Will Night Shift Workers Ratings of Well-being and Fatigue and Performance on Prospective Memory and Sustained Vigilance Tasks Recover After Three Nights Rest?

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Lucy Hudson

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Abstract

As the demand for a 24-hour world increases so does the need for more shift workers. To maintain the standard expected of them, shift workers often work long hours, including night work where their main opportunity for sleep is during the day. Research has found that shift workers experience fatigue, difficulties in cognition and impaired wellbeing after working shifts like these. Despite this, minimal research has been conducted to explore how many days of recovery should be rostered after one night shift. This study aimed to find evidence to guide workplaces on how many days of rest employees should be rostered to recuperate from one night of sleep loss. A sample of 39 night shift (n=22) and day shift workers (n=17) completed a five day experiment from pre-night shift to rest day three (or five consecutive days for controls) and were assessed in tasks of prospective memory, sustained vigilance, self-reported fatigue levels and self-reported affect to measure well-being. The results indicated that while there was no significant change in vigilant attention or prospective remembering across the five days that self-reported fatigue and positive affect experienced significant changes. These findings indicate that night shift workers may need two to three days of rest to recover from some of the effects from a night of sleep deprivation. However this study repeated with a larger sample size and stricter conditions could yield different results.

Key words: Fatigue, Sleep Deprivation, Shift Work, Prospective Memory, Wellbeing.

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Abbreviations List

AED	United Arab Emirati Dirham
COVID-19	Coronavirus Disease 2019
CSF	Cerebral Spinal Fluid
CT	Computed Tomography Scan
EEG	Electroencephalogram
GH	Growth Hormone
LTM	Long Term Memory
N1	Stage One Sleep
N2	Stage Two Sleep
N3	Stage Three Sleep
NREM	Non Rapid Eye Movement Sleep
NZD	New Zealand Dollar
PANAS	Positive and Negative Affect Scale
PERMA	Positive, Emotion, Engagement, Relationships, Meaning, Accomplishment
PGO	Ponto-Geniculo-Occipital
PM	Prospective Memory
PROMIS	Patient Reported Outcomes Measurement Information System
PVT	Psychomotor Vigilance Task
REM	Rapid Eye Movement Sleep
RM	Retrospective Memory
SCN	Suprachiasmatic Nucleus
STM	Short Term Memory
SWA	Slow Wave Activity

SWS	Slow Wave Sleep
WM	Working Memory
WOCL	Window of Circadian Low

‘‘Early to bed, early to rise, makes a man healthy, wealthy and wise.’’

Benjamin Franklin

Will Night Shift Workers Ratings of Well-being and Fatigue and Performance on Prospective Memory and Sustained Vigilance Tasks Recover After Three Nights Rest?

1.1 General Introduction

During our lifetime, many of us put our lives or the lives of our loved ones into the hands of others who we probably believe to be capable, trustworthy and prepared. These hands may belong to a pilot, a doctor or a fireman. How rested and refreshed do you trust your surgeon feels before she performs your heart valve surgery? What about the pilot flying your 17-hour midnight departure flight? Do you assume he is wide awake and alert? Would it shock you that your surgeon only finished her shift 12 hours ago and got six hours of sleep during the day before returning to work? All five of her nurses are also severely fatigued, and one has not slept in over 24 hours. The pilot flying your plane spent 12 hours at the layover destination, where he was given the opportunity to sleep during the day and then scheduled to transport 300 people halfway across the world that night. These examples are not infrequent exceptions or things that happen in other countries; modern-day pressures from companies have made situations like these a reality within reputable institutions that usually comply within the safety guidelines. As a result, shift workers worldwide are pushed to achieve their employers demands, but at what cost?

This thesis attempts to fill a gap in the research around the effects of sleep loss following a night shift and questions if returning to work within the two or three days following a night shift has a carry-over effect where the consequences (if any) of sleep loss are still impacting cognition and well-being. This research will attempt to capture the changes in cognition and well-being over five days and aims to find evidence for how many days off should be rostered after a night shift. The dependent variables for this research are prospective memory (PM) performance, sustained vigilance performance on a psychomotor vigilance task (PVT), well-being measured with the positive and negative affect scale (PANAS) and fatigue measured with a daily diary using an adapted version of the patient-reported outcome measurement information system (PROMIS). The dependent variables are measured over five levels of the independent variable, which are ‘day one’ to ‘day five’. The five days start with a baseline non-fatigued state, followed by immediate sleep deprivation after a night shift, and then end with three consecutive days of recovery. If the scores on days two, three, four or five become equal to the baseline level recorded on day one, that day will be the point considered to be recovered. To provide a comparison point, we will also recruit a control group. This control group will be non-night shift individuals, which will make it possible to highlight the effects of improvement due to practice, from improvement due to recovery.

By illustrating various research, the first section of this thesis introduces shift work, sleep, fatigue, prospective memory and well-being.

1.2 Definition of Shift Work

Shift work is defined by Costa (2003) as “a way of organising daily working hours in which different persons or teams work in succession to cover more than the usual eight-hour day, up to and including the whole 24 h” (p. 84). From an individual’s perspective, undertaking shift work requires working outside of the usual 9 AM to 5 PM, Monday to Friday workday. Shift work is usually broken down into ‘chunks’ or ‘shifts’ which may entail a morning shift, an evening shift or a night shift. Employees are assigned a shift on a roster to let them know which one they will be working. Not all shift work operates similarly; for example, individuals who work in the aviation sector will be required to cover certain flights or duties. In some industries, shift workers can be permanently assigned to the same shift; this would mean that an individual may always work nights while his colleague always works evenings. In other cases, employees are assigned to rotating shift schedules, where their work follows a pattern of days, nights and days off. In 2014 an American and European survey found that 15 to 30% of workers in Europe and America were engaged in shift work (Boivin & Boudreau, 2014). While in New Zealand, the number of employees working in night shift work has steadily increased over 10 years. In 2008 a survey reported, 202,200 individuals as working in night shift work; by 2018, this figure had risen to 323,000, an increase of

60% (Vance & McGregor, 2020). While shift work benefits the economy, the employer, the public and often the employee, it also comes with shortfalls. The most apparent shortfall is the tiredness and time spent away from friends and family. The less obvious shortfall is the disruption that shift work causes to an individual's circadian rhythm, health, well-being (Akerstedt, 2003; Ferri et al., 2016) and the safety hazards it may present (Lockley et al., 2007).

1.3 Definition of Sleep

Sleep, to all beings, is a fundamental part of life and has attracted interest from scientists for years. According to Sofroniou (2016), "Sleep is a normal, reversible, recurrent state of reduced responsiveness to external stimulation that is accompanied by complex and predictable changes in physiology" (p. 29). While sleep research has concluded that sleep is imperative, there is no current consensus on the biological need for sleep (Benington, 2000). Several established theories for why we sleep include; *the memory theory* (Wetzel et al., 2003), *the restorative theory* (Assefa et al., 2015), and *the waste clearing theory* (Xie et al., 2013). These theories will be discussed in more depth in the next chapter. Although these theories differ in their interpretation of the biological purpose of sleep, they agree that sufficient time asleep matters for sleep to fulfil its function (Hafner et al., 2017). As such, two hours of sleep is not equal to eight hours, and the effects of sleep deprivation are cumulative (van Dongen et al., 2003). As days of sleep restriction continue, an individual will enter a deeper state of sleep deprivation. This may have a noticeable effect on their cognitive performance and their psychological well-being (Leonard et al., 1998). To illustrate, a sleep-deprived shift worker that needs to maintain attention and alertness may find it harder to achieve this (Ganesan et al., 2019), and an employee who needs to remain level-headed in a stressful situation may struggle to regulate their emotions (Motomura et al., 2017).

The quantity of sleep is not the only indicator of a productive sleep. Quality of sleep is also essential (Pilcher et al., 1997). Human sleep comprises four stages, and the journey of progression through each stage and the number of cycles completed determines how productive the sleep was.

Sleep is made up of two distinct categories. The first is *non-rapid eye movement sleep* (Non-REM), and the other is *rapid eye movement sleep* (REM). Non-REM sleep is further categorised into three separate stages, stage one (N1), stage two (N2) and slow wave sleep (SWS). Each stage can be studied in closer detail by using an electroencephalogram (EEG), a device applied to the scalp, which uses electrodes to measure brain waves during sleep (Huang et al., 2020).

1.3.1 Stage One Sleep (N1)

Stage one sleep is the transition time between wakefulness and sleep. It is a very light stage of sleep and only lasts for a few minutes; many people will not realise they have been asleep during this stage. On an EEG, stage one sleep looks like slower brain wave frequencies (in comparison to wakefulness) and slow rolling eye movements (Patel et al., 2022).

1.3.2 Stage Two Sleep (N2)

Following stage one sleep is the onset of *stage two sleep*. Time spent in stage two sleep takes up 45 to 55% of sleep time. Brain waves slow down during this stage, heart rate and body temperature drop but it is still easy to wake a person from stage two sleep (Patel et al., 2022). The commencement of stage two sleep on an EEG is characterised by two primary markers: *k-complexes* and *sleep spindles* (Colten & Altevogt, 2006). K- complexes are large waveforms that stand out on an EEG, are seen more frequently in the first half of the night and are thought to have two main functions. The first is that they suppress arousal from sleep when the sleeping individual is introduced to external sensory information (Caporro et al., 2012). Secondly, k-complexes have been suggested to be a regular part of NREM sleep that is important for the consolidation of memories (Deibel et al., 2020). A sleep spindle typically follows a k-complex and is perceived as a burst of higher activity on the EEG waveform, lasting between 0.5 to 2 seconds. Sleep spindles are also thought to be involved in the consolidation of memory, as well as learning new things. Stage two sleep typically lasts between 10 to 25 minutes before moving on to the next stage (Caporro et al., 2012; Carskadon & Dement, 2011).

1.3.3 Slow-Wave Sleep (N3 & N4)

Slow wave sleep (SWS) is the deepest form of sleep and is also suggested to be the most restorative (Akerstedt et al., 1997). It is named after the characteristic slow frequency wave pattern on an EEG, otherwise called slow wave activity (SWA) (Dijk, 2009). During this stage, blood pressure drops (Javaheri & Redline, 2012) and breathing slows. SWS is thought to serve many different functions, including building immunity in the body against common immune threats (Moldofsky et al., 1986), cleaning the brain of debris (Fultz et al., 2019), and processing and consolidating declarative memory (Diekelmann et al., 2009). About 20% of human sleep time is spent in slow wave sleep, which generally lasts between twenty to forty minutes. If a person is awoken during SWS, they may experience *sleep inertia*, a groggy, disoriented feeling, accompanied by impaired cognitive performance (Trotti, 2016). After the SWS stage, a healthy adult would usually re-enter stage two, followed by stage one, before transitioning into REM Sleep.

1.3.4 REM (Rapid Eye Movement) Sleep

REM sleep is usually reached for the first time about 90 minutes into regular sleep (National Institute of Neurological Disorders and Stroke, 2017). On an EEG, this stage of sleep looks similar to wakefulness, and cerebral blood flow is also very similar to a person who is awake. However, during REM, the eyes move rapidly back and forth, and muscle tone drops off, meaning that the body is in a state of temporary paralysis (Siegel, 2005). At the onset of REM sleep, the brain stem sends signals to motor neurons in the spine and inhibits them, which causes the temporary paralysis of the muscles; this is referred to as *atonia* (Fraigne et al., 2015; Tubbs et al., 2019). Evidence suggests that REM sleep is vital for processing emotions from difficult events (Desseilles et al., 2010) and storing procedural memories (Diekelmann et al., 2009). During REM sleep, certain stress-associated neurotransmitters are suppressed; this is thought to have an impact on reducing negative emotions during waking hours (van der Helm et al., 2011). REM sleep typically occurs for more extended periods in the second half of the night than in the first. However, it will also appear more prevalently in a person finally sleeping after sleep deprivation, referred to as the REM rebound effect (Feriante & Singh, 2022). After a REM cycle, a healthy adult typically returns to NREM stage one, or stage two sleep and then cycles through all the stages again four or five times. However, sleep will not always follow a linear pattern (Tubbs et al., 2019).

1.3.5 The Two-Process Model of Sleep-Wake Regulation

Universally, there is an understanding that sleep occurs when it is dark, and wakefulness occurs during the day. This pattern is believed to occur because of two biological systems referred to as the *two-process model of sleep-wake regulation* (Borbely, 1982; Daan et al., 1984) that regulate the desire for sleep. The first is the *homeostatic sleep drive* (S drive), and the other is the *circadian cycle* (C drive).

1.3.6 Homeostatic Sleep Drive

The homeostatic sleep drive refers to sleep pressure that builds up as a result of wakefulness throughout the day. Increases in sleep pressure correlate with an increased desire to sleep, so within this system, tiredness is directly influenced by the number of hours an individual has been awake. During wakefulness, two areas of the brain, the hypothalamus and the thalamus, release neurotransmitters to the cerebral cortex to encourage alertness and promote arousal (Schwartz & Roth, 2008). Simultaneously, adenosine, a natural waste product produced by the brain, builds up (Herculano-Houzel, 2013; Saper et al., 2001; Saper et al., 2005). Once the adenosine has reached a certain level, it activates sleep control neurons which induce feelings of sleepiness (Brown et al., 2012). On average, 16 hours of wakefulness is adequate for most people to build up enough pressure to fall asleep (Walker, 2017). When sleep occurs, the pressure drops off; this process takes around eight hours. When an individual maintains wakefulness for an extended period, sleep pressure builds up so high that they may spontaneously fall asleep without meaning to. Sleep pressure can be relieved by taking naps, which is helpful for individuals wanting to stay awake longer throughout the night (Lovato & Lack, 2010). This technique could benefit night shift workers in maintaining alertness during their shifts (Sallinnen et al., 2002).

1.3.7 The Circadian Cycle

The circadian cycle is a 24-hour rhythm within the body which controls sleep-wake rhythms. It uses a combination of an internal timekeeper within the brain and external cues known as *zeitgebers* to feed information and make physical changes inside the body (Reddy et al., 2022). Multiple zeitgebers exist to assist the brain in syncing wakefulness with the natural day, including temperature (Pohl, 1998), social interactions (Honma et al., 2003) and exercise (Lewis et al., 2018). However, the most potent known zeitgeber for entraining the internal timekeeper is light (Roenneberg & Merrow, 2014). The internal timekeeper comprises the s*uprachiasmatic nucleus of the hypothalamus* (SCN) and the *retinohypothalamic tract* (Dibner et al., 2010). Light-sensitive cells in the retina of the eye feed information about light to the SCN, and then the SCN sends signals to halt the release of the sleep hormone melatonin (Brainard et al., 2001; Reddy et al., 2022; Welsh et al., 2010). Following this, the body temperature rises, promoting wakefulness (Arendt, 2010; Aulinas, 2019). When the sun sets and light signals disappear, the internal timekeeper adjusts accordingly by sending instructions to increase melatonin levels, thus inducing tiredness, lowering alertness and dropping the body temperature to help induce sleep (Auld et al., 2016).

Under normal conditions, the homeostatic sleep drive and the circadian cycle operate harmoniously to ensure a low level of sleep pressure during the day and an increased drive for sleep during the night (Cagnacci et al., 1992). However, the two systems can become misaligned by extended periods of wakefulness or external cues indicating wakefulness presenting during the night. An example is the blue light released from LED lighting, televisions and mobile phones (Blume et al., 2019). These devices can delay the release of melatonin as the retina sends signals that it is still receiving daylight (Duffy & Czeisler, 2009; Rafique et al., 2020; Wahl et al., 2019). The delay in the release of melatonin can cause an internal dissociation where sleep onset occurs later. However, the circadian rhythm still initiates wakefulness at the usual time, leading to shorter sleep (Christensen et al., 2016). *Jetlag* is another example of when the two systems become misaligned. Time zone changes due to rapid long-haul international travel can result in a desire for sleep during the daylight hours and difficulty initiating or maintaining sleep during the night hours. This is due to the endogenous circadian rhythms being out of sync with the external environment (Arendt, 2009; Arendt, 2010) as the internal timekeeper cannot instantly phase shift to sync with a new time zone (Waterhouse et al., 2007).

