues (Hidalgo et al., 2009; Jones et al., 2019; Merikanto & Partonen, 2014; Taylor & Hasler, 2018). Indeed, chronotype literature suggests that evening types are more likely to have shorter sleep periods overall even if they engage in longer sleep periods during non-working time (Merikanto et al., 2012). Unsurprisingly, they are also likely to experience a higher occurrence of fatigue during waking hours (Selvi, Gulec, Agargun, & Besiroglu, 2007; Wong, Zhang, Wing, & Lau, 2017).

Findings in the present study highlight that evening type participants experienced shorter sleep periods during on shifts as their working days involved early mornings. Some explained that they would attempt to compensate for this by 'catching up' on sleep during their time off. However, research suggests that sleep is not something that can easily be 'banked' or 'caught up' on and that individuals who engage in this type of sleep behaviour are likely to be disadvantaged overall (Depner et al., 2019).

Results indicated that evening type SOV participants were worst affected. This was since CTV participants were often able to catch up on sleep during their longer transfer times and onshore participants started work later than the other two groups and worked for shorter consecutive periods. However, the impact of this was significant in all three groups.

Recent research suggests that considering employee chronotype in shift work organisation would be beneficial for employee health and organisational productivity (Hittle & Gillespie, 2019; van de Ven et al., 2016; Yadav et al., 2016). Indeed, although evening types suffer more with daytime work, they are likely to show higher resilience to the demands of night-time work, a shift pattern that is notoriously detrimental to the health of many employees (Josephine Arendt, 2010; Ganesan et al., 2019). This may be difficult to implement in the present work environment, however it is important to consider chronotype as a factor in future fatigue research with a view to gaining a greater understanding of its impact in the current work environment and to work towards the prospect of supporting those who suffer with sleep and circadian difficulties due to their evening chronotype.

6.7.4 Recovery Summary

The three themes/sub-themes included in part 3 highlighted that obtaining adequate recovery can be challenging for individuals working in this environment. Theme 10 illustrated that participants were often unable to engage in effective recovery behaviours due to busy family lives. This supports findings from Mette et al (2019) who highlighted similar recovery barriers in a qualitative study of German offshore wind technicians.

Sub-theme 6 underscores the usefulness of exercise as a recovery tool supporting findings from Mette, Velasco Garrido, Preisser, et al (2018). However, participants highlighted that they were not able to utilise this due to high work demands, long hours and fatigue.

Theme 11 suggests that 'evening types' are disadvantaged in this work environment, particularly in the SOV group as work is categorised by early mornings resulting in diminished sleep.

6.8 Results and Discussion Conclusion

This study has investigated perception and experiences of fatigue in wind technicians and managers in three different wind industry working environments. A summary of identified themes/sub-themes identified is included in Table 16

Table 16- Summary of all Themes

Theme/Sub-theme	SOV	CTV	Onshore
Part 1- Fatigue Perception			
Theme 1- Multidimensionality of fatigue	**X**	**X**	**X**
Theme 2- Cumulative effect of fatigue- 'fatigue builds'	**X**	**X**	**X**
Sub-theme 1- Second week fatigue	**X**		
Theme 3- 'You just get on with it'- Fatigue Stigma	**X**	**X**	**X**
Sub-theme 2- 'I don't want that discussing' Stigma around Mental Health	**X**	**X**	**X**
Sub-theme 3- 'It's not macho to say that you're tired'	**X**	**X**	**X**
Sub-theme 4- Military Norms, Culture and Values	**X**		
Part 2- Environmental Factors			
Theme 4- Climbing- 'It's horrendous, I hate it'	**X**	**X**	**X**
Theme 5- Servicing	**X**	**X**	**X**
Sub-theme 5- Lifting and Shifting	**X**	**X**	**X**
Theme 6- 'Getting Bashed about on the Boat'		**X**	
Theme 7- Team Leader role- 'Too much to think about'	**X**	**X**	**X**
Theme 9- Family-Work Conflict	**X**	**X**	
Theme 8- Relations with colleagues- 'Pressure cooker environment'	**X**		**X**
Part 3- Fatigue Recovery			
Theme 10- 'I ain't got time for hobbies'	**X**	**X**	**X**
Sub- theme 6- Exercise aids recovery	**X**	**X**	**X**
Theme 11- Owls and Larks, Impact of Chronotype on Sleep	**X**	**X**	**X**

Results Group 1 considered how participants defined and perceived fatigue. Findings indicated that technicians in all three groups saw fatigue as a multidimensional and cumulative state. They also highlighted that a pervasive stigma existed around fatigue and related concepts such as mental health which manifested in similar ways across the three groups and may prevent fatigue from being reported until it is debilitating. For the present research, this suggested that subjective data may be biased by participants' reluctance to discuss or admit to experiencing fatigue. For wider fatigue management in the industry, this suggests a need for training around fatigue and mental health to address the stigma through education and culture change.

Results Group 2 included findings around physical, mental, and emotional demands in these working environments. Physical demands were described as being significant in all three groups with climbing and servicing highlighted as particularly arduous tasks with a focus on manual handling as tasks that caused high physical strain and vulnerability to severe injury as a consequence of fatigued operators. This emphasised a need for further research in this area to better understand the necessary physical testing, work planning and interventions needed to promote maximum safety in line with these demands. Mental demands were particularly associated with the team leader role in all three groups and work family conflict and team dynamics were regarded as emotional stressors due to the intense demands and socially demanding nature of these work environments. These environmental demands will be further investigated in study 2 which will aim to gather data on how they impact on fatigue over the course of a shift period.

Results Group 3 provided insight on participants' experiences of recovery during waking time and sleep. Findings indicated that participants in all three groups found recovery difficult during their time off due to being in stages of life that were synonymous with high levels of responsibility (e.g. having young children) and feeling the need to compensate for long periods of time spent working. It was also found that exercise was positively associated with recovery, but participants often felt unable to participate in consistent regimes due to work commitments and fatigue from work which highlights potential area for intervention to support effective recovery and fitness maintenance for health and safety.

Finally, findings on sleep highlighted that individual chronotype had significant influence on participants' ability to obtain enough sleep during work periods, with 'evening types' feeling the need to sleep for shorter hours and compensate for this during their time off and consequently experiencing drowsiness when having to endure early morning starts for work. The impact of the present work environment on sleep will be further investigated in study 2 using ACTI graphs and subjective sleep measurement.

Insight gained into factors with significant impact on fatigue in this study was used to inform the design of diaries used in study 2. This study will provide quantitative data on how employees experience demands and fatigue in this environment. The following chapter will consist of a description of the design and findings of study 2.

Chapter 7- Field Study of Fatigue in Offshore Wind Employees

7.1 Introduction

This chapter will consider study 2, a quantitative diary and sleep analysis of fatigue and sleep in wind industry employees. A quantitative diary method was chosen for this study due to its ability to track fluctuating participant states over a period of time within a naturalistic setting of their work and home environments (Ohly et al., 2010).

Although some recent studies have investigated relevant psychological concepts within the wind industry (e.g. Mette, Velasco Garrido, Preisser, Harth, & Mache, 2018, 2018; Velasco Garrido, Mette, Mache, Harth, & Preisser, 2018), most have focussed on interviews or questionnaire data. None so far have employed this specific methodology which will allow for greater insight into how participants experience fatigue and related states over the course of work and non-work periods. The following sections will consider relevant processes in the design and execution of this study.

7.1.1 Chapter Structure

As with the previous chapter, Chapter 7 will include the method, analysis, results and discussion. Part 1 (section 7.2) will consist of the presentation of research questions (section 7.2.1) as well as a discussion of ethical considerations (section 7.2.2), participant recruitment (section 7.2.3), study design (7.2.4) and procedure (7.2.5).

Part 2 (section 7.3) will focus on data analysis. Section 7.3.1 will discuss the analysis of data trends and impact of shift on outcome variables and section 7.3.2 will outline the method of analysis used to determine demands predicting fatigue.

Part 3 (section 7.4) will include study results. Results will be presented in three sections, each focusing on a different aspect of findings and implications. The first (section 7.4.1) will explore participants demographics and survey data. The second will consider the impact of work and shift design on fatigue (section 7.4.2.1), recovery (section 7.4.2.2) and sleep outcomes (section 7.4.2.3). This will first be done by comparing outcome variables between the two groups and then a deeper insight will be gained into SOV data by comparing results between the first and second on shift weeks. Finally, section 7.4.3 will explore the predictive value of work demands on fatigue outcomes. This will first be done for SOV participants in section 7.4.3.1 and then for CTV participants in section 7.4.3.6.

Part 4 will include a discussion which will explore each section of results in turn, starting with the impact of work and shift design on fatigue (section 7.5.1), then considering the impact of this on recovery (section 7.5.2) and sleep (section 7.5.3). Following this it will include a discussion of the predictive value of demands on fatigue (7.5.4). After these topics have been discussed, consideration will be given to the strengths 7.5.5) and limitations (section 0) of the study and finally, a conclusion will be presented in section 7.5.6.

7.2 Part 1- Study Design and Procedure

7.2.1 Research Questions

As discussed in Chapter 5, this project has five overarching research questions addressed in studies one and two (see section 5.5). Study 1 wholly addressed research question 1 (*"How is fatigue perceived by technicians and their managers?"*) and provided initial qualitative data on questions 2-5. Study 2 will aim to obtain quantitative data to further expand on questions 2-5 which are outlined in the table below along with further information about how they will be addressed in the present study design.

Table 17- Research questions addressed in study 2

Question 2	How does the experience of fatigue change during working and non-working time and throughout on shifts?	Addressed in part 1 through ANOVA.
Question 3	How does recovery and sleep change during working and non-working time and throughout on shifts?	Addressed in part 1 through ANOVA.
Question 4	How do workplace demands impact fatigue?	Addressed in part 2 through Multiple regression.
Question 5	How does the experience of fatigue and its antecedents compare in three different wind industry environments?	Addressed in parts 1 and 2.

7.2.2 Ethical Considerations

As with study 1, ethical approval was sought and received from the University of Hull's Business School (see Chapter 6, section 6.2.4). As was also the case with study 1, the present project was also based in psychology and so fully adhered to ethical processes outlined by the British Psychological Society (2014, 2017, 2018). Ethical approval was sought separately for each company included in the study, (see Appendix 5 for ethical approval conformation letters).

Consent and Debriefing

Each participant signed an informed consent form which clearly outlined the aims and process of the study (see Appendix 6). Participants were also provided with a 'debriefing document' once they had completed the study (see Appendix 7). As with the previous study, there was a potential risk that questions about negative incidents, adverse mental health or simply the experience of frequently reflecting on their feelings and experiences could have a negative impact on participants. The same approach was taken to address this study as in Study 1 in that participants were advised to contact the researchers who would refer them to relevant support services (see Chapter 6 section 6.2.4 for a more in depth description of this process).

Data Management

This study included the use of 19 participant diaries, each consisting of 60 pages. It also included completed questionnaires of all participants who had initially volunteered for the study (N=38). Once participants had completed their diaries, they were asked to post these directly to the researchers in a pre-stamped envelope to ensure confidentiality. Diaries and questionnaires were kept in a locked cabinet and they were not accessible to anyone outside of the research team.

Questionnaires of participants who were not included in the final sample were securely destroyed. The 'hard data' of participants who completed the study will be kept for five years after which it will be destroyed in line with the Data Protection Act (*2018*). Quantitative data from the diaries and questionnaires was manually transcribed into SPSS in files which were stored on the University of Hull's secure 'box' file system and only shared with the research team. Qualitative data (in the form of additional participant comments in diaries) were copied into Microsoft Excel and kept in the same secure file location.

Objective sleep data was stored within ACTI graph watches (model: wGT3X-BT) and could only be accessed through manually connecting the watches to a computer and extracting through the programme ACTI Life, which required a unique product key. This process was considered sufficiently inaccessible to justify the process of ACTI graphs being delivered to managers by participants at the end of data collection who then returned them to researchers. Data was then extracted using ACTI Life by the main researcher and all relevant files were stored in secure University of Hull Box folders.

7.2.3 Participants and Recruitment

Participants from onshore, SOV and CTV wind industry environments were recruited from two different organisations (SOV and CTV participants from the same organisation). The inclusion criteria specified that individuals currently working as operations and maintenance technicians or offshore managers and who spoke and understood English would be selected for participation.

Potential participants were invited to an information session within company-run health and safety training event. It was initially planned that this session and subsequent data collection would take place during late spring/summer in which workload was high and technicians would be at their busiest. This was considered important because it would reflect the potential magnitude of demands experienced in this work context. However, due to organisational pressures, recruitment sessions were delayed in all three groups, finally going ahead in September and October with data collection taking place from October to December (2019).

Participation in the study required relatively high levels of effort and dedication. Therefore, three methods were used for participant retention. The first was that the recruitment session highlighted potential long-term benefits of participation (e.g. promoting increased safety, health and wellbeing within the work environment) while ensuring that this was in no way coercive and met ethical standards. The second was that communication between the researcher and participants was established via email so that the researcher could regularly prompt continued participation. Finally, a participant incentive was offered by employers for groups 1 and 2 (SOVs and CTVs) consisting of restaurant vouchers to the value of £75.00 for completion. Unfortunately, for group 3 (onshore technicians) budget was not available to offer a participant reward.

It was initially thought that data collection would take place over the two months following the recruitment session. However, during the data collection period, it became clear that some participants had started later than intended or were unresponsive. To retain as many participants as possible, data collection time was extended by 1 month with a final date for submissions scheduled for mid-January 2020.

Despite retention efforts, participant numbers were lower than expected. However, datasets obtained for each participant were detailed and plentiful and still offered the potential for useful insights into the research questions.

Figure 11 demonstrates participant recruitment and retention throughout the study. Unfortunately, as group 3 (onshore) only returned two completed diaries, it was decided that this sample size would not be enough to include and so this group was not included in study 2 results. Table 18 shows the final sample of participants included in this study.

Figure 11- Diagram illustrating participant recruitment and retention

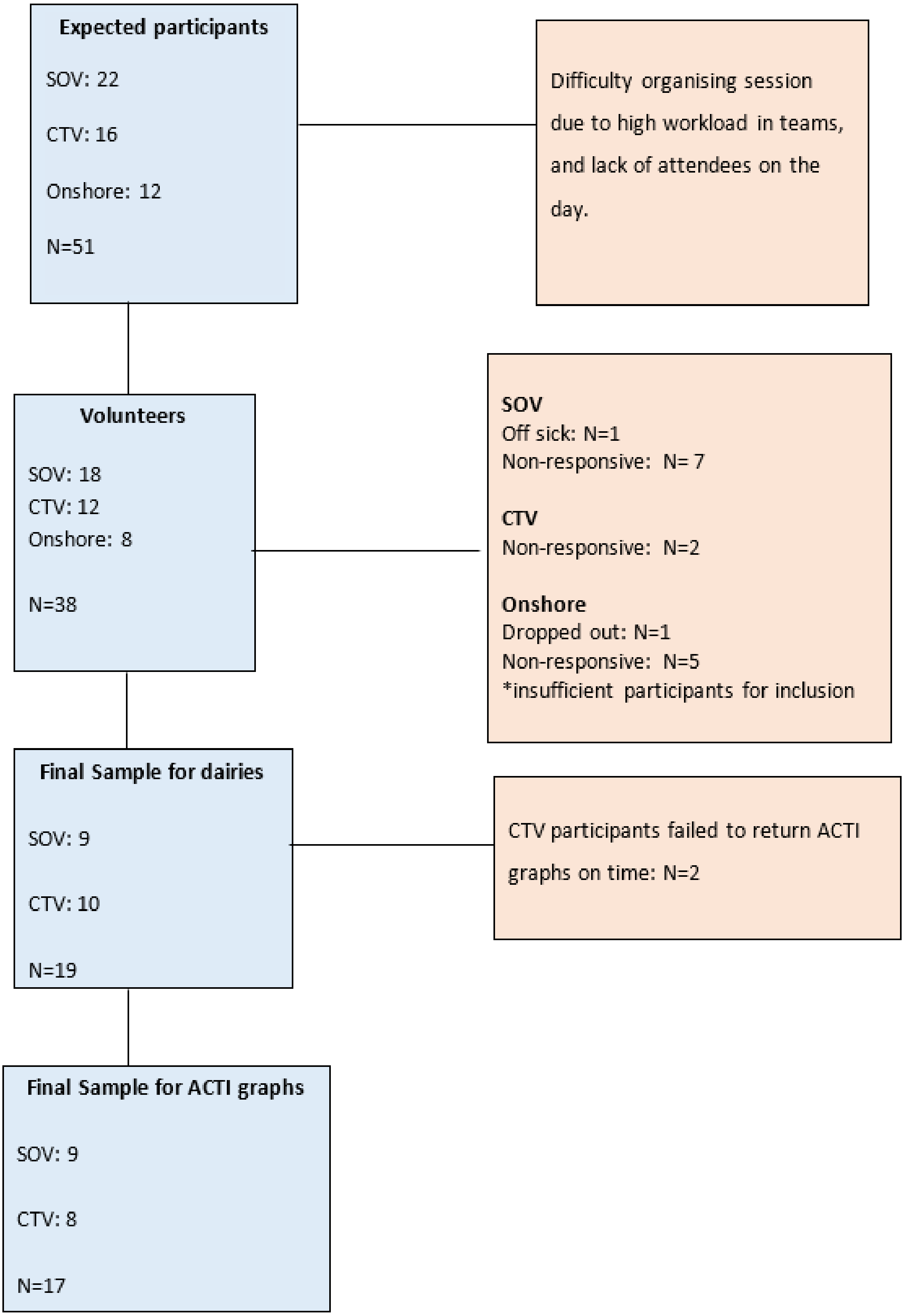


Table 18- Final sample of participants in Study 2

Group	Participants	Shift Pattern
Group 1 (SOV)	9 (28 days)	(2 weeks on, 2 weeks off)
Group 2 (CTV)	10 (28 days)	(1 week on, 1 week off repeated)

7.2.4 Study Design

This study collected data through two means: (1) a subjective diary designed to collect empirical data on the outcome variables of fatigue, sleepiness, anxiety, recovery and sleep quality/quantity and predictive variables of demands, work tasks, working hours etc and (2) ACTI graph measuring objective data on sleep quantity and quality.

Data collection took place over 28 days, to incorporate two weeks of working time (1 full on-shift for SOV employees and 2 full on-shifts for CTV employees) and two weeks of non-working time. This allowed for an appropriate amount of time to gain insight into how the outcome variables were affected over a period of working and non-working time.

All participants began with one week of off-shift time. For group 1 (SOV) this was at the beginning of their second week of off-shift and for group 2 (CTV) this was at the start of their 1 week of off shift. An outline of the data collection periods for the two groups is included below.

Figure 12- Group 1 (SOV) shift pattern in data collection period

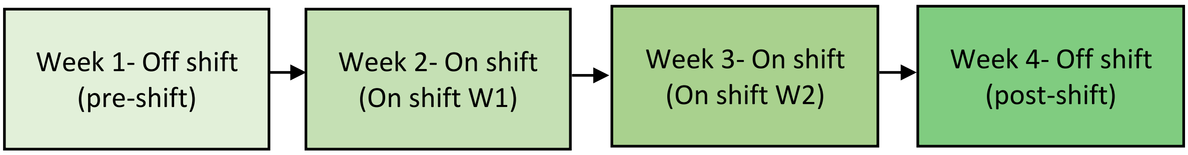
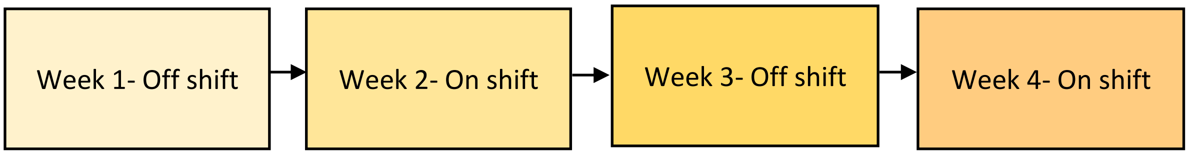


Figure 13- Group 2 (CTV) shift pattern in data collection period



As can be seen in Figure 12 the data collection period for group 1 allows for variables to be tracked over consecutive weeks of on-shift as well as insight into 'pre' and 'post' shift weeks. This was utilised during analysis.

Questionnaire

Initial questionnaire data was collected before participants began the diary aspect of the study (see Appendix 8). Content was based on relevant literature addressing individual and lifestyle factors that could have an overall impact on fatigue and related factors. This included questions on regular medication, smoking behaviour and caffeine intake (Zajdel, Oken, & Griesar, 2002; Davis et al., 2003, see chapter 2 section 2.6.7 for a more in-depth discussion on these factors).

As study 1 findings highlighted the benefits of exercise for recovery (see chapter 6, section 6.7.2), the Godin-Shepherd Leisure Time Physical Activity questionnaire was used to assess exercise behaviour. This has been validated as a reliable measure of general activity level in healthy adults (Amireault & Godin, 2015). Study 1 also highlighted that circadian type could impact sleep acquisition (see chapter 6, section 6.7.3). Therefore, an extract of the Ostberg Morning/Eveningness questionnaire was included (“One hears about “morning” and “evening” types of people. Which ONE of these types do you consider yourself to be? *rated from “Definitely morning” “Definitely evening”) (Horne & Ostberg, 1976).

Personality was assessed using a validated 10-item version of the ‘Big 5’ questionnaire (Rammstedt & John, 2006). Finally, work satisfaction (‘Taking everything into account, how do you feel about your job as a whole? 1= extremely dissatisfied, 7= extremely satisfied’) and relations with colleagues (‘Taking everything into consideration, how do you feel about your relationships with your colleagues? 1= extremely dissatisfied, 7= extremely satisfied’) was assessed using validated single item measures (Dolbier, Webster, Mccalister, Mallon and Steinhardt 2005).

This data provided useful background information facilitating an in-depth understanding of individual differences in line with results. However, it was not included in the final data analysis as the sample size was not deemed to be large enough for a focus on individual differences to be statistically significant. However, this could be useful for future research.

Diaries

Diaries were used due to their potential of gathering twice-daily data, thus allowing useful insight into the fluctuations of relevant factors during offshore shifts and non-working time. Although diary studies have been used to investigate fatigue in comparable work environments such as offshore oil (e.g. Haward, Lewis, & Griffin, 2009; Merkus et al., 2015; Wadsworth, Allen, McNamara, & Smith, 2008), this method has not yet been employed in the present work environment.

Diaries were designed to be filled in by hand as this meant that they would not be constrained by access to computers/iPads/internet. Different versions of the diary were created for each of the different groups to reflect environmental differences in the three workplaces. Designs were broadly similar, with differences in questions about work tasks and specific environmental factors.

Dairies were filled in twice per day, once in a morning shortly after waking up (see Appendix 9 for morning diary page) and once in the evening, shortly before going to bed (see Appendix 10 for evening diary page). They included a mixture of questions on demands, tasks, coping and workload and psychological scales to assess outcome variables (fatigue, sleepiness, boredom, anxiety and recovery). These questions will now be explored in more detail.

<u>Daily experience questions</u>

Questions on the content and experiences of participants' days covered six areas: 1. Working time, 2. Demands, 3. Coping, 4. Work Tasks, 5. Social Interaction, 6. Subjective State. Questions were informed by relevant literature presented previous chapters and by findings from study 1, where work related factors that could impact fatigue were identified. The following sections will include descriptions of each group of questions.

<u>Working time</u>

Participants were asked to state how much time they had spent working each day. Study 1 findings indicated that high administration demands could act as a stressor. Therefore, participants were also asked how much time they had spent on administration tasks that day.

<u>Demands and Coping</u>

Study 1 findings supported the notion that a variety of different 'types' of demands can give rise to fatigue (see Chapter 6 section 6.5.3). Physical, mental and emotional demands are all prominent in this work environment, so participants were asked to rate their exposure to different types of demands each day. This is consistent with research that highlights the predictive element of stressors on psychological strain as assessed through diary studies (Pindek, 2019). Participants were also asked to rate how well they thought they had coped mentally, physically and emotionally in the face of these demands.

Work Tasks

Questions around work tasks were developed in line with findings from study 1 regarding those that were deemed most demanding. These included questions on whether participants had acted as team leader (see Chapter 6 section 6.6.8) and the extent of climbing and manual handling demands.

Social Interaction

Study 1 indicated that relations with colleagues could be a prominent source of support (if positive) or strain (if negative) (see chapter 6, section 6.6.10). Therefore, participants were asked to rate how they felt they had got on with colleagues each day during working time.

Work-family conflict was also highlighted as a potential stressor (see chapter 6 section 6.6.9) so participants were asked to rate their level of work/family conflict while off shift (how much of day had been interrupted by thoughts of work) and family/work conflict (how much of their day had been interrupted by thoughts of their family) while on shift. They were also asked to rate how well they had got on with their families if they had been in contact during on shifts.

Subjective State

As study 1 findings highlighted that workplace stressors could contribute to physical illness, injury or discomfort (e.g. seasickness, see Chapter 6 section 6.6.5), questions were included on physical state including illness and discomfort that could be caused or exacerbated by work related factors. Questions were also included on mood disturbance and motivation as these factors are important when considering fatigue.

Psychometric Scales

Psychometric scales were used to assess the outcome variables of fatigue, sleepiness, boredom anxiety and recovery, they will be described in the following sections.

Multidimensional Fatigue Scale

Fatigue and related factors (sleepiness, boredom and anxiety) were assessed twice per day using a multidimensional scale (Earle, 2004). This scale was chosen because its multidimensional approach to fatigue assessment corresponded with the theoretical underpinnings of the present research project (see Chapter 2 section 2.10) and findings from study 1 indicated that participants experienced fatigue as a multidimensional concept, including physical, mental and emotional aspects.

Therefore, though the definition of fatigue in the present research is a general experience of 'psychological fatigue', the present study will measure three different 'types' of fatigue separately including mental, physical and emotional. This is important as though fatigue can be experienced as a generalised state, individual ability to differentiate between the experience of different fatigue types is recognised (e.g. Earle, 2004) and it is highly affected by the type of demands that an individual has experienced. For example, after climbing a mountain they would feel physically fatigued as opposed to writing an essay where they would feel mentally fatigued. These states can impact one another (e.g. research supports that feeling mentally fatigued decreases motivation to exercise) but effective recovery often depends on partaking in activities that will not add to this state (e.g. a run would not be an effective recovery method for physical fatigue, but it might help for mental fatigue). Therefore, it is useful in field research to understand the way participants experience fatigue.

Additionally, this measure includes the assessment of separate, but highly related states including sleepiness (see Chapter 2, section 2.6.9), extremely important due to its likely antecedents of sleep deprivation and associated safety issues, boredom and anxiety. It is useful to assess these factors as part of this study as they are alternative responses to high demands and effective markers of wellbeing.

This scale has been used in a similarly designed diary study (Earle, 2004) and reliability in the current study was high (Cronbach's a=.93).

<u>Recovery</u>

Recovery was assessed once per day in evening diary entries using the Sonnentag recovery experience questionnaire (Sonnentag & Fritz, 2007). The scale assesses recovery using four components: detachment (feeling distant from the demands of work), relaxation (feeling that no further demands are expected in the near future), mastery (learning new things and the enjoyment of hobbies) and control (the feeling of being able to decide what to do on one's own terms). This scale has been used in several similarly designed diary studies (e.g.Demerouti, Bakker, Sonnentag, & Fullagar, 2012) and reliability in the current research was high (Cronbach's a=.90).

Sleep Analysis

Sleep quantity and quality was a key outcome variable present study. Daily measures of objective and subjective sleep data were collected through diary entries and ACTI graph data which will be further explained in the following sections.

Subjective Sleep Data

Literature suggests that objective and subjective sleep analysis capture different dimensions of sleep (Aili, Åström-Paulsson, Stoetzer, Svartengren, 2017; Girschik, Fritschi, Heyworth, 2012). Therefore, participants were asked to provide subjective and objective data on sleep quality and quantity which could then be compared during analysis.

Participants were asked to provide subjective accounts of their sleep quantity and quality every morning. During on-shift entries, SOV participants were also required to provide details about whether they had experienced sleep disturbance relevant to sleeping on the SOV.

Objective Sleep Data

ACTI graphs were used to collect data on sleep quantity and quality. ACTI graphs are watch-like devices, generally worn on the wrist that record movement through accelerometers (Ancoli-Israel et al., 2003). The recording of activity/inactivity can be analysed to estimate wake/sleep based on the observation that there is less movement during sleep and more during wake. This generates results for sleep quantity including total sleep time. It also produces results for sleep quality including sleep efficiency (total time in bed minus total sleep time).