1.3.8 The Window of Circadian Low

The window of circadian low (WOCL) describes a point in the circadian rhythm where the body is powering itself to sleep at its most potent level. This low point typically occurs around 2 AM to 6 AM (Powell et al., 2008). During the WOCL, the internal body temperature drops to its lowest point, melatonin is at its peak of secretion, and the internal timekeeper is powering to induce or maintain sleep. This period is understood to be the most dangerous window for night shift workers as this is when they will be feeling the drowsiest, have the lowest levels of alertness and will be more likely to make mistakes (Arendt, 2010; Rajaratnam & Arendt, 2001). Similarly to the experience of night shift workers, when laboratory tasks are undertaken at night or after sleep deprivation, participants work against their circadian rhythm, which may have a negative effect on their performance. Conversely, participants completing psychological tasks during the day may have the benefit of alertness.

1.3.9 Measuring Sleep

When deciding whether an adequate sleep was achieved, most people would answer based on the hours of sleep they had. For researchers, sleep quality is evaluated by examining many biological processes. Sleep can be measured in many ways, and the most appropriate tool can be chosen for the research being undertaken (Etindele-Sosso, 2022; Fabbri et al., 2021; Ibanez et al., 2018; Landry et al., 2015). Actigraphy is a method of measuring motor activity during sleep, via a device worn on the wrist of the sleeper. It uses movement to estimate the total sleep time and if there were any periods of wakefulness during the night. Polysomnography uses electrodes attached to an individual while they sleep to monitor brain waves, muscle and eye movements. Heart rate, breathing rate and blood oxygen levels are also recorded. Other instruments for measuring sleep include, self-report sleep diaries, sleep questionnaires and vigilance tasks. Sleep research is still an evolving field, and future discoveries will hopefully build on the current markers of good sleep. The current acceptable sleep time for an adult (aged 18 to 64 years) is seven to nine hours in a 24-hour period (Hirshkowitz, 2015), and sleep is understood to be optimised when taken during the night (Jagannath et al., 2017). When total sleep time falls below this, there are correlations with an increased risk for developing psychological and physical health conditions (Ohlmann & O' Sullivan, 2009).

1.4 Definition of Fatigue

Work Safe New Zealand defines fatigue as being "a state of physical and/or mental exhaustion which reduces a person's ability to perform work safely and effectively; fatigue reduces alertness. This may lead to errors and an increase in workplace incidents and injuries" (New Zealand Government, 2017, p. 1). Moreover, Work Safe New Zealand explain that fatigue can result from several factors, including environmental, physical and emotional demands. However, they begin their list with work schedules at the top.

Fatigue is a challenging construct to assess as its effects span wide across many functions in the body. Rosekind (2005) explains that no biomedical or physiological measurements can be used to record it accurately, and any measurement taken will be a best estimate of the level of fatigue. Current instruments for obtaining these estimates include fatigue questionnaires, diary studies and performance-based tasks that assess reaction time and the number of errors. Although there is no perfect tool for detecting fatigue, it is established that sleep deprivation has adverse effects on cognition. Research that has been conducted in this area has documented the decrements it has on multiple domains such as, memory, reaction time, judgment, attention and emotional well-being, this research will be discussed in detail in the next chapter. However, the evidence that is available may not have translated into strict enough regulations to control the number of hours allowed to be spent at work. In the United States of America it is standard for a trainee doctor to spend up to 80 hours a week in the hospital they are training at, with shifts lasting as long as 28 hours (Park, 2017). This is at odds with current research which suggests that extended work shifts in the medical industry are associated with attentional failures and preventable medical errors (Barger et al., 2006). Furthermore, it can be theorised that shift workers in all industries could make fatigue related mistakes when working night shifts or long shifts.

1.5 Introduction to Prospective Memory

1.5.1 A Summary of General Memory

Memory is defined by Sternberg & Sternberg (2016) as “the means by which we retain and draw on information from our past experiences to use in the present” (p. 161). In other words, memory is the retrieval of things previously learnt. In the first instance memory can be divided into two broad categories: retrospective memory (RM) and prospective memory (PM). *Retrospective memory* is the memory used to recall events experienced in the past, and Tulving and Schacter (1992; 1994) describe that it can be further broken down into five major classifications. These classifications are episodic memory, semantic memory, procedural memory, short-term memory and perceptual priming. Each system is vast and comes with sub-classifications. At a glance, episodic memory is the memory of past experiences and events, semantic memory is for knowledge acquisition and retention. Procedural memory is the memory of how to complete a motor task, short-term memory is immediate retention of knowledge following acquisition. Finally, perceptual priming is non-conscious memory which refers to the improved ability to remember something because of previous exposure to the stimulus. At a higher level of distinction, RM can be divided into either implicit or explicit memory. Implicit memory is the memory of things unconsciously known, for example riding a bike. In contrast explicit memory is the memory of the things consciously known. Explicit memory encompasses episodic, semantic and short-term memory, while implicit memory covers procedural memory and perceptual priming. Baddeley et al. (2014) explain that retrospective memory operates using three steps: encoding, storage and retrieval. One of the first most influential models of memory was the ‘modal model’ (or multi-store model) produced by Atkinson and Shiffrin (1968). They explain that sensory information is perceived from the environment, processed and held in a sensory memory register. This information will then either be encoded and sent to a short term store known as short term memory (STM) or discarded depending on whether the information was attended to or not. They explain that in order to keep the items stored in STM they need to be rehearsed to avoid decay. According to Miller (1956), short term memory can only hold 7+- 2 items at one time. Following this, rehearsed items will be transferred to long term memory (LTM) and everything else will fade. LTM is an unlimited capacity storage area where all lasting memories are stored, including both implicit and explicit memory. The last stage of memory is retrieval. This is the process of taking and using previously stored information. There are three ways in which stored information is explicitly retrieved. The first is recall, in a recall memory situation the individual must bring forward the required information from memory without a cue or prompt. Recall memory is used when describing a story or writing an essay. A second form of retrieval is recognition, which uses partial memories or cues. When an individual is using recognition they are deciding whether a piece of information is something that they already know. Recognition is often easier than recall as one of the correct answers is already present and the individual only needs to make a choice, whereas with recall the individual must retrieve information from explicit memory and then decide whether it is correct or not. Finally there is relearning, relearning occurs when information that has been previously learnt and then forgotten is acquired. When this kind of learning takes place, the re-learnt information is often easier to learn and recall than brand new information.

1.5.2 Definition of Prospective Memory

As mentioned above, prospective memory (PM) is the second form of memory and is one of the focal points of this thesis. PM is the memory used to fulfil an intention; it is similar to RM in that it uses information that has been stored retrospectively. However, its purpose is to remember to carry out a planned task or intention at the appropriate time in the future. Often there is no obvious cue in the environment to carry out the intention. Therefore, it becomes something that an individual must 'remember to remember'. Common examples of PM use in daily life include remembering to take out the bin on recycling day or take medication in the morning. There are three types of PM: event-based, time-based and activity-based. Event-based tasks are prompted by an event or an external cue that occurs, such as seeing a friend and remembering to return their umbrella. Activity-based PM occurs when a task is carried out that is habitually followed by another task, whereby the first task prompts the next. Finally, time-based PM relies on the individual to monitor the time to know when to carry out the intention, for example watching a 7 PM television show (Kvavilashvili & Ellis, 1996). Time-based prospective memory is the least reliable form of PM because the individual must self-initiate the cue to check the time and then remember to carry out the task (Einstein et al., 1995). When distractions are present, it is easy to forget to check the time and miss a television show. In this respect, many day to day PM lapses are non-consequential. However, PM lapses can also happen in environments where the consequences bear the risk of being more profound. Lapses in high-pressure industries such as the aviation and the health care industry can lead to more serious outcomes. Dismukes and Nowinski (2007) found that one-fifth of aviation accidents or incidents can be put down to an action that should have been carried out but was forgotten. In many of these examples, it wasn't negligence that caused the incident but rather a lapse in memory due to interruptions, balancing multiple tasks and a busy and demanding environment. This finding emphasises how important it is to understand the processes behind PM and what conditions create vulnerability to lapses of it.

1.5.3 Measuring Prospective Memory

Einstein and McDaniel (1990) developed a paradigm to study PM. The paradigm allows the researcher to measure the PM performance of an individual by assessing the number of errors made during the task. The paradigm begins by engaging participants in an 'on-going task' for example, sorting words into living and non-living categories by pressing the appropriate keys on a computer. After a few minutes, the task pauses and the participants are given instructions to complete a second action unrelated to the on-going task whenever they notice a cue or target. The target could be words beginning with the letter 'L' while doing this the participants must continue with the initial on-going task.

A further key element of the paradigm is the administration of a delay between the new instructions and the onset of the task. The delay will usually involve a distraction task to reduce the likelihood of rehearsing the target instruction. When the trial finally starts, there is no reminder to complete the new action; participants must remember to initiate the new response by using the target as their cue. Performance is scored based on the number of targets that are correctly responded to.

1.5.4 Cognitive Processes Behind Prospective Memory

Research on memory has indicated that failures in PM are one of the most frequent memory errors made in day-to-day life (Kliegal & Martin, 2003). To understand what makes an individual more likely to experience a lapse in PM, the cognitive processes behind them need to be examined. Two processes have been proposed as key factors when remembering a delayed intention; these are a 'top-down mechanism' and a 'bottom up mechanism'. The top-down mechanism in prospective remembering works by keeping the intention in mind and relies on repeated rehearsal and monitoring the environment until it is time to execute the action. This process is dependent on working memory capacity and comes with a performance cost to other tasks as attentional resources must be dedicated to the constant monitoring and rehearsing. Alternatively, the bottom-up mechanism is suggested to be used for spontaneous retrieval whereby the delayed intention is spontaneously remembered when contact with an external cue or intention-related stimulus occurs. This mechanism is thought to rely on automatic processes, and has been described as feeling as though the intention 'pops into mind'. The *multi-process framework* is a theory developed by McDaniel and Einstein (2020) to support the view that both top-down and bottom-up mechanisms are used during prospective remembering. In their framework they refer to these two mechanisms as strategic and automatic processes and explain that the mechanism used is likely to depend on several factors. One such factor is the *importance of the prospective memory task*, whereby the more important the task is the more likely it is to be remembered. The model notes that tasks of higher importance likely illicit strategic monitoring over automatic processes. Tasks of lower importance are more likely to be left to automatic processes as strategic monitoring is too resource-demanding. Secondly, *the nature of the cues available* in the environment and how related they are to the delayed intention may impact the process used. Cues that are salient or distinctive may capture the attention of an individual and assist in switching their attention from an ongoing task to the delayed intention. Further, if the cue is related to the intended action, it will also increase the significance of the cue and facilitate automatic processes of remembering the delayed intention. The *difficultly level* and *type of ongoing task* being executed by an individual while trying to remember a delayed intention will also impact the mechanism used. As mentioned above, the focality of the prospective memory cue to the on-going task may have an impact on retrieval. If a delayed intention cue becomes part of an ongoing activity, then the action that needs to be executed may 'pop into mind' via the automatic processes, alternatively if the cue is in plain sight in the environment but not embedded in the ongoing task then it is less likely to prompt the retrieval of that intention. The difficulty level of a task will also impact retrieval; if the ongoing task is particularly engaging or demanding this may decrease the resources available for strategic processes to take place hence, leaving only the automatic, spontaneous processes to initiate retrieval. The authors note that demanding tasks will likely have a negative effect on prospective remembering overall. Finally, the model proposes that *cognitive and personality differences* among the individual remembering the intention will affect the mechanism used in retrieval. Some individuals may have a larger capacity for working memory, while others may prefer to hold intentions in mind and favour this over spontaneous retrieval under some conditions.

All of the above is thought to impact the kind of *planning* that takes place prior to delaying an intention. The theory suggests that the amount of planning that is undertaken could increase the chance of remembering a delayed intention by decreasing the need for spontaneous retrieval (McDaniel & Einstein, 2020).

1.6 Definition of Wellbeing

Well-being is defined by the Oxford Dictionary (1989) as "the state of being or doing well in life; happy, healthy, or prosperous condition; moral or physical welfare" (volume XX, p. 122). More scientifically put, '*affective well-being*' refers to how often and how much a person experiences either positive or negative moods, otherwise known as *positive* or *negative affect* (Luhmann, 2017). The notion of well-being goes back as far as 322 BC, when Aristotle, an ancient philosopher presented a theory of happiness. His work centred around the question of 'what is the ultimate purpose of human existence?' for which his answer was happiness. Through the years the importance placed on well-being has fluctuated, and in recent times a culture of living a fast-paced 'always-on' life has emerged. The notion that working longer hours with less sleep would result in a successful life became the norm for many. Fortunately, the concept of well-being and affect has made a resurgence as well as the effect that sleep loss could have on overall well-being. As such, several studies have been conducted to improve the understanding between sleep and affect which are discussed in chapter two. In light of this resurgence, theories have emerged to attempt to explain what it is to have a positive wellbeing.

1.6.1 The PERMA Model

The PERMA model is an acronym and framework used to explain the building blocks required to achieve a positive well-being (Seligman, 2012). The model makes two initial assumptions; the first is that well-being and happiness are two distinct conditions. Happiness is a feeling held at a specific point in time while well-being is an overall way of viewing life and its challenges. The second assumption is that every individual is unique and the different elements of the PERMA model will effect each person differently. The first element of the model is positive emotion, and requires that an individual with a positive wellbeing will look at the past and toward the future with positive feelings. Secondly, an individual will need to have engagement. Engagement refers to an activity in life that one is passionate and committed to. The third element is positive relationships, and argues that positive, fulfilling relationships with others will amplify existing positive emotions. Having meaning or purpose in life is the fourth element of the model and final element is accomplishment, which refers to setting goals and achieving them. The PERMA model can help improve individuals' well-being by comparing each element to actuality and identifying areas for improvement.

1.6.2 The Network Theory of Well-being

The *network theory of well-being* declares that several factors contribute to an individual's positive well-being (Bishop, 2012). Positive feelings or emotions such as joy or contentment must be present. Secondly, attitudes like optimism and hope must exist. Traits of perseverance and friendliness should be demonstrated and finally, one should have successful interactions with the world. For example, hobbies, strong relationships and professional accomplishment. The network theory explains that each of these different categories do not attribute to well-being in a person on their own, rather wellbeing is created by each of these characteristics being present together as a whole. The theory adds that these characteristics do not appear independently and that one characteristic flows into the next to form a network. For example, professional achievement may not have arisen without the positive trait of perseverance, and perseverance may not have existed without an optimistic attitude. Thus, becoming a positive cycle that feeds into itself. Lastly, the theory acknowledges 'negative networks' and the inter-connectivity of these states. For example, a negative professional life can feed into feelings of sadness, problematic relationships, sleep issues and a poor outlook.

The two theories agree that well-being is an active and ongoing process throughout life and share concepts of meaning, purpose and belonging. However, these theories do not acknowledge how health and physical conditions impact well-being on a daily and long term basis. Such as, when illness or fatigue is present, or how well-being could be influenced from certain lines of work.

1.6.3 Wellbeing and Shift Work

As well as a challenging schedule, the nature of shift work often presents another requirement. Doctors, nurses, police and flight attendants report that their jobs require a high emotional workload (Brewin et al., 2020; Hochschild, 1983; Rogers et al., 2014) . *Emotional Labour* is the requirement for employees to control the emotions used at work, and to only use the emotions that are requested of them by their workplace (Hochschild, 1983). As it is natural for an emotion to appear spontaneously in response to a situation, emotions that are not deemed as acceptable will need to be supressed and replaced with the correct emotion (Kinman & Leggetter, 2016). Any job that works alongside other people requires a certain level of emotional labour but professions where the individual deals with traumatic events, maintains a constant cheerful persona or provide compassion and empathy to others will carry a higher load. Because of this, there is often a higher concentration of emotional labour in hospital settings, and specifically in nurses (Bolton, 2001). While providing genuine care and support to patients and their loved ones is an integral part of nursing, continuous emotional labour can lead to exhaustion outside of work, which may impact well-being and can lead to burnout (Vermaak et al., 2017).