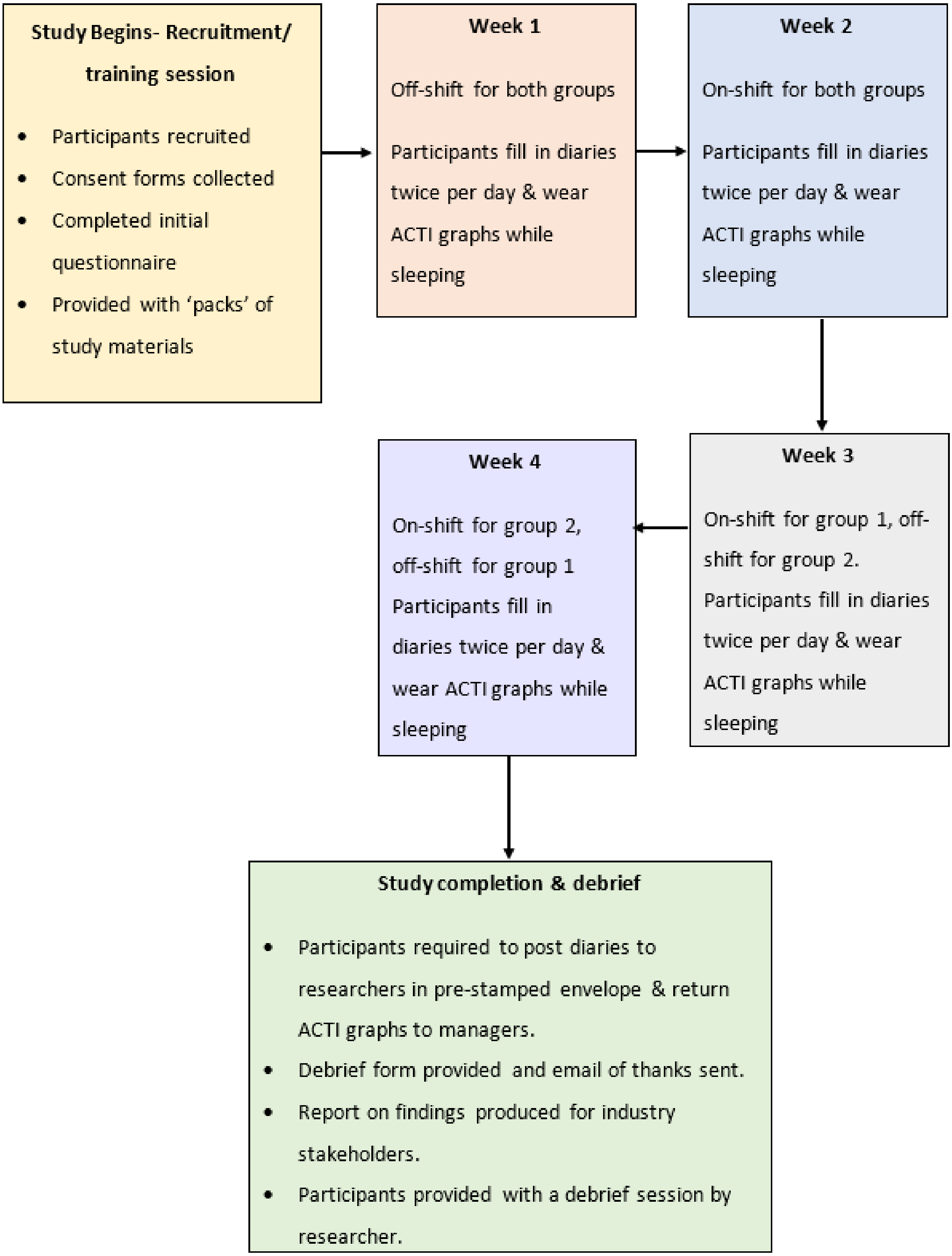
ACTI graphs are regarded as a moderately accurate and non-invasive method of sleep analysis (Ancoli-Israel et al., 2003). The use of ACTI graphs for sleep analysis has been validated in numerous studies on normal and disordered participants (e.g. Johnson et al., 2020; Smith et al., 2018). Particularly relevant to the present study is research using ACTI graphs to track sleep in railway employees as part of a diary study (Gerhardt et al., 2020) and Riethmeister's study that used actigraphy to measure sleep in 2 week on/off offshore oil workers (Riethmeister et al., 2018).

Participants in the present study were each provided with an ACTI graph and instructed to wear it on the wrist of their non-dominant hand each night while they slept (as per manufacturers' instructions). At the end of the study, data was extracted from the ACTI graphs using the relevant computer programme where it was then analysed.

7.2.5 Study Procedure

Figure 14 outlines the procedure of the present study which involved four weeks of data collection including diary entries and sleep analysis.

Figure 14- Diagram depicting the structure of Study 2



7.3 Part 2- Data Analysis

Once data collection was complete, the content of participant diaries was copied into SPSS and sleep data was extracted from ACTI graphs for analysis. The following sections will describe this process of analysis. They will begin by explaining procedures used to analyse data for data trends and impact of shift on outcome variables (section 7.3.1) and then will focus on work related predictors of fatigue in section 7.3.2.

7.3.1 Analysis of Data Trends and Impact of Shift on outcome variables

Changes in outcome variables over the data collection period were determined by analysing how they deviated from participants' average scores at key points. Data was converted to standardised z scores for each participant, showing how their score compared to their average for the data collection period for each day. This data was averaged for participants in each group to create a group average z score for each day.

Data from both groups was initially analysed using 2x2 mixed ANOVAs (shift, group, shift*group) to determine whether outcome variables were significantly different between on and off shifts and whether there was a significant difference in scores between the groups.

Further analysis focused on the SOV group as their shift pattern of consecutive weeks spent on shift allowed for consideration of how the outcome variables were affected from the 'pre shift' week to 'on shift week 1, on shift week 2' and the 'post shift' week. Potential differences between these weeks were evaluated using a repeated measures 4X4 ANOVA (pre shift, on shift week 1, on shift week 2 & post shift) and post hoc Bonferroni tests. Part 1 consists of an exploration of these results.

7.3.2 Analysis of Demands Predicting Fatigue

Multiple regression was used to evaluate the predictive effect of work-related demands on fatigue. This was done using participants' daily ratings of mental, physical and emotional demands and fatigue. Multiple regressions were performed for each outcome variable (e.g. mental fatigue, physical fatigue) separately. Results were then assessed for significance and placed into a heatmap displaying the magnitude of their predictive values on fatigue. Part 2 includes an account of these results.

7.4 Part 3- Study 2 Results and Discussion

The following sections will include results of study 2. Initially, demographic and survey data will be presented in section 7.4.1. Following this, section 7.4.2.1 will consider trends in the outcome variables of fatigue, recovery, and sleep using ANOVAs to analyse results. Section 7.4.3 will explore work-related predictors of fatigue and other factors. Finally, section 7.5 will include a discussion of all the results and their relation to theory and practice.

7.4.1 Participant Demographics and Survey data

Group 1 (SOV)

SOV participants (N=9) were all male and aged between 19 and 48 (M=35.1, SD=8.4). Though this was a small sample size, it was representative of most individuals from the feasible sample set.

Their job roles ranged from 'WT1' (entry level wind technician) to 'Operations Manager' (in charge of the offshore team, not involved in turbine work), with most participants working as 'WT3s' (mid-level wind technicians). The majority of participants' previous job roles were in the armed forces (N=5) with others having worked as wind technicians in other companies (N=2), other types of technicians (N=1) or in other unspecified roles (N=1). Most participants were married or co-habiting with a partner (N=8) and just over half had caring responsibilities (e.g. children) (N=5).

<u>Group 2 (CTV)</u>

CTV participants (N=10) were mostly male (N=8) but included two females and were aged between 22 and 43 (M=32.7, SD=7.03). This was an entire team of CTV technicians and so represented all the feasible sample set.

Job roles ranged from WT1 to WT4 (higher level wind technician with some management responsibilities) with the majority working as WT4s (N=5). Previous job roles were evenly split between the armed forces (N=3), wind technicians in other companies (N=3) and other types of technician (N=3) with one participant having worked in another unspecified role. Half of participants were married or co-habiting (N=5) with others reporting to be 'in a relationship, not living together' (N=3) or single (N=2). Half of participants had caring responsibilities (N=5).

<u>Lifestyle Data and Individual Differences- Group 1 (SOV)</u>

Most SOV participants did not smoke (N=8) and none reported taking regular medication or sleep aids. Caffeine consumption was reported at a mean of 3.67 units per day (1 unit=a cup of coffee/2 cups of tea) with over half of participants reporting that their caffeine intake increased when offshore (N=6). All participants were 'active' according to the Godin Leisure Time Exercise questionnaire as scores ranged from 25-56 (M=41.9, SD=11.13) and 24+ is classed as 'active' (Amireault & Godin, 2015). Data on whether exercise behaviour changed while offshore was split with equal amounts of participants reporting no change (N=3), that exercise increased (N=3) and that it decreased (N=3).

Just over half of participants reported themselves to be either ‘rather more’ or ‘definitely more’ morning types (N=5) while the others were ‘evening types’ (N=4). Participants generally rated their feelings of their job highly on a scale of 1-7 (M=5.5, SD=1.06), as well as their feelings about their relationships with their colleagues (M-5.89, SD=1.05).

Group 2 (CTV)

None of the CTV participants smoked. Two reported taking regular medication, three took prescription sleeping pills while two reported using ‘other’ methods to aid sleep. Mean caffeine consumption was reported at 1.86 (SD=.90) and all participants stated that their caffeine intake did not change during offshore time. Scores on the Godin Leisure Activity questionnaire ranged from 9 (moderately active) to 62 (active) (M=32.2, SD=17.27). Equal numbers of participants reported that their exercise level increased while on shift (N=4) and decreased during this time (N=4) with two reporting no change.

Just over half of participants were ‘rather’ or ‘definitely’ evening types (N=6). They also generally had high ratings of their job (M=5.8, SD=1.03) and their colleague relations (M=6.6, SD=.52).

7.4.2 The impact of shift on fatigue, recovery and sleep

This section will focus on trends in the data over the collection period (4 weeks) and how the outcome variables changed depending on point in the shift pattern. It will first consider results for fatigue and related factors (subsequently referred to as 'fatigue'), then non-sleep recovery and finally sleep.

The following sections will compare the outcome variables between on shift and off shift and groups (SOV and CTV). Further analysis will consider SOV data by week to gain insight into how the outcome variables are impacted from the 'pre shift' week to 'on shift week 1', 'on shift week 2' and the 'post shift' week as this group's shift pattern allows for this specific comparison and this could add useful data for considerations around shift planning for this type of offshore worker.

7.4.2.1 Fatigue, Sleepiness, Anxiety & Boredom

Results discussed in this section will mostly focus on standardised average scores (z scores) to understand deviations from individuals' average ratings. However, it is initially useful to gain an impression of the range of individual ratings on the multidimensional fatigue scale from non-standardised ratings. For reference, Table 19 includes score ranges and descriptions of severity that have been retrospectively added in line with results. Table 20 depicts means and standard deviations of SOV fatigue scores for each week of data collection.

Table 19- Fatigue scores and level of severity

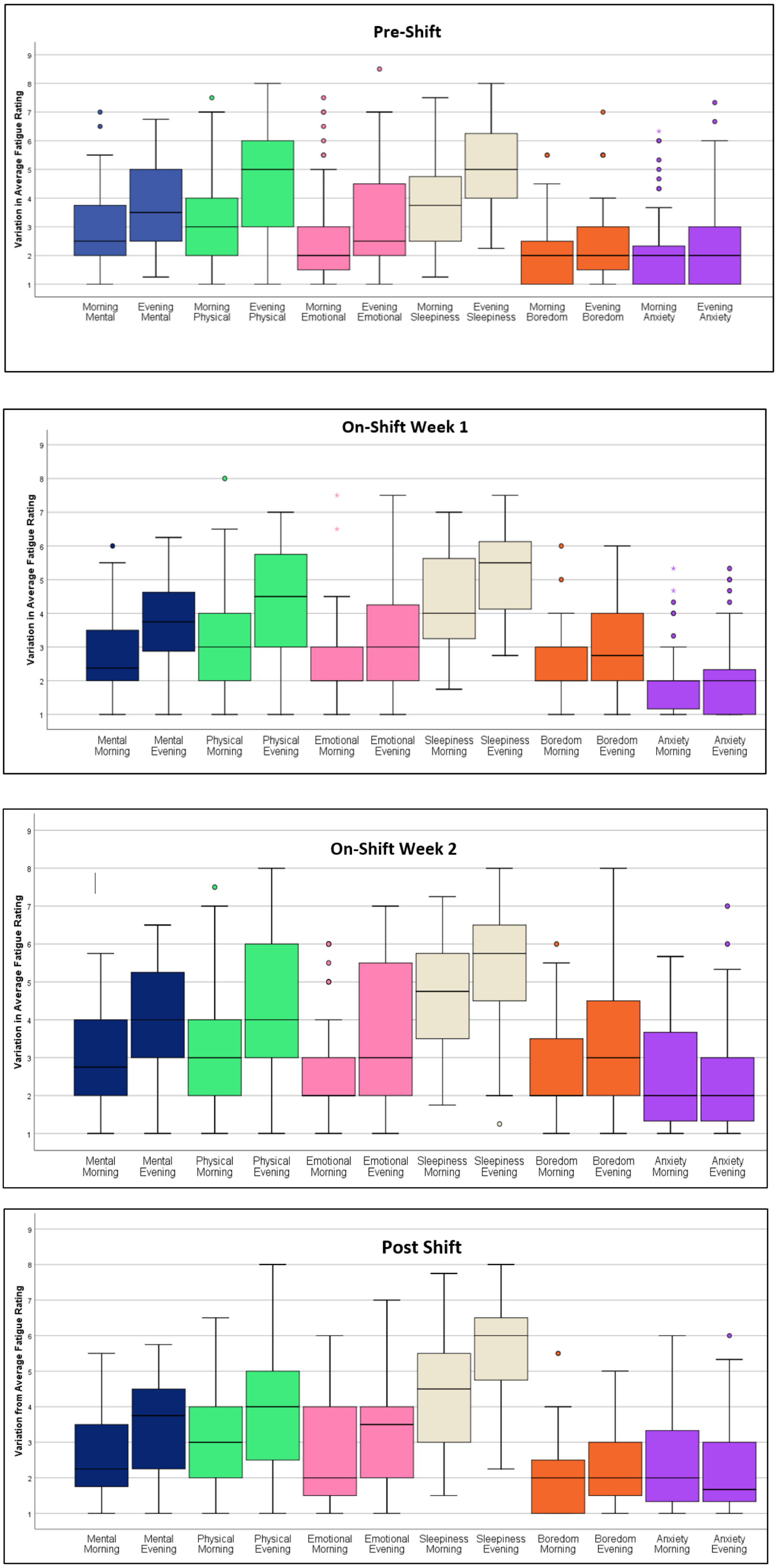
Score	Level of severity
1-3	Low
4-6	Moderate
7-9	High

Table 20- Means and standard deviations of fatigue for the SOV Group

Variable	**Week 1 (N=9)** *Pre-shift*				**Week 2 (N=9)** *On-shift W1*				**Week 3 (N=9)** *On-shift W2*				**Week 4 (N=8)** *Post-shift*			
	Morning		**Evening**		**Morning**		**Evening**		**Morning**		**Evening**		**Morning**		**Evening**	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Mental	*3.1*	*.98*	*4*	*1.2*	*2.9*	*.86*	*4.1*	*1.3*	*3.3*	*1.1*	*4.5*	*1.7*	*2.9*	*1.2*	*3.7*	*1.7*
Physical	*3.3*	*1.3*	*4.8*	*1.5*	*3.1*	*1.2*	*4.6*	*1.5*	*3.8*	*1.6*	*4.9*	*1.8*	*3.3*	*1.4*	*4.2*	*1.8*
Emotional	*2.7*	*1.3*	*4*	*2.1*	*2.7*	*1.1*	*4.3*	*2.1*	*3.2*	*1.5*	*4.8*	*2.3*	*2.8*	*1.2*	*5.4*	*2.2*
Sleepiness	*4.1*	*.97*	*5.4*	*1.3*	*4.1*	*.88*	*5.5*	*1.5*	*4.7*	*1.1*	*5.6*	*1.5*	*4.2*	*1.2*	*5.5*	*1.9*
Boredom	*2.4*	*1.3*	*2.8*	*1.2*	*2.4*	*.94*	*3*	*1.1*	*2.8*	*.84*	*3.6*	*1.2*	*2.1*	*.77*	*2.4*	*.87*
Anxiety	*2.1*	*1.1*	*2.5*	*1.3*	*2.1*	*.99*	*2.2*	*1*	*2.4*	*1.1*	*2.6*	*1.3*	*2.2*	*1*	*2.4*	*1.1*

As can be seen on Table 20 and Figure 15 average scores were generally at a low to moderate level of severity, but most have high levels of deviation in individual scores. Morning scores are generally lower with evening scores increasing in severity and ratings are generally higher during on shift periods, particularly in week 3 (on shift week 2). Indeed, some scores, e.g. evening sleepiness in week 2 are notably high for average scores. Boredom and anxiety tended to have the lowest ratings with sleepiness being typically the most prevalent strain outcome. Figure 15 includes boxplots to show individual variation in fatigue ratings for each week of data collection.

Figure 15-Box plots showing variation in SOV fatigue ratings for each week



Box plots in Figure 15 illustrate the range of individual ratings for each week and show that although average ratings generally indicated a low to moderate level of severity, most outcome variables included extreme high and low ratings. The following sections will address these considerations for the CTV group.

Table 21 Means and standard deviations of fatigue for the CTV Group

Variable	**Week 1 (N=10)** *Off-shift*				**Week 2 (N=10)** *On-shift*				**Week 3 (N=10)** *Off-shift*				**Week 4 (N=10)** *On-shift*			
	Morning		**Evening**		**Morning**		**Evening**		**Morning**		**Evening**		**Morning**		**Evening**	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Mental	*3.4*	*.92*	*3.9*	*1.3*	*3.4*	*1.1*	*3.9*	*1.6*	*2.7*	*1.2*	*3*	*1.4*	*2.9*	*1.4*	*3.2*	*1.3*
Physical	*3.6*	*1.2*	*4.5*	*1.2*	*3.5*	*1.5*	*4*	*1.8*	*2.6*	*1.4*	*3.3*	*1.7*	*2.9*	*1.3*	*3.7*	*1.7*
Emotional	*3.1*	*1*	*3.8*	*1.2*	*2.4*	*.84*	*2.8*	*1.4*	*2.1*	*1.3*	*3.7*	*2.1*	*2.1*	*1.2*	*3.1*	*1.7*
Sleepiness	*4.5*	*.98*	*4.3*	*1.4*	*4.8*	*1.6*	*4.8*	*1.6*	*4*	*1.3*	*4.3*	*1.2*	*4.1*	*1.2*	*4.5*	*1.6*
Boredom	*3.2*	*.7*	*3.3*	*1.2*	*2.8*	*.94*	*3.1*	*1.4*	*2.2*	*1*	*2.6*	*1.4*	*2.6*	*1.2*	*2.8*	*1.4*
Anxiety	*2.6*	*.8*	*2.8*	*1.1*	*2*	*.71*	*2.1*	*.84*	*2*	*1*	*1.9*	*1*	*2.1*	*1.1*	*2*	*1.1*

Table 21 illustrates that as with the SOV group, average ratings of fatigue were low to medium with increases in the evening and during on shift time. Scores in this group are generally lower than the SOV group which could be due to the effect of spending less time offshore, but could also be due to the fact that CTV participants were less busy during the season in which data was collected (see section 7.2.3 for a detailed explanation of this). As with SOV participants, boredom and anxiety tended to have lower scores whereas sleepiness ratings tend to be higher. Figure 16 and 17 include boxplots showing individual variation in fatigue ratings for on shift and off shift.

Figure 16 and Figure 17- Box plots showing variation in SOV fatigue ratings for each week

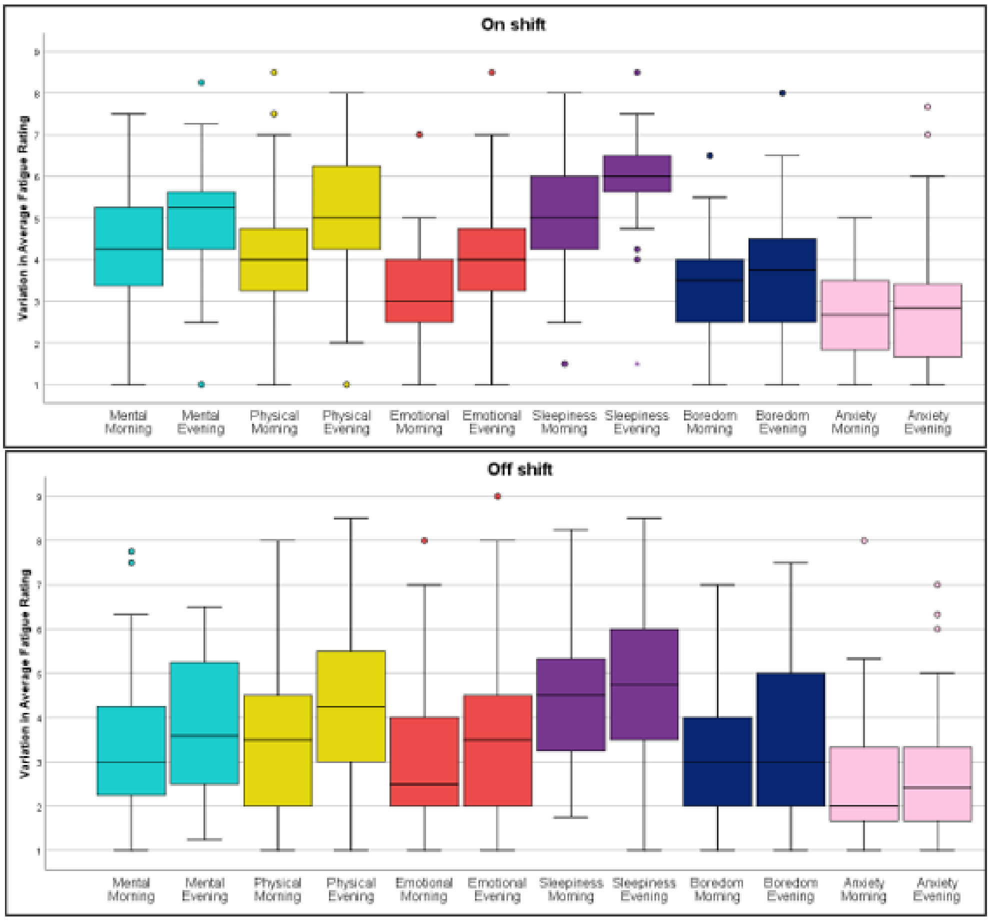


Figure 16 and 17 show that fatigue ratings were generally more varied during the off-shift period with on shift ratings higher and less varied. This is particularly the case for evening sleepiness in which average scores were notably higher during on shift time. Results from ANOVAs performed to determine whether there were significant differences between on shift and off shift and the two groups will be considered in the following sections.

Comparison of Fatigue Between Shift and Group

2X2 (shift, group, shift*group) mixed design ANOVAs were performed for all fatigue-related outcome variables to determine whether ratings were significantly different during on shift compared to off shift (shift), whether there were significant differences in ratings between groups (group) and whether there was an interaction between these factors (shift*group). To test assumptions of normality and homogeneity of variance, following the guidance of Field (2013), Shapiro Wilk and Levene's tests were performed on all variables which were all non-significant (p>.05).

Table 22 shows results from the 2X2 ANOVA with significant findings highlighted in bold. Though differences in shift and group were shown for most variables, significant findings were only found for three variables that are highlighted in bold.

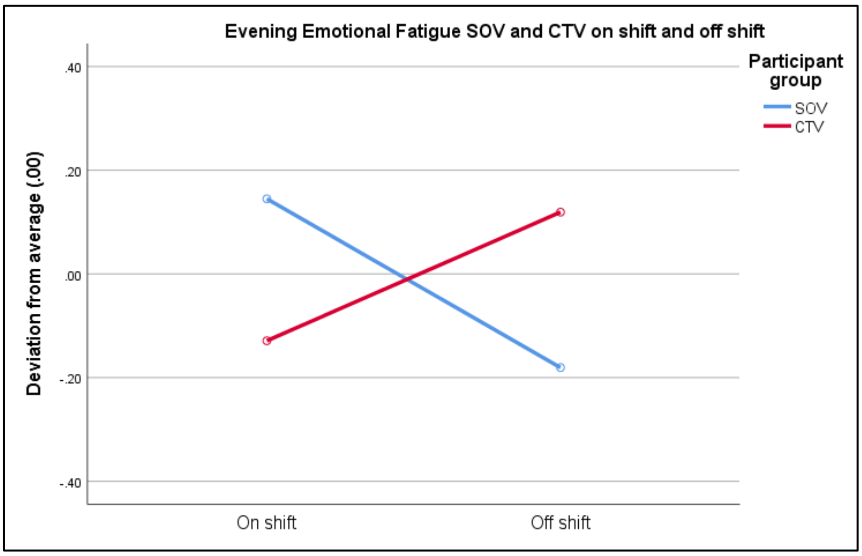
Table 22- Results of 2X2 ANOVA comparing fatigue ratings based on shift and group

Variable	Shift*Group		Shift		Group	
	Morning	Evening	Morning	Evening	Morning	Evening
Mental F	*F.225, p.641*	*F3.41, p.082*	*F=1.36, p.260*	*F4.21, p.056*	*F.621, p.442*	*F.488, p.494*
Physical F	*F.327, p.575*	*F2.21, p.155*	*F=.60, p.448*	*F.044, p.836*	*F037, p.849*	*F2.12, p.164*
Emotional F	*F.2.81, p.112*	***F6.44, p.021****	*F=.428, p.522*	*F.117, p.736*	*F.688, p.728*	*F3.186, p.092*
Sleepiness	*F.169, p.686*	*F.386, p.543*	*F2.61, p.124*	*F.253, p.622*	*F.655, p.430*	*F.826, p.722*
Boredom	***F5.92, p.026****	***F15.13, p.001*****	***F6.42, p.021****	***F10.2, p.005*****	*F1.25, p.274*	*F3.2, p.092*
Anxiety	***F5.17, p.036****	*F3.45, p.081*	*F.511, p.484*	*F1.37, p.258*	*F.006, p.939*	*F.005, p.943*

*DF=(1,17) *=Significant at .05 **=Highly significant, <.01*

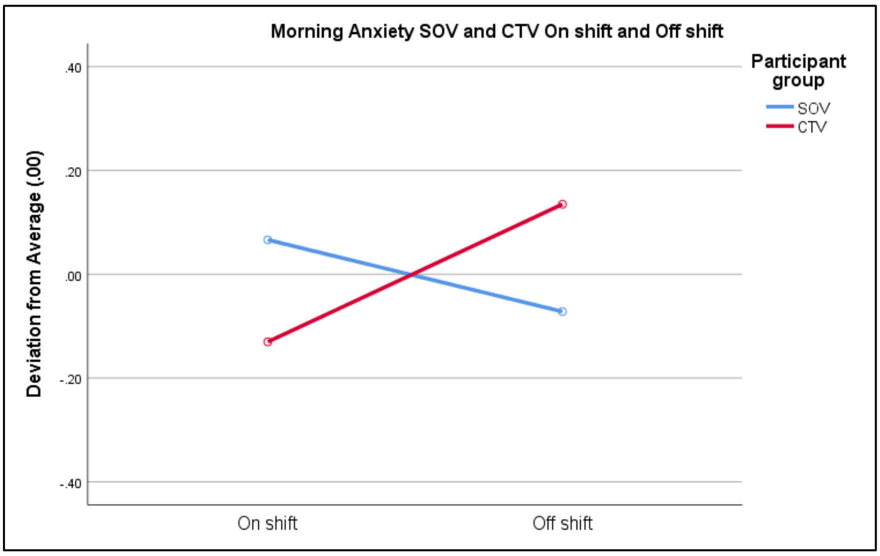
As can be seen in Table 22 a significant interaction of shift*group was found for evening emotional fatigue (F(1,17)6.44, p=.021) meaning that the impact of being on shift or off shift was significantly different depending on group (SOV or CTV). These results are illustrated in Figure 18 which shows that level of variation was almost identical for both groups (.20 to -.20) but in opposite directions (SOVs had +.20 emotional fatigue during on shift and CTVs had -.20). This means that although SOV participants experienced below average evening emotional fatigue during their off shift and above average during on shift time, CTV participants had higher levels during their off shift and lower during the on shift.

Figure 18- Line Graph Showing Shift*Group interaction on Evening Emotional Fatigue



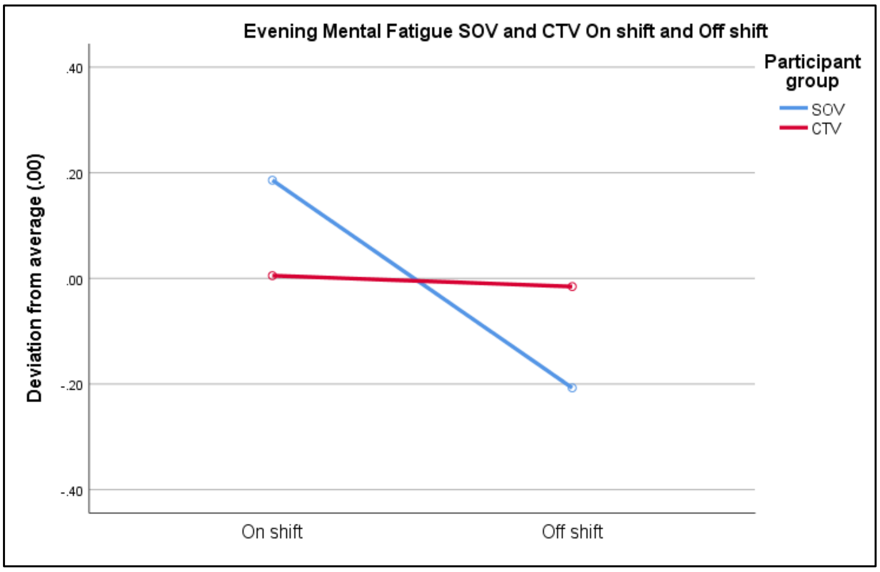
A similar pattern was shown for morning emotional fatigue, though results were not significant (see Appendix 11). Additionally, a significant interaction of shift*group was found for morning anxiety (F(1,17)5.17, p=.036) which shows a similar pattern of interaction as for emotional fatigue can be seen on Figure 19.

Figure 19 Line Graph Showing Shift*Group interaction on Morning Anxiety



Though not significant, similar findings were observed for evening anxiety (see Appendix 12) and evening physical fatigue (see Appendix 13).

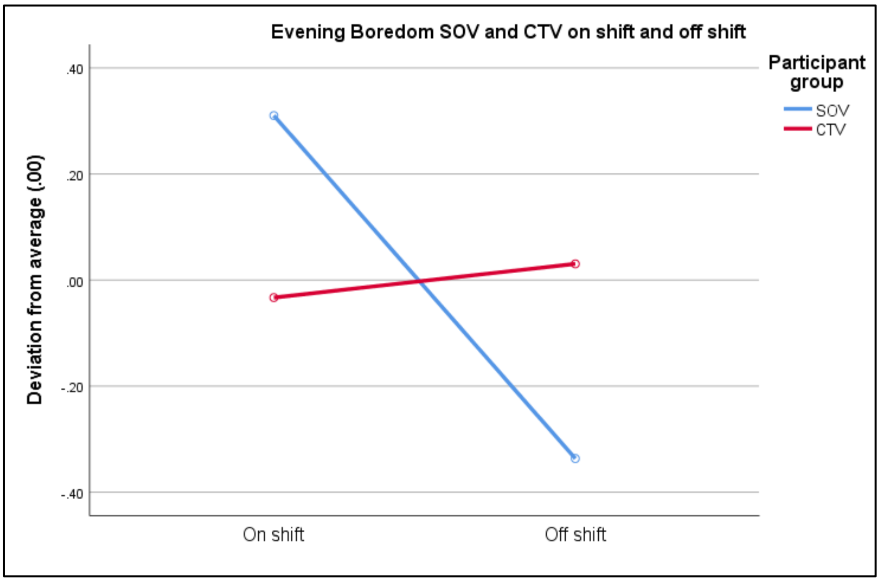
Figure 20 Line Graph Showing Evening Mental Fatigue



For evening mental fatigue the main effect of shift was close to significant at <.05, (F(1,17) 4.21, p=.056) meaning that evening mental fatigue was overall higher on shift than off shift as shown in Figure 20. As illustrated by Figure 19 It is interesting to note that for SOV participants, results were similar to evening emotional fatigue (around +.20 on shift and -.20 off shift). However, for CTV participants there was little change in ratings between on and off shift.