1.6.4 Shift Work and Mental Health

Extended periods of time that are spent caring for others at work or sleeping during the day often means missing important social occasions. Situations like these can put strain on both the shift worker and their families and can drive feelings of loneliness (Finn, 1981; Wyatt & Marriott, 1953). Additionally, time spent sleeping during the day instead of helping with children has been found to correlate with marital instability (Davis et al., 2008) and the role-overload shift workers feel to balance their work-family time and make up for their absence can lead to sleep loss (Williams, 2008). Due to the increased prevalence of shift work an array of research has been dedicated to investigating the relationship between sleep loss and physical illness, but the question of the long-term effects on wellness and mental health also demand attention.

Depression is a common mental health condition affecting at least 280 million people worldwide (World Health Organisation, 2021). It is classified as a mood disorder that causes persistent feelings of sadness and a loss of interest in previously enjoyable activities (Zigmond & Snaith, 1983). The exact cause of depression remains unknown. However, a relationship between an unhealthy lifestyle and depression has been found to be connected across multiple research studies. These studies have found associations between depression and sleep quality, smoking, low physical activity and poor diet to name a few (Cabello et al., 2017; Sampol et al., 2021; van Gool et al., 2007) Research on shift workers has found a prevalence of unhealthy lifestyle patterns, such as disruptions to circadian rhythms, extensive periods of sleep loss, obesity, physical inactivity, burnout, poor diet and smoking (Breslau et al., 1996; Brum et al., 2020; Ford & Kamerow, 1989; Hulsegge et al., 2020; Hulsegge et al., 2021; Jamal, 2004; KivimAki et al., 2010; Oyane et al., 2013) as well as dealing with the complexities of a work life balance (Rutenfranz, 1977). Thus, the finding of an increased risk of depression in night shift workers (Driesen et al., 2011; Kim et al., 2011; Scott et al., 1997) is not surprising.

The concepts and literature outlined in the introduction provide an initial foundation to the topic of shift work and some of its associated outcomes, highlighting why additional research in the area of night shift work and recovery periods could be of importance. The following section will further delve into these concepts and the interactions between them to create a full picture of the current knowledge and understanding.

Chapter Two: Literature Review

The purpose of this chapter is to review the current findings in the literature surrounding sleep, prospective memory, sustained vigilance and wellbeing and any established links between them, and shift work.

2.1 Significance of sleep

As discussed in the introduction, short term cognitive impairment is a reoccurring theme after experiencing sleep loss, which has resulted in the establishment of different theories to explain why sleep loss affects optimal brain functioning. There are many well-established theories for the function of sleep (Horne, 1988), but no one agreed upon answer. The following section outlines some of the leading theories in the literature.

2.1.1 The Memory Consolidation Theory

Creating and recalling a memory is a basic ability humans and other animals use to ensure survival. The idea that memories could be consolidated after being acquired was first suggested by Muller and Pilzecker (1900) and assumes that memory is vulnerable to being disrupted for some time after new learning occurs. Further research on memory consolidation, identified the potential involvement of sleep in this process after the recall of memory items improved in a group of participants that had slept, compared to a group of participants who hadn't (Jenkins & Dallenbach, 1924). Multiple modern studies have since confirmed the role of sleep in memory consolidation, making it a widely accepted theory (Diekelmann & Born, 2010; Walker & Stickgold, 2004). The theory proposes that waking hours are for encoding and processing information (Rasch & Born, 2013), while sleep strengthens unstable new memories and integrates them into long-term memory.

It is thought that both REM sleep and SWS play a crucial role in consolidating memories. During SWS, a reactivation of recently encoded memories occurs, transforming the representations into long-term memories. It is then thought that REM sleep strengthens and stabilises these memories (Rasch & Born, 2013).

2.1.2 The Trash Removal Theory

A compelling study by Xie et al. (2013) discovered a process that occurs in the brain during sleep that they describe to be similar to "taking out the trash" at the end of each day. They discovered that while mice sleep, cerebral spinal fluid (CSF) moves through a glymphatic system within the brain, thus, flushing out toxic waste products and debris that have built up due to information processing during the day. In addition, they discovered that the spaces between the cells in the brain increase by 60% while sleeping to allow the CSF to flow through more efficiently. Adenosine is one of these items of "trash" proposed to be cleared out in the glymphatic system. As discussed in the first section, adenosine is slowly released into the brain throughout the day. During sleep, adenosine levels decrease. However, if sufficient sleep during the night is not reached, the dizzy, irritable feeling felt the next day can be a result of leftover adenosine that the glymphatic system had not yet cleared out. A second protein associated with increased periods of wakefulness is B-Amyloid (Brown et al., 2016). Current research suggests that if too much B-Amyloid debris builds up due to repetitive sleep deprivation, this could contribute to plaque in the brain and the development of neurodegenerative diseases such as dementia (Spira & Gottesman, 2017).

2.1.3 The Immune Regulation Theory

The immune system is the body's defence against infection, diseases and illness. Several studies have been completed measuring the impact of sleep deprivation on the immune response in the human body. Sleep-deprived individuals are 4 times more likely to develop a cold than non-sleep-deprived individuals (Prather et al., 2015). Other research has demonstrated that sleep-restricted participants have a 50% lower immune response after receiving a vaccine than a rested control group (Spiegel, 2002). Sleep deprivation could be a risk factor for developing an auto-immune disease (Hsiao et al., 2015). Sleep deprivation correlates with enhanced inflammatory markers associated with type 2 diabetes and cardiovascular disease (Besedovsky et al., 2012; Mullington et al., 2010). These studies suggest that sleep plays a clear role in immune system efficiency. A lack of sleep appears to negatively impact the immune system increasing vulnerability to viruses and serious health conditions later in life.

2.1.4 The Restorative Theory

The Restorative Theory was proposed by Oswald (1976) and proposes that sleep is a time where the body and brain go through a process of restoration to regain what was lost during waking hours. "I was led to write of slow (NREM) sleep that 'its chief function is for bodily restitution, while REM sleep may be chiefly for brain repair" (Oswald, 1976, pp 15). The theory is backed up by multiple lines of evidence displaying signs of restoration during sleep (Benington & Heller, 1995; Luboshitzky et al., 1999; Weitzman et al., 1974). During SWS, growth hormone (GH) is released from the pituitary gland, which plays a role in tissue repair and growth (Van Cauter & Plat, 1996). Other research has found that during SWS, there is an increase in blood flow to the muscles, which suggests that during sleep, there is an emphasis within the body on repairing and regenerating muscles and cells. A study conducted on marathon runners found a significant increase in total sleep time and SWS after running a 92-kilometre race (Shapiro et al., 1981).

2.1.5 The Motivation Hypothesis and the Cognitive Lesion Hypothesis

Early ideas in this field were the *motivation hypothesis* and the *cognitive lesion hypothesis*. The motivation hypothesis argued that lack of sleep led to feelings of sleepiness and low motivation which encouraged individuals to do less and gain more sleep to re-supply the body with energy while the cognitive lesion hypothesis suggested that sleep deprivation caused a temporary functional lesion in the brain (Dinges & Kribbs, 1991; Dorrian et al., 2005).

These first ideas were updated by a new theory known as the *lapse hypothesis* (Williams et al., 1959) The lapse hypothesis explained that functioning level was the same in an individual before and after sleep deprivation but performance after sleep deprivation was distinguished by moments of 'low arousal' or transient lapses in cognition where subjects were momentarily unable to respond to a task. According to this theory, during the lapses 'sleep intrusions' or microsleeps occur (Doran et al., 2001). Subsequent research on sleep deprived individuals suggested that there were a number of limitations with the lapse hypothesis. Firstly the hypothesis assumes that responses between the lapses (or periods of microsleeps) are normal, however other research provides evidence showing an overall slowing of reaction time during tasks which increases as sleep deprivation increases (Dinges et al., 1997). A second limitation is the 'time on task decrement' which refers to the tendency for sleep deprived individuals to get worse at a task the longer it lasts for (Doran et al., 2001) which suggests that there is a gradual worsening of performance as opposed to brief lapses. Lastly, the hypothesis cannot account for 'errors of commission' or false alarms, which is when an individual responds to something when there was no need for them to respond. Research has shown that errors of commission are positively related to hours of wakefulness (Lim & Dinges, 2008) and have been suggested to be the outcome of a subconscious compensatory aid used to perform better when suffering from sleep deprivation (Dorrian et al., 2001). If the lapse hypothesis was correct, the above points would have only been witnessed during a lapse and not increasingly throughout the tasks.

2.1.6 The Wake-State Instability Hypothesis

The *wake-state instability hypothesis* (Doran et al., 2001) was developed as a solution to the problems found with the lapse hypothesis, and aimed to explain variability in sleep deprived performance. It acknowledges that task performance between lapses can be slow with increasing errors, and posits that as sleep loss continues, performance will become more variable due to sleep mechanisms acting on the brain to drive sleep. However, simultaneously a further endogenous system within the brain is working to sustain attention and alertness. The interaction of these two systems is thought to cause an unstable state that can change within seconds, leading to the high variability in functioning. The unstable nature of functioning is believed to lead individuals to use compensatory strategies to perform better which can then lead to errors of commission (false alarms) in tests of vigilance. In conclusion, these theories are not an exhaustive list of all current theories. However, they provide insight into the vast possibilities and benefits of sleep. It is commonly accepted that the function of sleep is still unknown and that no one theory can explain the exact purpose of sleep. A likely scenario is that a combination of theories can account for the function of sleep.

2.2 Recovery Sleep

During sleep studies, the method to which sleep deprivation is administered varies from study to study due to the research aims and questions that are posed. Acute sleep deprivation is when participants are kept awake for one extended period of time, for instance a 24-hour stretch while other studies may explore the effects of chronic sleep deprivation and sleep debt by restricting the available hours of sleep over a number of days (Alhola & Polo-Kantola, 2007).

A study conducted by Philip et al. (2012) compared the symptoms of acute vs chronic sleep deprivation on a group of adult males aged between 46 to 55 years. The study specifically investigated self-perception of sleepiness, objective sleepiness and reaction time. Acute sleep deprivation was classed as one full night of sleep loss and chronic sleep deprivation was set as five consecutive nights of four hour sleeps. Prior to the study being undertaken participants were required to have had three nights of normal sleep, and baseline measures were recorded to note their usual functioning level. Symptoms of sleep deprivation were found in the sleep restriction group after one night of reduced sleep, and the scores became progressively worse as they moved through the days. On day three, their symptoms were equal to the symptoms of one full night of no sleep. Another similar study conducted by Belenky et al. (2003) recruited 66 male and female participants to a 14 day sleep study. Three days were initially spent acclimatising to eight hour sleep nights and on the third day baseline measures were taken. Following this, participants were randomly grouped into nightly nine hour, seven hour, five hour or three hour sleeps and the assigned duration of sleep time was to remain consistent for seven days. Each day of the study involved a sustained vigilance task, a sleepiness questionnaire, EEG's, and a test to measure the speed of sleep onset . On days 11 through to 13, recovery sleep was administered and on day 13 a final measure was taken. The results found that the group allocated nine hours of sleep each night maintained a steady level of performance across the week, while the group who were given seven hours of sleep saw an increase in reaction time in the sustained vigilance task across the week. Both the five hour and three hour nightly opportunity for sleep groups displayed an increase in reaction time and an increase in lapses across the week. Interestingly, while the three hour sleep group were able to recover back to baseline levels after one night of normal sleep, it was the five hour and seven hour sleep opportunity groups that did not return to baseline after three days of normal sleep. The authors stated a possible reason for this could be that the brain undergoes adaptations which allow it to stabilize its performance and function at a reduced level, thus protecting the brain from injury that could occur from reduced sleep. They believe this state could run into the recovery period meaning that the protective barrier is limiting a quick recovery back to baseline levels.

A third study conducted by Banks et al. (2010) recruited 159 men and women aged between 22 to 45 years for a 12-day laboratory sleep study. They hypothesized that the degree of recovery sleep gained would positively correlate with the amount of time allocated for recovery. Participants were randomly placed into either a control group or the experimental group. Both groups began the experiment with two nights of 10 hour 'time in bed' periods and their baseline measures for alertness and sleepiness were collected. Following these two nights, the experimental group were allocated four-hour sleep periods for the next five nights. In contrast, the control group were able to sleep without restriction. At the completion of the five sleep-restricted nights, all subjects were placed into one of six sleep recovery conditions. The conditions were either 0, 2, 4, 6, 8 or 10 hours of sleep recovery, and alertness and sleepiness measures were repeated following the sleep. The results supported their hypothesis in that as the time available for recovery increased, so did the level of recovery. However, even with 10 hours of sleep recovery, the sleep restricted participants had still not returned to their baseline level. The results from the above studies emphasise the hypothesis that sleep deprivation has a lasting effect, and that an adequate period of recovery is important to get back to an optimal functioning level. The length of recovery period however, has not been determined.

As mentioned in the introduction, some shift workers are allocated day-hours to recover from a night of sleep loss. This benefits companies, as it allows workers to be assigned consecutive night shifts. This poses the question of whether day time sleep is equal to night time sleep.
A study by Smith-Coggins et al. (1994) monitored six physicians during two 24-hour periods. The first was a day shift followed by a night-time sleep, and the second was a night shift followed by a day sleep. In both conditions the physicians completed questionnaires that pertained to their mood, had their sleep architecture recorded, and completed simulated medical scenarios where their task time and accuracy were recorded. The research found that the physicians who worked the night shift and slept during the day spent significantly less time in bed, achieving almost three hours less sleep than the day shift physicians. The sleep architecture of the night shift physicians was also different; as they had 47% less REM sleep (72.9 minutes) than the day shift physicians (138.3 minutes). When looking at their performance and accuracy in the hospital simulations, it was found that the day shift physicians were faster at intubation (31.56 seconds compared to 42.2 seconds). It was also noted that the night shift physicians neglected some portions of procedures, while the day shift group were able to remain accurate throughout their shift. Finally the mood ratings of the night shift physicians were recorded as significantly more tired, less happy and had less clear thoughts.

The reasons behind why day time sleep appears to be less productive than night time sleep are yet to be fully understood. Some evidence suggests that humans may sleep longer when sleep is initiated in the evenings as this is when body temperature begins to drop as the WOCL approaches (Arendt, 2010; Weaver; 2020; Weaver et al., 2021). The second reason for less optimal sleep during the day could be due to the demands from daily life playing on the individual's mind. Leading them to wake up earlier than they should in order to get things done or fulfil childcare responsibilities (Maume et al., 2010).

A lack of recovery sleep following a night shift is not the only issue that shift workers contend with. The shift length of many duties can dramatically exceed the standard eight-hour work day of standard workplaces. International aircrew can be rostered duties that span as long as 20 hours, and nurses in some countries work shifts up to 24 hours in length (Stimpfel & Aiken, 2013). As expected, research has found that employees who work shifts lasting 12 hours in length, report experiencing higher levels of fatigue than employees ending eight-hour shifts (Rosa et al., 1989), with the last four hours being the hardest (Rosa, 1995). The effects of long periods of wakefulness can be dangerous, and pose a risk to the safety of their work (Baker et al., 1994). Accident rates have been found to double after working 12 consecutive hours (Hanecke et al.,1998) and triple after 16 straight hours (Akerstedt, 1994). In addition, the risk of activities undertaken outside work increases when working shifts longer than 12 hours (Laundry & Lees, 1991).

The level of risk was demonstrated in a study by Williamson and Freyer (2000), who recruited 39 male and female participants between the ages of 30 and 49. The participants were placed in two groups and assigned to either an 'alcohol consumption group' or a 'sleep deprivation group' and alternated so that both groups participated in both conditions (crossover design). The participants in the sleep deprivation group were kept awake for up to 28 hours. During this time, they were administered tests in vigilance, reaction time, coordination, divided attention, perception, memory and grammatical reasoning. The alcohol consumption group completed the same set of tests while simultaneously receiving a dose of alcohol every 30 minutes. This was repeated four times and designed to give the participants a blood alcohol level of 0.025, 0.05, 0.075 and 0.10%.