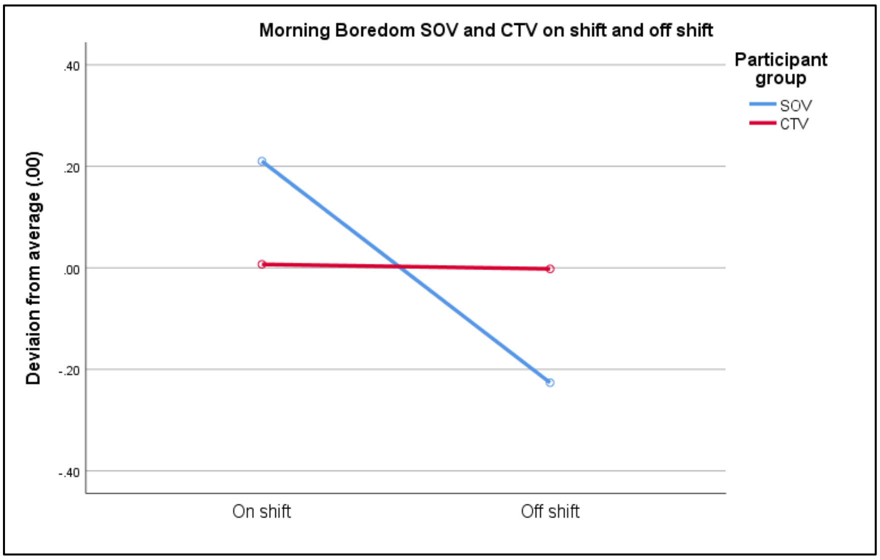
For previously discussed measures, CTV participants had lower ratings of fatigue when on shift and higher when off shift in contrast to SOV participants who appeared to experience higher strain when on shift and lower off shift. For evening mental fatigue, SOV results remained consistent with this trend, however CTV results showed no major difference in ratings between on and off shift. This suggests that being on shift made little difference for average CTV mental fatigue ratings but for SOV participants, caused higher strain as can be seen in Figure 20. This pattern was similar for evening sleepiness (see Appendix 14) and boredom (morning and evening) which will now be discussed.

Figure 21- Line Graph Showing Evening Boredom On and Off shift for both groups



For evening boredom, a highly significant main effect was found for shift (F(1,17)=10.2, p=.005), with evening boredom being higher on shift, although this effect is clearly attributable to the high mean score for SOV workers. There was no main effect for group (F(1,17)=3.2, p=.092), although the ANOVA did also show a highly significant interaction of shift*group (F(1,17)=15.13, p=.001), revealing that the negative effect of being on shift was only present for SOV workers, which is understandable given their on-board evening limitations. This was the strongest significant interaction found, due to the variation in SOV on shift vs off shift ratings (around +.30 on shift vs around -.35 off shift) as illustrated in Figure 21.

Figure 22- Line Graph Showing Morning Boredom On and Off shift for both groups



A significant interaction of shift*group was also found for morning boredom (F(1,17)= 5.92, p=.026). These results followed a similar pattern to evening boredom, with the negative effects of on-shift only being present for SOV participants. Though less extreme than for evening boredom, there was a notable increase in SOV average morning boredom ratings during on shift (+.20) vs off shift (around -.25) whereas CTV ratings remained constant across these conditions as illustrated in Figure 22. Similarly, there was a significant main effect of shift (F(1,17)=6.42, p=.021) with on shift boredom being higher than off shift. But there was no main effect of group (F(1,17)=1.25, p=.274).

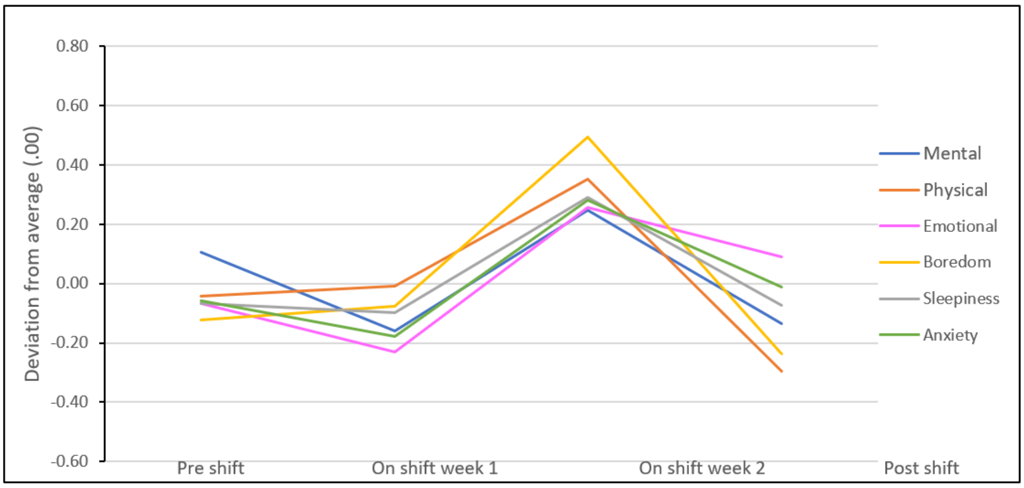
It is interesting that ratings of boredom were particularly significant and could be explained by the confinement and lack of variation in SOV living and working conditions during the on shift. The impact of the SOV shift pattern will be further explored in the following section where SOV results will be considered more closely.

Comparison of fatigue, sleepiness & anxiety for SOV participants at four key points in the data collection period

After comparing fatigue related outcome variables using shift and group, further analyses were performed only on SOV data, to gain a deeper understanding of how their shift pattern impacted these variables. This was done for each outcome variable using a one-way ANOVA with 4 levels (pre shift, on shift week 1, on shift week 2 and post shift) to explore the patterns of responses across the four weeks of shift. Following this, post-hoc Bonferroni tests were performed, as required, to determine where the significant differences lie between each week of the data collection period (pre shift, on shift week 1, on shift week 2 and post shift).

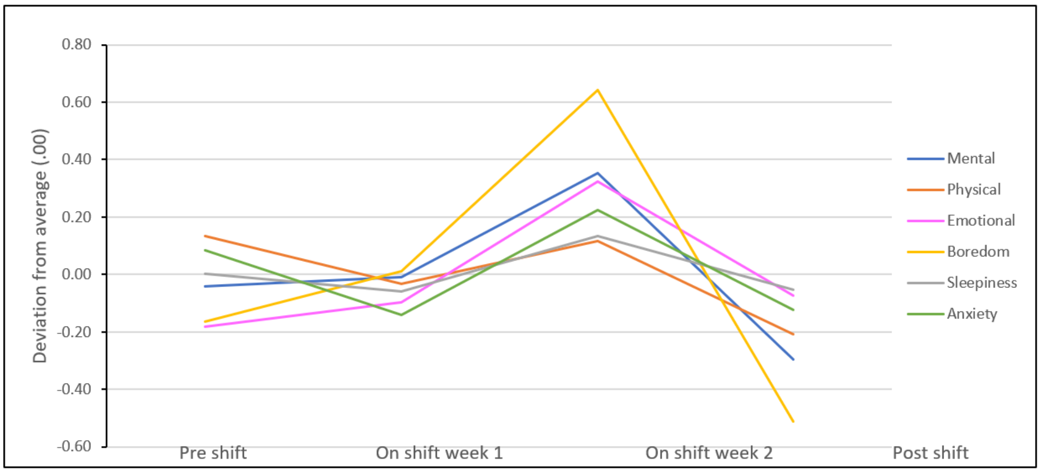
To test assumptions, Shapiro Wilk and Mauchly's test of Sphericity were performed on all data to check for normality and sphericity. Data was found to be normally distributed, with the exception of evening emotional fatigue post-shift ($p=.029$), evening boredom on shift week 1 ($p=.025$), morning anxiety on shift week 1 ($p=.018$) and evening anxiety post shift ($p=.004$), which were all negatively skewed. Data all met the assumption of sphericity apart from evening anxiety ($p=.004$). These abnormalities were likely caused by a combination of relatively small sample size and a tendency towards lower results, but with the occurrence of some higher scores. It was decided that efforts to trim data would lead to the removal of valuable data and therefore analysis would continue, but with abnormalities in the datasets accounted for

<u>Figure 23- Line graph depicting morning fatigue, sleepiness and anxiety ratings for the SOV group over 4 weeks</u>



Note: Y axis ranges from -0.6 – +0.8 to accommodate larger variances

<u>Figure 24- Line graph depicting evening fatigue, sleepiness and anxiety ratings for the SOV group over 4 weeks</u>



<u>Figures 23 and 24</u> show results found in this analysis for morning and evening ratings of fatigue and related factors. They show a clear mean increase in fatigue and related factors in on shift week 2 for morning and evening ratings.

Despite a clear pattern of morning fatigue ratings increasing in on shift week 2 (see <u>Figure 23)</u> the ANOVAs did not reveal any significant findings. This is likely to be caused by low power due to the small sample size. There was no significant main effect found for evening mental fatigue. However, a Bonferroni post hoc showed a highly significant difference between on shift week 2 and post shift (p=.008).

As can be seen on Figure 24 this suggests a relatively high level of evening mental fatigue during on shift week 2 followed by a sharp decrease in mental fatigue ratings in the post shift week. This suggests a clear cycle that mental fatigue increases during on shift week 2, potentially due to a build-up of mental fatigue during on shift week 1 and then sharply decreases during the post-shift week indicating a relatively quick recovery from this during the first week of off shift time. However, this appears to steadily increase during the second off-shift week suggesting that mental fatigue increases as the on shift gets closer.

The ANOVA also revealed a highly significant effect of shift for evening boredom (F(3,21)=21.2, p<.001). The magnitude of this finding in comparison to other variables can be seen in Figure 24. This was further explained by post hoc Bonferroni tests which showed a significant difference between the pre-shift week and on shift week 1 (p=.009) meaning that evening boredom was higher during the first on shift week than it had been in the pre-shift week. A significant difference between on shift week 1 and on shift week 2 was also revealed (p=.027) showing that boredom ratings continued to increase during the on shift and reached a peak during the second week. Furthermore, a highly significant difference was found between on shift week 2 and the post shift week (p<.001), this time highlighting a decrease in boredom ratings between the second on shift week and the first week that participants were off shift and at home.

Findings in this analysis highlight that fatigue and related factors generally increased during on shift time for SOV participants with a point of high strain during on shift week 2.

7.4.2.2 Recovery

Recovery is considered here as an important aspect of information to support work scheduling. The following tables depict non-standardised average recovery scores for each week (recovery scale ranged from 1-5, higher scores indicated better recovery).

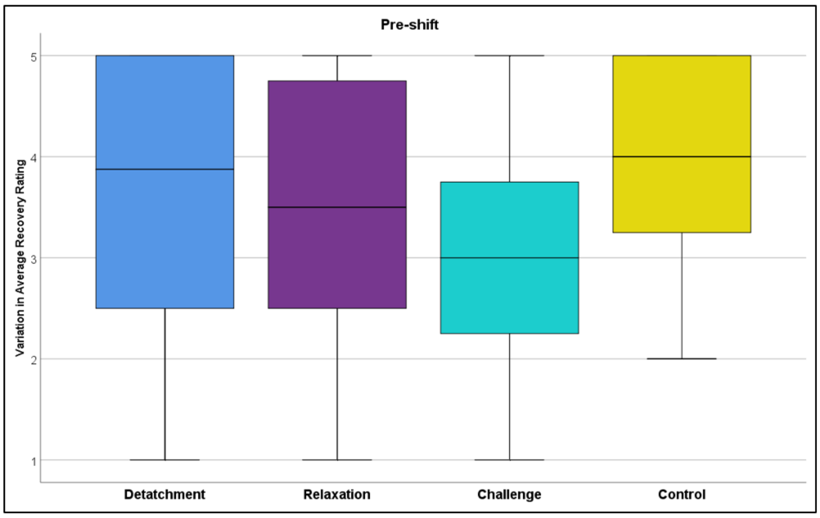
Table 23- SOV Recovery Means and Standard Deviations

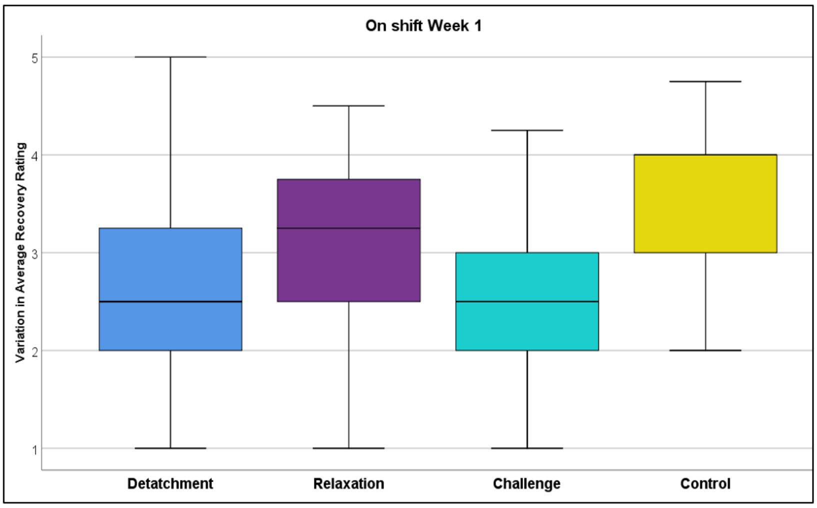
Variable	**Week 1 (N=9)** *Pre-shift*		**Week 2 (N=9)** *On-shift W1*		**Week 3 (N=9)** *On-shift W2*		**Week 4 (N=8)** *Pre-shift*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Detachment	*3.5*	*.87*	*2.5*	*.63*	*3.1*	*.99*	*3.1*	*1.2*
Relaxation	*3.4*	*.85*	*3.2*	*.45*	*3.0*	*.74*	*3.6*	*.52*
Challenge	*2.9*	*.57*	*2.5*	*.74*	*2.1*	*.66*	*3.0*	*1.0*
Control	*4.0*	*.78*	*3.5*	*.52*	*3.5*	*.89*	*3.6*	*.58*

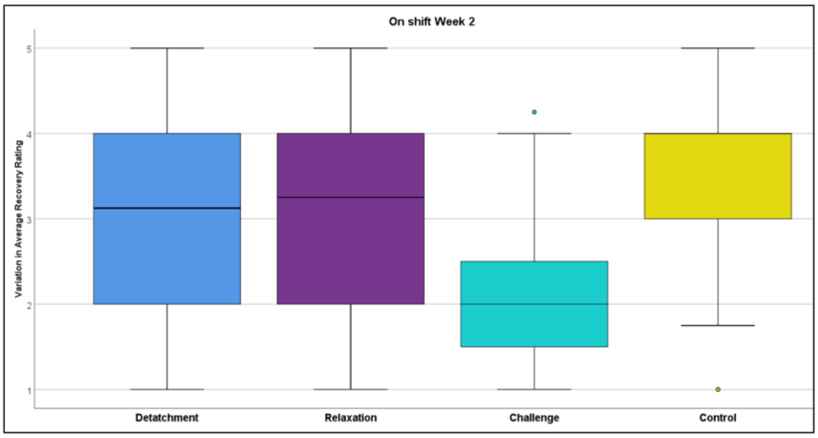
As can be seen in Table 23 average recovery scores were relatively high during off shift time but tended to be lower during on shift weeks, particularly for detachment and challenge. Although average results were moderate, there were notable patterns of variations, which are illustrated in

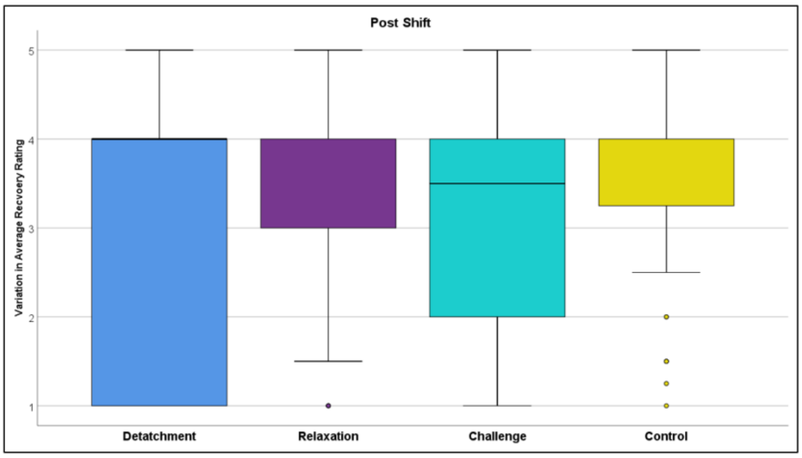
Figure 25.

Figure 25- Box plots showing variation in SOV recovery ratings for each week









As can be seen in

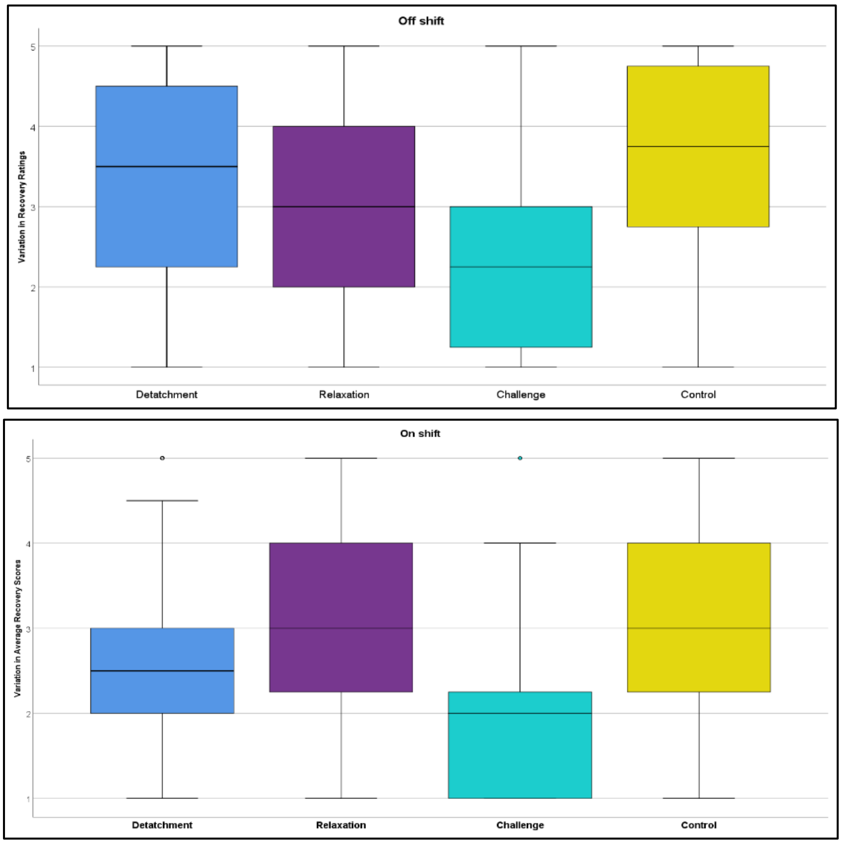
Figure 25 there were large variations individual recovery ratings particularly for detachment in pre-shift, on shift week 2 and post shift, relaxation in pre shift and on shift week 2 and challenge in the post shift. The pre shift week shows scores generally clustering around higher recovery ratings whereas scores notably decrease during on shift weeks and although they increase in the post shift week, do not regain pre-shift levels.

Table 24- CTV Recovery Means and Standard Deviations

Variable	Week 1 (N=10)		Week 2 (N=10)		Week 3 (N=10)		Week 4 (N=10)	
	Off-shift		*On-shift*		*Off-shift*		*On-shift*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Detachment	*3.3*	*.73*	*2.7*	*1.0*	*3.3*	*.88*	*2.8*	*.85*
Relaxation	*3.3*	*1.2*	*3.1*	*1.4*	*2.6*	*1.4*	*2.6*	*1.5*
Challenge	*2.4*	*.61*	*1.9*	*.76*	*2.3*	*.69*	*2.1*	*.81*
Control	*3.6*	*.78*	*3.0*	*.84*	*3.4*	*.77*	*3.3*	*.81*

Similar to the SOV group, Table 24 shows that average recovery ratings were moderate throughout the data collection period with higher scores tending to be for control, relaxation and detachment during off shift weeks. The variable 'challenge' has lower ratings throughout the data collection period with notable declines during on shift weeks. Detachment also has notable decrements during on shift time.

Figure 26- Box plots showing variation in CTV recovery ratings for each week



As with SOV results, Figure 26 shows that CTV ratings had a high level of individual variability, suggesting that some people are much more able to recover from the effects of work than others. It is interesting to note how average ratings and variation changed between on shift and off shift. This is particularly notable with detachment which has a higher average (3.3) and variation (scores clustering around 2.7- 4.5) than during the on shift (scores clustering around 2-3). Interestingly, ratings of relaxation did not differ much, and lower ratings were more common during the off shift. Challenge and control were both notably lower during the on shift.

ANOVAs were performed to determine whether there were significant differences between on shift and off shift and findings from the two groups will be presented in the following section.

Comparison of recovery between shift and group

A 2X2 (shift, group) mixed design ANOVA was performed on each of the four recovery variables. Prior to this, the following methods were employed to test assumptions of normality and homogeneity of variance. A Shapiro Wilk test was performed to test the assumption of normality. All variables were non-significant ($p>.05$) apart from 'detachment, CTV off shift' ($p=.030$). Upon further investigation, it was found that this deviation from normality was caused by one outlier ($z=-.34$). It was decided that this would be left in the dataset as though it was lower than most other scores, it was an accurate representation of that participants' recovery ratings. Levene's tests were performed to test for homogeneity of variance which were all non-significant ($p>.05$) indicating that data met this assumption.

As can be seen in Table 25 all but one recovery variable (relaxation) had a significant main effect of shift There were no significant interactions for shift*group and no significant main effects for group meaning that recovery ratings were similarly impacted by being on or off shift for both groups.

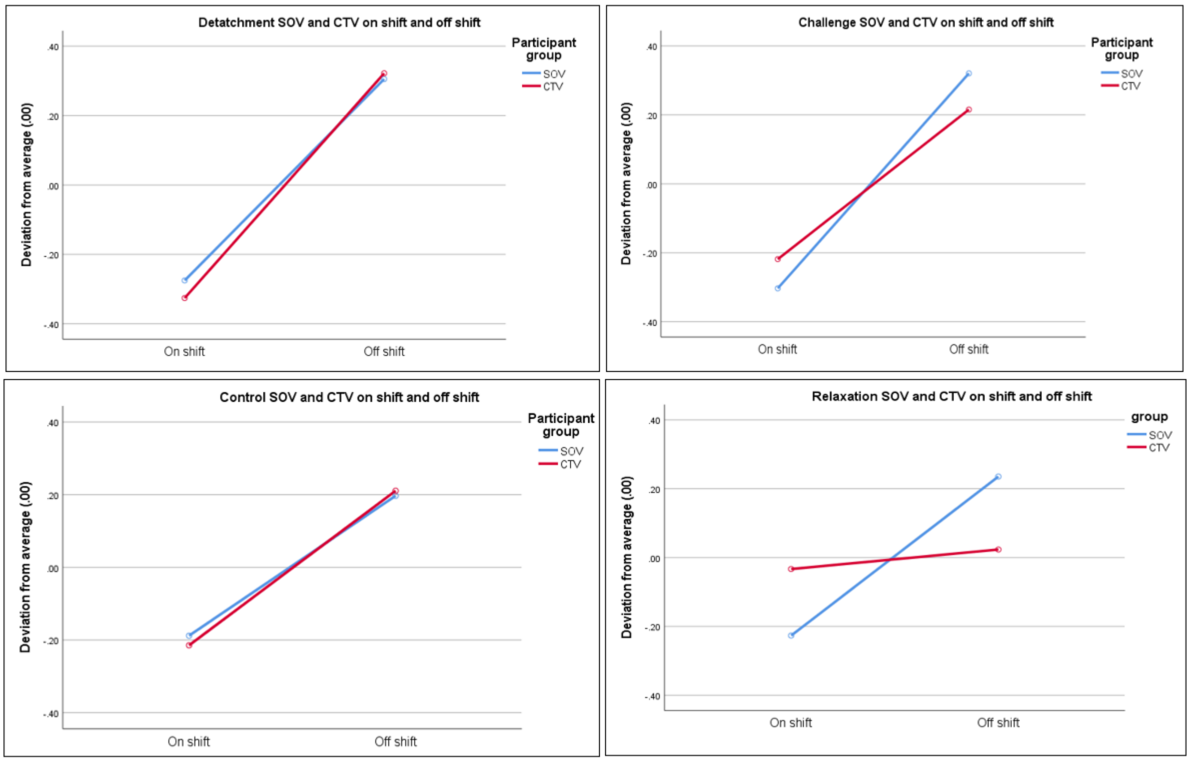
Table 25- Results of 2X2 ANOVA comparing recovery ratings based on shift and group

Recovery			
Variable	**Shift*Group**	**Shift**	**Group**
Detachment	*F(1,16) .107, p=.748*	***F(1,17) 21.12, p>.001****	*F(1,16) 1.97, p=.179*
Relaxation	*F(1,17) 2.31, p=.147*	*F(1,17) 3.79, p=.068*	*F(1,17) .892, p=.358*
Challenge	*F(1,17) .429, p=.521*	***F(1,17)13.34, p=.002****	*F(1,17) .429, p=.521*
Control	*F(1,17) .015, p=.904*	***F(1,17)6.1, p=.024****	*F(1,17) .0204, p=.657*

**=Significant at .05 **=Highly significant, <.01*

As can be seen in Table 25 the ANOVA revealed a highly significant effect of 'shift' for detachment (F(1,16) 35.65, p>.001) and challenge (F(1,17)13.34, p=.002) and a significant effect for control (F(1,17)6.1, p=.024). As revealed by Figure 27, recovery ratings were very similar for both groups, in that these three factors (detachment, challenge and control), were rated significantly poorer during on shift time compared to off shift time.

Figure 27- Line Graphs of Detachment, Challenge and Control On and Off shift for both groups



It is interesting that these results are so similar between the groups, as they suggest that their work environments have a similar effect on their feelings of detachment, challenge and control during recovery time, despite the clear difference in work environment. This perhaps would not have been expected, as offshore participants did not leave their work environment whereas CTV participants returned home.

Results are not so similar for relaxation. Though CTV participants have a small decrease in relaxation during on shift time, this is not as extreme as for the SOV group and results are not significant. This is interesting and suggests that SOV participants were prevented from entering a relaxed state during on shift time due to their work environment but were able to gain this during off shift time while at home. A deeper analysis of SOV results will be conducted in the following section.

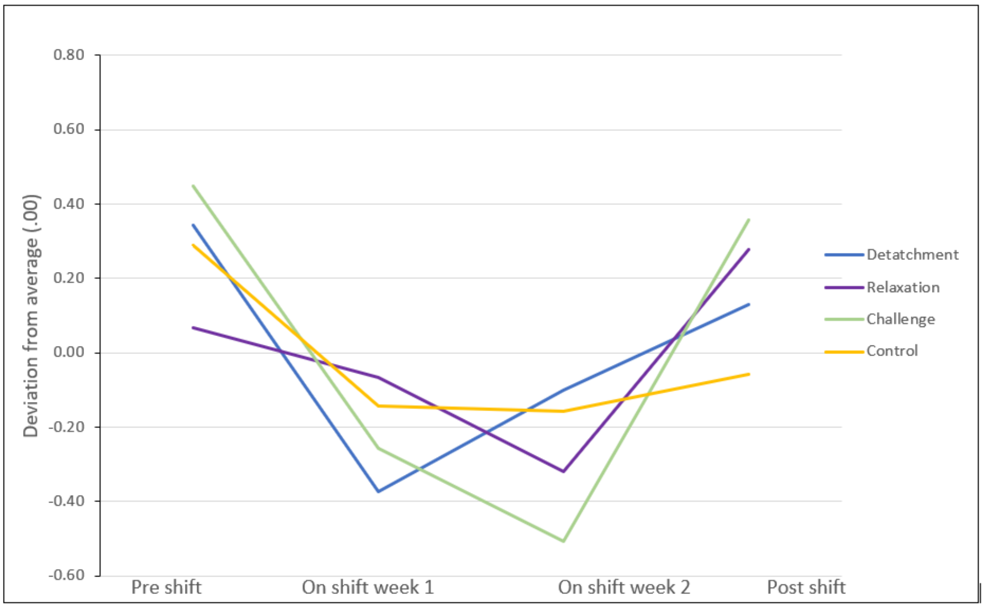
<u>Comparison of recovery for SOV participants at four key points in the data collection period</u>

A one-way ANOVA with 4 levels of shift type (pre shift, on shift week 1, on shift week 2 and post shift) was performed to determine whether there was an effect of shift. Following this, post-hoc Bonferroni tests were performed to determine whether there were differences in recovery ratings between each week. Assumptions testing showed that data was normally distributed (Shapiro Wilk, p>.05) and did not violate the assumption of homogeneity of variance (Levene's test, p>.05).

Results showed a notable decrease in recovery during the on shift for all variables. However, as can be seen on

Figure 28 different recovery variables had notably different low points between the two on shift weeks. Detachment ratings dipped during the first on shift week and then increased during the second week, possibly as participants became acclimatised to being away from home. However, relaxation and challenge reached low points during the second week of on shift time, possibly due to a build-up of strain during the work period. Interestingly, control dipped when participants began their on-shift time and maintained a relatively low level throughout the course of the on shift and does not recover to pre-shift levels even in the post shift week. Therefore, it is only in their second consecutive week of off-shift that they 'recover' with regards to this dimension.

Figure 28- Line graph depicting recovery ratings for the SOV group over 4 weeks



Despite clear patterns in the descriptive data, significant results were only found for one variable (challenge). This lack of significant findings for other variables is likely due to insufficient power.

The one way ANOVA to compare recovery for the four shift weeks revealed a highly significant effect of 'shift' on challenge (F(3,21)=7.12, p=.002) and post-hoc Bonferroni tests showed a significant difference between pre shift and on shift week 1 (p=.028) and pre-shift and on shift week 2 (p=.045) illustrating that ratings of challenge were significantly lower during on shift time. This effect can be seen on

Figure 28 in which challenge declines throughout the on shift and is notably low in week 2 (-0.55). This could be linked to results of boredom ratings (see section 7.4.2.1) as participants felt less challenged and so were more bored during this time.

Now that recovery during waking time has been considered, it is important to focus on how sleep changed throughout the data collection period. This will be done in the following section.

7.4.2.3 Sleep

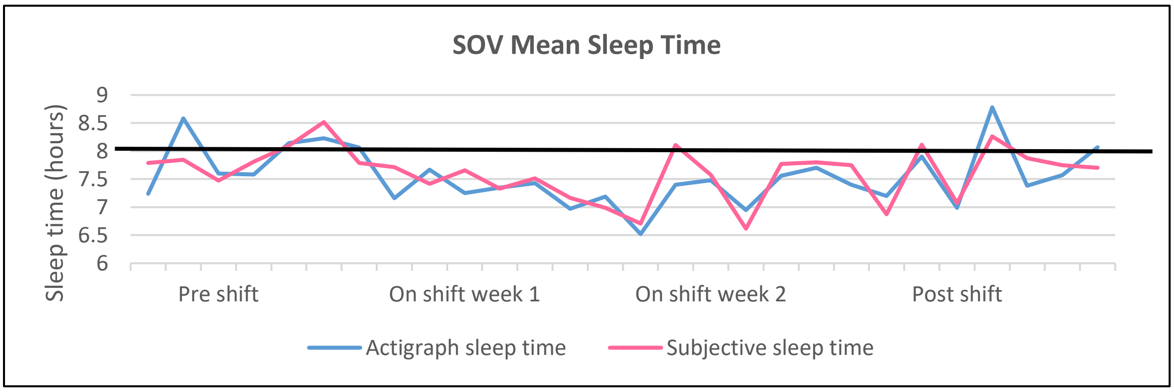
This section will first consider sleep time (hours) of both groups across the period of data collection. It is useful to initially examine pre-standardised data for this as sleep time has objective significance when considering fatigue and wider health (e.g. obtaining less than 6.5 hours of sleep is generally seen to be hazardous, see chapter 2 section 2.6.3 for a detailed discussion of this). Data will be presented in line graphs to show general trends and then in box plots to illustrate the range of individual scores for each major stage in shift patterns. After this, comparisons will be made between objective and subjective sleep time measures.

Following this, a wider variation of sleep factors will be considered including objective and subjective measures of sleep quality. Data will be analysed in the same manner as in the previous sections to determine whether there are significant differences in their occurrence at key points data collection period and between the groups.

Sleep Time

Figure 29 depicts subjective and objective sleep times for SOV participants throughout the data collection period. A line is provided as a reference point at 8 hours, which is widely regarded as an optimal sleep time for adults (note, a range of 7-8 hours is regarded as adequate) (Hirshkowitz et al., 2015).

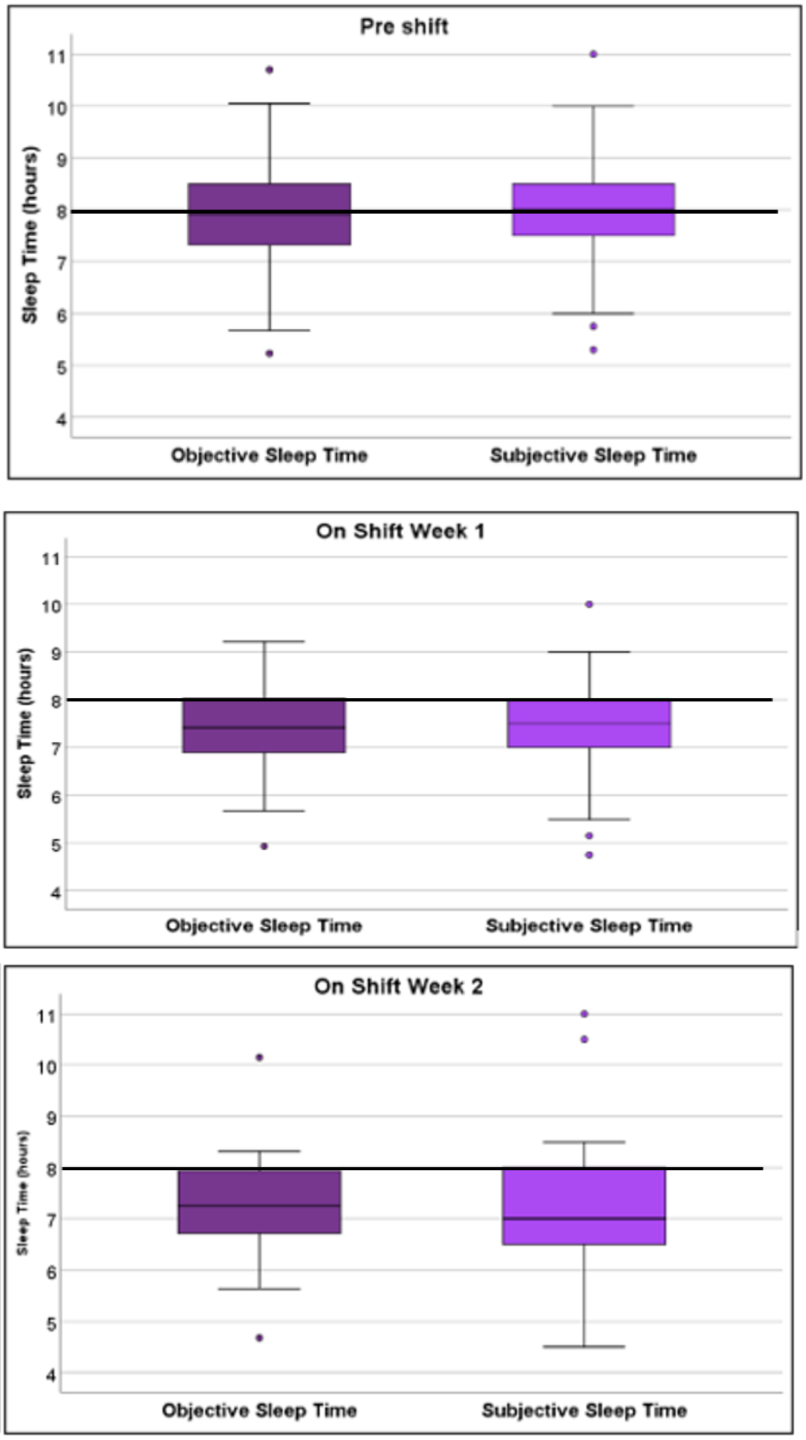
Figure 29- Line graph depicting average objective and subjective sleep times for SOV participants over 4 weeks

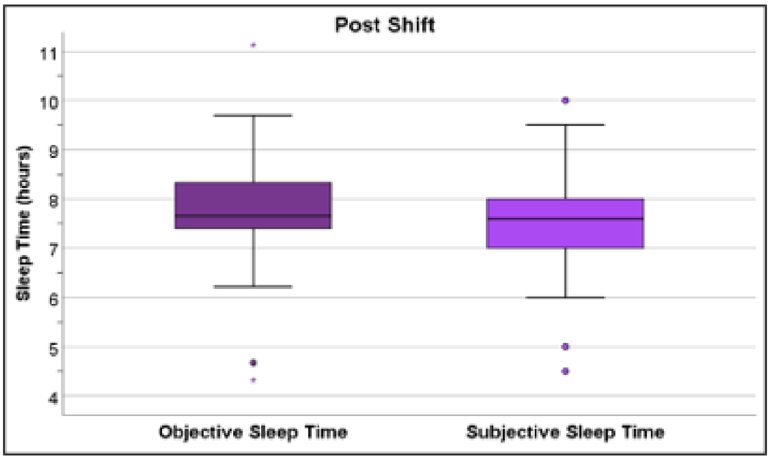


As can be seen on Figure 29 SOV participants tended to experience longer periods of sleep during their pre-shift week with averages ranging from around 7.5 to 8.5 hours. This notably dropped during on shift week 1 where average sleep time consistently declines throughout the week reaching a low of 6.5 at the beginning of on shift week 2, below adequate time. Sleep time then increases to a healthier level (although subjective sleep time seems to over-estimate this increase in comparison to objective measures) indicating a rebound effect meaning that longer sleep periods are experienced to recover from previous decrements. During the post shift, sleep time is generally within a healthy range, but rather variable indicating small dips and rebounds during this period. Individual variations in sleep times are explored in

Figure 30 and should be considered alongside this data.

Figure 30- Box plots depicting individual variation in objective and subjective sleep time (hours) for SOV participants





As can be seen in

Figure 30 individual sleep times have a wide variation, generally ranging from 5.5 to 10 hours. Sleep times tended to be higher but have a wider range during the pre-shift week with average scores around 8 hours and lower with less variation during on shift weeks one and two with most times below 8 hours. Interestingly subjective sleep time ratings in on shift week 2 have a wider range and include lower sleep times, suggesting that participants may attribute feelings of higher fatigue at this time in their shift to having less sleep, even if this was not necessarily the case. Objective sleep times were as low as 4.5 hours during on shift week 2 which highlights a potential safety issue.

Sleep times tend to be higher during the post shift week, but average times do not cluster around the optimal time of 8 hours as they do in the pre-shift week and there are notable differences between objective and subjective times, with subjective times generally lower. Sleep times for CTV participants will now be considered.

Figure 31- Line graph depicting average objective and subjective sleep times for CTV participants over 4 weeks

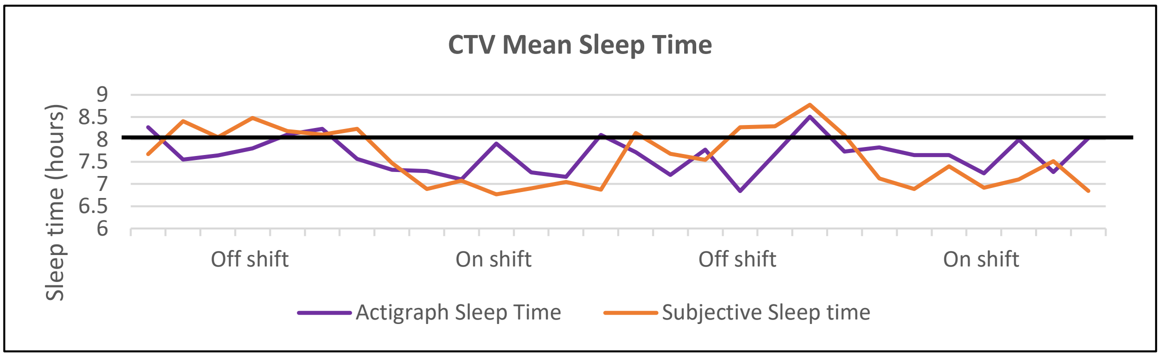
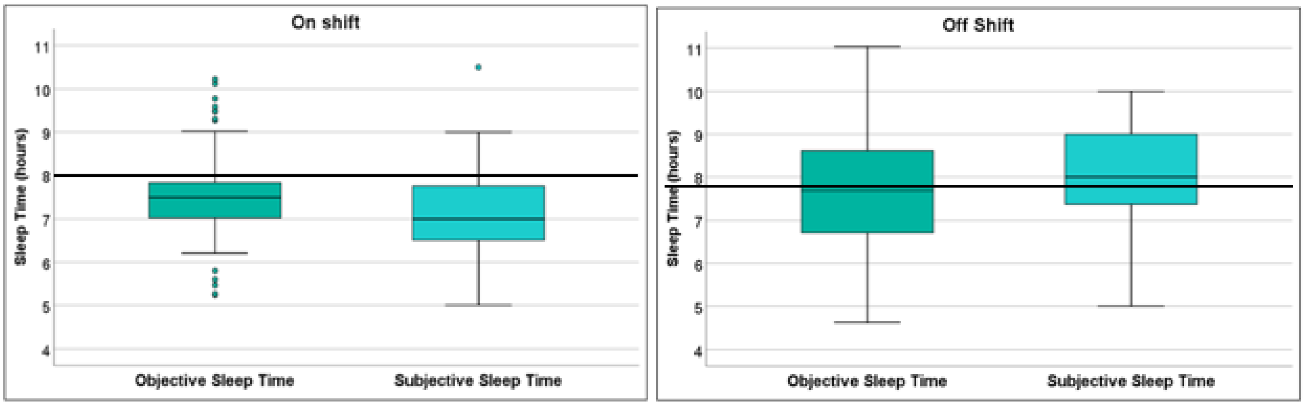


Figure 32- Box plots depicting individual variation in objective and subjective sleep time (hours) for CTV participants



As with SOV sleep times, a notable difference can be seen in Figure 31 and Figure 32 between sleep times during off shift and on shift time. During off shifts, average sleep times tend to be around 7.5 to 8 hours whereas during on shifts sleep times tend to be around 6.5 to 7.5 hours.

It is important to note that the number of participants included in subjective sleep measures (collected through diary entries) were higher than those included in objective sleep measures (collected through ACTI graphs). This is because participants sometimes failed to wear the ACTI graph watches even though they had filled in the diary entries (see Figure 11). Table 26 compares the average amount of participants included in each measure per week calculated from entries per day for each group.

Table 26- Number of participants included in objective and subjective sleep measures per week

Sleep Participants				
	Week 1	**Week 2**	**Week 3**	**Week 4**
SOV Subjective Sleep	*8*	*9*	*8*	*7*
SOV Objective Sleep	*8*	*9*	*8*	*4*
CTV Subjective Sleep	*8*	*9*	*9*	*7*
CTV Objective Sleep	*7*	*7*	*7*	*5*

Paired samples t-tests were performed to determine whether there were significant differences between objective and subjective sleep times for both groups. Results are illustrated in Table 27.

Table 27- T-test results showing differences between objective and subjective sleep time measures for both groups

Objective/Subjective Sleep				
	Week 1	**Week 2**	**Week 3**	**Week 4**
SOV Sleep times	*t=-1.35, p=.18*	*t=-1.56, p=.13*	*t=-3.6, p=.72*	*t=.85, p=.41*
CTV Sleep times	***t=2.87, p=.007***	*t=1.9, p=.061*	*t=-1.87, p=.07*	***t=2.9, p=.005***

As can be seen in Table 27 SOV objective and subjective sleep times showed no significant differences. However, CTV objective and subjective sleep times were significantly different in weeks one and four. This could be due to the differences in numbers of participants in the two conditions or could be reflective of differences in perceived and actual sleep time in CTV participants. This suggests that it is important to obtain objective measures to ensure accuracy.

Sleep time and quality

Table 28 depicts non-standardised means and standard deviations of sleep measurements. This includes objective and subjective sleep times (hours of sleep) and subjective sleep quality (rated on a scale from 1 to 9, higher number indicates higher quality of sleep).

Table 28- Means and standard deviations of sleep data for SOV Participants

Variable	**Week 1** *Pre-shift*		**Week 2** *On-shift W1*		**Week 3** *On-shift W2*		**Week 4** *Post-shift*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Obj sleep	*7.9*	*.64*	*7.2*	*.58*	*7.4*	*.5*	*7.8*	*.57*
Subj sleep	*8*	*.9*	*7.4*	*.6*	*7.6*	*.84*	*7.8*	*.59*
Sleep quality	*6.2*	*1.1*	*6.3*	*.64*	*6.3*	*.71*	*6.8*	*1.1*

Sleep times were discussed in detail in section 7.4.2.3 yet it is interesting to note that the lowest average rating of sleep quality (pre shift) corresponds with the highest rated sleep time in the same pre-shift week. It is also notable that average sleep quality is the same for both on shift weeks showing that although average sleep quantity increased in on shift week 2 there was no increase in perceived quality. Figure 33 shows the range of individual variation of average scores per week which will subsequently be discussed.

Figure 33- Box plot depicting individual variation in subjective sleep quality (scale of 1-9)

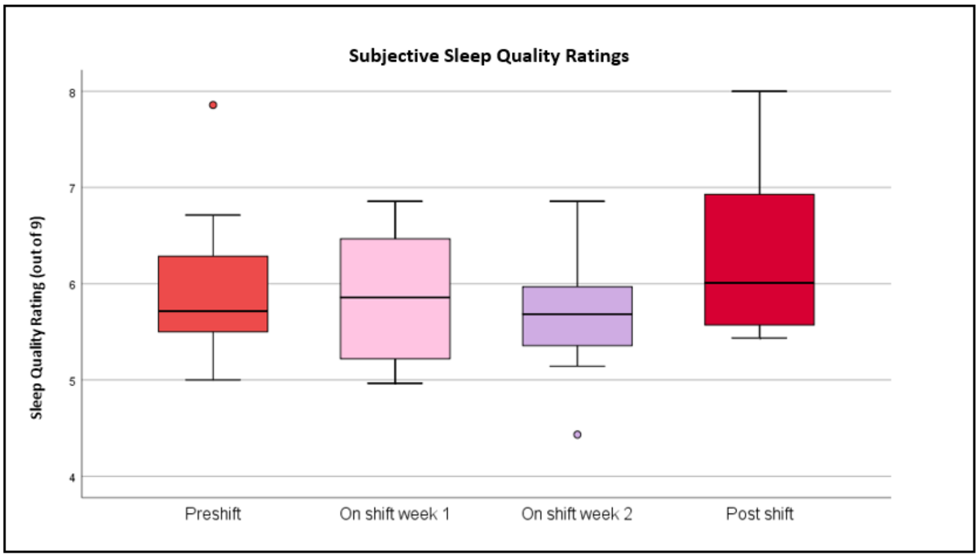


Figure 33 shows a comparison individual variation in average sleep quality ratings for each week. It shows that individuals' average scores were no lower than 5 (except for one in on shift week 2 that was 4.5) but that they were no higher than around 6.7 apart from in the post-shift week.

Table 29- Means and Standard Deviations of sleep data for CTV Participants

Variable	Week 1 *Off-shift*		Week 2 *On-shift*		Week 3 *Off-shift*		Week 4 *On-shift*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Obj sleep	*7.9*	*.71*	*7.5*	*.63*	*7.6*	*.59*	*7.5*	*.78*
Subj sleep	*8.4*	*.71*	*7.2*	*.89*	*8.2*	*.65*	*7.2*	*.42*
Sleep quality	*5.9*	*1.0*	*6.1*	*1.1*	*6.2*	*.86*	*6.1*	*1.4*

As with the SOV group, Table 29 shows that the week with the highest average sleep time (week 1) corresponded with the lowest average rating of sleep quality. It is also interesting to note that sleep quality in week 1 (off shift) was lower than on shift weeks. Figure 34 shows the range of individual variation of average scores for on shift and off shift which will subsequently be discussed.

Figure 34- Box plot depicting individual variation in sleep quality (scale of 1-9)

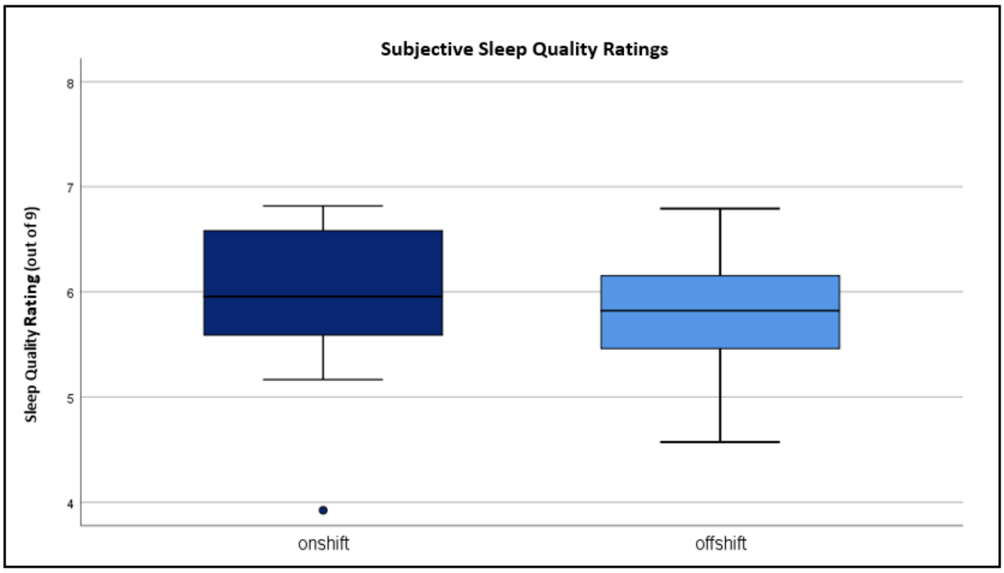


Figure 34 highlights that individual average sleep quality ratings tended to be higher during on shift time. This is surprising as sleep opportunity was likely to be decreased during this time. However, it could be reflective of increased activity during off shift time (e.g. socialising or travel) and routine disruption.

Comparison of Sleep Quantity and Quality between Shift and Group

As with previous variables, a 2X2 mixed ANOVA was performed to determine the impact of shift and group on the outcome variables. To test assumptions of normality Shapiro Wilk tests were performed which were all non-significant ($p>.05$). Levene's tests, performed to test homogeneity of variance, were all non-significant apart from subjective sleep quantity off shift ($p=.041$) this was deemed sufficiently close to give the results credibility.

Table 30 includes the results of ANOVAs with significant results in bold. There were no significant main interactions, but significant results were found for 'shift' on objective and subjective sleep quantity.

Table 30- Results of 2X2 ANOVA comparing sleep based on shift and group

Variable	Shift*Group	Shift	Group
Objective sleep quantity	*F(1,15)2.02, p.175*	***F(1,15)12.68, p.003*****	*F(1,15)2.02, p.175*
Subjective sleep quantity	*F(1,17).2.04, p.172*	***F(1,17)44.5, p<.001******	*F(1,17)1.89, p.197*
Subjective sleep quality	*F(1,17).425, p.523*	*F(1,17)1.1, p.310*	*F(1,17).112, p.742*

**=Significant at .05 **=Highly significant, <.01*

As can be seen in Table 30, the ANOVA revealed a very large and highly significant main effect of 'shift' on subjective sleep quantity (F(1,17)44.5, p<.001) and a large and highly significant main effect on objective sleep quantity (F(1,15)12.68, p=.003). This and the fact that neither of these variables had other significant interactions or main effects shows that both groups obtained significantly less sleep during their on shifts indicating that being on shift had a negative impact on sleep acquisition. This effect is illustrated in Figure 35.

Figure 35- Line Graphs of objective and subjective sleep quantity On and Off shift for both groups

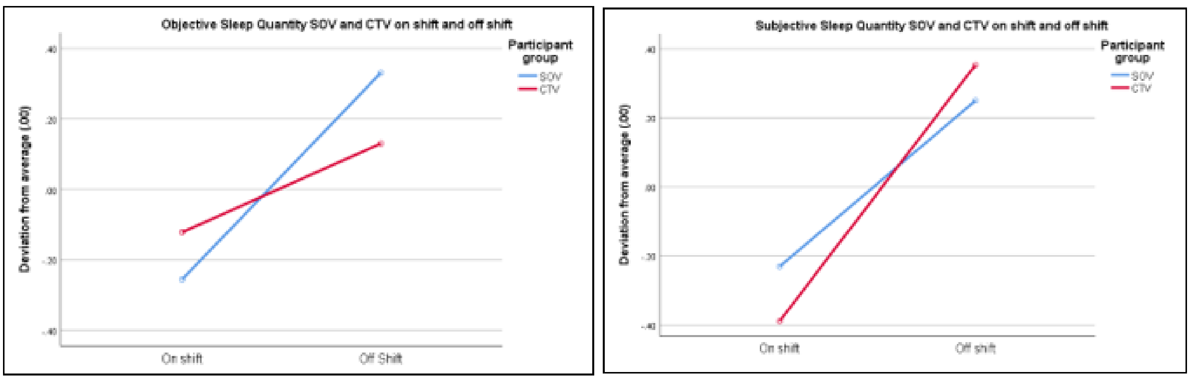
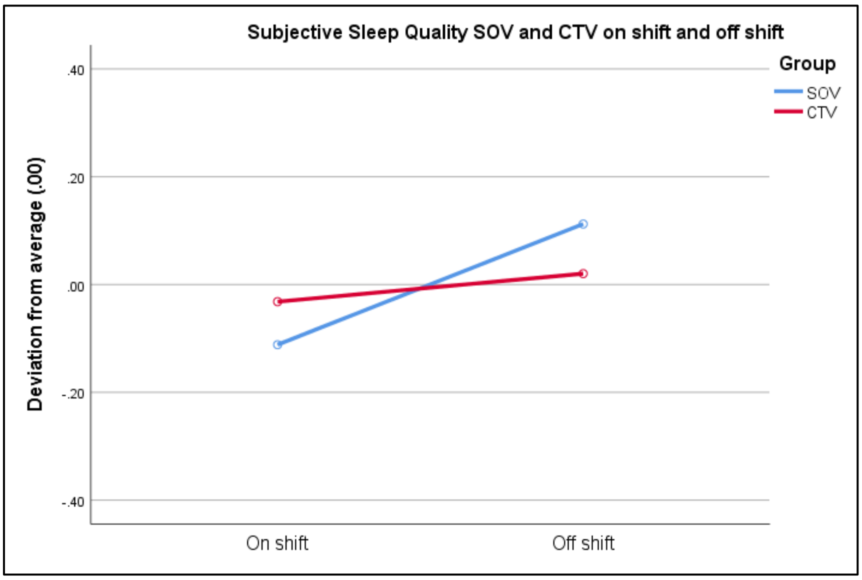


Figure 35 shows that though both groups have lower ratings of subjective and objective sleep quantity, there is a notable difference between these two measures. For objective ratings, the impact of shift was more notable than for CTV participants (although this interaction did not reach significance). SOV participants had notably below average ratings during the on shift (around -.30) and higher during the off shift (around +.35) whereas CTV scores showed a similar pattern yet were less influenced by shift type. This pattern of effects was different for subjective ratings as although subjective sleep ratings for sleep quantity were again worse on shift for both groups, the impact of shift was great for CTV participants, with a more dramatic variation between on shift (-.40) and off shift (around +.37).

Figure 36- Line Graph of Subjective Sleep Quality



Both groups had lower ratings of subjective sleep quality in the on shift compared to the on shift. However, SOV participants seemed to be affected more severely by this. Though these differences were low and not significant, it is still worth noting as they indicate that SOV participants tended to have lower sleep quality during their on-shift time whereas CTV participants were less affected. This could be because they were able to return home to sleep. Figure 36 illustrates these results.

Therefore, sleep quantity, rather than quality was significantly lower during on shift time compared to off shift time for both groups. For both groups, during off shifts, average sleep times were around eight hours and during on shifts average sleep times were around 7.5 hours. This does not initially appear concerning as 7.5 hours is still within a healthy range. However, this is an average taken throughout the period and includes much lower sleep times and higher recovery sleeps as discussed in section… It must also be highlighted that obtaining enough sleep is fundamental for ensuring safe behaviour in high hazard environments and so gaining optimal sleep is of upmost importance in this work environment. An in-depth analysis of SOV sleep variables will now be explored.

Comparison of Sleep for SOV participants at four key points of data collection

As with previous variables, a one-way ANOVA with 4 levels (pre-shift, on shift week 1, on shift week 2 and post-shift) was conducted to determine whether there was an effect of shift on SOV sleep results. Following this, post-hoc Bonferroni tests were performed to determine whether there were significant differences between each week. Shapiro Wilk tests showed that all data was normally distributed apart from subjective sleep quality pre shift ($p=.05$), as data included some extreme scores. It was decided that analysis would continue as results were representative of participants' scores. Macaulay's test of sphericity showed no significant results ($p<.05$).

<u>Figure 37- Line graph depicting sleep quantity for the SOV group over 4 weeks</u>

Results indicated clear decrements in sleep quantity during on shift time and lower sleep quality until the post shift week. There are some notable differences between objective and subjective sleep quantity as can be seen in

<u>Figure 37</u> objective measures showed a notable decrease in sleep acquisition during on shift week 1 followed by an increase in week 2 indicating a rebound effect.

However, subjective sleep quantity showed a higher estimated level of sleep in the pre-shift week and a consistently low level throughout the on shift and during the post shift week. This is particularly interesting as pre-shift sleep quantity seems to be overestimated. This could potentially indicate that participants associated an increased experience of strain in on shift week 2 with a lack of sleep. It could also suggest that participants still may have felt sleep deprived during this time due to the inefficient way individuals recover 'sleep debt'. So, participants may have rated themselves as having lower sleep as they still ‘felt’ sleep deprived during this time even though they were objectively obtaining more sleep.

The ANOVA revealed a highly significant effect of shift for subjective sleep quantity ($F(3,21)5.73$, $p=.005$). This was further explained by post hoc Bonferroni tests that revealed the significant difference in subjective sleep times was between the pre shift week and on shift week 1 ($p=.05$), Findings for objective sleep quantity were not significant ($F(3,15)2.96$, $p=.066$), thus illustrating the significant decrease in subjective results was not mirrored (significantly) by objective results, although the patterns are fairly similar.

As can be seen in

Figure 37 subjective sleep quality remained at a below-average level until the post shift week where it notably increases. This indicates that sleep quality is impacted during the week before going on shift, potentially due to anticipation of going offshore. Though this result was not significant, the pattern is still noteworthy. Sleep results indicate that being on shift had a negative impact on sleep quantity which, objectively was experienced as a notable decrease in on shift week 1 and an increase over the following two weeks but subjectively was experienced as a generally low level during shift time and an increase during the post shift week. Sleep quality seemed to be more affected in the week before embarking on shift and did not recover until the post-shift week.

7.4.2.4 Impact of work and shift design on fatigue, recovery and sleep summary

Findings presented in this section suggest that being on shift had a prominent impact on fatigue and related factors for SOV participants and less of an impact for those in the CTV group. This is illustrated with significant interactions for shift*group for evening emotional fatigue and morning anxiety showing that SOV participants experienced higher occurrences of these factors during on shifts whereas these were lower for CTV participants. This was also shown in results for evening mental fatigue with near-significant results showed that SOV participants had higher ratings of this on shift while CTV ratings had little difference between on and off shifts.

Despite on shift fatigue ratings being higher for SOV participants, results on most recovery variables showed similar trends between the groups with detachment, challenge and control lower for both groups during on shift time. The only notable difference was with relaxation in which SOV participants had lower levels during on shift time whereas the CTV group showed little change. Findings on sleep quantity showed that both groups had similar decrements during on shift time. It is striking then that SOV fatigue related outcomes seemed to be more affected during on shift time when sleep and recovery variables were similar between the groups. To investigate this further, it is useful to consider the impact of work demands on fatigue related outcome variables which will be done in part 2.