The study compared the two groups and concluded that participants awake for 16.91 to 18.55 hours had equivalent test scores to someone with a blood alcohol level of 0.05%. A reading of this level of blood alcohol in New Zealand will result in a fine. The participants awake for between 17.74 and 19.65 hours equalled the participants with a blood alcohol level of 0.10%. This level of blood alcohol in New Zealand would result in prosecution and a criminal charge (New Zealand Transport Agency, n.d; Land Transport Act 1998, s.11). If the decrement in performance witnessed in the above study can be translated into real-world effects, then this study highlights that at 17 hours of consecutive wakefulness many people would be functioning at the level of a person who had been deemed unsafe to operate a vehicle. Conversely, many professions with a high level of responsibility have likely sustained wakefulness beyond 17 hours if they are working a night shift. It can be assumed that many people wouldn't feel safe flying with a pilot after consuming alcohol, but the same level of concern is likely not applied when a sober pilot starts a night shift at 11pm.

2.3 Sustained Vigilance and Sleep Deprivation

Mentioned in one of the above studies was a sustained vigilance task which was used to measure cognitive performance following sleep restriction. Sustained vigilance is a key cognitive function for individuals working in roles of high responsibility as it is the ability to hold concentration or attention on a task over an extended period of time. A meta-analysis conducted by Lim and Dinges (2010) investigated literature from 70 sleep-deprivation articles. They looked at six domains of cognition: simple attention, complex attention, working memory, processing speed, short-term memory and reasoning in participants who had gone one night without sleep. They found that short-term sleep deprivation had a negative effect on most cognitive domains, however simple attention and vigilance were the two domains that were the most affected by sleep deprivation. They noted that this finding was particularly relevant to jobs where one needs to sit and monitor, have situational awareness or maintain sustained attention on something for extended periods of time, such as pilots, nurses or air traffic controllers. The authors of the meta-analysis suggest that poor performance on vigilance tasks should be viewed as a signal of a sleep deprived individual and should serve as a warning of further detrimental cognitive functions. They recommended that any countermeasures developed to prevent workplace accidents in sleep deprived individuals should be focused on improving or compensating simple attention.

The Psychomotor Vigilance Task (PVT) is a widely utilised method of measuring sustained vigilance. According to multiple pieces of research, decreases of performance in 'vigilant attention' are one of the most common side effects of sleep deprivation (Hansen, 2019; Neri et al., 2002; van Dongen & Dinges, 2005). The PVT measures the ability of an individual to sustain attention and their response time to a target. The traditional PVT is a 10 minute task designed by Dinges and Powell (1985) and works by having individuals sit and monitor a screen, and respond by pressing a button as soon as they see a counter appear. The target will appear at random intervals between 2 and 10 seconds, and measures reaction time and false starts. An advantage of the PVT is that it does not produce a practice effect making it an ideal test to administer over multiple days of sleep deprivation or sleep debt recovery (Dinges et al., 1997). A draw back of the PVT is the time it takes to administer, in many applied settings it is too lengthy to be practical. A study by Basner et al. (2011) hypothesised that a three-minute version of the PVT would be as sensitive to picking up sleep loss deficits in participants, as well as having the advantage of being a faster test to complete. The participants in this study consisted of 43 individuals in a partial sleep deprivation group, which involved five nights in a sleep laboratory with only four hours of sleep, and 31 individuals in a total sleep deprivation group who were required to remain awake for 33 hours. The original PVT and the new three-minute version were administered to both groups every two hours. The results from the study were that while the three-minute version of the PVT was not as sensitive as the traditional PVT, it still yielded a large effect size in the total sleep deprivation group, and a medium to large effect size in the partial sleep deprivation group. The authors concluded that the three-minute version of the PVT is still a reliable way of detecting the effects of sleep deprivation and the slight trade-off in sensitivity is worth the advantages that a shorter version of the PVT brings.

2.4 Prospective Memory and Sleep Deprivation

Akin to sustained vigilance, memory is another key function in roles where individuals carry responsibility for the lives of others. Scientists have been interested in the relationship between sleep and memory for decades, leading to research investigating the link between hours of sleep and performance in retrospective memory tasks (Stickgold, 2004). A common trend across these studies is that sleep is advantageous in both procedural and declarative memory (Plihal & Born, 1997; Smith, 2001). Another branch of memory that has received less attention, but may still be just as sensitive to sleep deprivation is prospective memory (PM). Errors in PM have contributed to multiple incidents, some involving the loss of life (Dismukes, 2012; National Transportation Safety Board, 2001) which makes it a crucial area to be developed and understood in sleep and shift work research. The earliest research in PM began with studies using real-life scenarios, such as having participants remember to ring their researcher and mail a postcard on a certain day (West, 1988). These kinds of studies carried a level of uncertainty as there was no way to monitor whether participants were self-initiating or using an external cue to remind themselves to post the letter. To address these difficulties, McDaniel and Einstien (1990) designed the PM laboratory paradigm and were able to monitor participants and record their results in a laboratory environment. The paradigm involves engaging participants into an ongoing activity. Once they are fully engaged and focused on the task a new instruction is given; to remember to perform an unrelated task at some point in the future. The paradigm allows the researchers to measure the number of trials where the participant remembered to execute the PM task while simultaneously continuing with the ongoing activity.

A study by Grundgeiger et al. (2013) undertook research using Einstein and McDaniel's PM paradigm (1990). The study compared a non-sleep deprived group and a group deprived of sleep for 25 hours, on PM tasks across two categories: higher resource-demanding tasks and lower resource-demanding tasks. They found that PM performance was worse in the sleep-deprived group across all domains assessed. Meaning that the participants suffering from sleep loss performed worse than the rested participants on the ongoing task, both resource levels of the PM task, had a slower reaction time on tasks of vigilance and rated themselves as more sleepy on the KSS (Karolina Sleepiness Scale). The authors concluded that this study supports the theory that sleep deprivation affects prospective memory performance globally, increasing the chance of forgetting to carry out an intention regardless of how resource-demanding a task is.

Diekelmann et al. (2013) also posited that sleep may also have an effect on PM. He explored this theory by splitting 56 adults into a sleep opportunity group and a no sleep opportunity group, and all participants were allocated a task to carry out in two days' time. The study's results found that 100% of the participants in the sleep opportunity group remembered to carry out the task. In comparison, only 61% of the participants in the no sleep group remembered the intention. The authors concluded that the acquisition of slow-wave sleep could be particularly important for remembering delayed intentions.

A further study by Diekelmann et al. (2013) took individuals from the same pool of participants and measured their abilities in a further PM task. The group of participants was then split into two, one group was assigned to the sleep deprivation condition while the other was allowed to sleep. The next day the participants were all sent home, spent the day awake and then had a normal sleep at home before returning to the laboratory to do the prospective memory test again. The results found that the non-sleep deprived group had an enhanced performance compared to the sleep-deprived group, with the participants from the sleep deprivation condition making 50% more errors, even though they had gone home for a night of sleep. This study corroborates the first study and demonstrates that one night of sleep is not enough to recover from a night of sleep deprivation.

A study by Esposito et al. (2015) evaluated the effect of total sleep deprivation on a time-based prospective memory task. The experiment involved a control group that maintained a regular sleep-wake cycle, and an experimental group that were kept awake for 24-hours. Following the period of wakefulness, all participants completed a PVT and a PM task. The results found that the sleep-deprived participants performed significantly worse in the vigilance task as well as in the time-based prospective memory task. As well as supporting the theory that prospective remembering is sensitive to sleep loss, this study specifically highlights relationship between sleep deprivation and crucial time-monitoring. Occupations like nurses are frequently asked to complete a task like check a patient's blood glucose levels in 20 minutes. Without an external cue to remind them, tasks could easily be forgotten during a night shift or if an individual is sleep deprived.

Another study conducted by Scullin and McDaniel (2010) took a group of individuals, and randomly assigned them to one of three conditions: a 20-minute wake delay, a 12-hour wake delay or a 12 hour sleep delay. The experiment consisted of two sessions separated by the delay they had been assigned to. During session one, participants were given several tasks to complete and a PM instruction to execute in the session following the delay. During the second session participants completed several tasks and embedded in three of the tasks were the prospective memory targets that needed to be responded to. The findings from the experiment provided further evidence that sleep is crucial to solidifying a prospective memory intention, as the participants in the 12 hour sleep delay group were more likely to remember carry out the prospective memory instruction than those who did not sleep.

In his meta-analysis, Diamond (2019) discusses six primary factors that contribute to a PM lapse and interrupt awareness of a planned intention. He identifies these as habitual behaviour, distractions/interruptions, multi-tasking, absence of a reminder cue, acute/chronic stress, and sleep deprivation. Habitual routines, distractions, multitasking and absences of external cues are labelled as 'acute conditions' that can occur during the delay period of the PM intention increasing the chance of a lapse occurring. On the other hand, stress and sleep deprivation are labelled as 'global detrimental influences' which contribute to the likelihood of a lapse. The combination of a likely environment with a global detrimental influence, like sleep deprivation or stress produces the most favourable condition for a PM lapse to thrive. He explains that compensatory aids such as checklists and rules can be implemented to help minimise the chance of a PM error occurring in a high-risk environment. However, detrimental influences like sleep loss are processes from within and must be identified and managed accordingly. Using this information, workplaces that present the combination of both a likely environment and have workers operating under potential detrimental influences should consider ways to manage the risk presented.

These studies demonstrate that sleep loss affects PM intentions; thus, highlights the question of how sleep deprived professionals could be affected within their workplace. The following paragraphs are examples taken from real life scenarios where fatigued shift workers have been affected by lapses of PM.

2.4.1 Prospective Memory Lapse in the Medical Industry

A nurse working at a hospital describes the effect that her fatigue had on the life of a patient. She explains that she was working her third night shift in a row, feeling so exhausted that her eyes felt hot and sunken. In the early hours of the morning she was balancing several patients, some of whom were very difficult, when a new patient was admitted to her care. The nurse asked a junior nurse look over the patient for her and then received the information that the patient was scoring a ‘six’ which made her a high priority patient. The nurse contacted a doctor and they worked to get her temperature down and infection under control. Once it was taken care of the nurse decided to leave the patient to sleep so she could get back to the rest of her work, telling herself she would go back to check on her soon. However, due to how busy the ward was the nurse forgot to go back to check on her and forgot to tell anyone else about her condition and didn’t remember until three hours had passed. Additionally, the nurse who was in charge of doing the routine morning checks was held up with another patient. When the nurse finally got to her, the patient was looking and feeling severely unwell. The patient was diagnosed with sepsis and the small number of available medical staff in the ward jumped into action to help her. The woman ended up in intensive care and was very lucky to have not lost her life (Ward, 2015).

2.4.2 Prospective Memory Lapse in the Aviation Industry

A McDonnell Douglas MD-82 was flying from Dallas Fort Worth airport to Little Rock airport in Arkansas, United States of America. The flight was being operated by a very experienced captain and a less experienced first officer. Before departure the flight crew received weather advisories informing them of multiple severe thunderstorms en-route. This meant that the aircraft they were supposed to be taking over was delayed in landing into Fort Worth, which impacted the time they could depart. This flight was the last flight for the crew at the end of a 14 hour day, and if their flight was delayed the crew would not have been able to operate this last sector as it would exceed the maximum number of hours allowed for safe operation in the airlines policy. To avoid this happening the airline arranged another plane for the crew to take which meant that the crew were able to depart 36 minutes before their cut off time. During the flight the crew were again advised of severe weather at the arrival location and were told to speed up in an attempt to land before the weather got worse. As the aircraft approached the airport, a thunderstorm was occurring directly over them, visibility was extremely poor and they lost sight of the runway. The pilots made an error in judgment by rushing the landing procedures to get the plane on the ground as soon as possible, and in doing this they skipped the pre-landing checklist. They then realized that they hadn't armed the auto spoiler, or set the automatic breaking system. The auto spoilers job is to improve breaking ability. As the plane came down for its final approach the crosswind exceeded the limit for landing however the captain chose to not abandon the approach. A number of seconds after the aircraft touched down in Little Rock, the plane slid along and off the end of the runway, struck multiple structures along the way before crashing through a security fence, down a bank and then into a steel structure. The captain of the flight and 10 passengers were killed in the accident. The accident report came to the conclusion that the causes of the crash were the poor judgement from the crew which led them to fail to discontinue their approach in poor weather and forgetting to complete the prelanding checklist which ultimately meant that they landed without the auto spoilers and auto breaks armed. Fatigue was classified as a contributing cause of the accident which was said to have impaired their performance (National Transportation Safety Board, 2001).

These stories serve as examples of accidents with the same denominator, they are cases where trained individuals have forgotten to perform an intention and demonstrate how seemingly small lapses in high pressure and high responsibility environments can result in tragedy or near misses (Collins et al., 2007). The aviation example began with pilots performing a habitual routine, they likely flew planes multiple times per week and have probably landed at that same airport in poor weather previously. While performing the habitual routine the pilots were using retrospective procedural memory, and much of it would be implicit. Comparatively, this routine is the 'ongoing task' that is being simulated in the PM paradigm discussed earlier. When the severeness of the storm became apparent and the work load became more demanding, the pilots found themselves in a situation that was no longer routine. At this point in the flight the pilots would normally be setting the plane up to land and completing their pre-landing checklist. However, due to the distraction of the situation they were faced with they skipped it. Leaving the items on the checklist to be completed using recall memory alone. However, in order to 'remember to remember' the pilots either need to keep the intention to arm the spoilers and set the automatic breaks in their minds (strategic processes) or they needed an external cue to remind them to do so (automatic/spontaneous processes). As discussed, in an engaging and demanding environment the resources available to hold an intention in mind can diminish. In this example, the external cue and planning strategy of having a checklist failed and a spontaneous retrieval did not occur for either of the pilots. This resulted in a prospective memory lapse and a fatal aviation accident.

2.4.3 Sleep loss, Mistakes and Work Environments

The prevalence of mistakes, and specifically PM lapses within workplaces are not always known as mistakes are often minor, or dealt to within the institution. Studies that measure trained professionals and their response to sleep loss within their work environments are hard to come by due to access limitations. To mitigate this researchers use other ways of assessing and measuring what occurs in these environments. Nowinski et al. (2003) collected and analysed a number of aviation safety reports which contained information relating to pilot errors that occurred in the flight deck. From the reports received, 75 were related to some form of memory error, and all but one of these errors was an error of PM. Another method of collecting information about incidents and experiences within a workplace environment is via a focus group. A study by Danielsen et al. (2013) conducted a focus group study on a group of 44 surgeons who regularly work night shifts at a hospital, with shifts that could last up to 24 hours with one day off for recovery. The study aimed to further the understanding of a surgeons experience of fatigue in the workplace and the results of the focus group revealed several key themes. Every doctor in the group reported that night shifts caused a negative physical response in their bodies, particularly around the 2 AM to 6 AM window. They all spoke of having to work slower, experiencing irritability, having issues with multi-tasking, and many described themselves as feeling like ‘zombies’. Communication difficulties were another area that came up among many of the doctors, who described themselves as having a negative communication style with their patients, snapping at younger colleagues and not being able to think of the correct word when asking for an instrument during surgery. Another finding from the study was that every surgeon reported making an error in the past due to sleep deprivation and many of these errors were a result of a lapse in PM. Common examples that were given were: forgetting to book patients for CT (computed tomography) scans and other extra examinations, forgetting to add notes about a patient into the medical chart, loosing concentration or flow in tasks and forgetting steps in less common or non-routine surgeries. In order to mitigate these risks, the surgeons explained that they write the steps for the surgery onto a whiteboard as a reminder and when completing non-surgical tasks, they write notes and only work on one thing at a time. When questioned about sleep recovery following a night shift, the surgeons reported disturbances in sleeping patterns, and that after working a 24-hour shift two days of rest was not enough to feel normal again.

A further study by Barger et al. (2006) invited medical interns to participate in an anonymous survey which questioned working hours, hours of sleep, number of extended shifts and medical errors over a series of months. The results observed an increased number of fatigue-related medical errors, including errors that resulted in the death of a patient during shifts that lasted 24 or more hours. During months where at least five extended shifts were worked, the interns were seven times more likely to make medical errors, and the authors noted that guidelines for medical interns allow shift lengths of up to 30 hours nine times per month. This research highlights that extended shifts lead to reduced attention and an increase in fatigue related errors.