7.4.3 Impact of work demands on fatigue

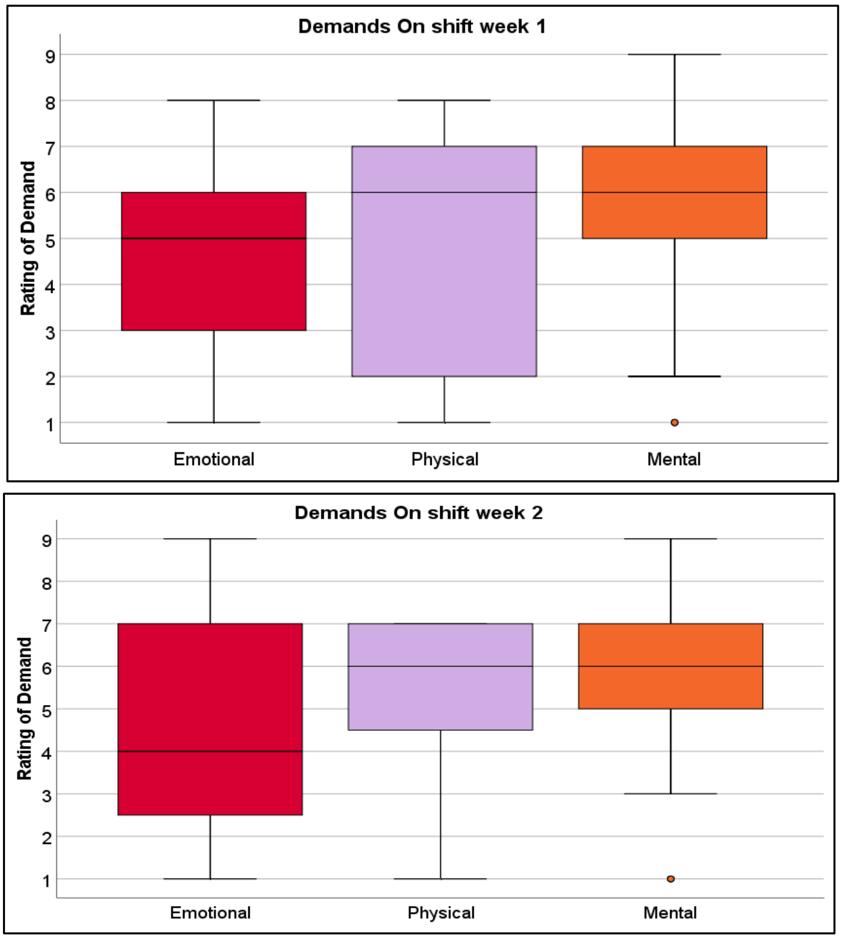
This section will address research question 2- *'How do workplace demands impact fatigue?'*. This will be done using multiple regression using the Enter method (Field, 2016) to determine the predictive effect of mental, physical and emotional demands on fatigue outcomes during on shift time. Data was analysed to determine how demands experienced during the day related to fatigue scores that evening and the following morning.

Assumptions of independent errors, homoscedasticity and linearity were tested using a combination of VIF scores and regression plots (Field, 2016). All VIF scores were within the range of 1 to 10 suggesting that multicollinearity had not occurred in any of the variables. Normality plots suggested that data was approximately normally distributed although some variables were negatively skewed (e.g. emotional fatigue during evenings in on shift week 1). It was decided that this was an accurate representation of the spread of data in this cohort as most participants scored themselves as low, but with some notable examples when emotional fatigue had been particularly high, therefore higher scores were still included. Scatter graphs showed data that were evenly spread.

Results are outlined in the following sections with box plots depicting the occurrence and variation of demands. For an overview of results discussed and at end of this section heat maps from both groups are included for an overview of results and for ease of comparison. Results will first be considered for the SOV group which will explore on shift week 1 and 2 separately. Following this, data will be explored for CTV participants.

7.4.3.1 The Impact of Demands on Fatigue on for SOV Participants

Figure 38- Box plot showing variation in ratings of demands in SOV on shift weeks 1 and 2



To support further exploration of factors predicting fatigue, the nature of work demands was recorded by participants. Each evening, participants were required to rate the demands they had experienced that day on a scale of 1-9. Figure 38 shows that ratings of demands was varied during on shift week 1.

For on shift week 1, ratings of emotional demands ranged from 1 to 8 but tended to cluster around 3 to 6, which when considering a likely culture of avoiding acknowledgement of emotions in this work environment (see chapter 6 section 6.5.8) is noteworthy. This could be due to the emotionally charged nature of embarking on a period of offshore work in which participants left their families for a period of two weeks and acclimatised to life offshore.

Ratings of physical demands included a high amount of individual variation but with a relatively high mean which could be reflective of high physical demands when working but of regular stand down days for weather in which participants were not required to undertake physical tasks. Ratings of mental demands were generally higher with less variation which could be reflective of the omnipresent mental demands of offshore life.

In on shift week 2 emotional demands tended to be more varied incorporating the whole spectrum of the scale but with a lower average of 4 compared to the previous week's average of 5. Physical demands had the same mean as on shift week 1 (6), but with less variation in individual ratings and mental demands were very similar to week 1. The following sections will assess the predictive value of these demands on fatigue.

7.4.3.2 On shift week 1 Evening

A regression using a model including three types of demands (emotional, mental and physical) was performed on evening fatigue variables to assess the impact of demands on these factors. The predictive effect of this model and individual demands will be discussed for each fatigue outcome variable.

Predicting evening mental fatigue from multiple work demands: The regression produced a large and highly significant prediction model, with demand accounting for 36% of evening mental fatigue (R^2= .362, p<.001). This effect was explained by a strong predictive relationship of mental demands on mental fatigue (ß=.521, p=.002).

Emotional demands (ß=.140, p>.05) and physical demands (ß=.-.051, p>.05) did not significantly predict evening mental fatigue.

Predicting evening physical fatigue from multiple work demands: To assess the work demand factors predicting physical fatigue, a regression model was performed on evening physical fatigue including three types of demands (emotional, mental and physical). A similarly large and highly significant predictive model was found for physical fatigue, with demands accounting for 34% of evening physical fatigue (R^2= .343, p<.001). Again, this effect was explained by the strong predictive relationship of mental demands on physical fatigue (ß=.499, p<.01). Surprisingly, neither physical demands (ß=.222, p>.05) nor emotional demands (ß=-.089, p>.05) significantly predicted physical fatigue in week one.

Predicting evening sleepiness from multiple work demands: The regression was then applied to sleepiness. This produced a large and highly significant predictive effect indicating that demands accounted for 44% of sleepiness (R^2= .440, p<.001). This was explained by the strong predictive relationship with mental demands (ß=.582, p<.001). Predictive effects were not found for emotional demands (ß=.126, p>.05) or physical demands (ß=-.025, p>.05).

Predicting evening emotional fatigue from multiple work demands: The regression model for demands (emotional, mental and physical) was applied to emotional fatigue. This produced the largest predictive effect and a highly significant predictor model, with demands accounting for 59% of fatigue outcomes (R^2= .587, p<.001). This was explained by the strong predictive relationship of emotional demands on emotional fatigue (ß=.744, p<.001). Predictive effects were not found for physical demands (ß=-.161, p>.05) or mental demands (ß=.111, p>.05).

Predicting evening boredom from multiple work demands: This model was then applied to boredom. It produced a moderate but highly significant predictive effect suggesting that demands accounted for 28% of evening boredom (R^2= .277, p<.001). This was explained by a strong predictive relationship with emotional fatigue (ß=.524, p=.002). No predictive effects were found for physical (ß=.168, p>.05) or mental demands (ß=-.130, p>.05).

Predicting evening anxiety from multiple work demands: Finally, the model was applied to anxiety. It produced a large and highly significant predictive effect indicating that demands accounted for 34% of evening anxiety (R^2= .341, p<.001). This effect was explained by a strong predictive relationship of emotional demands (ß=.517, p=.002). There were no significant predictive effects for physical demands (ß=-.049, p>.05) or mental demands (ß=-.118, p>.05).

Physical demands were not found to have a significant predictive relationship with any of the outcome variables suggesting that mental and emotional demands were the most impactful during this time.

7.4.3.3 On shift week 1 morning

This analysis process was then performed on fatigue ratings from the following mornings to determine how demands the previous day predicted morning fatigue ratings.

No significant effects were found for the impact of demands on mental fatigue (R^2 .127, p>.05), physical fatigue (R^2 .120, p>.05), sleepiness (R^2 .056, p>.05) or boredom (R^2 .119, p>.05) (see Figure 40). This suggests that these effects from the previous day did not sustain to the next morning. However, it seems that the impact on emotional fatigue and anxiety did carry over to the next day as will be explored in the following sections.

Predicting morning emotional fatigue from multiple work demands: The regression model produced a significant predictive effect for the impact of demands on emotional fatigue suggesting that demands experienced the previous day accounted for 30% of morning emotional fatigue (R^2= .303, p<.001). This was explained by a highly significant predictive relationship with emotional demands (ß=.692, p<.001). No significant predictive effects were found for physical demands (ß=-.169, p>.05) or mental demands (ß=--.295, p>.05) (see Figure 40 for a visual representation of this).

Predicting morning anxiety from multiple work demands: Results from the regression model showed significant predictive effect for anxiety indicating that demands experienced the previous day accounted for 22% of anxiety the following morning (R^2= .216, p=.005). This was explained by a strong predictive relationship with emotional demands (ß=.549, p=.002). As with emotional fatigue, this was not significantly predicted by physical demands (ß=-.167, p>.05) or mental demands (ß=-.296, p>.05). Though not significant, it is interesting to note that mental demands had a negative predictive relationship with morning emotional fatigue and anxiety. This suggests that higher mental demands could have a protective value for emotional fatigue and anxiety (see Figure 40 for a visual representation of this).

7.4.3.4 On shift Week 2 Evening

The regression model was then applied to data from on shift week 2 evening fatigue ratings and as with evening results from the previous week, produced significant effects for all fatigue outcome variables.

Predicting evening mental fatigue from multiple work demands: The regression model produced a significant effect indicating that demands accounted for 42% of variance of evening mental fatigue (R^2= .423, p=.001). This is more than in evening results for on shift week 1 and is explained by a predictive relationship with emotional demands (ß=.431, p=.020). Surprisingly, this was not significantly predicted by mental demands (ß=-.403, p>.05) or physical demands (ß=--.203, p>.05).

Predicting evening physical fatigue from multiple work demands: The regression model produced a significant effect for physical fatigue with demands predicting 22% of evening physical fatigue (R^2= .219, p=.045). Despite this, there were no significant predictive relationships with emotional (ß=.082, p>.05), mental (ß=.364, p>.05) or physical demands (ß=.063, p>.05). This could simply be due to low power and the initial low level of significance of the effect.

Predicting evening sleepiness from multiple work demands: The model produced a significant effect for sleepiness indicating that demands predicted 29% of variance in sleepiness outcomes (R^2= .287, p=.012). Though as with physical fatigue, this was not explained by significant predictive values of emotional (ß=.267, p>.05), physical (ß=-.146, p>.05) or mental demands (ß=.413, p>.05). Again, this could be due to low power.

Predicting evening emotional fatigue from multiple work demands: The regression produced a very large and highly significant effect of the demand model on emotional fatigue suggesting that demands accounted for 60% of the variance in emotional fatigue (R^2= .601, p<.001). This was explained by a highly predictive relationship with emotional demands (ß=.778, p<.001). There were no significant predictive effects of physical demands (ß=-.163, p>.05) or mental demands (ß=.095, p>.05).

Predicting evening boredom from multiple work demands: A large and significant effect of the model was found indicating that demands accounted for 36% of the variance in boredom (R^2= .358, p=.002). This was explained by a large and highly significant predictive relationship with emotional demands (ß=.752, p<.001). Boredom did not have a significant predictive relationship with physical (ß=-.235, p>.05) or mental demands (ß=-.321, p>.05). It is interesting that physical and mental demands had negative predictive relationships with boredom (though not significant) and indicates that higher demands in these areas could protect against boredom.

Predicting evening anxiety from multiple work demands: Finally, there was a large and highly significant effect suggesting that the demand model accounted for 51% of the variation in evening anxiety (R^2= .510, p<.001) which is considerably larger than during on shift week 1. This was explained by a large and highly significant predictive relationship with emotional fatigue (ß=.623, p<.001). As with other outcome variables, there was no significant relationship with mental (ß=.201, p>.05) or physical (ß=-.112, p>.05) demands though again, it is interesting that physical demands negatively predicted evening anxiety.

It is interesting that findings for this week were heavily associated with emotional demands and outcomes and suggests heightened sensitivity to emotional stressors during this time.

7.4.3.5 On shift Week 2 Morning

The regression model was then applied to fatigue ratings for on shift week 2 mornings. In contrast to on shift week 1 morning results, findings revealed significant effects of the model on all fatigue outcome variables with notably high predictive effects which will now be investigated.

Predicting morning mental fatigue from multiple work demands: Results showed that the model had a highly significant effect on morning mental fatigue indicating that demands of the previous day accounted for 47% of mental fatigue the following morning (R^2.469= p=.002). This was explained by a strong predictive relationship with emotional demands (ß=.449, p=.022) but surprisingly no significant relationship with mental demands was found (ß=.351, p=>.05). This was also the case for physical demands (ß=-.035, p>.05).

Predicting morning physical fatigue from multiple work demands: The regression produced a large predictive effect indicating that demands from the previous day accounted for 43% of variance in physical fatigue experienced the following morning (R^2= .425, p=.002). A highly predictive relationship with mental demands was found (ß=.758, p=.003), further explaining this. This was not predicted by emotional (ß=-.115, p>.05) or physical demands (ß=-.057, p>.05). Surprisingly, both variables had a negative predictive relationship with the outcome variable, though not significant.

Predicting morning sleepiness from multiple work demands: The regression produced a moderate predictive effect for sleepiness suggesting that demands from the previous day accounted for 26% of the variance in sleepiness the following morning. However as with evening sleepiness, this was not predicted by mental (ß=.532, p>.05), emotional (ß=-.035, p>.05) or physical (ß=-.001, p>.05) demands.

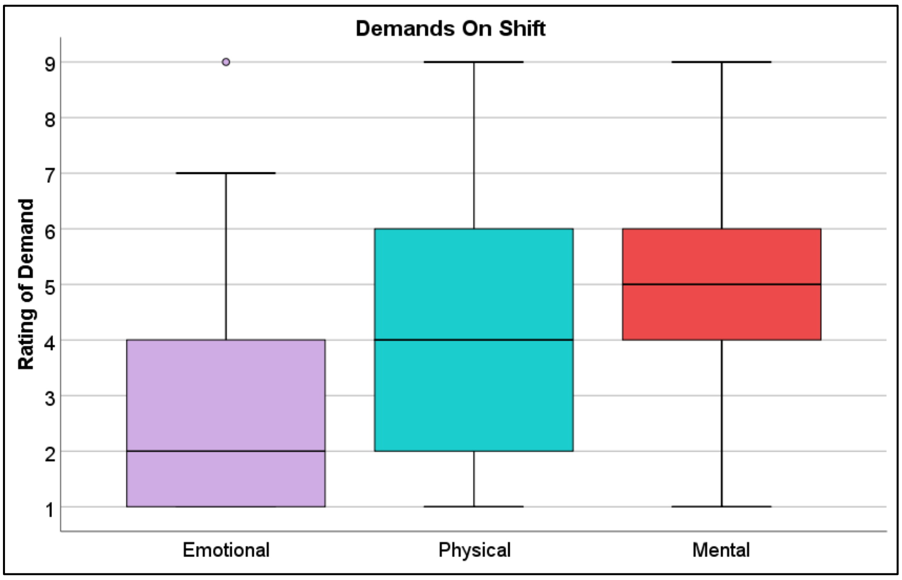
Predicting morning emotional fatigue from multiple work demands: A large and highly significant effect was found indicating that demands from the previous day accounted for 76% of variation in morning emotional fatigue (R^2= .756, p<.001). This is the largest effect found from both weeks and indicates that the impact of demands on emotional fatigue became stronger throughout the on-shift period. This was further explained by the positive significant relationship with emotional (ß=.634, p<.001) and mental demands (ß=.388, p=.020). Physical demands had a negative predictive relationship with morning emotional fatigue; however, this was not significant (ß=-.114, p>.05).

Predicting morning boredom from multiple work demands: A significant effect was found for morning boredom indicating that demands from the previous day accounted for 29% of morning boredom (R^2= .292, p=.023). A large and highly significant positive predictive relationship was found for emotional demands (ß=.614, p=.007) and no significant relationship was found for mental demands (ß=-.133, p=>.05) or physical demands (ß=-.024, p=>.05).

Predicting morning anxiety from multiple work demands: A significant effect was found suggesting that demands from the previous day predicted 44% of anxiety the following morning (R^2= .442, p=.001). This was explained by a large and significant positive predictive relationship was found for emotional fatigue (ß=.503, p=.012). No significant relationship was found with mental (ß=.182, p=>.05) or physical demands (ß=.052, p=>.05).

7.4.3.6 The Impact of Demands on Fatigue for CTV Participants

Figure 39- Box plot showing variation in ratings of demands



As can be seen in Figure 39 ratings of demands varied greatly with including the whole scale for physical and mental demands and ranging from 1-7 for emotional demands. Mean scores are lower than for the SOV group.

7.4.3.7 Evening fatigue ratings

Following the same process as was used for SOV results (see section 7.4.3.2), regressions were performed to assess the impact of demands on fatigue outcome variables for the CTV group. Significant results were found for all fatigue variables apart from boredom (R^2= .068, p=.090).

Predicting evening mental fatigue from multiple work demands: Results revealed significant effects on mental fatigue suggesting that the demand model accounted for

20% of variation in mental fatigue (R^2= .198, p<.001). This was explained by a highly significant predictive relationship with physical demands (ß=.415, p<.001). Surprisingly mental demands were not significantly predictive of mental fatigue (ß=.113, p=>.05) and emotional demands was also not significantly predictive of this (ß=-.054, p=>.05).

Predicting evening physical fatigue from multiple work demands: A small but significant effect was found for physical fatigue indicating that the demand model predicted 16% of variation in evening physical fatigue (R^2= .160, p=.001). This was significantly predicted by physical demands (ß=.417, p<.001) and not by mental (ß=.052, p>.05) or emotional demands (ß=-.097, p>.05).

Predicting evening sleepiness from multiple work demands: Again, a small but highly significant effect was found suggesting the demand model accounted for 18% of evening sleepiness (R^2= .175, p<.001). This was explained by a highly significant predictive relationship with physical demands (ß=.438, p<.001). Relationships with mental (ß=-.106, p>.05) and emotional demands (ß=.025, p>.05) were not significant.

Predicting evening emotional fatigue from multiple work demands: The regression revealed a comparatively large predictive effect for emotional fatigue suggesting that the demands model accounted for 31% of variance in this outcome (R^2= .309, p<.001). This was explained by significant positive relationships with emotional (ß=.454, p<.001) and physical demands (ß=.217, p=.035). Mental demands had a negative but non-significant relationship with emotional fatigue (ß=-.073, p>.05).

Predicting evening Anxiety from multiple work demands: The regression revealed a highly significant predictive effect for anxiety (R^2= .269, p<.001) indicating that demands explained 27% of the variance for this outcome variable. This was explained by a strong predictive relationship with emotional demands (ß=.508, $p<.001$). There were no significant relations with physical (ß=.124, p.>.05) or mental demands (ß=-.157, $p>.05$).

7.4.3.8 Morning fatigue ratings

This analysis was then performed on CTV morning fatigue ratings. Results showed that there were no significant effects for mental fatigue (R^2= .090, $p>.05$), physical fatigue (R^2= .044, $p>.05$), sleepiness (R^2= .060, $p>.05$) or boredom (R^2= .068, $p>.05$). However, there were significant effects for emotional fatigue and anxiety which will now be discussed.

Predicting morning emotional fatigue from multiple work demands: A large and significant effect was found indicating that demands from the previous day accounted for 30% of the variation in emotional fatigue the next morning (R^2= .304, $p<.001$). This was explained further by the finding that emotional demands had a significant positive predictive relationship with emotional fatigue (ß=.387, p=.005). Neither mental (ß=.060, $p>.05$) or physical demands (ß=.195, $p>.05$) had a significant relationship with this outcome variable.

Predicting morning anxiety from multiple work demands: Significant a large and highly significant predictive effect was found suggesting that demands from the previous day accounted for 34% of the variance in anxiety the following morning (R^2= .343, $p<.001$). This was further explained by a significant predictive relationship with emotional demands (ß=.552, $p<.001$). As with the previous outcome variables, significant relationships were not found for mental (ß=.051, $p>.05$) or physical demands (ß=.007, $p>.05$).

Figure 40- Heat map of SOV workplace factors predicting fatigue

SOV		Mental		Physical		Emotional		Sleepiness		Boredom		Anxiety	
		Eve	*Morn*	*Eve*	*Morn*	*Eve*	*Morn*	*Eve*	*Morn*	*Eve*	*Morn*	*Eve*	*Morn*
Demands	*W1*	***		***		***	***	***		***		***	**
	W2	***	**	**	**	***	***	**	*	**	**	***	**
Emotional	*W1*					***	***			**		**	**
	W2	*	*			***	***			***	**	***	**
Physical	*W1*												
	W2												
Mental	*W1*	**		**				***					
	W2				**		*						

Figure 41- Heat map of CTV workplace factors predicting fatigue

CTV	Mental		Physical		Emotional		Sleepiness		Boredom		Anxiety	
	Eve	*Morn*	*Eve*	*Morn*	*Eve*	*Morn*	*Eve*	*Morn*	*Eve*	*Morn*	*Eve*	*Morn*
Demands	***		**		***	***	***				***	***
Emotional					***	**					***	***
Physical	***		***		*		***					
Mental												

Heat map Key

Group				
R^2	<.10	.11-.19	.20-.29	.30+
P Value	>.05 (N/A)	01-.05*	<.01 **	<.001***
Factor				
ß	<1	1-2.9	3-4.9	5+
P Value	>.05 (N/A)	.01-.05*	<.01 **	<.001***

Figure 40 and Figure 41 provide a visual representation of results for both groups. As can be seen, demands generally had a stronger predictive relationship with fatigue for the SOV group which notably increased during on-shift week 2. In comparison, for CTV participants, demands generally only had a weak predictive relationship with fatigue for evening ratings. This is with the exception of the predictive relationship between demands and emotional fatigue and anxiety which were moderately to highly significant for both groups in morning and evening ratings. These findings will be further discussed in the following section in the context of overall study results.

7.5 Part 4- Discussion

Results suggested that SOV participants had higher levels of all types of fatigue during the on shift whereas CTV participants' fatigue ratings were either lower during on shift time or consistent between on and off shifts. Despite this, recovery ratings and sleep quantity showed similar decrements during the on shift and increases during off shift time for both groups. This indicates that fatigue was not wholly impacted by sleep quantity and recovery.

Analysis on the impact of work demands on fatigue suggested that work demands had a more prominent predictive effect on SOV fatigue outcomes than for the CTV group, particularly during SOV on shift week two. This implies that fatigue is heavily impacted a multitude of factors including work demands and that the onset of fatigue can be cumulative. These results will now be discussed in more detail with the following sections focusing on a group of results as they were presented in part 3.

7.5.1 The impact of work and shift design on fatigue

Fatigue and related factors were consistently higher for SOV participants during the on shift (see section 7.4.2.1) whereas CTV results were either relatively consistent between on and off shift time (as with evening mental fatigue, evening boredom and morning boredom) or higher during the off-shift time (as with evening emotional fatigue and morning anxiety). This suggests that the SOV work environment encompassed higher fatigue related strain. Viewed in the context of Karasek's DCM model (Karasek, 1979, see Chapter 2 section 2.8), these results would make sense. Although both environments encompass high demands a low control during working time, the SOV environment has an added aspect of low control during non-working time. This element of ‘low decision-making latitude’ experienced by SOV participants during their recovery time may have contributed to higher overall strain during their on-shift time. This is particularly pertinent when considering the fact that CTV participants were often able to stay at home during weather days, of which there were an increased amount during the winter data collection period, whereas SOV participants had to remain on the vessel. Therefore, CTV participants had a higher level of control over their time during unexpected weather days.

Aspects of these results are still surprising as it would be expected that CTV participants would show higher levels of fatigue while on shift compared to their off shift, though perhaps to a lesser degree than SOV participants. Though this could be due to a lower strain work environment due to their relative increased level of control over their time outside of work and on weather days, it could also be attributed to high strain in CTV participants’ home environments during the off shift. It would be beneficial to examine this in further research as the present sample size is not sufficiently large to draw conclusions.

Deeper analysis of SOV results showed that all fatigue factors increased considerably in on shift week 2 (see Figure 23 and 24) suggesting a cumulative impact of fatigue during working time supporting findings in study 1 in which participants highlighted the cumulative impact of fatigue and higher occurrences in on shift week 2 (see Chapter 6, section 6.5.4). This suggests that strain builds during the first week of the shift resulting in a higher baseline of fatigue during the second week from which recovery is more difficult. This supports wider theories on the build-up of fatigue over periods of consecutive shifts (Sonnentag & Zijlstra, 2008, see Chapter 3, section 3.3.1)

Though all fatigue ratings were notably higher during on shift week 2, evening boredom showed the most dramatic increase (see Figure 24) implying two things. The first is that boredom is a more binary state in comparison to fatigue and anxiety variables meaning that it does not require a period of recovery and is more likely to be quickly abated by changing task. Therefore, the magnitude of evening boredom results does not simply suggest that boredom was more prevalent, but rather that fluctuations in boredom were more dramatic due to the reduced need for recovery in comparison to other variables such as fatigue and anxiety.

The second implication is that SOV participants were experiencing symptoms of 'cabin fever', an experience of restlessness, boredom and irritability caused by being in a confined living space for too long (Rosenblatt et al., 1984). This is consistent with research by Mette, et al (2017) in which offshore wind technicians described experiences of cabin fever that were particularly impacted by the occurrence of weather days in which they were unable to leave the ship. This represents a particular risk for employees in the SOV environment due to their increased time spent on shift and their lack of ability to leave the vessel when not working. Thus, a combination of more time spent working and confinement to their work environment and literally 'at sea' could contribute to the increase in fatigue and especially boredom during this second week.

Research based in the wind industry environment supports the present findings suggesting that for SOV employees, lack of separation from work and home was a key emotional stressor (Velasco Garrido, Mette, Mache, et al., 2018). Indeed, wider research indicates that low spatial work-home boundaries are related to poor psychological detachment from work (Sonnentag & Bayer, 2005). In line with this and with results from the present study, it would be congruent to suggest that SOV participants would have lower levels of recovery during the on shift, particularly detachment than CTV participants. This, however, was not the case as will be discussed in the following section.

7.5.2 The impact of work and shift design on recovery

Patterns of recovery ratings for detachment, control and challenge were notably similar between the groups with both experiencing lower levels of these variables during on shift time and higher during the off shift (see Figure 27). It is interesting that CTV participants experienced similar decrements even though they were not confined to the vessel during non-working time. This suggests that experiences of detachment and control are not simply mediated by physical environment. However, this diminished recovery did not appear to impact fatigue ratings for CTV participants.

The only notable difference in recovery between the groups was with relaxation. SOV participants had lower ratings of relaxation during the on shift and CTV participants had a lack of difference in ratings between working and non-working time (see Figure 27). This indicates that CTV participants were more able to relax during on shift time and suggests that relaxation is particularly important for fatigue recovery in this environment. Recent research has indicated that the decreased ability to relax during leisure time is highly related to negative experiences during work time specifically around goal attainment (Parker et al., 2020).

Deeper analysis of SOV results show that relaxation, as well as challenge follow the same pattern (in reverse) as fatigue variables as they are notably lower during on shift week 2 (see

Figure 28). This combined with fatigue results paints the picture of an individual who is fatigued, bored and apathetic- likely due to a build-up of strain in their environment. Relaxation is heavily associated with activities that promote this positive state e.g. yoga, meditation (Parker et al., 2020). These activities are not mandatory for relaxation to occur, but it may be helpful to consider interventions that promote these activities so that recovery could be increased for SOV technicians during on shift time.

Findings suggest that this work environment negatively impacts challenge, control and detachment for both groups and relaxation for the SOV group. However, wider results imply that this experience of diminished recovery did not lead to higher fatigue for CTV participants. This also appeared to be the case with sleep quantity as will be considered in the following section.

7.5.3 The impact of work and shift design on sleep

Though sleep deprivation is often thought of as the sole contributory factor to fatigue (see Chapter 2 section 2.6.8), results in this study showed that both groups had similar sleep decrements during on shift time (see Figure 35). This is likely due to decreased opportunity for sleep due to early starts and long work hours in both work environments. This mirrors findings from Riethmeister et al (2019) who found similar results in their sample of offshore oil workers (see Chapter 6, section 6.5.4 for a discussion of this study).

Unlike Riethmeister, the present research did not demonstrate a clear relationship between diminished sleep quantity and fatigue outcomes for both groups as CTV fatigue ratings did not notably increase during on shift time. This was perhaps because the present research employed a multidimensional fatigue model based on psychological fatigue whereas Riethmeisters' model was directly related to the experience of sleepiness. Present findings challenge the notion that increases in fatigue are simply caused by sleep decrements (e.g. Dawson & McCulloch, 2005, see Chapter 2, section 2.6) and support the notion that fatigue should be investigated at a multidimensional level.

Further analysis of SOV results showed that objective sleep quantity decreased during on shift week 1 and increased during on shift week 2 (see

Figure 37). However, subjective sleep quantity remained similarly low throughout the on-shift period indicating two things. The first is that objective sleep decrement was not immediately causational of fatigue increase (as fatigue was higher in on shift week 2). Though sleep deprivation in on-shift week 1 could have had an indirect influence on the higher fatigue ratings seen during on-shift week 2. The second is that estimations of sleep quantity could have been lower due to the experience of fatigue (e.g. individuals attributed the feeling of higher fatigue to the assumption that they had gained less sleep).

Though findings on sleep *quantity* showed relatively little difference between the groups, findings on sleep *quality* were different between the groups (see Figure 36).

On further inspection of SOV results, sleep quality ratings formed an interesting pattern with notably low scores from the pre-shift week to on shift week 2 which do not increase until the post-shift week. This suggests that both the work environment and the anticipation of beginning a period of offshore work impacts sleep quality, though more research (e.g. with more participants) would be needed to substantiate this.

Therefore, fatigue ratings are notably different between the two groups with and though it is likely that they played an important role, there is little evidence that recovery or sleep have wholly caused this discrepancy. It is important to additionally consider the third factor of workplace demands to determine whether this provides further insight into fatigue in this environment.

7.5.4 The impact of demands on fatigue

Results on the predicted effects of workplace demands present several interesting findings. The first is the notably higher impact of demands for SOV participants compared to CTV (see Figure 40 & Figure 41). As sleep and recovery variables are similar for both groups, this is the only group of variables that could be seen to explain the variance in SOV and CTV fatigue outcomes.

The most extreme differences can be seen in SOV on shift week two where the effect of demands from the previous day have a more prominent carryover effect to the next morning. This indicates that fatigue has an enduring impact during this time potentially due to a build-up during week one, supporting previous assertions around the cumulative impact of fatigue in this environment.

Another notable finding is the lack predictive effect of physical demands for the SOV group. In fact, physical demands tended to have a negative predictive effect of fatigue, though this was not significant. This could be due to the positive impact of exercise during leisure time as was suggested in study one (see Chapter 6, section 6.7.2). It would be useful for further research to separate the impact of workplace physical demands with those imposed through leisure time physical activity to understand the separate impact of these two factors on fatigue.

A third prominent finding Is the strong impact of demands on emotional fatigue and additionally the impact of emotional demands on other fatigue factors (e.g. anxiety) for both groups. Again, this challenges the notion that fatigue in high hazard industries is simply a question of sleep-deprivation and that emotional demands are only relevant in caring roles. Findings from study 1 highlighted that emotional demands in this environment typically include negative colleague relations and family work conflict (see Chapter 6, sections 6.6.9 & 6.6.10). Fatigue management interventions would therefore benefit from an awareness of these factors as they seemed to be a consistent source of strain for both groups.

Results are interesting and present opportunities for improved fatigue management in this industry. However, the present study also had some key limitations. Strengths and limitations will be discussed in the following sections.

7.5.5 Study Strengths

This study was an exploratory investigation into fatigue in a unique environment. As research had not previously investigated employee fatigue in this work environment (see Chapter 4) it provides a novel perspective on the subject. Results suggested that the multidimensional method of conceptualising and measuring fatigue (Boksem & Tops, 2008; Hockey, 2013; Earle, 2004; Inzlicht, 2013; Kuppuswamy, 2017) was appropriate due to the lack of clear independent relationship between fatigue and factors with which it would ordinarily be solely related to, e.g. sleep (see Chapter 2 section 2.6 and Chapter 3 sections 3.2 and 3.6 for detailed discussions on this). Though further data would be needed in order to determine whether these trends were replicable on larger samples, the present study provides a methodology which can be refined and utilised to investigate fatigue using a multi-dimensional approach.

Study Limitations

The present study had several limitations. A notable weakness is the small sample size which makes results difficult to generalise to the wider industry. A reason for this in the present study design was the use of paper diaries which made recording and processing of results time consuming for participants and the researcher. Future research could aim to use a more streamlined method of data collection (e.g. an online app). Research examining the use of electronic vs paper data collection in diary studies tends to suggest that initial response rates are higher when using app-based methods, however this has a tendency to reduce over the course of studies (Kvavilashvili, 2018). Therefore, this design would need to be applied thoughtfully, potentially with the addition of response reminders as suggested by Lowenstein-Barkai & Lev-On (2019).

Furthermore, the times at which fatigue was recorded represented participants' experience of fatigue before and after work, rather than during working time. Data was collected at these times as it was predicted that the response rate would be lower if participants were asked to complete diaries during their working days. Although studies with similar designs have also only collected subjective data before or after work (e.g. Riethmeister et al., 2019), it would be interesting to collect data during working time as this would allow for greater insight to be gained on the risk of fatigue while participants are working in high hazard environments.

Another limitation is the time of year in which data collection took place. As previously mentioned, this was a quieter time both groups but particularly for CTV participants who often were not required to travel to work due to weather days. Though this is representative of what could occur during this time of year, it would be beneficial to gain insight into periods which encompass a higher workload (e.g. the summer months) to gain a more rounded view of the general experiences of wind technicians.

The present study therefore presents a useful basis for future research to investigate fatigue with a multi-dimensional methodology but should be considered as an early insight to this.

7.5.6 Conclusion

<u>Comparison of SOV and CTV Results</u>

Results of this study suggested that the SOV work environment was associated with higher levels of fatigue than the CTV environment, particularly during the second on shift week which was likely influenced by a build-up of strain. Though it is clear that participants from both groups experienced decrements in sleep and recovery during on-shift time, this increase in fatigue was not found for the CTV work environment.

Part 2 results indicated that fatigue outcomes were influenced by work related demands which was more severe and enduring for the SOV group, particularly during on shift week 2. Results emphasise the high strain characteristics of the SOV work environment that appear to be higher, at least during this time of year, than the CTV group, and exacerbated by a longer time spent on shift.

Key findings from SOV Results

The key findings of this research are that fatigue appeared to have a cumulative impact on SOV-based technicians that was particularly prevalent during their second week on shift. Cumulative fatigue did not appear to be independently and immediately caused by sleep loss as sleep quantity appeared to increase during the time that fatigue was at its highest. However, the impact of sleep quality is interesting as SOV participants appeared to experience lower sleep quality than CTV participants whilst on-shift.

Results on the predictive impact of demands suggested that demands increased in their predictive value during the second week of on-shift time, particularly emotional demands, suggesting that either participants were more sensitive to demands during this time due to pre-existing fatigue and/or that demands themselves had a cumulative impact on fatigue. This highlights the multidimensional and cumulative nature of fatigue in this environment, meaning that fatigue cannot simply be attributed to one factor (e.g. sleep loss).

Chapter 8- Thesis Conclusion

8.1 Introduction

This final chapter will summarise findings of the present research and their theoretical implications. In line with the pragmatic methodology underpinning this research, it will also present solutions for improved fatigue management in the wind industry based on these findings. Furthermore, it will outline how research would be expanded and improved in future studies and finally, a discussion of how the project has aided researcher development will be included.

8.1.1 Chapter structure

This chapter will begin with a summary of theory and literature encapsulated in Chapters 2, 3 and 5 in section 8.2. Following this, section 8.3 will consider the major findings of the present research included in Chapters 4, 6 and 7 and how they could progress theoretical and applied practice. This will include consideration of the overall research questions and how these were addressed throughout the thesis.

Section 8.4 will present industry recommendations underpinned by the present research findings and section 8.5 will determine how the present research model could be improved and expanded for future research projects. Finally, section 8.6 will consider how undertaking the present research as a PhD project has facilitated the development of research skills for the lead researcher.

8.2 Summary of theory and literature

As fatigue is a concept that lacks a robust definition in literature (Matthews et al., 2012), it was important for the present thesis to employ a major focus in this area. This was undertaken in Chapters 2 and 3 with Chapter 5 employing a philosophical and methodological focus on the design and employment of research. This section will summarise the main theoretical discussions and underpinning concepts of these chapters and the following section will explore how primary research could be seen to support, dispute or further these theories.

Chapter 2- Towards a definition of fatigue

Chapter 2 considered relevant research around fatigue as a psychological concept and its history of research in applied settings. Major theoretical discussions included the perception of fatigue as an energy decrement which could be overcome through limitation in movement (e.g. Taylor, 1911; Baumeister et al., 1994) versus fatigue as a motivation moderator influenced by multidimensional factors (e.g. Boksem & Tops, 2008; Earle, 2004; Earle, Hockey, Earle, & Clough, 2015; Hockey, 1997). This reached the conclusion that fatigue is most likely the consequence of a subconscious cost/benefit analysis based on allocation of effort, particularly for activities requiring the pre-frontal cortex (tasks requiring higher cognitive functioning, e.g. learning a language) and is influenced by multiple factors (see section 2.5.4).

The prevalent notion that fatigue is simply a consequence of sleep deprivation (e.g. Darwent, Dawson, Paterson, Roach, & Ferguson, 2015; Dawson & McCulloch, 2005) was also explored. This highlighted that sleep is a complex state which is often over-simplified (Walker & Rechtschaffen, 2009, see section 2.6.1). It is a vital aspect of the recovery process (Cappuccio et al., 2010) and sleep deprivation is an important predictor of fatigue (Ma et al., 2015). However, it is not the only predictor, though research often views fatigue and sleep propensity (sleepiness) as interchangeable concepts (Shen, Barbera, & Shapiro, 2006, see section 2.6.9). It was proposed that this is an erroneous assumption as it undermines the multidimensional nature of fatigue and would prevent fatigue management systems from recognising the multitude of stressors that could lead to fatigue outcomes.

A major theoretical aspect of fatigue discussed in Chapter 2 was the impact of demands, control and strain (section 2.8). This was underpinned by the theory and research of Karasek (2008; 1979; 1990) who proposed the ‘Demand Control Model’. This encompassed the notion that work environments would cause high strain if they had high demands and offered little control to individuals around how tasks would be undertaken (Karasek, 1979). Karasek later introduced the concept of ‘buffers’, factors that could help to offset the negative impact of strain factors, such as social support (Karasek & Theorell, 1990). Karasek’s model provides a useful format in which to view fatigue in the workplace as it demonstrates the relationship between work-related factors, strain and fatigue.

Discussion in Chapter 2 then considered the consequences that fatigue can have on individual cognition and behaviour (section 2.9). This was discussed in the context of compensatory control, the notion that if a task cannot be easily abandoned, an individual will persevere at strain (Frankenhaeuser, 1986) while decreasing effort on secondary tasks (Earle et al., 2015; Hockey, 1997; Sperandio, 1978). Though traditional fatigue research tends to focus on degradation of performance on a primary task (e.g. ability to change a light bulb), the compensatory control theory suggests that it would be more accurate to consider performance in secondary tasks as an indicator of fatigue (e.g. checking whether the ladder is safely pitched). This has obvious safety implications for work environments, particularly those with multiple hazards.

Based on the theoretical framework presented in this chapter, a definition of fatigue in the context of the present research was presented in section 2.10. This definition asserted that fatigue is a state in which individuals feel weary and have an aversion to further effort. It is essentially a signal to desist with 'costly' tasks and switch to something that offers a higher intrinsic reward (Boksem & Tops, 2008; Robert. Hockey, 2013; Inzlicht & Marcora, 2016). Tasks that have high activation of the pre-frontal cortex and offer little opportunity for control are particularly associated with the onset of fatigue (Petruo et al., 2018; Zanto et al., 2011). Individuals are also more likely to experience the earlier onset of fatigue if they are in a non-optimal state (e.g. they are sleep deprived, emotionally unstable, etc).

In the context of the wind industry work environment, an individual experiencing fatigue may not be able to adhere to their fatigue signals and switch to a more intrinsically beneficial task and therefore will continue to work at strain. This would likely lead to compensatory control after-effects meaning that they would be less likely to engage in secondary tasks, which could cause a safety risk (Earle et al., 2015, see section 2.10.1).

Chapter 2 laid the theoretical foundations for an applied investigation into fatigue and presented a working definition for the present research. Chapter 3 then built on these foundations to consider how fatigue in work environments is currently researched and managed.

<u>Chapter 3- Fatigue research and management in the workplace</u>

Chapter 3 consisted of a literature review of fatigue research and management in occupational settings. This included consideration of the historical context of workplace fatigue research. It explored workplace fatigue risks in the context of safety, health, wellbeing and productivity to understand the context of how fatigue is currently viewed and managed. As well as this, consideration was given to separate, but linked concepts such as stress and burnout. Furthermore, theoretical and practical consideration was given to fatigue risk management in workplaces.

A major argument of this chapter was that fatigue research is erroneously one-dimensional with the concept lacking a central definition (see section 3.2.3). This was illustrated with the focus on 'compassion fatigue' in caring roles (Sinclair et al., 2017) and the emphasis on sleep deprivation in transport and aviation (Caldwell, 2005; Lynn Caldwell, Chandler, & Hartzler, 2012). Though these sectors are different, both encompass multiple stressors and fatigue cannot simply be managed through control of one factor.

In section 3.2.6 movement towards a multidimensional approach for fatigue research and management was discussed and an example of this from Techera et al (2016) was presented. This presented an interesting account of how multidimensional factors can affect and inter-link with fatigue. Yet it did not account for some additional factors that were highlighted as important in the present research including the cumulative impact of fatigue over consecutive shifts, the influence of emotional demands (e.g. colleague relations and work-family conflict) and the influence of low control, high strain work environments.

Following this, some of the major fatigue risks associated with work were discussed in the context of safety, health and wellbeing. Underpinning all of these risks was the notion that working longer hours and consecutive shifts drastically increases fatigue risks and associated negative consequences (Dembe et al., 2005, see section 3.3.1). This relies on the notion that fatigue has a cumulative affect causing an increased need for time spent on recovery (Sonnentag & Zijlstra, 2008).

A central point of the discussion around fatigue and safety was the impact of safety culture on effective fatigue management. This highlighted the merits of a 'just culture' which focuses on systemic solutions to safety issues rather than punitive approaches which rely on blaming and punishing individuals for safety incidents (Dekker, 2014). Adoption of a just culture would make fatigue reporting more open and solutions focused (see section 3.3.3.1).

Discussions on health and wellbeing also presented an optimistic view that the negative impact of fatigue on these factors can be mitigated through positive work design (see section 3.3.8). It was suggested that this should be done through addressing the stigma around mental health (Bharadwaj et al., 2017), ensuring that fatigue management systems incorporate a multidimensional view of fatigue-related stressors (Kalmbach et al., 2015; Torquati et al., 2018) and encouraging positive task engagement (Ilies et al., 2017).

Discussion of the concepts of stress and burnout in sections 3.3.11 and 3.3.13 highlighted the highly related nature of these states to fatigue. Though the experience of stress is different to fatigue, the two states often occur in concert and stress can directly influence the onset of fatigue (Hockey, 2013). Burnout, a state associated with extreme emotional fatigue (Maslach & Schaufeli, 2017), is generally associated with caring roles (Maslach et al., 2001). However, research discussed in this section questioned the notion that burnout should simply be associated with these types of roles and suggested that emotional demands from a variety of non-human facing roles can also lead to fatigue and burnout (Demerouti et al., 2002; Guan et al., 2017). This suggests that multidimensional fatigue models should include awareness of the impact of emotional demands in non-human-facing roles.

Section 3.4 explored workplace approaches to fatigue risk management. A major finding in this area was that fatigue risk management systems tend to be prescriptive and sleep focussed (Arendt, 2010; Dall'Ora et al., 2016; Dawson & McCulloch, 2005). Major developments in this area generally focus on a greater employment of technology to 'predict' fatigue, rather than a movement towards holistic fatigue models (Fang et al., 2015; Hopstaken, van der Linden, Bakker, & Kompier, 2015). This is an issue as technological fatigue models often do not account for the multiple factors involved in the fatigue process.

Finally, a consideration of work environments like the wind industry (oil and gas, maritime and construction) was included. A prominent finding in this area was around perception of fatigue in the maritime industry (section 3.5.2). This highlighted the notion that the 'macho culture' associated with this industry perpetuates a systemic fatigue issue in which employees avoid the acknowledgement and discussion of fatigue and wider human factors issues (Houtman, Miedema, Jettinghoff, Starren, Heinrich, Gort, & Wulder, 2005). This signalled a potential issue for fatigue management that could potentially be present in the wind industry which encompasses many overlapping characteristics.

Chapter 3 placed fatigue research into the context of the workplace and highlighted many operational difficulties associated with effective fatigue management. Chapter 4 encompassed a systematic review focussed on human factors research in the wind industry. However, as this is a novel area of research, it will be included in section 8.3 as a primary research output. The following section will include a summary of the major points included in Chapter 5, an exploration of the philosophical and methodological underpinnings of the present research.

Chapter 5- Philosophical and Methodological Underpinnings

Chapter 5 was a discussion of the philosophical and methodological underpinnings of the present research which ultimately presented five questions to be addressed in the primary research.

Discussion first focused on the formulation of an underpinning ontology (perception of reality) for the present research. After discussing the objectively focussed stance of realism and the contextually focussed stance of relativism (Clarke & Braun, 2017, see sections 5.2.2 & 5.2.3), it was decided that the present research would adopt the ontology of critical realism. This stance recognises the existence of an objective truth, but additionally understands that this truth cannot be divorced from its subjective structures (Madill et al., 2000, see section 5.2.5). Thus, this philosophy allows for the use of multiple methods to understand both the objective reality and the subjective structures obscuring it (Clarke & Braun, 2017).

An exploration of epistemology (the nature and extraction of knowledge) followed a similar process to that of ontology (see section 5.3) with the stance of contextualism decided on for the present research. Contextualism is underpinned by the notion that the truth is ‘out there’ but must be viewed in context with its surrounding circumstances (Tebes, 2005, see section 5.3.4).

Consideration was then given to the methodological underpinnings of the present research (section 5.4). Due to the applied nature of this research and the fact that a central aim was to address a real-world problem, the methodological stance of pragmatism was decided on. This focuses on doing 'what works' to facilitate controlled change in a chosen environment (Goldkuhl, 2012, see section 5.4.2).

After considering the underlying philosophical approaches, five research questions were presented to be addressed in the primary research. These will be explored in the following section along with the major findings of the primary research outputs.

8.3 Major findings of primary research

This project aimed to gain an understanding of how operations and maintenance employees in the wind industry experienced fatigue, how this was impacted by workplace factors, what the potential implications of this were and what could be done to manage it. This was encapsulated in 5 research questions included in Table 31.

It was initially expected that these questions would be wholly addressed in studies 1 and 2 (Chapters 6 & 7). However, upon reflection, findings from the systematic review provided a useful basis of knowledge for some of the questions as will be indicated in table 31.

Table 31- Research Questions Addressed in this Thesis

Question/ Component	Measurement & location of findings
Question 1- How is fatigue perceived by technicians and their managers?	Qualitative interviews (Chapter 6, section 6.5)
Question 2- How does the experience of fatigue change during working and non-working time and throughout on shifts?	Systematic review (Chapter 4, section 4.4.1) Qualitative interviews (Chapter 6, sections 6.5.5, 6.7.1) Quantitative field study (Chapter 7, sections 7.4.2.4 & 7.5.1)
Question 3- How does recovery and sleep change during working and non-working time and throughout on shifts?	Systematic review (Chapter 4, section 4.4.1) Qualitative interviews (Chapter 6 section 6.7) Quantitative field study (Chapter 7, sections 7.4.2.2, 7.4.2.3, 7.5.2 & 7.5.3)
Question 4- What are the key factors affecting employees' experience of fatigue and related factors in this working environment?	Systematic review (Chapter 4, section 4.5) Qualitative interviews (Chapter 6 section 6.6) Quantitative field study (Chapter 7 sections 7.4.3.1, 7.4.3.6 & 7.5.4)

Question 5- How does the experience of fatigue and its antecedents compare in three different wind industry environments?	Qualitative interviews (throughout Chapter 6, section 6.4) Quantitative field study (throughout Chapter 7, section 7.5).

This section will explore key findings of the three research outputs.

Chapter 4- Systematic Review

This systematic review aimed to synthesise all relevant research on human factors in the wind industry to generate useful findings around employee fatigue. Though the review did not identify any research that specifically addresses fatigue, it highlighted that the wind industry environment is associated with numerous risks for high strain work. This included mental, emotional, physical and sleep related stressors (see Figure 10).

Findings from this review highlighted that there is an emerging trend of research into psychosocial strain in this environment. This was exemplified by the 'Best off' project which used psychological models to gain an understanding of mental, emotional and sleep related strains in the German offshore wind industry (e.g. Mette et al, 2019; 2017; 2018). These findings highlighted that the offshore environment is synonymous with multiple strains. Mette (2018) found that their sample of offshore wind technicians scored higher on work-related stress risks compared to a norm sample. This was linked to the presence of high demands and low opportunity for detachment suggesting a high strain environment where effective recovery could be an issue (Karasek, 1979; Sonnentag & Fritz, 2007).

Furthermore, research suggested that the offshore wind environment was detrimental to sleep quality (Velasco Garrido, Mette, Mache, et al., 2018). In this study, 47.9% of surveyed wind technicians indicated that their sleep quality was worse during working time. Findings from these studies highlighted the variety of mental, emotional and sleep related stressors present in this environment that are likely to impact strain and fatigue. This is concerning when considering the definition of fatigue presented in Chapter 2 in which multiple stressors would make an individual more vulnerable to unsafe behaviour (see section 2.10.1).

However, findings also indicated the presence of factors that could protect against job related strain. Mette et al (2018) indicated that support from colleagues was perceived as a job resource by wind industry employees. This supports the demand/control/support model proposed by Karasek and Theorell (1990) and highlights the need for positive colleague relations in this socially intense environment. Furthermore, findings from a qualitative study by Mette et al (2017) indicated that offshore wind technicians had high levels of intrinsic motivation for their jobs. When viewed in the context of motivational models of fatigue, this suggests that employees may have a higher tolerance for fatigue-related stressors in their environment (Boksem & Tops, 2008; Csikszentmihalyi, 1997; Inzlicht et al., 2014). This highlights the potential merits of employing positive work design in this environment (Ilies et al., 2017, see Chapter 3 section 3.3.8).

Research on physical strain in the offshore environment provided an insight into both the physiological challenges associated with common wind technician tasks, e.g. vertical ladder climbing (Barron, 2020; Barron et al., 2017; Stewart & Mitchell, 2018) and the wider context of operational training and regulations (Preisser et al., 2019). These studies highlighted the unique nature of physical demands in this industry and the need for bespoke regulations and management techniques to support employees in coping with them.

Though studies in this environment did not directly address fatigue, they did represent a growing interest in human factors in this work environment. They highlighted the large variety of strains associated with work in this environment supporting the need for a multidimensional approach to fatigue research and management as proposed in Chapter 3 (see section 3.2.6). A limitation of this research was its focus on offshore SOV wind technicians and lack of studies considering other wind industry environments representing a need to diversify research in this way as the present research aimed to do.

This review provided an excellent basis of knowledge on which to build with the present primary research in studies 1 and 2 which addressed strain in three different wind industry work environments with a direct focus on fatigue.

<u>Chapter 6- Study 1- Qualitative Interviews</u>

Study 1 consisted of a qualitative investigation into how wind industry workers from three different environments (SOV, CTV and onshore) experienced fatigue in their work. This was done through conducting interviews with wind technicians and operational managers (see Chapter 6, section 6.2).

Major findings included the notion that participants in all groups perceived fatigue as a multidimensional experience. This supports the theoretical argument that fatigue is influenced by multidimensional factors (e.g. Boksem & Tops, 2008; Earle, 2004; Earle, Hockey, Earle, & Clough, 2015; Hockey, 1997) and disputes the common perception of fatigue as a simple consequence of sleep deprivation (e.g. Darwent, Dawson, Paterson, Roach, & Ferguson, 2015; Dawson & McCulloch, 2005).

As well as being multidimensional, fatigue was described to have a cumulative impact as participants described a build-up of fatigue over days and weeks. This supports the notion that once fatigue is built through long working hours in low control conditions (Karasek, 1979), the need for recovery increases and sufficient recovery becomes more difficult to obtain (Sonnentag & Zijlstra, 2008). Findings indicated that employees in this environment are particularly susceptible to this affect.

The cumulative impact of fatigue was especially highlighted for SOV participants who emphasised the impact of 'second week fatigue' (see Chapter 6, section 6.5.5). This described the impact of fatigue built up during the first week of offshore work and remaining at a high level during the second week. This suggests a higher level of safety, health and wellbeing risks associated with compensatory control after-effects during this time (Earle et al., 2015; Hockey, 1997; Sperandio, 1978).

Results also suggested a prevalent stigma around the discussion and experience of fatigue. This echoed findings in other qualitative fatigue investigations (e.g. Steege & Rainbow, 2017). This stigma was attributed to the existence of a 'macho culture' in this environment. Participants described a pressure to fit in with stereotypically masculine behaviours including the need to 'suffer in silence' with issues such as fatigue and mental ill health (see Chapter 6, section 6.5.10). In the SOV group, an additional theme around the impact of experience in military careers had on both a reluctance to discuss fatigue and related concepts but also an attitude of perseverance beyond personal limits (see Chapter 6, section 6.5.11). This highlighted a risk that fatigue and strain would not be discussed until its impact became unbearable and therefore much more difficult to manage.

This mirrors findings in the marine industry highlighting that macho culture perpetuates systemic fatigue issues in which fatigue is ignored despite its existence (Houtman et al, 2005) suggesting that negative behaviours in this area will persist unless decisive action is taken. This emphasises the need to address prevalent stigmas around fatigue and mental health (Bharadwaj et al., 2017) and link to the need for a 'just culture' around fatigue reporting (Dekker, 2014).

Results around work related strain highlighted the intense and unique physical demands associated with the role and largely supported studies highlighted in the systematic review (e.g. Barron et al., 2018; Peter James Barron et al., 2017; Alexandra Marita Preisser et al., 2016; Stewart & Mitchell, 2018, see Chapter 4, section 4.4.3). As with relevant studies in this environment, climbing was highlighted as a significant physical demand. Interestingly, this was particularly synonymous with onshore wind technicians, as though onshore turbines are not as high as those used offshore (see Figure 2 and Figure 4), these technicians are required to climb much more due to the absence of lifts. Findings supported relevant literature highlighting the need for interventions to lessen the physical strain of climbing on these employees (e.g. Barron, 2020).

Findings also emphasised the considerable emotional burden associated with wind industry roles. This included the high impact of family-work conflict supporting findings from Mette et al (2019) who identified this as an issue for offshore wind employees (see Chapter 4 section 4.4.1 & Chapter 6 section 6.6.9).

They also highlighted the considerable impact of colleague relations, both as a stressor and a buffer, particularly in SOV and onshore environments where social conditions were intense with close, isolated working and living conditions and social behaviour required to successfully navigate this was described as complex (see chapter 6, section 6.6.10). The 'buffering' effect of colleague relations identified in these results supports Karasek and Theorell's job demands/support model (Karasek & Theorell, 1990) and relevant research conducted in the wind industry environment (Mette, Velasco Garrido, Preisser, et al., 2018). However, the finding that colleague relations could also act as a stressor questions the simplicity of this buffering impact. These findings emphasised the need for high levels of emotional intelligence when navigating the complex social behaviours required to realise the benefits of colleague support in this environment (see section 6.6.10). This represented a novel finding for research in this work environment which would be worthy of further attention.

The prominent impact of emotional stressors indicated in these findings supports the notion that emotional demands are relevant and worthy of attention when studying non-caring roles (Demerouti et al., 2002; Guan et al., 2017). It also highlights the potential risks of burnout in these roles, both due to the existence of multiple emotional stressors and the culture of stigma around discussion of mental health and related issues. This, again, emphasises the need for research and interventions to employ a multidimensional focus including an awareness of emotional stressors and strains (see Chapter 3, section 3.2.6).

Findings from this study indicated that strains in this environment are plentiful and interact in complex ways. For example, an individual who is fatigued from climbing would be more likely to be short tempered with a colleague, thus causing emotional strain from negative colleague relations. Additionally, the cumulative impact of fatigue means that individuals are likely to exist in a state of high susceptibility to the negative impacts of fatigue for large proportions of on shift time, placing them at risk of averse safety and health behaviours (Earle et al., 2015; Hockey, 1997; Sperandio, 1978). This is particularly the case for SOV participants due to their longer time spent offshore and lack of separation from their work environment.

Underpinning all these strains was a ubiquitous stigma around the discussion and reporting of fatigue and related concepts which must be addressed in fatigue management strategies. Study 2 sought to build on these findings by undertaking a quantitative investigation of fatigue and sleep in this work environment.

Chapter 7- Study 2- Quantitative Field Investigation

Study 2 presented a quantitative investigation of fatigue, sleep and recovery in a naturalistic setting of participants' work environments (see chapter 7, section 7.2). It included participants from two wind industry environments (SOV and CTV) as onshore participants were unable to be included (see section 7.2.3). It tracked subjective ratings of fatigue, sleep and work demands as well as objective sleep ratings over four weeks, encompassing two weeks of working and non-working time for both groups (see Figure 12Figure 13). It aimed to determine whether fatigue, recovery and sleep outcomes were different depending on whether participants were on shift or off shift and whether there were differences in outcomes between the two work environments. Furthermore, it aimed to determine to what extent work demands predicted fatigue outcomes.

Findings revealed that SOV participants had notably higher ratings of fatigue while on-shift whereas the CTV groups showed little difference in fatigue scores between the on and off shift (see chapter 7, section 7.4.2.1). Despite this, sleep and recovery appeared to be similarly impacted by being on shift for both groups with sleep quantity and recovery ratings showing similarly significant decrements during this time (see Chapter 7, sections 7.4.2.2 & 7.4.2.3). This is interesting and suggests that fatigue cannot simply be explained by sleep or recovery decrement, as is commonly attempted in organisational research and practice (e.g. Darwent, Dawson, Paterson, Roach, & Ferguson, 2015; Dawson & McCulloch, 2005) and as with other findings supports a multidimensional approach to fatigue research (see Chapter 3, section 3.2.6).

Further analysis showed that SOV participants experienced notably higher levels of fatigue during the second week of the on shifts (see Figure 23 and 24), providing potential explanation to higher SOV fatigue scores. This heightened fatigue was present in week 2 despite the finding that sleep quantity was not lower during this time (see

Figure 37). This suggests that the cumulative impact of fatigue first identified in study 1 (see Chapter 6, section 6.5.4) and supported by present findings impacted fatigue ratings to a greater extent than sleep acquisition.

This finding endorses the notion that the need for recovery increases as fatigue builds and that a period of recovery and sleep will be less effective after two cumulative working days than it will be after one (Sonnentag & Zijlstra, 2008; Thompson, 2019) This highlights a unique risk factor associated with the SOV work environment, particularly associated with the second offshore week. More generally, it emphasises a need to include an awareness of cumulative fatigue in fatigue models and associated work planning.

Analysis on the predictive impact of work-related demands highlighted two major findings. The first was that emotional demands were highly predictive of fatigue for both groups (see Figure 40 & Figure 41). This highlights the high impact of emotional strain in this environment, again supporting the importance for emotional strain to be included in fatigue investigations for non-caring industries (Demerouti et al., 2002; Guan et al., 2017) and supporting findings from study 1 (see Chapter 6, section 6.6.7).

The second was that demands generally had a stronger predictive impact on SOV fatigue outcomes, particularly during on shift week 2 in which morning fatigue was strongly predicted by demands experienced the previous day (see Figure 40). This is the only measure of strain that was notably different for SOV participants compared to CTVs and indicates a heightened sensitivity to demands during this time due to a build-up of fatigue, again emphasising the cumulative impact of fatigue in this environment.

Findings in all three research outputs highlighted the multidimensional and cumulative nature of fatigue as well as the surprisingly prominent impact of emotional stressors on fatigue outcomes. This supports and expands on motivational models of fatigue (e.g. Boksem & Tops, 2008; Fiona Earle, 2004; Fiona Earle et al., 2015; Robert. Hockey, 2013) by emphasising the cumulative nature of fatigue over several days. It would be beneficial for research to investigate this effect further and in different work environments.