The above literature supports the notion that extended periods of time at work, night work and short or day time opportunities for sleep are at odds with optimal functioning, are detrimental to cognition and increase the prevalence of PM errors. These findings highlight that night shift work leads to a possible decline in safety within workplaces. Thus, support the view that adequate recovery days should be rostered following night work.

While there has been a wide range of research conducted into the relationship between sleep deprivation and cognitive difficulties, a lesser known topic is how sleep deprivation affects mental health and well-being, and whether long-term night shift work could have lasting psychological effects.

2.5 Well-being and Sleep Deprivation

Well-being is an important concept to consider when assessing the overall health of a person, as a good sense of well-being can lead to better physical health outcomes, increased productivity, and more enjoyment in both a personal and professional context (Kubzansky et al., 2001; Lox et al., 1999; Lyubomirsky et al., 2005; Lyubomirsky et al., 2006). Thus, this section of the literature review examines the research surrounding sleep deprivation, shift work and well-being.

An investigation was conducted by measuring the fatigue and mood of a group of medical residents thrice during their working day (Zohar, 2005). The study aimed to understand whether sleep fragmentation and duration influenced emotional reactions to an event. It concluded that higher levels of fatigue correlated with elevated negative emotions when experiencing disruptive events and decreased positive emotions when experiencing optimistic events.

A second study found that a group of sleep-deprived individuals rated themselves significantly less happy, more depressed, more exhausted and angrier than a rested control group when rated on 36 mood-related adjectives. A further finding from the research was that there was no difference in scores between two-night and one-night of sleep deprivation, indicating that one night of sleep loss is just as bad as two (Paterson, 2011).

Several theories have been proposed to explain the relationship between lack of sleep and low emotion. The *emotional brain network theory* suggests that sleep deprivation affects the prefrontal cortex and affects the ability to inhibit and control negative emotions (Dahl & Lewin, 2002). A further theory developed by Walker and van der Helm (2009), posits that REM sleep strongly affects balancing emotional states and that a lack of REM sleep can increase negative feelings and reduce positive emotions. The authors believe this is because REM sleep (and dreaming) creates the perfect chemical conditions to balance and 'depotentiate' emotional memories. Without REM sleep, prior negative memories and conflict are not resolved, leading to increased negative mood. The *emotional information processing theory* presented by Kahn et al. (2013) argues that sleep alters memory processing by unbinding emotions from memories and consolidating the emotional element (Payne & Kensinger, 2010). Therefore, individuals experiencing sleep deprivation will not be able to process their emotions from that day to their full capacity. According to this theory, sleep deprivation may also impact new memories as the study found that new neutral and positive memories had their encoding disrupted by sleep deprivation (Walker & van Der Helm, 2009). The authors concluded that more emphasis was placed on remembering negative emotions from events, while neutral or positive emotions were forgotten. The authors describe this as a 'negative remembering bias' and state that it could account for the correlation between sleep deprivation and depression (Mayers & Baldwin, 2006). Moreover, there is the *cognitive-energy model*. The model explains that positive outcomes will appear less pleasing to an individual, and adverse effects will be more irritating when sleep-deprived. The authors suggest that the reason for this is that when a person feels low on energy, they are less capable of engaging in a positive situation and experiencing the feelings of happiness that they normally would. Likewise, when facing a negative situation, the low levels of energy exaggerate the feelings of irritation and lower the threshold of tolerance that would usually be held (Kahn et al., 2013; Zohar et al., 2005).

Akerstedt and Torsvall (1978) conducted a longitudinal study of shift workers looking at how wellbeing changed over time for a group of 400 steel workers. A baseline measure was taken by administering a questionnaire to the group of workers. These workers were working a rotational shift roster of a day shift, an early morning shift, an evening shift and a night shift. The questionnaire consisted of items relating to sleep, mood, gastrointestinal functioning and the fulfilment of social roles, as well as questions relating to sleep length, attitude to work and absence from work due to sick leave. A few months after the baseline measure some of the workers schedules were changed which resulted in a number of them no longer working night shifts. These workers showed a significant increase in all of the above categories, dramatically improving their subjective ratings of wellbeing. A second longitudinal research trial studied 60 Australian nurses over 15 months of shift work. At the beginning of the trial all nurses were assessed on a psychological symptom measure. The measure that was used was the general health questionnaire (GHQ) which consisted of 12 questions relating constructs such as happiness, confidence and self - worth. During the 15 months just over half of the nurses began to work night shifts, while the others continued to only work during the day. At the end of the 15 months all the nurses were measured on the GHQ again, the results found that the nurses who worked night shifts had a significant increase in psychological symptoms compared to their baseline measure. The authors commented that the study provided clear evidence that night work has a strong negative effect on psychological well-being. (Bohle & Tilley, 1989). The above studies suggest a link between sleep deprivation, working night shifts and poor well-being but do not mention whether recovery periods could help to improve well-being.

Research by Totterdell et al. (1995) questioned whether self-ratings of well-being and psychological recovery in nurses could be improved by increasing the number of rest days scheduled after a shift. Their results found that well-being was most severely impacted on the first rest day following a shift, and began to improve after the second rest day. However, this improvement was only found across the day shift nurses and not the night shift nurses. They posited that night shift workers might require more time to recover or the measures they used may not have been sensitive enough to record well-being accurately. It could be these night shift workers were experiencing such high loads of poor well-being that a few days off following a shift was not enough to improve it. Another study conducted by Blasche et al. (2017) assessed well-being recovery in nurses following two 12-hour shifts. Their study followed the nurses over a period of three rest days following the two shifts and found that the nurses experienced worse well-being while at work, than on the rest days following the two shifts. These scores then improved each day from rest day one, through to rest day three. The authors concluded that at least three non-work days should be provided following two consecutive 12- hour shifts. Returning to work prior to this was suggested to cause an accumulation of *allostatic load* which is an overload of stress on the body. The authors note that by allowing nurses to have adequate time off work, is in turn improving patient safety so that they can continue to focus and care about the patients they are looking after.

Further research into recovery time for low levels of well-being following a night shift or within-subject designs where wellbeing is assessed before and after a period of recovery is difficult to find in the literature and poses an area for further research which this study hopes to contribute to.

2.6 Summary

To summarise, a study by Akerstedt et al. (2000) found that one day of recovery was never enough to allow an individual to recover after night work, and that two days would normally be sufficient unless there had been a dramatic adjustment to the circadian rhythm in which case three to four days of recovery may be necessary. This finding was supported by Kecklund et al. (1994) who recommended that three days off should be provided to an individual to recover after a period of night shifts and Haluza et al. (2019) who endorsed at least three days off after two consecutive night shifts to recover from impaired well-being. Meijman (1981) assessed 98 shift workers on their fatigue levels and quality of sleep across seven days, and found that that during their days off the night shift workers reported higher fatigue levels and worse sleep quality than the morning and evening shift workers. The author concluded that the four days provided rest was not enough for the night shift workers to recover from the effects of night shift work.

The need for 24/7 workers in the modern world, such as air crew, medical staff and emergency responders means that night shift work is here to stay. However, the research that has been conducted indicates that the guidelines around shift length and hours of rest for cognitive and emotional recovery may need to be reassessed.

2.7 Aims and Hypotheses

2.7.1 Research Aims

Individuals working in shift work roles may work extended shifts, night shifts, consecutive shifts, shifts with minimal rest or a combination of all of the above. As a result of this, shift workers may struggle to obtain quality sleep and suffer cognitive and psychological consequences. The primary aim of the current research was to acquire evidence that could initiate new discussions about rest and recovery following a night shift, and provide a starter template that could be developed by further research and eventually be used by employers. The findings and literature discussed in the study could also be used to provide education around improving safety, health and productivity in the workplace. While there is research on sleep, fatigue, vigilance, prospective memory and well-being individually, there is a gap in the literature examining how these constructs change over a period of sleep deprivation and recovery. This research is unique in the sense that it monitors a group of night shift workers before and after a night shift and then over a period of recovery while taking daily measures of prospective memory, vigilance, fatigue and well-being.

2.7.2 Hypotheses

The literature reviewed suggests that night shift work results in cognitively impaired individuals who are more prone to lapses in PM, have a slower reaction time, struggle to maintain a positive well-being and suffer from fatigue. Therefore the dependent variables that were chosen to focus on in this study were PM performance, performance on a PVT and self-report scores in well-being (affect) and fatigue. Based on the findings from the literature review, it was proposed that three days off work following a night shift would be used as the timeframe to assess improvement in cognitive and wellbeing measures. Thus the study utilises a five-day window to monitor changes before and after a night shift. The following hypotheses are proposed:

Hypothesis One:

H1a: If provided with three nights rest after a night of sleep deprivation, we expect to see a quadratic (u-shaped) trend in shift workers performance on prospective memory (PM) tasks from pre-sleep deprivation to day five: that is, a decrease in PM performance with immediate sleep deprivation followed by a recovery of scores with rest. The control group scores are expected to remain consistent throughout the five days.

H1b: We expect PM performance on day five to be no different from PM performance pre-sleep deprivation (day one).

Hypothesis Two:

H2a: If provided with three nights rest after a night of sleep deprivation, we expect to see a quadratic (u-shaped) trend in shift workers performance on a psychomotor vigilance task (PVT) from pre-sleep deprivation to day five: that is, a decrease in performance on the PVT with immediate sleep deprivation followed by a recovery of performance with rest. The control group scores are expected to remain consistent throughout the five days.

H2b: We expect PVT performance on day five to be no different from PVT performance pre-sleep deprivation (day one).

Hypothesis Three:

H3a: If provided with three nights rest after a night of sleep deprivation, we expect to see a quadratic (u-shaped) trend in shift workers self-reported ratings of fatigue from pre-sleep deprivation to day five: that is, an increase in fatigue scores with immediate sleep deprivation, followed by a recovery of scores with rest. The control group scores are expected to remain consistent throughout the five days.

H3b: We expect fatigue scores on day five to be no different from fatigue scores pre-sleep deprivation (day one).

Hypothesis Four:

H4a:If provided with three nights rest after a night of sleep deprivation, we expect to see a quadratic (u-shaped) trend in shift workers self-reported ratings of well-being (affect) from pre-sleep deprivation to day five: that is, a decrease in well-being (affect) ratings with sleep deprivation, followed by an increase in well-being ratings with rest. The control group scores are expected to remain consistent throughout the five days.

H4b: We expect well-being ratings on day five to be no different from well-being ratings pre- sleep deprivation (day one).

Chapter Three: Method

3.1 Overview

The current research was a multi-day study with 'laboratory style' tasks and two questionnaires conducted online via each participant's own keyboard-enabled computer. The inspiration for a five-day study came from research by Blasche et al. (2017), who assessed the well-being of nurses over three rest days following two days of day shift work. The current study added to this by measuring PM, sustained vigilance, fatigue, and well-being. The PM paradigm designed by Einstein and McDaniel (1990) was utilised for the study. However, to bring some diversity to the flow of the task and in an attempt to increase engagement, the study took inspiration from research by McFarland and Gilsky (2009) by utilising their idea of a multi-choice trivia quiz as the ongoing task portion of the PM paradigm. For the target identification portion of the paradigm, the study drew inspiration from Park et al. (1997) and used changing patterned backgrounds as the PM target. This research was pre-registered with the Open Science Framework (https://osf.io/pxbq3/?view_only=8aa553ae7b1c470ea4ea55f8658e398a), therefore the hypothesis, method, eligibility and mode of data analysis were decided before data collection. G*power was used to determine the sample size for an equivalence test (two single sample t-tests) with α set at 0.025 (because there are two tests) and power set to 0.80. This gave a sample size of N=34 to detect a difference of d=0.5 (sized medium effect). G*power was used to determine the sample needed for a trend analysis. N=50 would allow us to detect an equivalence test effect of at least d=0.4, which was doubled to include control participants (total N=100)

3.2 Design

A mixed (5x2) design was used during the research process to investigate the study question. This was undertaken by comparing a group of individuals currently employed as night shift workers with a group of individuals who never work night shifts over five days of repeated trials. The inclusion of the non-night shift group was to provide a point of comparison for how performance might change naturally in the absence of fatigue. The independent variables for this study were 'day' and 'group', and the dependent variables were PM performance, sustained vigilance performance on the PVT, self-reported fatigue and self-reported affect (as a measure of well-being).

For the independent variables, 'day' included 'day one', 'day two', 'day three', 'day four' and 'day five', while 'group' included 'night shift workers' and 'control's'. For the night shift group, 'day one' was completed when the participant had not worked a night shift for five days and was classified as a non-fatigued baseline measure. 'Day two' was completed immediately upon returning home from a night shift. Finally, 'day three'. 'day four' and 'day five' were completed on the three consecutive days rostered off after a night shift. The control group completed the five days consecutively and were asked to confirm that they had not missed a night of sleep in the previous five days before the experiment. For the dependent variables, 'PM performance' was measured using McDaniel and Einstien's (1990) PM paradigm and focused on target hits, reaction time and false alarms. Sustained Vigilance was measured using the PVT and focused on reaction time and false alarms. Self-reported fatigue was measured with an adapted short form daily fatigue diary measure from the Patient-Reported Outcomes Measurement Information System (PROMIS), and finally, well-being was measured using the Positive and Negative Affect Schedule (PANAS – Short form) questionnaire.

3.3 Participants

The individuals invited to participate in the study's experimental group were night shift workers who, at some point, would be rostered a shift that was followed by three days off. As previously mentioned, a control group of non-night shift workers was also recruited for the study.

Of the 142 individuals who registered an expression of interest to participate in the study, only 39 participants completed all five days of the experiment. Of these 39, 22 were night shift workers, and 17 were non-night shift workers serving as a control group. All participants lived in New Zealand or The United Arab Emirates. The reason for not being able to recruit the 100 participants as planned was because of a lack of interest from the study population, this may have been due to factors such as job losses or high work pressure related to COVID-19. The night shift group were employed across various industries, including aviation, medical, emergency and transport. The professions of the day participants were not recorded as it was not necessary to have a profession to participate in the day condition.

The participants in the study ranged in age from 23 to 59; however, the mean age was 41.1. Of the 39 participants, 23 were female, and the other 16 were male. Table one displays further socio-demographic characteristics of the sample.

Table 1

Sociodemographic characteristics of participants.

Characteristic	Night Shift n=22 (56.42%)	Control n=17 (43.58%)
Age in years: M (SD)	39.7 (11.3)	43 (14.1)
Sex: female (%)	59.09%	58.82%
Partner at home (%)	72.73%	100%
Dependent children (%)	72.73%	47.06%
Years of shift work: M (SD)	9.54 (10.29)	N/A
Shift type: rotating shift style (%)	86.36%	N/A
Sleep aids to fall asleep: yes (%)	9.09%	N/A
Industry: aviation (%)	22.73%	N/A
Industry: medical (%)	36.36%	N/A
Industry: emergency response (%)	22.73%	N/A
Industry: other night work (%)	18.18%	N/A

The following inclusion criteria were used when recruiting participants for the night shift condition:

(1) Currently working a job where you are permanently or sometimes rostered a night shift (for this study, a night shift is defined as "time spent at work during the night, where you are unable to sleep, that lasts at least 7 hours and takes up the majority of your night").

(2) You must not get more than 3 hours of solid sleep during your night shift.

(3) The chosen night shift is followed by three rostered days off (or two days plus a shift that starts later in the day).

(4) Can speak and read English fluently (self-report).

(5) Access to a computer and a reliable internet connection.

(6) Not taking any medication that affects attention.

(7) No self-report of sleep disorders.

(8) Are in your local time zone (have been for five days)

When recruiting participants for the day condition, the following inclusion criteria were applied:

(1) You cannot be employed in night shift work

(2) You must get 7-9 hours of sleep every night during the experiment

(3) Not suffering from any jetlag or long-term sleep deprivation

(4) Can speak and read English fluently

(5) Access to a computer and a reliable internet connection,

(6) Not taking any medication that affects attention,

(7) No self-report of sleep disorders

(8) Are in their local time zone (have been for five days)

Participants were informed that if drinking a coffee or having a nap was normal before driving home from a night shift, they should continue to do this prior to completing their sleep deprivation condition as their safety in driving is the highest priority. If coffee or a nap was had, it was recorded before the experiment started.

3.3.1 Participant Recruitment

Participants were primarily recruited by emailing staff working for organisations that employ night shift workers and asking them if their company was interested in participating in the study (see appendix A). Companies that were interested then identified staff among their workforce that fit the inclusion criteria and invited them to fill out an online expression of interest form. Participants were also recruited via social media and word of mouth.

Once the potential participants had completed the expression of interest form, they received an email with the study information sheet (see appendix B), the inclusion criteria, a link to start the first part of the experiment and a unique code. The unique code was so participants could retain some anonymity during the experiment; the code separated the data from their names, and participants were not asked to state the name of their employer. The list containing the unique codes matched with the participant's contact email was locked in a drawer and only accessible by the lead researcher. These measures kept the data report anonymous but allowed a way to link the participant to the data to track which participants had completed all five days.

3.4 Ethical Review

The Human Ethics Northern Committee at Massey University reviewed the ethics application for this research. They approved the study to be undertaken on the 10th of December 2019. Reference NOR 19/56.

3.5 Procedure

3.5.1 Enrolment

On 'day one' of the experiment, participants were presented with information about the study, a reminder about the eligibility criteria and consent information. Following the consent page, they were given an initial questionnaire which included demographic information and information about the sleep they had acquired before beginning the experiment (all of the above can be found in appendix C). Only after reading and agreeing to the consent were the participants able to continue the experiment. To thank each participant for contributing to the research, everyone who completed all five days received either an NZD 20 voucher or an AED 50 voucher, depending on whether they were based in New Zealand or the United Arab Emirates.

3.5.2 Data Collection Process

There were five levels of the 'day' independent variable in this mixed design which each participant completed. The content across the five levels was repeated every day and consisted of a prospective memory task (PM), a psychomotor vigilance task (PVT) and ended with two questionnaires measuring wellbeing/affect (PANAS) and fatigue (PROMIS). The night shift group were asked several additional questions each day relating to their shift work schedule and hours of rest.

Day one aimed to capture baseline performance levels when not suffering from sleep deprivation. To be eligible to record their baseline measure, participants were asked to confirm that they had not missed a night of sleep for the past five nights.

For the control group, days two, three, four, and five ran consecutively after day one. Alternatively, the night shift group were asked to start day two on the morning they returned home from a night shift. Days three, four and five were completed on the three consecutive days off after the night shift.

3.6 Stimuli and Materials

3.6.1 Prospective Memory Task

The experiment began with a PM trial which consisted of a general knowledge trivia game with an embedded prospective memory task and followed the same format as McDaniel and Einstein's (1990) PM paradigm. A selection of multi-choice trivia questions and answers were sourced from various general knowledge databases online (see appendix D). Each trivia question was accompanied by four possible answers and presented over one of six black and white patterned backgrounds (see appendix E). One of these backgrounds was set as the designated target background and was shown to the participant before the PM trial started. The time available for the participant to view the target background was not controlled, and participants clicked ‘continue’ when they were ready to begin.

The format of Einstein and McDaniel’s (1990) PM paradigm begins with a set of practice trials, where the participants can get comfortable following the instructions for the ongoing task without a memory component. The practice round consisted of seven multi-choice trivia questions, and participants were instructed to respond as quickly and as accurately as possible by selecting one of four possible answers. A 30-second countdown timer accompanied each question on the upper left-hand side of the screen, and selections were made using the mouse or trackpad on their computer. After selecting, the participants were informed whether their answer was correct; if not, the correct answer appeared in green. The game automatically moved on to the next question if the timer ran out. At the end of the practice trials, participants received their overall score and average response times.

Following the practice trial (and before the main trial commenced), the participants were informed of an extra task. If a pre-specified background appeared on their screen, they would need to remember to press the space bar as quickly as possible *instead* of selecting an answer for the quiz question. The extra instruction in the paradigm is to measure prospective memory. At the same time as receiving this instruction, the target background was shown to them on their screen. This was the only opportunity for the participants to remember the pattern.

As mentioned above, six different background patterns randomly alternated behind each trivia question. However, only one of these backgrounds was the pre-specified ‘target background’ to which the participants were to remember and respond. As the experiment ran for five days, the quiz questions and the specified target background changed each day to increase interest and reduce the chance of the background becoming easier to memorise. The target background order was also randomised among the participants in case one pattern was easier to remember.

The final component of the PM paradigm is the administration of a distraction task presented between the practice session and the main task. For the current study, the distraction task was a five-minute navigation game where participants must find their way out of a maze. According to McDaniel and Einstein (1990), the purpose of the distraction task is to present a delay which reflects day-to-day prospective memory situations where an individual may get distracted between setting and performing an intention. The participants were not informed that the maze results were not collected or used in the analysis in case it reduced the incentive to work hard on the maze and reduced the effect of the distraction. The ongoing task began immediately after the distraction task concluded. The task was presented in the same format as the practice trial and included 30 multi-choice trivia questions that participants were to answer. During these 30 questions, the target background appeared five times randomly and was non-repeating, which meant that the same participant would never see the same pattern twice in a row. Once all 30 questions were answered, the PM portion of the experiment was complete. Number of targets hit, reaction time to responding to targets and false alarms were recorded.

3.6.2 Psychomotor Vigilance Task

The psychomotor vigilance task (PVT) immediately followed the PM trial. The PVT was designed by Dinges and Powell (1985) and is a well-established tool used to assess sustained attention. Basner and Dinges (2011) verified the task to be sensitive to changes in sustained attention due to sleep deprivation when used over 10 minutes. A 10-minute PVT was not practical for the current study, so a five-minute PVT was utilised. The three-minute PVT has been demonstrated to be less sensitive to changes in attention due to sleepiness but is still a useful tool when time does not allow for a longer version (Basner, Mollicone & Dinges, 2011). A five-minute PVT was chosen as a compromise to minimise the length of the task and maximise its sensitivity. Before the task began, participants received instructions to monitor their screen and press their space bar as soon as a three-digit counter appeared on the screen. The counter appeared on the screen at random points between 1000ms – 5000ms, with an inter-trial interval of 250ms. Reaction time to responding to the counter and false alarms were recorded.

3.6.3 Positive and Negative Affect Schedule – Short Form

Following the PVT, participants were presented with the Positive and Negative Affect Schedule (PANAS). The PANAS is a 5-point psychometric scale developed by Watson et al. (1988). It is a self-report questionnaire and is a reliable tool for measuring mood and emotion (Crawford & Henry, 2004; Mackinnon et al., 1998); it has also been widely used across clinical settings and communities as a measure of affect (Merz et al., 2013). The scale used in this study was the short form (SF) scale, a shorter, more concise version of the original (see appendix F). The PANAS-SF consists of 20 items; 10 describe positive affect (interested, excited, strong, enthusiastic, proud, alert, inspired, determined, attentive and active). The remaining 10 describe negative affect (distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery and afraid). Higher ratings of positive affect in an individual reflect a higher prevalence of positive emotions, while the opposite is true for higher scores in negative affect. The PANAS-SF recognises that it is possible to feel both negative and positive emotions at the same time. Participants answered each item on the scale without any time pressure, rating them from one (not at all) to five (extremely). An overall score for positive affect and an overall score for negative affect was recorded for each participant. A high positive affect score reflects an individual with enthusiasm, productivity, energy and a positive engagement with life. In contrast, a low positive affect score indicates an individual with lethargy or sadness.[1]

[1] [1] From "Development and validation of brief measures of positive and negative affect: The PANAS scales," by D. Watson, L. A. Clark, and A. Tellegen, 1988, Journal of Personality and Social Psychology, 54, 1063-1070. Copyright © 1988 by the American Psychological Association. Reproduced with permission. No further reproduction or distribution is permitted without written permission from the American Psychological Association."

A high negative affect score can indicate distress, anger, discontent or disengagement and a low negative affect score indicates a calm state (Watson et al., 1988).

[2]3.6.4 Patient Reported Outcomes Measurement Information System -Daily Fatigue Form

The 'patient reported outcomes measurement information system' (PROMIS) is a set of measures created to evaluate and track patient-reported outcomes within both physical and mental health. The measures can be used in adults and children and are valid in clinical and community settings (PROMIS Health Organisation, n.d.). The PROMIS includes a fatigue scoring instrument termed the '7- day recall fatigue item bank', which is used to assess fluctuations in fatigue after a seven-day period. The tool can assess symptoms that suggest mild feelings of tiredness to a sustained sense of exhaustion (PROMIS, 2016). Criticisms relating to a recall bias have been raised, where the concern is that accuracy of scores could be reduced as the user must think back to the previous seven days (Broderick et al., 2008). Due to this, and because of a lack of reliable daily fatigue tools, Christodoulou et al. (2014) adapted the 7-day recall fatigue item bank into a daily diary research tool. Evaluation of this tool determined that adaptation of the scale did not affect the measurement properties. Fatigue fluctuations of participants in the current study were measured using the adapted diary version of the PROMIS fatigue scale (see appendix G).

Each day during the five days of the experiment, participants answered the following questions with: never, rarely, sometimes, often or always.

In the last day…

1. How often did you feel tired?
2. How often did you experience extreme exhaustion?
3. How often did you run out of energy?
4. How often did you fatigue limit you at work or home?

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[2] Copyright permission could not be obtained for the adapted PROMIS scale as the author could not be reached. Full references of the paper that introduced the adapted scale and the original scale have been included in the reference section.

5. How often were you too tired to think clearly?

6. How often did you feel tired even when you hadn’t done anything?

7. How often did you have to push yourself to get things done because of your fatigue?

Each participant received an overall fatigue score calculated using the PROMIS fatigue scoring manual (PROMIS, 2016). Following the questionnaire, the trial ended, and participants were reminded to return to the portal the next day.

Chapter Four: Results

The current research focused on measuring a group of shift workers before and after a night shift and then tracking recovery over three consecutive days. A two-part analysis was conducted to determine whether three days of rest was long enough for the shift workers to recover from the cognitive and emotional effects (if any) of a night of sleep deprivation. Firstly, a 5x2 mixed repeated measures ANOVA was conducted on the dependent variables using the Statistical Package for the Social Sciences (SPSS) (Statistics for Windows, Version 29) to look for evidence of a quadratic change in scores from day one (pre-sleep deprivation) to day five (third day of rest). For this ANOVA, the within-subjects factor was 'day' (day one - five) and the between-subjects factor was group (shift workers vs controls). The control group were a group of non-night shift workers that were included following the rationale that if the shift worker's scores change across the five days, the meaningful outcome is whether they change differently to a sample of non-shift workers. Following this idea, a mixed design ANOVA was conducted on each of the dependent variables and the variables that reported a statistically significant interaction with the night shift group then underwent a quadratic trend analysis to determine whether a 'U' shaped pattern of recovery (or an inverted 'U' if this trend was better) occurred over the five days of the study. For each of the ANOVAs, Mauchly's test of sphericity was conducted to test whether the assumption of sphericity was met. If the test was statistically significant, the Greenhouse-Geisser correction was applied to the results. Partial eta squared (ηp^2) was used as a measure of effect size. For the second part of the analysis, equivalence testing was conducted using the 'two one-sided tests' procedure (TOST) in Jamovi (The Jamovi Project, 2021) to determine whether the scores on 'day five' were statistically equivalent to the scores on 'day one', indicating that full recovery was complete. The Smallest Effect Size of Interest (SESOI) was set at Cohen's d= 0.5, which was decided based on research by Norman, Sloan and Wyrwich (2004), who claimed that there is a relatively consistent difference of half a standard deviation across many health outcomes. Before analyses began, all data was entered into Microsoft Excel to clean the data and remove the data of participants that did not complete all five days of the experiment.

4.1 Descriptive Statistics

Table 2, 3, 4, 5 and 6 present the descriptive data for the experimental group and the controls, for the PM task, the PVT, the PROMIS fatigue diary and the PANAS results across the five days of the experiment.

Table 2

Day One (Baseline): *Means (M) and Standard Deviations (SD) for the dependent variables.*

		Night Shift Workers M (SD)	Control Group M (SD)
Prospective Memory	Target Hits	1.82 (2.085)	2.12 (2.147)
Prospective Memory	False Alarms	1.86 (2.436)	1.65 (2.760)
Prospective Memory	Target Reaction Time	5451.55 (1533.720) ms	5995.94 (1290.334) ms
PVT	Reaction Time	314.95 (130.598) ms	351.25 (58.872) ms
PVT	False Alarms	7.50 (7.564)	9.88 (7.680)
PANAS	Positive Affect	28.77 (7.46)	29.88 (6.48)
PANAS	Negative Affect	12.95 (4.41)	13.24 (4.16)
PROMIS Fatigue Diary	Fatigue Score	47.69 (7.70)	47.46 (7.00)

Note. Prospective memory: mean number of targets responded to correctly, mean number of false alarms and mean reaction time to respond to a target; PVT: psychomotor vigilance test mean reaction time and mean number of false alarms; PANAS: positive and negative affect scale, mean affect for positive and negative; PROMIS: patient reported outcomes measurement information system, mean scores from a fatigue daily diary.

Table 3

Day Two (Sleep Deprivation) : Means (M) and Standard Deviations (SD) for the dependent variables.

		Night Shift Workers M (SD)	Control Group M (SD)
Prospective Memory	Target Hits	2.64 (2.036)	2.94 (2.193)
Prospective Memory	False Alarms	0.77 (1.602)	0.59 (1.970)
Prospective Memory	Target Reaction Time	5985.32 (1647.004) ms	6841.59 (1787.503) ms
PVT	Reaction Time	323.72 (118.646) ms	356.18 (79.672) ms
PVT	False Alarms	8.82 (17.885)	25.18 (28.877)
PANAS	Positive Affect	18.73 (6.43)	28.94 (6.81)
PANAS	Negative Affect	12.73 (2.91)	11.88 (2.39)
PROMIS Fatigue Diary	Fatigue Score	54.10 (7.24)	44.35 (7.19)

Note. Prospective memory: mean number of targets responded to correctly, mean number of false alarms and mean reaction time to respond to a target; PVT: psychomotor vigilance test mean reaction time and mean number of false alarms; PANAS: positive and negative affect scale, mean affect for positive and negative; PROMIS: patient reported outcomes measurement information system, mean scores from a fatigue daily diary.

Table 4

Day Three (Rest Day One): Means (M) and Standard Deviations (SD) for the dependent variables.

		Night Shift Workers M (SD)	Control Group M (SD)
Prospective Memory	Target Hits	3.27 (2.186)	3.12 (1.996)
Prospective Memory	False Alarms	0.50 (0.964)	0.65 (0.862)
Prospective Memory	Target Reaction Time	5878.59 (1763.747) ms	6071.06 (1555.631) ms
PVT	Reaction Time	304.16 (116.728) ms	342.26 (60.430) ms
PVT	False Alarms	5.91 (5.5715)	13.59 (16.711)
PANAS	Positive Affect	21.41 (2.95)	18.41 (2.76)
PANAS	Negative Affect	20.91 (3.53)	19.18 (2.94)
PROMIS Fatigue Diary	Fatigue Score	59.29 (9.80)	44.51 (8.09)

Note. Prospective memory: mean number of targets responded to correctly, mean number of false alarms and mean reaction time to respond to a target; PVT: psychomotor vigilance test mean reaction time and mean number of false alarms; PANAS: positive and negative affect scale, mean affect for positive and negative; PROMIS: patient reported outcomes measurement information system, mean scores from a fatigue daily diary.

Table 5

Day Four (Rest Day Two): Means (M) and Standard Deviations (SD) for the dependent variables.