Results also have applied significance for the wind industry as they highlight the need for interventions focusing not just on individual behaviour, but also on organisational culture and design. They also signal a wider need for fatigue investigations to understand the multidimensional nature of fatigue. On a pragmatic level, findings were used to formulate potential industry interventions for the improved management of fatigue as will be discussed in the following section.

8.4 Industry Recommendations based on Findings

Though further research will be needed to substantiate suggested actions, results from the present research suggest that several interventions would be beneficial for the improvement of fatigue management in this industry. These will be discussed in the context of primary secondary and tertiary interventions at an individual or organisational level (see chapter 3 section 3.4 for a discussion of organisational interventions). Suggested interventions do not suggest specific rules around fatigue management (e.g. “do not let employees work for longer than 10 hours”) as it is important to understand that fatigue is a fluid concept and therefore must be managed on a case by case basis in line with industry demands. Instead suggested interventions focus on improved work design and fostering a culture that promotes affective fatigue management.

Some interventions will be relevant for all wind industry environments and some are specifically aimed at one environment (e.g. onshore, offshore SOV) which will be stated. Interventions focused on general fatigue risk management will first be discussed. Following this, actions to support the management of physical strain will be explored followed by suggestions for the alleviation of emotional strain. Finally, potential interventions for improved recovery will be discussed.

The first three recommendations focus on fatigue risk management and how the industry can improve this through work design. An initial and expensive suggestion is a primary, organisational intervention (see Table 1) and recommends that the industry should move towards the cultivation of a 'just culture' around fatigue reporting. Literature discussed in Chapter 3 (section 3.3.3.1) supported the adoption of a 'just culture' around safety and the expansion of this to fatigue reporting (e.g. Dekker, 2017).

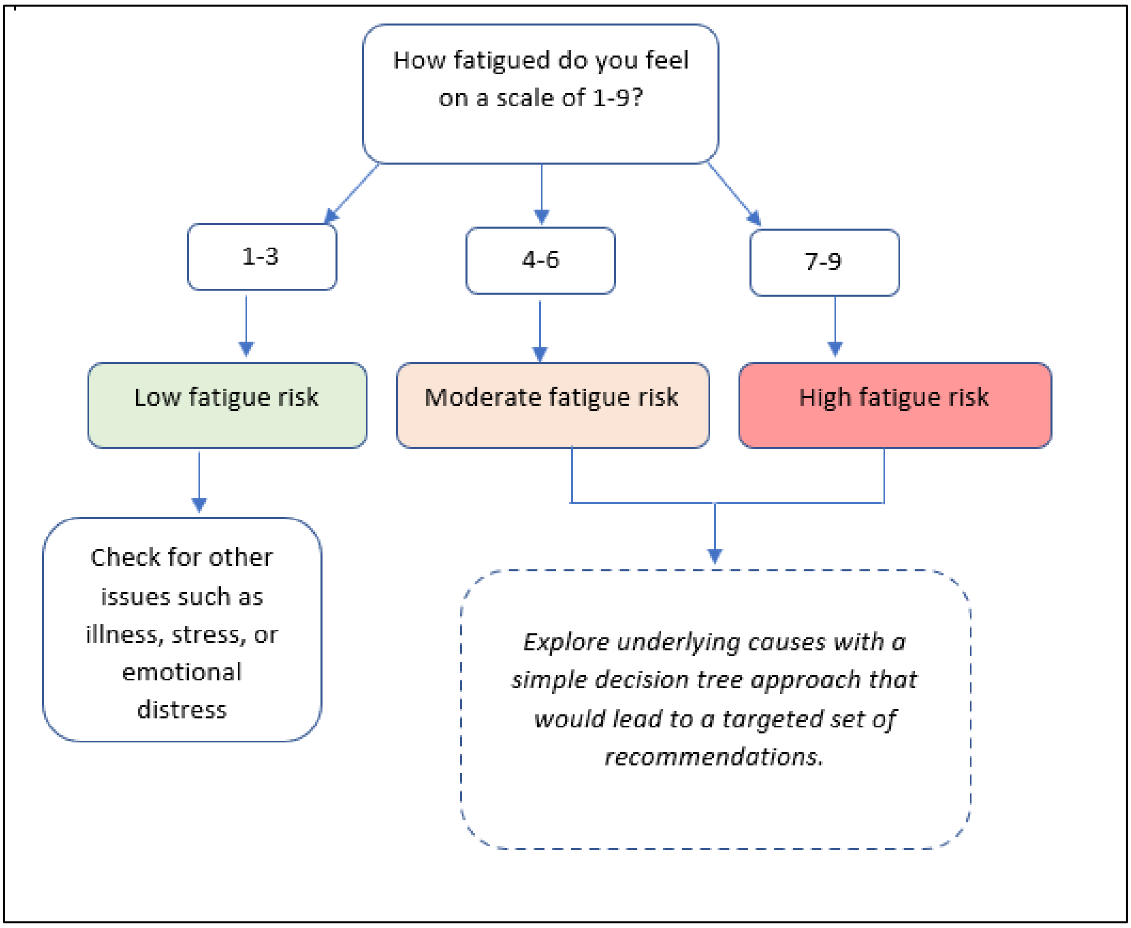
The need for this cultural shift was highlighted by findings from study 1 indicating the presence of a stigma around fatigue and related issues (see Chapter 6, sections 6.5.8, 6.5.9 & 6.5.10). As well as adding an additional emotional burden, this lack of acknowledgement of fatigue issues likely means that problems will only be reported when they reach peak severity (see Chapter 6, section 6.5.9). The cultivation of the 'just culture' is a primary organisational intervention and would require high levels research and planning to foster a more accepting and open culture around fatigue.

The second suggestion is also in the category of fatigue risk management at a primary organisational level and follows on from the previous suggestion. It suggests the high-level design of a fatigue risk management plan. Unlike the traditional approach to fatigue risk planning explored in Chapter 3 (see section 3.4.1), this method should not be prescriptive but should encourage managers to take the fatigue risk seriously and manage it as they would any other safety risk.

This should include providing adequate sleep opportunity as a first action, but this should not be viewed as the only appropriate action to manage fatigue in support of a multidimensional approach. In this instance, the use of a bio-mathematical modelling to prevent sleep deprivation could be incorporated (see Chapter 3 section 3.4.2). However, this should be viewed as an initial step to limit fatigue caused by sleep deprivation and not a cohesive fatigue management system. The plan should focus on best practice around fatigue reporting and appropriate actions and should incorporate a diagnostic tool which will be discussed in the following paragraph.

The third suggestion presents a means of addressing fatigue once it has been reported and therefore is suggested at a tertiary organisational level. Its focus is on the development of a diagnostic tool to use in the event of fatigue reporting. In line with the findings of this research and wider literature (e.g. Boksem & Tops, 2008; Earle, 2004; Earle, Hockey, Earle, & Clough, 2015; Hockey, 1997) it would operate on the understanding that fatigue is a multi-dimensional experience and would simply provide managers with a structure of how to address a highlighted fatigue risk with employees. An outline of how this tool could be designed is pictured in Figure 42 and would be subject to further developments in line with industry specification. The tool focuses on fatigue risk assessment and management and would be designed to identify and identify solutions to alleviate stressors relevant to the individuals' experience of fatigue.

Figure 42- Example of diagnostic tool that could be used for fatigue management in industry



The second group of recommendations focuses the improved management of identified physical strains. Initially, a primary intervention at an individual level for all three wind industry environments is put forward. This involves ensuring that wind technicians have the appropriate level of physical fitness to cope with the demands of the role. Literature included in the systematic review highlighted that physical fitness standards had not been developed accurately in line with demands in the industry (Preisser et al., 2016). This particularly affected climbing demands as this industry requires vertical climbing over significant height which places a significantly different type of strain to pitched ladder climbing (Barron et al., 2018). Furthermore, results in Study 1 emphasised the burden of this physical demand and highlighted that the impact of this can worsen as technicians age (see Chapter 6, section 6.6.2). Therefore, the first recommendation is that physical fitness standards are revised in line with ecologically valid physical demands so that it can be ensured that technicians able to cope with the demands of this role.

Following this, a recommendation based on the maintenance of physical fitness for technicians is presented. This is a secondary intervention at an individual level and Is relevant to all three environments. It suggests that physical training and recovery practices should be incorporated into work planning. This is not only based on findings around the high physical demands associated with the role found in relevant literature (e.g. Barron et al., 2018; Mette, Garrido, Preisser, et al., 2018; Garrido, Mette, Mache, et al., 2018) but also on findings from the present research suggesting that leisure time exercise helps to prevent fatigue and improve wellbeing (see Chapter 6 section 6.7.2). Additionally, this is congruent with wider literature highlighting health decrements for manual workers who do not partake in leisure time exercise (Holtermann et al., 2018).

This intervention is particularly relevant for SOV employees who are confined to the SOV throughout the on shifts with little else outside of work apart from an on-board gym. The provision of a prescriptive fitness and recovery regime would help to give structure and encouragement around exercise. This could also include specific actions and to foster relaxation which findings from study two showed was an issue in this environment (see Chapter 7, section 7.5.2).

Additionally, it is suggested that the industry should consider the consideration of climb assist or training on climbing technique, particularly in the onshore environment. This is a secondary organisational intervention suggested in line with relevant literature (Barron et al., 2017) and findings from study 1 (see Chapter 6, section 6.6.2). The provision of climb assist would likely alleviate the physical strain of climbing that was highlighted as a major issue in this environment. It is possible that climb assist would be deemed too difficult to employ due to associated costs (see Chapter 6 section 6.6.2). In this event, training on effective climbing technique should at least become part of the employee onboarding procedure in line with findings from the systematic review and study 1 which suggested that technique is important for preventing physical strain when climbing (see Chapter 4 & Chapter 6 section 6.6.2).

The third group of recommendations focuses on managing emotional strain synonymous with the wind industry environment. An initial recommendation concentrates on the stigma around discussion of emotional strain and fatigue in this environment and is suggested at a secondary individual level. Findings from study 1 on the stigma around fatigue and related concepts (see Chapter 6, section 6.5.8) highlighted the need for training on fatigue and mental health awareness for employees in all wind industry environments. Though this might not fully eradicate stigma it would address the lack of knowledge that is synonymous with existence of stigma around these issues (Thornicroft et al., 2016).

Additionally, it is suggested that the presence of an onsite welfare support employee would provide direct preventative support to employees in these environments. Not only with this acts as a buffer for technicians, but it would also alleviate the strain on managers who are currently required to provide emotional support on top of their additional duties. This is in line with relevant research directly highlighting the benefits of this provision (Mette, Velasco Garrido, Harth, et al., 2018) and study 1 and 2 findings around high levels of emotional strain caused by feelings of isolation and lack of support in this environment (see Chapter 6 section 6.6.7 & Chapter 7 section 7.4.3.1).

The final intervention focuses on in improving recovery for offshore SOV employees. Though recovery is not the only factor to consider for fatigue management, findings from study 2 highlighted that recovery was compromised for this group. Though this was the case for SOV and CTV participants (see Chapter 7 section 7.5.2), there is a unique opportunity to improve fatigue recovery in the SOV environment due to the fact that these employees remain in on the SOV during their recovery time. Additionally, SOV employees appeared to be more severely impacted by fatigue in their work environment, likely due to the cumulative impact of fatigue. A plan targeted at improving recovery could mean that this time is more effective, thus slowing the cumulative impact of fatigue during on shift time.

This links to the suggestion around structured physical exercise plans (see page 365) and suggests that a structured recovery plan should be devised around Sonnentag's recovery model (Sonnentag & Fritz, 2007) for these employees. Care would need to be taken that this was not prescriptive or enforced as this could mitigate a feeling of control from employees, which is important for effective recovery (Sonnentag & Fritz, 2007). However, having access to appropriate activities to promote recovery is likely to improve fatigue during on shift time. This would need to be done in line with a plan that focuses on the management of work demands in line with fatigue risk management.

All the discussed suggestions would need to be applied in a bespoke manner in line with organisational practices and demands. However, it is important to ensure that a consistent approach to fatigue management is employed throughout the industry and that fatigue risks are treated with appropriate seriousness. Table 32 'presents an overview of these suggestions.

Table 32- Suggested interventions based on research

Suggested Intervention	Wind Industry Environment	Intervention level	Category

Foster a just culture around fatigue reporting.	Offshore SOV, CTV & onshore	Primary, organisational	Fatigue risk management
Build a fatigue management plan incorporating high strain factors identified in the present research.	Offshore SOV, CTV & onshore	Primary, organisational	Fatigue risk management
Develop and use a diagnostic tool to use if an employee reports fatigue (see Figure 42).	Offshore SOV, CTV & onshore	Tertiary, organisational	Fatigue risk management
Develop physical fitness assessment with greater accuracy.	Offshore SOV, CTV & onshore	Primary, individual	Physical
Incorporate physical training and recovery into work plans.	Offshore SOV, CTV & onshore	Secondary, individual	Physical, general wellbeing
Consider the application of climb assist, or at least training on climbing technique.	Onshore	Secondary, individual	Physical
Incorporate training on fatigue awareness and mental health.	Offshore SOV, CTV & onshore	Secondary, individual	Emotional, general fatigue management
Consider employing an on-site welfare support officer.	Offshore SOV and Onshore	Secondary, organisational	Emotional
Incorporate structured plan focussed on recovery and leisure for week 2 of SOV on shift.	Offshore SOVs	Tertiary, individual	Recovery

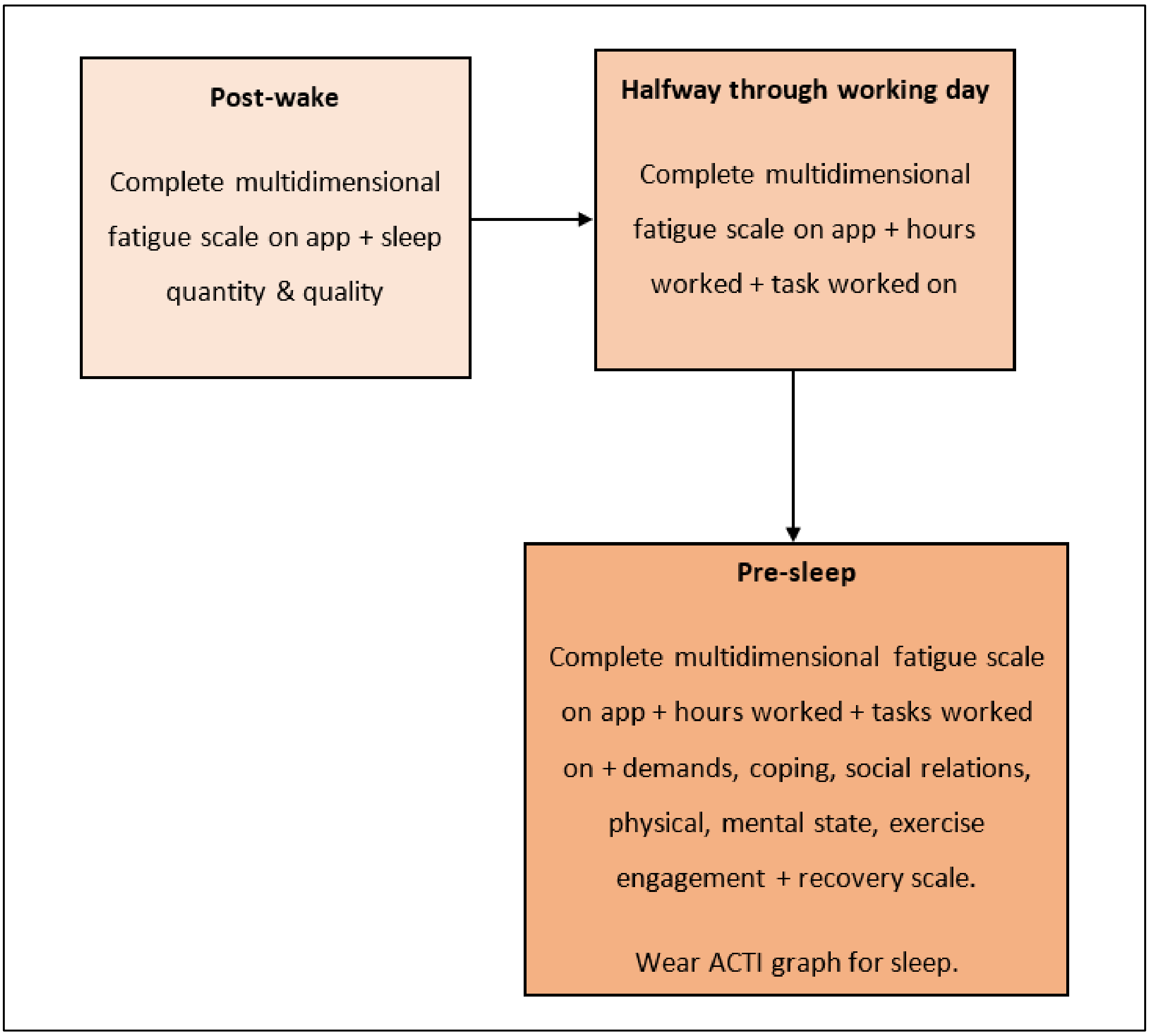
8.5 Future Research

The present research employed a novel method for fatigue related data collection with a multidimensional approach. As the sample size employed in both studies was relatively small, future research would benefit from collecting data from a wider population of wind industry employees. This is especially relevant as major UK offshore wind farms are now moving to 24 hour working including night time work, which poses a high risk for fatigue issues (Ørsted, 2019). It would be useful to use the present data as a comparison for subsequent data collected.

Additionally, future research should be conducted with diversity in mind. The present study used a group of demographically homogenous participants and therefore findings are only relevant to a specific group of people (e.g. white men, many with backgrounds in the military). However, as the wind industry currently has a drive to cultivate a more diverse workforce including the target of employing 30% women (Department of Business Energy and Industrial Strategy, 2019), research would need to include a wider variety of individuals to be relevant for this. Even the homogenous group included in the original research have issues with fatigue during work (particularly SOV employees) and this is likely to increase for those less used to working in such extreme environments.

With a larger participant sample in mind, the present method of data collection in Study 2 would need to be adjusted to promote a greater ease of data acquisition and analysis. Additionally, it would be beneficial for fatigue data to be collected during working time, rather than just before and after work. This would give accurate insight into fatigue risk during work time and provide greater understanding of associated immediate safety risks. To facilitate this, it would be beneficial to collect data in the form of an 'app' which would improve ease of participant entry and circumvent the need for researchers to transcribe data into a computer. Therefore, a simpler app-based design would ideally be employed for future research as outlined in Figure 43.

Figure 43- Simplified data collection method for future research



This would allow for similar processing of results to study 2 but have a simpler research design and data collection method as well as greater accuracy of fatigue risk while working. If the larger sample size can include greater diversity of participants, it would be beneficial to include further interviews utilising the same research design used in Study 1 (see chapter 6) to ensure that a detailed perspective of individuals in less represented groups (e.g. women) is able to be included.

The inclusion of a larger participant group could allow for benchmarking data to be collected and would provide a basis for industry wide guidelines on fatigue management which would have large scale benefits for the industry and help to promote sustainable work planning.

8.6 Researcher Development

This section will be written in the first person to allow for the researcher to reflect on their personal experience of undertaking the present research project.

Over the course of the last three years I have undertaken this research for my PhD in psychology. The characteristics of this project led to a huge amount of personal development as a researcher.

This project first required the acquisition of a comprehensive understanding of fatigue, a complex and often misunderstood concept. Therefore, I initially gained skills in the deep understanding of psychological phenomena and explaining this in the context of applied research. I believe that this will benefit my skills as a researcher throughout my career.

As well as this, placing an emphasis on philosophical underpinnings of the present project challenged my understanding of the nature of reality and how this is heavily affected by subjective experience. This not only developed my personal understanding of the world around me but also helps me to formulate my approach as a researcher. I feel that this is particularly relevant for industry-based research as this requires the constant negotiation between academic and applied understanding of real-world issues.

Additionally, as the present research was a mixed-methods project I developed skills and understanding in both qualitative and quantitative research. I feel that this not only allowed me to gain a thorough perspective of the subject at hand, but also emphasised the benefits of employing these two methods together in future research. I now hope to employ a similar methodology when approaching larger scale industry based research projects as it allows for a rich basis of data from qualitative interviews to be expanded through the use of statistical methods meaning that meaningful interventions can be suggested and employed.

This project was and applied investigation and therefore encompassed its own challenges Including a lack of control of how research was conducted and the need to manage the expectations and needs of a client organisation. From this I developed skills as an applied researcher including the balance of academic rigor with a pragmatic approach to undertaking organisational-based research. I learnt that traditional assumptions around sample size and power could not be utilised for the present research and so had to find other means in which to make the research meaningful and useful.

During this project I gained skills in understanding a complex psychological phenomenon and applying this understanding to researching a real-world problem and developing solutions to solve it. I feel that not only have I developed tangible skills in research methods, my conceptualisation of the world itself is vastly different from when I began the project. I am now motivated to apply these this newfound understanding and skills to the development of wider scale research to help to further bridge the gap between academic research and industry practice.

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Appendix 1- Ethical Approval Letters for Study 1

UNIVERSITY OF HULL

Professor Terry Williams,
Dr Fiona Earle

Faculty of Business, Law & Politics
Research Office
University of Hull
T +44(0)1482 463536
E h.carpenter@hull.ac.uk

Ref: HUBSREC 2018/03 30 August 2018

Dear Terry and Fiona

Research Title: [redacted] fatigue study: SOV and CTV based Technicians

Thank you for your research ethics application.

I am pleased to inform you that on behalf of the Faculty of Business, Law and Politics Research Ethics Committee at the University of Hull, Dr Ashish Dwivedi has approved your application on 29 August 2018. You now have permission to proceed with the research.

I am advised by the committee to remind you of the following points:

- You must comply with the Data Protection act 1998;
- You must refer proposed amendments to the committee for further review and obtain the committee's approval prior to implementation (except only in cases of emergency where the welfare of the subject is paramount).
- You are authorised to present this University of Hull Research Ethics committee letter of approval to outside bodies in support of any application for further research clearance.

On behalf of the committee may I wish you every success with your research.

Yours sincerely,

Hilary Carpenter
Secretary,
Research Ethics Committee
Faculty of Business, Law and Politics

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31st October 2018

Ref: HUBSREC 2018/10

Dear Professor Terry Williams, Dr Fiona Earle and Stefi McMaster,

Research Title: [redacted] fatigue study: Onshore wind technicians

Thank you for your research ethics application.

I am pleased to inform you that on behalf of the Faculty of Business, Law and Politics Research Ethics Committee at the University of Hull, Dr Ashish Dwivedi has approved your application on 31st October 2018. You now have permission to proceed with the research.

I am advised by the committee to remind you of the following points:

- You must comply with the Data Protection act 1998;
- You must refer proposed amendments to the committee for further review and obtain the committee's approval prior to implementation (except only in cases of emergency where the welfare of the subject is paramount).
- You are authorised to present this University of Hull Research Ethics committee letter of approval to outside bodies in support of any application for further research clearance.

On behalf of the committee may I wish you every success with your research.

Yours sincerely,

Gul Dag
Research Support Administrator
Research and Enterprise Office
Faculty of Business, Law and Politics

Faculty of Business, Law and Politics
University of Hull
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Appendix 2- Study 1 Consent Form

[redacted] & THE UNIVERSITY OF HULL

RESEARCH INTO HEALTH, SAFETY AND WELLBEING: FATIGUE IN WIND TECHNICIANS

EMPLOYEE CONSENT FORM

Background

Orsted and the University of Hull have entered into a collaboration to study the impact of work on stress, fatigue and wellbeing in wind technicians.

This research aims to gain an understanding of the challenges faced in wind energy working environments and how these can affect technician fatigue.

This interview aims to understand the challenges of your work and how this could affect your levels of fatigue.

What will be involved:

You will be required to participate in a recorded interview with a researcher. This will last approximately 1-1.5 hours.

How your data will be used

We will require you to provide the following information:

- Age and gender (used only for describing the participant group)
- Relevant background information including work experience

This information will be anonymised before sharing with the wider Orsted project team in a summary report format. Your anonymised data may also be part of academic publication of the research, although data will again be anonymised and aggregated to only represent broad group findings - your personal responses will not be attributable to you in any way.

The processing of sensitive personal data

Your personal data will be deleted following a period of 5 years after completion of the study. Any personal data you provide will be anonymised in any report(s) produced and you will not be personally identifiable from any such reports. If you would like further information about how your personal data will be used and processed, please contact Stefi McMaster, University of Hull on direct dial 07503173428 or email s.mcmaster@2017.hull.ac.uk.

By signing and returning the slip attached to this letter, you consent to our processing your data for the above purposes.

The provision of your consent is entirely at your option and your refusal will have no adverse consequences.

I consent to my data being processed only in the manner, and for the purposes, described above in relation to the project. I understand that this consent is entirely at my option, that all data will be confidential and anonymised prior to inclusion in any reports, and that my refusal will have no adverse consequences or other impact on any decisions made relating to my employment.

I also confirm the following:

Appendix 3- Study 1 Debrief Form

Fatigue study: Offshore Wind Technicians

PRINCIPAL INVESTIGATOR: STEFI MCMASTER
PhD Researcher, University of Hull

Co-investigators:
Dr Fiona Earle, Senior Lecturer, University of Hull
Professor Terry Williams, Risk Institute, University of Hull

DEBRIEFING INFORMATION
Thank you for your participation in this interview. As previously outlined, the aim of the interview is to explore fatigue and wellbeing in your line of work.

No deception has been used during the study, and the findings will be used to ensure the final study design measures the appropriate aspects of impact and provides a better understanding of the risks and how they can continue to be addressed.

Anonymity
As detailed in the Consent Form, all of the information you have provided will be anonymised, and results will only be presented as group findings. Your personal information will not be paired with your data at any point.

Data Protection
In accordance with data protection and ethical guidelines, data will be securely stored for 5 years. After this time, all raw data and personal information will be destroyed.
You retain the right to withdraw your data at any point, but it is important that you retain your unique ID to ensure we can identify your data.

If you have any concerns, comments, or questions about this research, please to contact,

Stefi McMaster
Department of Psychology
University of Hull
07503173428
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Appendix 4- Study 1 Interview Structures

<table>
<tr><th><u>Technician Interview Areas</u></th><th><u>Notes</u></th></tr>
<tr><td><u>Introduction</u>

We are collecting information about how fatigue affects operations and maintenance technicians with a view to understand the challenges you face and suggest solutions to improve wellbeing. We aim to minimise fatigue problems both in the long and short term.

Fatigue is a feeling of weariness and a sense that you do not want to commit any more effort to the task that you are working on.

Confidentiality – ethics rules and principles around information sharing and right to withdraw
Confirm overall interview consent and specific audio recording consent - explain data management, control and constraints on how information will be anonymised and reported
Their role in the project – What they need to do for the interviews and going forwards</td><td><u>Aims</u>

1. To explain the aims of the project and interviews
2. To make them feel comfortable that their answers will be anonymous
3. Establish our research credibility and ethics
4. To build a rapport and gain buy-in for the interviews: this is something that aims to help them.</td></tr>
<tr><td><u>interviewee info</u>

1) Age
2) Amount of time spent in role
3) Employment background- where did you work previously? Was this similar to your current role?
4) What made you decide to apply to your current role? How is it similar/different to your previous roles?
5) How do you generally feel about your job/role? What do you like about it? What do you dislike about it?
6) Home life- are you married/ do you have a partner? Do you have children? How old are your children? Who do you live with? Do you have caring responsibilities for anyone else?
7) What are your hobbies? What do you generally like to spend time doing when you're not at work? E.g. on a night, or on a weekend.</td><td>Need to understand their interview data in the context of their work and personal background

If they have young children (e.g. babies), they are likely to experience sleep disruption.

If they have hobbies which they engage in and enjoy outside of work, this might help fatigue recovery.</td></tr>
<tr><td><u>Exploring their role</u>

<u>Initial questions</u>

1) Job Role – What is your job title? Tell me what responsibilities you have in your job- what do you spend most of your working time doing?
2) Shift pattern – What is your regular shift pattern? How much time do you spend offshore at a time? How long are your shifts? Are your shifts normally the same, or do they change for any reason?</td><td>Useful to gain an idea about the complexity of their role and whether they have any management responsibilities.</td></tr>
</table>

When does your shift technically begin, e.g. when you leave your accommodation, when you get onto the boat, or when you arrive at the first turbine? 3) **If your shift patterns vary, which pattern do you prefer? Why?** 4) **Do you normally have any secondary duties to complete once you have finished on the turbine?** 5) How many people do you tend to work closely with on your shifts? Do you usually work with the same people, or can this change? How would you describe your relationship with the person/people you work with? **Detailed questions** 1) **Talk me through a typical day** * probe: How is a normal day structured, what do you do? – travel, nature of work, workload, balance of tasks / timings / working hours / breaks / environment / context / 'team' 2) **Variability** Is every day the same? *Probe: What differs? What leads to changes? Consequences of any variability/changes? 3) **Impact** How does your work affect you? 4) What is the **best aspect of your job?** 5) If there was **one aspect of your work that you could change**, what would that be? *What aspect of your work do you think is the greatest impact on your wellbeing in the short and longer term? 6) **What aspects of your role normally make you feel stressed?** 7) **How do you normally feel at the start of the week? How do you normally feel at the end of the week?** 8) If you start to feel tired or drowsy during a shift, what do you tend to do? 9) Do you tend to use caffeine to feel more 'awake' when at work? **Breaks** • How much opportunity do you get to take breaks throughout the day? Do you stop completely to eat lunch, or do you do this in combination with another working activity? What do you normally do if you do have a break?	Need to determine how their shift pattern may affect their fatigue. Do they always work the same hours, do their hours increase when they have to travel, or is this time accounted for as part of their shift? How much time do they get to sleep and recover between shifts? Probe questions when there is any mention of fatigue, tiredness or stress. 'what made you feel this way', 'what was the result of this'? Probe if worst aspect/thing they would change is related to stress/tiredness/fatigue. 'what made you feel this way', 'what was the result of this'? If you have no opportunity to take breaks, why is this? How much control do you have over your time management?
Visioning - The next questions involve you thinking about particular scenarios…	What about the bad day might affect fatigue/tiredness/stress?