		Night Shift Workers M (SD)	Control Group M (SD)
Prospective Memory	Target Hits	3.23 (2.069)	3.06 (2.076)
Prospective Memory	False Alarms	1.00 (2.160)	0.71 (1.213)
Prospective Memory	Target Reaction Time	5721.59 (1616.316) ms	6013.71 (1342.415) ms
PVT	Reaction Time	305.59 (108.556) ms	393.46 (141.647) ms
PVT	False Alarms	7.27 (7.977)	16.12 (23.627)
PANAS	Positive Affect	25.91 (7.75)	24.59 (6.44)
PANAS	Negative Affect	12.27 (2.54)	11.76 (2.56)
PROMIS Fatigue Diary	Fatigue Score	49.34 (7.97)	43.86 (7.52)

Note. Prospective memory: mean number of targets responded to correctly, mean number of false alarms and mean reaction time to respond to a target; PVT: psychomotor vigilance test mean reaction time and mean number of false alarms; PANAS: positive and negative affect scale, mean affect for positive and negative; PROMIS: patient reported outcomes measurement information system, mean scores from a fatigue daily diary.

Table 6

Day Five (Rest Day Three): Means and Standard Deviations (SD) for the dependent variables.

		Night Shift Workers M (SD)	Control Group M (SD)
Prospective Memory	Target Hits	3.14 (2.031)	3.35 (2.120)
Prospective Memory	False Alarms	1.23 (1.901)	0.53 (1.179)
Prospective Memory	Target Reaction Time	5820.50 (2026.425) ms	5830.65 (1655.127) ms
PVT	Reaction Time	297.90 (105.323) ms	381.553 (120.254) ms
PVT	False Alarms	9.23 (10.814)	17.76 (22.679)
PANAS	Positive Affect	29.27 (6.78)	26.82 (6.97)
PANAS	Negative Affect	12.77 (2.32)	13.82 (4.03)
PROMIS Fatigue Diary	Fatigue Score	44.34 (7.92)	43.13 (9.93)

Note. Prospective memory: mean number of targets responded to correctly, mean number of false alarms and mean reaction time to respond to a target; PVT: psychomotor vigilance test mean reaction time and mean number of false alarms; PANAS: positive and negative affect scale, mean affect for positive and negative; PROMIS: patient reported outcomes measurement information system, mean scores from a fatigue daily diary.

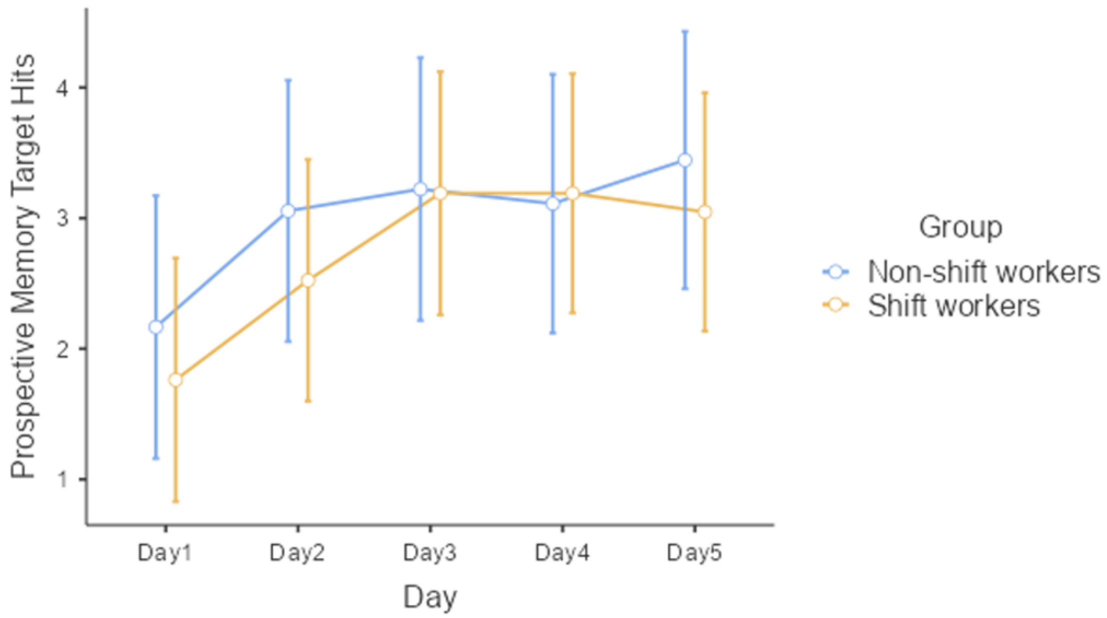
4.2 Primary Analyses

4.2.1 Prospective Memory

For PM target hits, Mauchly's test of sphericity was statistically significant, therefore a Greenhouse-Geisser correction was applied to the ANOVA results. The ANOVA that was conducted was not statistically significant $F(2.83, 104.77) = 0.380$, $p = .756$, $\eta_p^2=.010$. As seen in figure 1, performance in the PM target hits increases from day one to day five for both the night shift group and the control group, with no quadratic trend present. The equivalence test that was conducted for the night shift group found that performance was significantly better on day five than on day one $t(21)=2.910$, $p=.711$. Additionally, the difference between 'day one' and 'day five' overlapped with the upper bound of *d*=0.5, t(21) = 0.565, *p* = .711, which indicates that the scores on day one and day five for the night shift group are significantly different and not equivalent.

Figure 1

Prospective Memory Target Hits for Night Shift Workers and Controls.

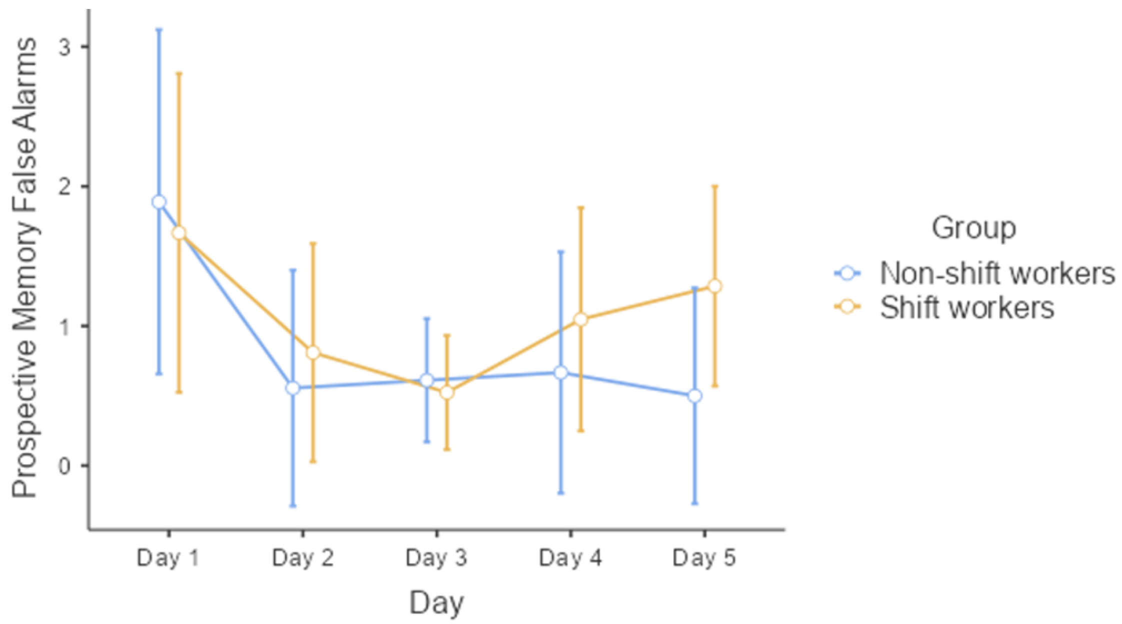


Note: Estimated marginal means for night shift workers and controls for PM target hits across days one to five. Error bars are set at 95% confidence intervals.

For PM target false alarms, Mauchly's test of sphericity was statistically significant, hence a Greenhouse-Geisser correction was again applied to the ANOVA results. The ANOVA that was conducted was not statistically significant, $F(2.98, 110.13) = 0.306$, $p = .819$, $\eta_p^2 = .008$. Figure 2 displays a general performance increase (less false alarms occurred) across days one to five for both the night shift group and the control group, with a slight increase in false alarms in the last two days for the night shift group. As such, no quadratic shape was present. The equivalence test that was conducted for the night shift group found that performance did not significantly differ between day one and day five, $t(21) = 1.374$, $p = 0.184$. Additionally, the difference between the two time points overlapped with the lower bound of d = 0.5, $t(21) = 0.971$, $p = .171$. This outcome implies that prospective memory false alarms are not significantly different and not equivalent between day one and day five.

Figure 2

Prospective Memory False Alarm Rates for Night Shift Workers and Controls.

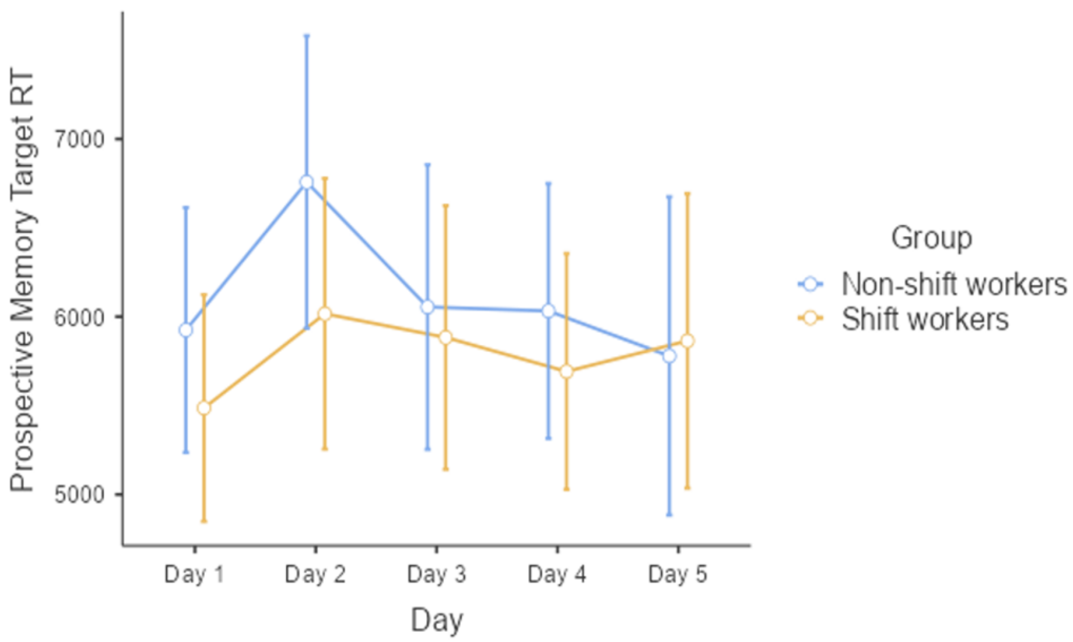


Note: Estimated marginal means for night shift workers and controls for PM false alarms across days one to five. Error bars are set at 95% confidence intervals.

For the PM target reaction time, Mauchly's test of sphericity was also statistically significant, meaning that a Greenhouse-Geisser correction was applied to the ANOVA results. The ANOVA was not statistically significant, $F(3.14, 116.10)=1.30$, $p = .277$, $\eta_p^2 = .034$. Figure 3 shows that the night group had slower reaction times on 'day two' when we expect them to show signs of sleep deprivation. However, this trend was also seen in the control group. The equivalence test that was conducted reported that the difference between performance on 'day one' and 'day five' was not statistically different $t(21) = -1.534$, $p = .140$. However, as the difference between 'day one' and 'day five' overlapped with the upper bound of $d = 0.5$, $t(21) = -0.811$, $p = .213$ this indicates that the prospective memory reaction time is not different and not equivalent between 'day one' and 'day five'.

Figure 3

Prospective Memory Target Hit Reaction Time for Night Shift Workers and Controls.



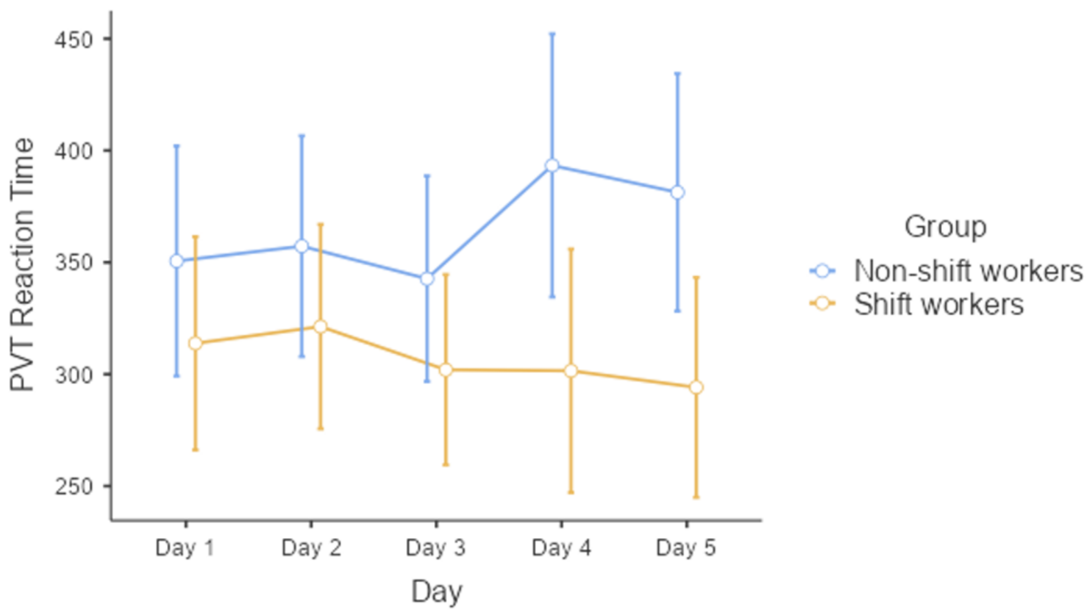
Note: Estimated marginal means for night shift workers and controls for PM target hit reaction time across days one to five. Error bars are set at 95% confidence intervals.

4.2.2 Psychomotor Vigilance Test (PVT)

For the PVT reaction time, Mauchly's test of sphericity was also statistically significant, which meant that the Greenhouse-Geisser correction was applied to the ANOVA results. The ANOVA was not statistically significant $F(2.98, 110.26) = 2.040$, p = 0.113, $\eta_p^2 = 0.52$. Figure 4 shows that performance across the five days remained fairly consistent for both night shift workers and controls. The equivalence test reported that performance between 'day one' and 'day five' was not significantly different for the night shift group $t(21) = -1.060$, p = 0.301. However, the difference between day one and day five crossed over the lower bound $d=0.5$, $t(21) = 1.285$, $p = 0.106$ which signifies that PVT reaction time is not different and not equivalent between 'day one' and 'day five'.

Figure 4

Psychomotor Vigilance Task Reaction Time for Night Shift Workers and Controls.

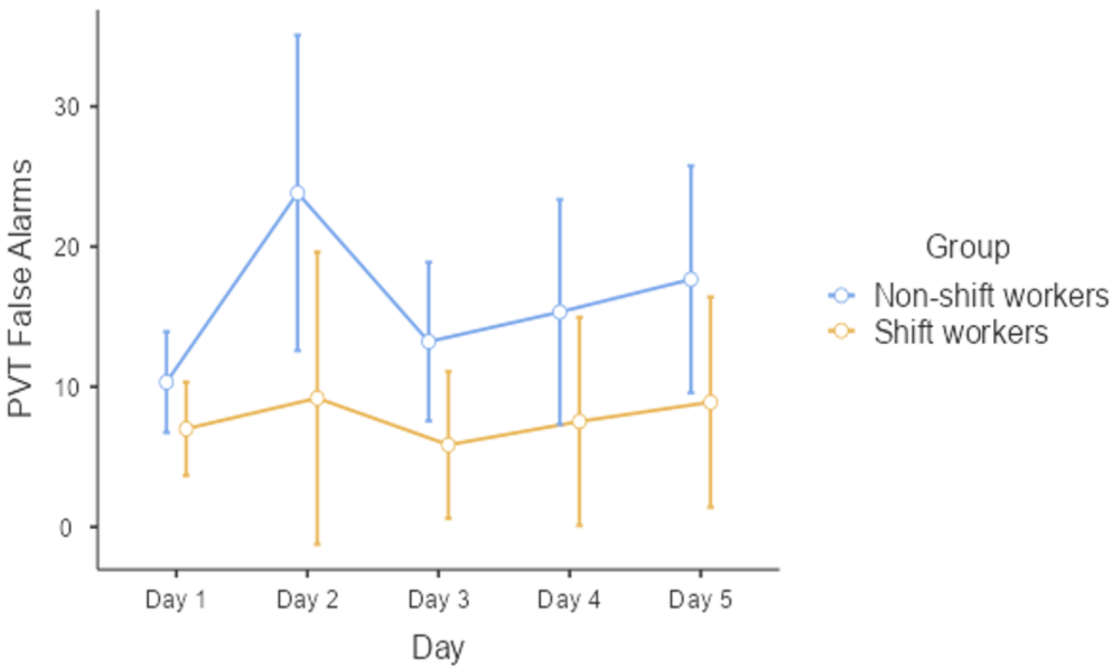


Note: Estimated marginal means for night shift workers and controls for PVT reaction time across days one to five. Error bars are set at 95% confidence intervals.