1) **Imagine a day when you are very tired** by the end of it- what made you feel tired, describe a day that would result in that state. 2) **Imagine a day when you are very energetic** at the end of it, what would make you feel energetic. Describe a work day that would result in this state. **Fatigue –related errors** Think back over the past few months of your work. Do you remember making any mistakes that you think are due to being tired or stressed at work, or between your shifts? If so, what happened? What were the consequences? If it happened at work, did you report it? (if they didn't report the error)- why did you choose not to report it? If you do feel fatigued (e.g. like your performance and safety might suffer due to tiredness) or stressed when at work, do you tend to share this with your colleagues or supervisor, or would you be more likely to keep it to yourself? If the latter, why is this?	Aims to understand the culture around the reporting of fatigue, and fatigue-related errors. What are the barriers to reporting?
Transit – • How long does it normally take you to get to the first turbine? • How do you get from the vessel onto the turbines (e.g. 'walk to work', ladder). Have you always done it this way? If not, what did you do before? • How does transit make you feel?	Aim is to determine how transit and travelling between turbines affects fatigue.
Physical demands – to what extent do you have to engage in climbing activities? (explore max and min climbs) If so- describe how this affects you? (explore psychological effects) How do you tend to feel afterwards? And for how long? How do you think it affects the rest of that shift's work? Yes this carry over is important How do you tend to feel at the end of the shift? Other than climbing, what activities that you undertake in your shift would you say are physically demanding? Does your work take place in confined conditions? Do you have to contort yourself in order to carry this work out? If so, how long do you do this for on average per shift?	Aim is to determine the effect of physical work and working at height on fatigue.

In an average shift, are you required to lift any heavy objects? If so, how does this make you feel? How often do you normally undertake this kind of task? **Noise** When working on or near turbines, how much are you bothered by the noise that they make? Probe: what affect do you think this has? How long does it affect you for? E.g. after you have finished work? **Physical activity outside of work** After completing work, do you feel that you have the energy to complete any kind of physical activity, such as exercise or sports?	
Mental tasks – Do you feel capable of undertaking the mental tasks required of you throughout the course of your shifts, or do you find them difficult? How do you feel once you have completed a mental task (e.g. fixing a turbine)? Does it make you tired? How do you feel once you have completed a number of mental tasks (e.g. fixed a number of turbines)? Do you feel tired? Stressed? How would you describe the mental tasks that you regularly undertake? Are they generally exciting and interesting? Or are they routine and boring?	Aim is to understand fatigue caused by mental tasks Probe: What are the results of your feelings?
End of day - What is your end of shift routine? * How do you feel at the end of a typical working day, on finishing your work and returning to dock/SOV? Probe: what do you think are the main causes of your 'end of the day' state? If you think about the factors which lead to this state, what proportion would each one contribute? **End of shift period –** How do you feel at the end of a period of continuous shifts? E.g. at the end of the week. How does this compare to the feeling at the end of the day on your first shift?	Exploration of 'end of day' subjective experience and perceived causal factors Understand fatigue and the factors which contribute to it Probe: If they say that they feel tired, ask how long it normally takes them to feel 'back to normal' over the weekend/on holiday. (maybe ask them to draw 'fatigue line' on some paper)
Routine after a shift/before starting next shift –	

What is your normal routine when you have finished a shift, and have another one the next day? Are you able to relax? Do you socialise? Do you tend to drink alcohol? If so, how much? Do you exercise? Do you engage in hobbies that you enjoy? Do you feel that you are able to decide how you spend your time during this period? Are you able to forget about the pressures of work during this period? Probe: If not, why not?	Aim is to gain an insight into their recovery behaviours between shifts. Questions are based on Sonnentag recovery behaviours questionnaire (Sonnentag, 2007) and focus on whether participants are able to detach from work and if they feel in control of their time when they are not working (important for adequate recovery).
Sleep – Tell me about your shift patterns during the working week (e.g. on nights when you have finished a day of work, and then have another one the next day). Do you sleep better or worse than you do during time off (at home)? How many hours of sleep would you say that you normally get during a period of shift work? Do you have trouble getting to sleep? Do you have trouble with waking up during the night? Do you normally feel refreshed when waking up after a night of sleep and before starting a new shift, or tired? **Summing up** Re-cap on all of the major stressors that they have mentioned to be significant and ask them which one they feels contributes most to their feelings of fatigue/stress.	Aim is to determine how their work affects their sleep and how sleep quality is likely to affect their fatigue during a shift.
Debrief Thank you very much for taking the time to answer my questions. It has been great to speak to you about this. The information that I've gained from this will contribute to a research project that I am undertaking with the university of hull into causes and consequences of technician fatigue.	

It may be shared with your employer, but only in a very general way, and your individual answers will not be identified to them. If you would like to withdraw from the study at any point, you are completely free to do so and your information will not be included. Do you have any questions about the research? If you do have any further questions, or anything you would like to discuss further, please feel free to contact me on- s.mcmaster@2017.hull.ac.uk.	

Appendix 5- Study 2 Ethical Approval Letter

UNIVERSITY OF HULL

Professor Terry Williams,
Dr Fiona Earle

Faculty of Business, Law & Politics
Research Office
University of Hull
T +44(0)1482 463536
E h.carpenter@hull.ac.uk

Ref: HUBSREC 2018/03

30 August 2018

Dear Terry and Fiona

Research Title: Orsted fatigue study: SOV and CTV based Technicians

Thank you for your research ethics application.

I am pleased to inform you that on behalf of the Faculty of Business, Law and Politics Research Ethics Committee at the University of Hull, Dr Ashish Dwivedi has approved your application on 29 August 2018. You now have permission to proceed with the research.

I am advised by the committee to remind you of the following points:

- You must comply with the Data Protection act 1998;
- You must refer proposed amendments to the committee for further review and obtain the committee's approval prior to implementation (except only in cases of emergency where the welfare of the subject is paramount).
- You are authorised to present this University of Hull Research Ethics committee letter of approval to outside bodies in support of any application for further research clearance.

On behalf of the committee may I wish you every success with your research.

Yours sincerely,

Hilary Carpenter
Secretary,
Research Ethics Committee
Faculty of Business, Law and Politics

Faculty of Business, Law and Politics
University of Hull
Hull, HU6 7RX
United Kingdom

http://www2.hull.ac.uk/Faculties/fblp/hubs.aspx

Appendix 6- Study 2 Consent Form

[redacted] & THE UNIVERSITY OF HULL

RESEARCH INTO HEALTH, SAFETY AND WELLBEING: FATIGUE IN WIND TECHNICIANS

EMPLOYEE CONSENT FORM

Background

Orsted and the University of Hull have entered into a collaboration to study the impact of work on stress, fatigue and wellbeing in wind technicians.

This research aims to gain an understanding of the challenges faced in wind energy working environments and how these can affect technician fatigue.

This study aims to understand the challenges of your work and how this could affect your levels of fatigue.

What will be involved:

Over a period of 4 weeks, you will be required to:

- Fill in an initial one-off survey during training
- Fill in a diary (provided) twice per day- morning and evening.
- Wear an ACTi graph (watch-like device) while sleeping.

How your data will be used

We will require you to provide the following information:

- Age and gender (used only for describing the participant group)
- Relevant background information including work experience

This information will be anonymised before sharing with the wider Orsted project team in a summary report format. Your anonymised data may also be part of academic publication of the research, although data will again be anonymised and aggregated to only represent broad group findings - your personal responses will not be attributable to you in any way.

The processing of sensitive personal data

Your personal data will be deleted following a period of 5 years after completion of the study. Any personal data you provide will be anonymised in any report(s) produced and you will not be personally identifiable from any such reports. If you would like further information about how your personal data will be used and processed, please contact Stefi McMaster, University of Hull on direct dial 07503173428 or email s.mcmaster@2017.hull.ac.uk.

By signing and returning the slip attached to this letter, you consent to our processing your data for the above purposes.

The provision of your consent is entirely at your option and your refusal will have no adverse consequences.

I consent to my data being processed only in the manner, and for the purposes, described above in relation to the project. I understand that this consent is entirely at my option, that all data will be confidential and anonymised prior to inclusion in any reports, and that my refusal will have no adverse consequences or other impact on any decisions made relating to my employment.

I also confirm the following:

- I have read and understood the information provided about the Project: YES/NO
- I have had the opportunity to ask questions and discuss the Project: YES/NO
- All such questions have been answered satisfactorily: YES/NO
- I have received enough information about the Project: YES/NO
- I understand that I am free to withdraw from the interviews stage at any time without having to give a reason: YES/NO
- I agree to take part in the Project: YES/NO

This Project has been explained to me to my satisfaction, and I agree to take part. I understand that I am free to withdraw at any time.

PARTICIPANT NAME:

SIGNED: **DATED:**

Appendix 7- Study 2 Debrief Form

Fatigue study: Offshore Wind Technicians

PRINCIPAL INVESTIGATOR: STEFI MCMASTER
PhD Researcher, University of Hull

Co-investigators:
Dr Fiona Earle, Senior Lecturer, University of Hull
Professor Terry Williams, Risk Institute, University of Hull

DEBRIEFING INFORMATION

Thank you for your participation in this study. As previously outlined, the aim of the study is to explore fatigue, wellbeing and sleep in your line of work.

No deception has been used during the study, and the findings will be used to ensure the final study design measures the appropriate aspects of impact and provides a better understanding of the risks and how they can continue to be addressed.

Anonymity

As detailed in the Consent Form, all of the information you have provided will be anonymised, and results will only be presented as group findings.

Data Protection

In accordance with data protection and ethical guidelines, data will be securely stored for 5 years. After this time, all raw data and personal information will be destroyed.
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If you have any concerns, comments, or questions about this research, please to contact,

Stefi McMaster
Department of Psychology
University of Hull
01482 465552
s.mcmaster@2017.hull.ac.uk

Appendix 8- Study 2 Questionnaire

Questionnaire

Name________________

How old are you?__________

What kind of job role were you in before you started this one?

Armed forces ☐ Wind technician role in other company ☐ Student/unemployed ☐ other type of technician ☐

Other ☐

What is your gender?

Male ☐ Female ☐ Other ☐ Prefer not to say ☐

What is your marital status?

Married/cohabiting with partner ☐ In a relationship, not living together ☐ Single ☐ Other ☐

Do you have caring responsibilities for children/anyone else?

Yes ☐ No ☐

Please answer the following questions in the context of the last year

Do you smoke? Yes ☐ No ☐

If you answered yes, how many cigarettes do you smoke on average per day?______________

Does the amount you smoke change when you go offshore?

No ☐ Increases ☐ Decreases ☐

How many caffeinated beverages/supplements do you have per day (including caffeine pills?) ______________

Does the amount of caffeine you have change when you are offshore?

No ☐ Increases ☐ Decreases ☐

What substances do you use to help you get to sleep?

None ☐Over the counter sleeping pills ☐ Prescription sleeping pills ☐ Other (please specify) ______________

How many times per week on average, do you do the following kinds of exercises for more than 15 minutes during your free time?

a). Strenuous exercise (heart beats rapidly)- e.g. running, football, squash, vigorous swimming ☐

b). Moderate exercise (not exhausting)- e.g. fast walking, tennis, easy cycling, fast-paced yoga ☐

c). Mid/light exercise (minimal effort)- e.g. light yoga, golf, easy walking ☐

Does the amount of exercise you undertake change when you are offshore?

No ☐ Increases ☐ Decreases ☐

One hears about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?

Definitely a "morning" type ☐

Rather more a "morning" type than an "evening" type ☐

Rather more an "evening type than a "morning" type ☐

Definitely an "evening" type ☐

Taking everything into consideration, how do you feel about your job as a whole?

Extremely dissatisfied Extremely satisfied

1 2 3 4 5 6 7

Taking everything into consideration, how do you feel about your relationships with your colleagues?

Extremely dissatisfied Extremely satisfied

1 2 3 4 5 6 7

I see myself as someone who…	**Disagree strongly**	**Disagree a little**	**Neither agree nor disagree**	**Agree a little**	**Agree strongly**
…is reserved	1	2	3	4	5
…is generally trusting	1	2	3	4	5
…tends to be lazy	1	2	3	4	5
…is relaxed, handles stress well	1	2	3	4	5
…has few artistic interests	1	2	3	4	5
…is outgoing, sociable	1	2	3	4	5
…tends to find fault with others	1	2	3	4	5
…does a thorough job	1	2	3	4	5
…gets nervous easily	1	2	3	4	5
…has an active imagination	1	2	3	4	5
…is considerate and kind to almost everyone	1	2	3	4	5

Appendix 9- Study 2 Morning diary page

Diary Page 2: On-shift day 1 (of 14) Date:_________

PART 1 – Morning (time of completion? ___:___am)

How would you estimate the quality and quantity of your sleep last night? Please circle the response that is the best fit for you.

Sleep quantity (hrs / mins)	____ hrs ____ mins

Sleep Quality (please circle)	*Very Poor* *Very Good* 1 2 3 4 5 6 7 8 9
Was your sleep adversely affected by any of the following factors?	Noise ____________ Yes / No Vessel motion____________ Yes / No Stress/anxiety____________ Yes / No Other (please note):

How do you feel right now?	*Strongly disagree*								*Strongly agree*
1. I feel mentally tired	1	2	3	4	5	6	7	8	9
2. I feel bored	1	2	3	4	5	6	7	8	9
3. I feel somewhat sleepy	1	2	3	4	5	6	7	8	9
4. I feel detached & uninterested	1	2	3	4	5	6	7	8	9
5. I don't feel like making much of an effort	1	2	3	4	5	6	7	8	9
6. I feel emotionally drained	1	2	3	4	5	6	7	8	9
7. I feel like closing my eyes and having a nap	1	2	3	4	5	6	7	8	9
8. I feel worn out physically	1	2	3	4	5	6	7	8	9
9. I feel uneasy	1	2	3	4	5	6	7	8	9
10. I feel physically tired	1	2	3	4	5	6	7	8	9
11. I feel unable to concentrate	1	2	3	4	5	6	7	8	9
12. I feel tense / on edge	1	2	3	4	5	6	7	8	9
13. I feel worn out emotionally	1	2	3	4	5	6	7	8	9
14. I feel irritated and annoyed	1	2	3	4	5	6	7	8	9
15. I feel wide awake	1	2	3	4	5	6	7	8	9
16. I feel drowsy	1	2	3	4	5	6	7	8	9
17. I feel mentally drained	1	2	3	4	5	6	7	8	9

What is your expected work pattern for today? Please estimate the **rough** proportion of your time (out of 100%) that you anticipate spending under each of the following headings.
N.B this may be 100% for one activity, or you may expect a proportion of your time to be split across a range of activities.

Expected work activity	**Expected %age**
1) Stood Down – not required for duty, remaining on SOV	
2) Stood Down for weather reasons, remaining on SOV	
3) Trouble Shoot stand by, remaining on SOV	
4) Trouble Shoot – deploying to WTG from SOV	
5) WTG annual service	
6) Balance of Plan – Latchway Yo-Yo replacement or rectification	
7) Balance of Plan – escorting statutory inspection team	
8) General Duties on SOV – safety day planning, tool checks etc	
9) Management Duties on SOV – DOM only	
10) Other - deployed to WTG	
11) Other – remaining on SOV (sailing to port etc)	

Do you expect that you will have to climb to the top of the turbine today?	Yes / No
If yes, how many times do you think you will have to climb to the top of a turbine?	

Appendix 10- Study 2 Evening diary page

PART 2 – Evening (time of completion? ___:___pm)

How do you feel right now?	*Strongly disagree*								*Strongly agree*
1. I feel mentally tired	1	2	3	4	5	6	7	8	9
2. I feel bored	1	2	3	4	5	6	7	8	9
3. I feel somewhat sleepy	1	2	3	4	5	6	7	8	9
4. I feel detached & uninterested	1	2	3	4	5	6	7	8	9
5. I don't feel like making much of an effort	1	2	3	4	5	6	7	8	9
6. I feel emotionally drained	1	2	3	4	5	6	7	8	9
7. I feel like closing my eyes and having a nap	1	2	3	4	5	6	7	8	9
8. I feel worn out physically	1	2	3	4	5	6	7	8	9
9. I feel uneasy	1	2	3	4	5	6	7	8	9
10. I feel physically tired	1	2	3	4	5	6	7	8	9
11. I feel unable to concentrate	1	2	3	4	5	6	7	8	9
12. I feel tense / on edge	1	2	3	4	5	6	7	8	9
13. I feel worn out emotionally	1	2	3	4	5	6	7	8	9
14. I feel irritated and annoyed	1	2	3	4	5	6	7	8	9
15. I feel wide awake	1	2	3	4	5	6	7	8	9
16. I feel drowsy	1	2	3	4	5	6	7	8	9
17. I feel mentally drained	1	2	3	4	5	6	7	8	9

What was your actual work pattern today?
Please estimate the **rough** proportion of your time (in hours / minutes) that you spent under each of the following headings.

Actual work activity	**Hours / minutes spent**
1) Stood Down – not required for duty, remaining on SOV	
2) Stood Down for weather reasons, remaining on SOV	
3) Trouble Shoot stand by, remaining on SOV	
4) Trouble Shoot – deploying to WTG from SOV	
5) WTG annual service	
6) Balance of Plan – Latchway Yo-Yo replacement or rectification	
7) Balance of Plan – escorting statutory inspection team	
8) General Duties on SOV – safety day planning, tool checks etc	
9) Management Duties on SOV – DOM only	
10) Other - deployed to WTG	
11) Other – remaining on SOV (sailing to port etc)	
If you were working on a turbine, how did you get there? (tick the appropriate option)	
1) Walk to work	
2) CTV transfer	
3) Daughter craft transfer	

Did you have to climb to the top of a turbine today?	Yes / No
If yes, how many times did you climb up a turbine?	
Did you act as team leader today?	Yes / No
How high were your manual handling demands today (1=very low, 4-5 =average, 9 =extremely high)	1 2 3 4 5 6 7 8 9

If you were *stood down* today, how did you manage your time?

Actual stand down activity	**Hours / minutes spent**
1) General administration – catching up on emails, filling in time sheets and closing down work cards	
2) Preparing for next work scope – planning, briefing or developing RAMS, AWPs etc	
3) Undertaking safety checks of PPE and other equipment	
4) Assisting in the Warehouse – manual handling, clearing equipment and general house keeping	
5) No work allocated	
6) Sick – stood down to room	

Working time

How much time did you spend working today?	hrs_____mins_____
How much of this time was spent completing duties such as filling in timesheets, and having team meetings?	hrs_____mins_____

Please circle the number that most describes how you felt this evening for each of these items

About your activities today?	*Low* *High*
Physical demands	1 2 3 4 5 6 7 8 9
Mental demands	1 2 3 4 5 6 7 8 9
Emotional demands	1 2 3 4 5 6 7 8 9
How well do you feel you coped with your demands today?	*Not at all well* *Very well*
Mentally	1 2 3 4 5 6 7 8 9
Physically	1 2 3 4 5 6 7 8 9
Emotionally	1 2 3 4 5 6 7 8 9
How well do you feel you got on with those around you today?	1 2 3 4 5 6 7 8 9
If you have been in contact, how would you rate your interactions with your family or friends from home today?	*Positive* *Negative*
	1 2 3 4 5 6 7 8 9

How have you been today?	*Not at all* *A little* *A lot*
Headaches	1 2 3 4 5 6 7 8 9
Stomach pain / disturbance	1 2 3 4 5 6 7 8 9
Blurred vision	1 2 3 4 5 6 7 8 9
Mood Disturbance	1 2 3 4 5 6 7 8 9
General aches & pains	1 2 3 4 5 6 7 8 9
Motion sickness/ seasickness	1 2 3 4 5 6 7 8 9
Did you feel motivated today?	1 2 3 4 5 6 7 8 9
How much has your work life been affected by thoughts about your family?	*Not at all* *Very much*
	1 2 3 4 5 6 7 8 9

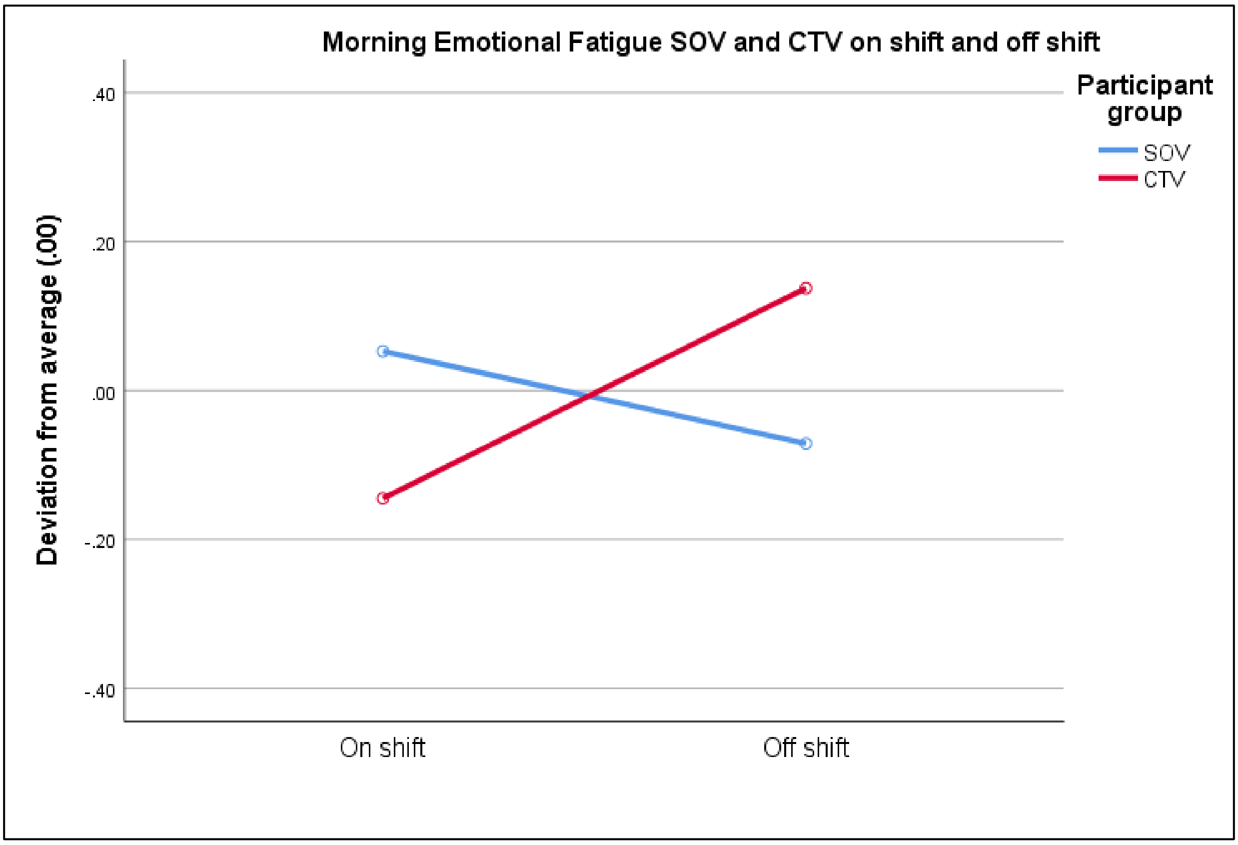
During my off-job time this evening...	1= totally disagree 2= disagree 3= neutral 4= agree 5= totally agree
I forgot about work	1 2 3 4 5
I didn't think about work at all	1 2 3 4 5
I distanced myself from work	1 2 3 4 5
I got a break from the demands of work	1 2 3 4 5
I kicked back and relaxed	1 2 3 4 5
I did relaxing things	1 2 3 4 5
I used the time to relax	1 2 3 4 5
I took time for leisure	1 2 3 4 5
I learned new things	1 2 3 4 5
I sought out intellectual challenges	1 2 3 4 5
I did things that challenged me	1 2 3 4 5
I did something to broaden my horizons	1 2 3 4 5
I felt like I could decide for myself what to do	1 2 3 4 5
I decided my own schedule	1 2 3 4 5
I determined for myself how I spent my time	1 2 3 4 5
I took care of things the way I want them to be done	1 2 3 4 5

How many caffeinated beverages did you consume today?

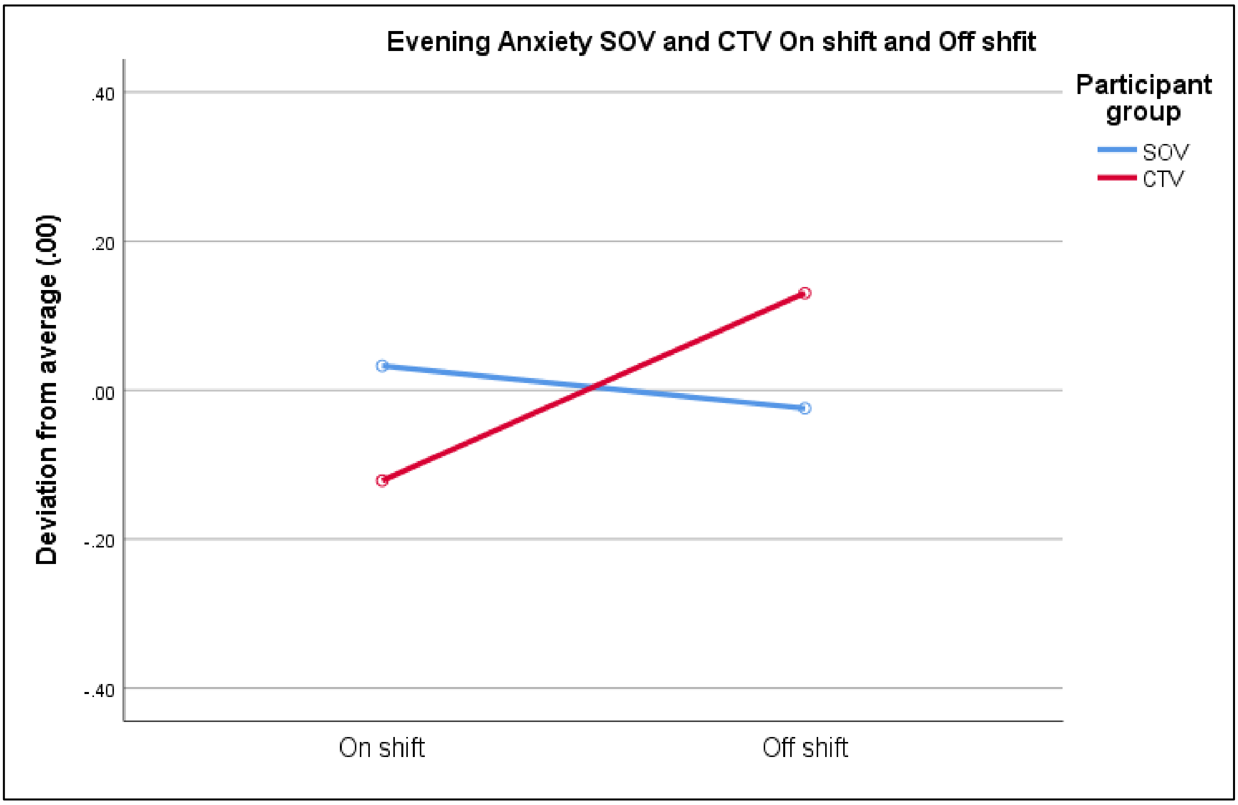
Did you take any medication today that could have influenced your levels of tiredness? Yes / No
Do you have any comments about your sleep and wellbeing today that may help us interpret today's data?

Thank you for your participation today ☺

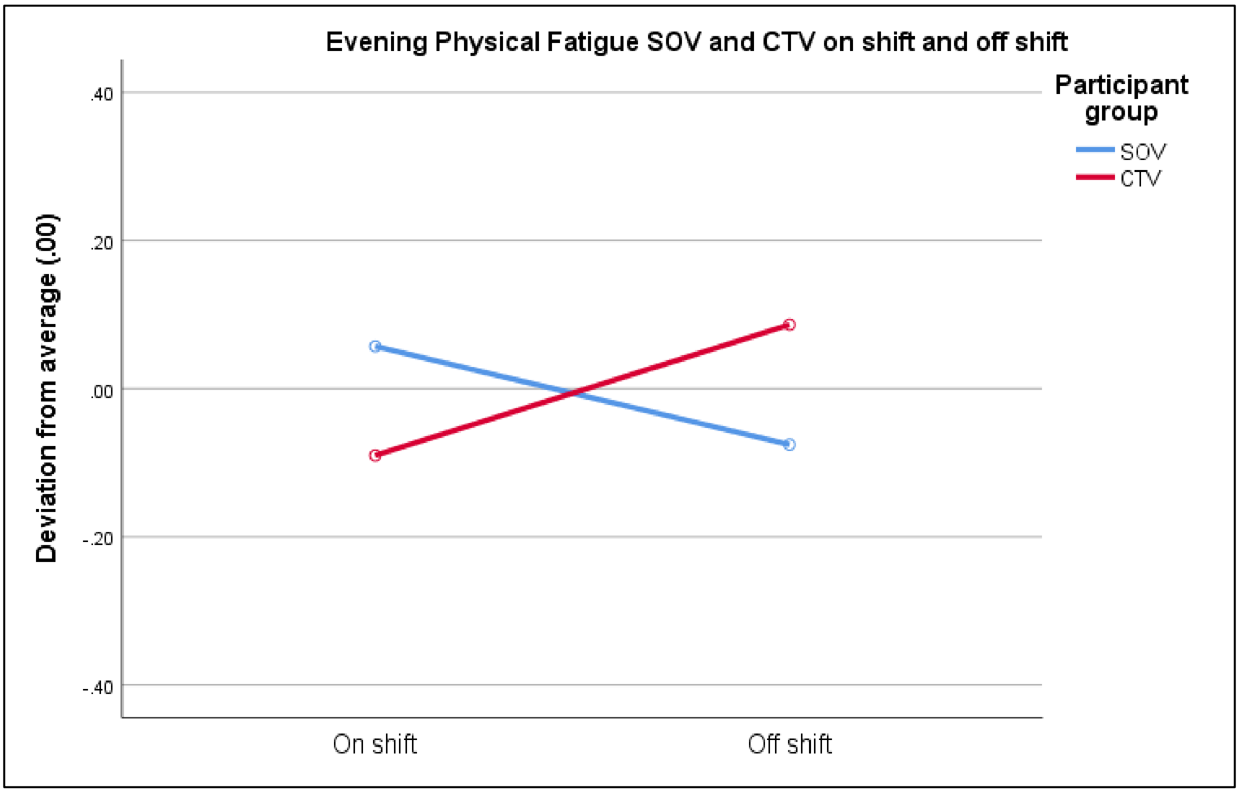
Appendix 11- Study 2 morning emotional fatigue graph



Appendix 12- Study 2 evening anxiety graph



Appendix 13- Study 2 evening physical fatigue graph



Appendix 14- Study 2 evening sleepiness graph