For PVT false alarms, Mauchly's test of sphericity was again statistically significant, meaning that a Greenhouse-Geisserr correction was applied to the ANOVA results. Again, the ANOVA was not statistically significant $F(2.80, 103.76) = 1.172$, $p = 0.323$, $\eta_p^2 = 0.031$. Figure 5 shows that performance for the PVT remained relatively consistent throughout the five days, with a slight increase on day two for the night shift group but no quadratic shape present. The equivalence test showed that performance on 'day one' and 'day five' was not statistically different for the night shift group $t(21) = 0.774$, $p = 0.448$. However, the difference between the two time points crossed over the upper bound $d = 0.5$, $t(21) = - 1.571$, $p = 0.066$ which indicates that PVT false alarms are not different and not equivalent between 'day one' and 'day five'.

Figure 5

Psychomotor Vigilance Task False Alarms for Night Shift Workers and Controls.



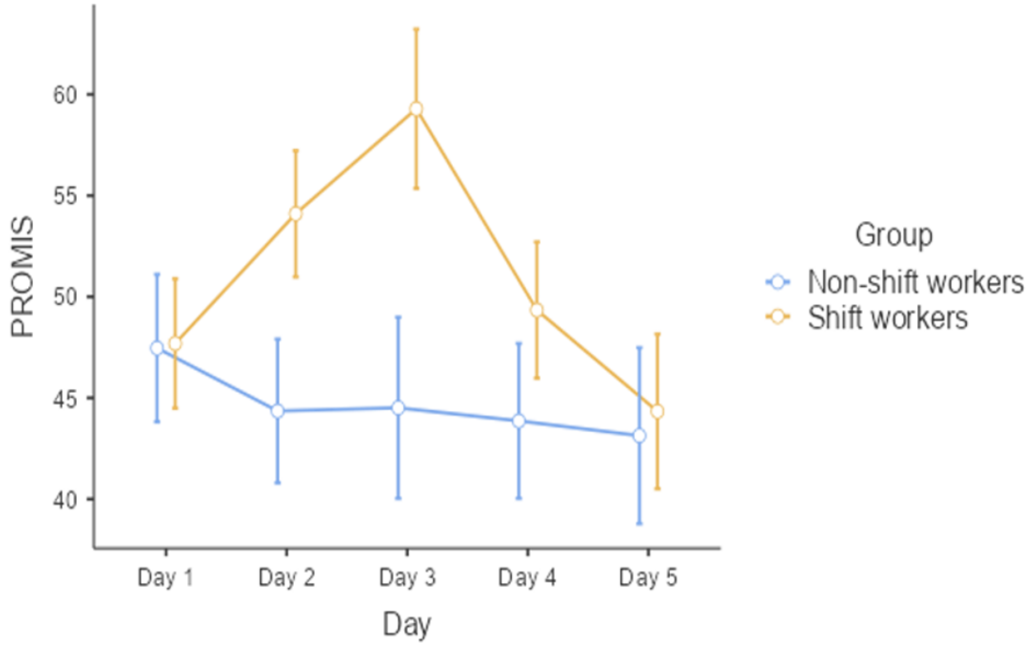
Note: Estimated marginal means for night shift workers and controls for PVT false alarms across days one to five. Error bars are set at 95% confidence intervals.

4.2.3 PROMIS Fatigue Scale

For the PROMIS fatigue daily diary Mauchly's test of sphericity was also statistically significant hence again the Greenhouse-Geisser correction was applied to the ANOVA results. The results reported that the ANOVA was statistically significant $F(3.22, 119.23) = 8.447$, $p < 0.001$, $\eta_p^2 = 0.186$ and the main effect of day ($F(3.22, 119.23) = 8.451$, $p < 0.001$, $\eta_p^2 = 0.186$) and group ($F(1,37) = 11.730$, $p = 0.002$, $\eta_p^2 = 0.241$ were also both statistically significant. As this result was significant the night shift data underwent a quadratic trend analysis for the main effect of day on night shift workers, this result also came back statistically significant $F(1, 21) = 32.973$, $p <0.001$, $\eta_p^2 = 0.611$, this finding indicates that there was a quadratic trend detected in the results. Figure 6 portrays a inverted 'U shape' for the night shift worker group (with the highest level of fatigue being reported on 'day three') which indicates that the scores had returned to baseline by day five. Whereas the control group displays a relatively constant performance over the five days. Equivalence testing found that performance was not significantly different between 'day one' and 'day five' $t(21) = -1.494$, $p = 0.150$. However, the difference between the two time points crossed over the lower bound $d = 0.5$, $t(21) = 0.851$, $p = 0.202$ which suggests that the PROMIS fatigue daily diary scores on 'day one' and 'day five' are not statistically different and are not statistically equivalent.

Figure 6

PROMIS Fatigue Daily Diary for Night Shift Workers and Controls.



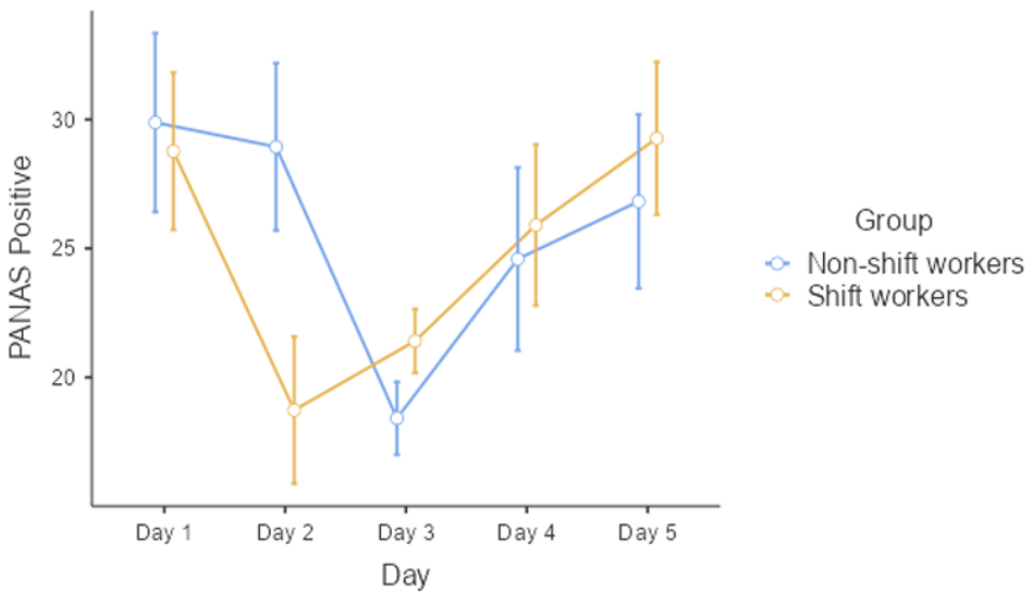
Note: Estimated marginal means for night shift workers and controls for PROMIS fatigue daily diary across days one to five. Error bars are set at 95% confidence intervals.

4.2.4 Positive and Negative Affect Schedule

For the PANAS positive, Mauchly's test of sphericity was not statistically significant, so no correction was applied to the ANOVA results. The interaction between day and group $F(4, 148) = 14.230$, $p < 0.001$, $\eta_p^2 = 0.278$ and the main effect of day $F(4, 148) = 26.486$, $p < 0.001$, $\eta_p^2 = 0.417$ were both statistically significant. However, the main effect of group ($F(1,37) = 0.328$, $p = 0.570$, $\eta_p^2 = 0.009$ was not statistically significant. A quadratic trend analysis for the night shift group was conducted for the main effect of day which was statistically significant $F(1, 21) = 50.521$, $p < 0.001$, $\eta_p^2 = 0.706$. Figure 7 demonstrates a 'U' shaped pattern for the night shift group with the biggest dip being on day 2 although there was also a 'U' shaped pattern present for the control group, with the biggest dip on day 3. Equivalence testing for the night shift group found that the performance at 'day one' was not statistically different to the performance on 'day five' $t(21) = 0.413$, $p = 0.684$. As well as this, the difference between the two time points was significantly smaller than the upper equivalence bound (t =(21) = -1.932, $p = 0.033$) and significantly larger than the lower equivalence bound ($t(21) = 2.758$, $p = 0.006$) which indicates that the PANAS positive is statistically equivalent between 'day one' and 'day five' implying that recovery to baseline had taken place on day five.

Figure 7

PANAS-SF Positive Affect for Night Shift Workers and Controls.

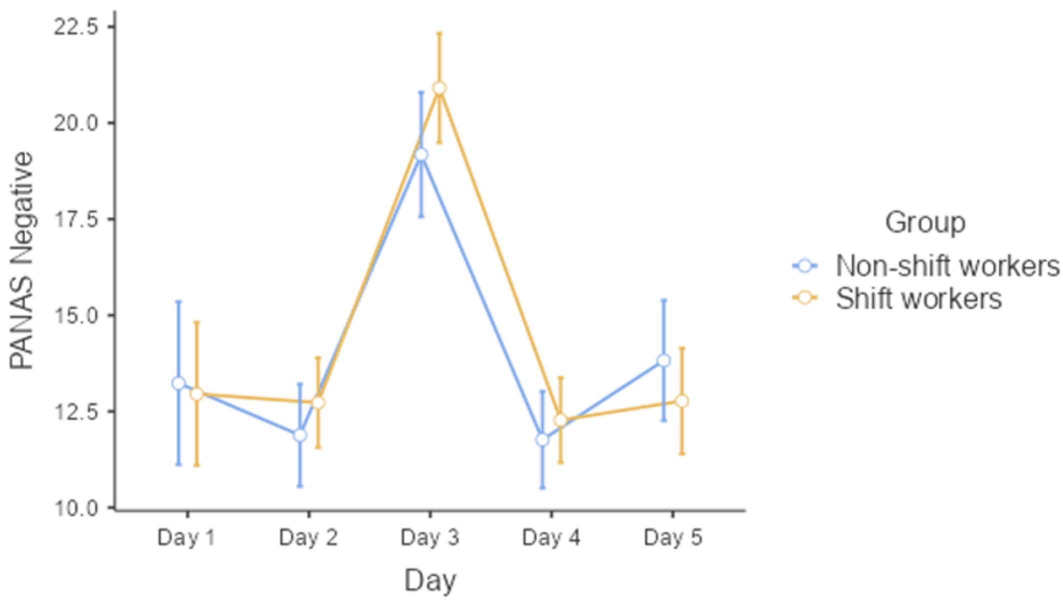


Note: Estimated marginal means for night shift workers and controls for PANAS-SF positive affect across days one to five. Error bars are set at 95% confidence intervals.

For the PANAS negative, Mauchly's test of sphericity was statistically significant, so a Greenhouse-Geisser correction was applied. The ANOVA was not statistically significant $F(3.09, 114.21) = 1.431$, $p = 0.232$, $\eta_p^2 = 0.037$. Figure 8 shows the night shift group experienced a spike in negative affect on day three, aside from this the ratings of affect remained fairly consistent throughout the five days. However, the same pattern was witnessed for the control group. Equivalence testing found that performance was not significantly different between days 1 and 5, $t(21) = -0.186$, $p = .855$. Additionally, the difference between the two time points for the night shift group was significantly smaller than the upper equivalence bound ($t(21) = -2.531$, $p = .010$) and significantly larger than the lower equivalence bound ($t(21) = 2.160$, $p = .021$), which implies that performance between day one and day five on the PANAS for negative affect is statistically equivalent.

Figure 8

PANAS-SF Negative Affect for Night Shift Workers and Controls.



Note: Estimated marginal means for night shift workers and controls for PANAS-SF negative affect across days one to five. Error bars are set at 95% confidence intervals.

4.3 Exploratory Analyses:

The descriptive statistics indicated that there was a trend where night shift workers were feeling worse in terms of well-being and fatigue on day three (first rest day) than day two (sleep deprived). PROMIS fatigue scores ($t(21) = 2.655$, $p = .015$, $d = 0.566$) and PANAS negative affect ($t(21) = 10.798$, $p < .001$, $d = 2.302$) scores were found to be significantly higher on day 3 than on day 2, but PANAS positive affect scores were not significantly different, $t(21) = 1.936$, $p = .066$, $d = 0.413$.

Chapter Five: Discussion

The effects of fatigue and acute prolonged wakefulness have been a popular topic of study for some time. Although the topic of sleep is complex, there is extensive evidence to suggest that there are neurological and psychological consequences to missing a night's sleep (Dula et al., 2001; Lim & Dinges, 2010; Pilcher & Huffcutt, 1996; Rutenfranz et al., 1977). These consequences have been highlighted during research that measures and assesses different aspects of cognitive and mental health function after sleep loss. One such cognitive consequence is an impairment in PM function (Diekelmann et al., 2013; Scullin & McDaniel, 2010). A second widely accepted impairment is a decline in sustained vigilance, attention and reaction time (Belenky et al., 2003). The PVT, a sustained vigilant attention and reaction time task, has become a popular instrument for measuring cognitive deficits after sleep deprivation (Basner & Dinges, 2011; Dorrian et al., 2005). More recently, researchers have begun to examine the relationship between sleep deprivation and psychological well-being. The evidence in this field indicates a possible link between sleep loss and the onset of mental health problems, such as depression (Driesen et al., 2011; Kim et al., 2011; Mayers & Baldwin, 2006).

The central purpose of the current study was to extend the research in the field of shift work, fatigue and well-being by assessing the effects of a single night shift on cognition and mental well-being. The study was unique because it measured a group of night shift workers on measures of prospective memory, sustained vigilance, well-being and fatigue from pre-night shift to three days post-night shift. This research focused on finding evidence to support the ideal number of rest days following a night shift for employees to be rested enough to return to work. Initially, the study focused on airline pilots and flight attendants as these professions work challenging hours with minimum rest and high responsibility. However, due to COVID-19, the availability of shift workers in these industries was limited, and the scope was widened to include night shift workers from all professions. The inclusion of all night shift industries in this research is beneficial as implications of returning to work while still fatigued in all high-risk settings should be taken seriously, as minor accidents in any industry can result in compromised safety.

The objectives of this study were first to assess how a group of sleep-deprived night shift workers responded to both a prospective memory task and vigilance task and to monitor how their scores changed over a period of recovery. Secondly, we aimed to assess whether self-reported fatigue and well-being scores worsened after a night shift and then improved over the period of recovery.

The experiment was conducted by inviting night shift workers to complete a five-day study and then comparing their performance to a control group of day shift workers on the same five-day experiment. The control group was incorporated to show how task performance changed without sleep deprivation. This was to ensure that any improvement in the night shift workers was due to recovery, not increased skill or a practice effect.

Research suggests that it could take up to three nights of sleep for shift workers to recover from cognitive and emotional effects accrued from a night of sleep deprivation (Akerstedt et al., 2000; Blasche et al., 2017; Kecklund & Akerstedt, 1995; Knauth et al., 1978). To provide evidence for this in the current study, we expected to see two main patterns across all measured domains. Firstly we expected to see a down-up quadratic trend from day one (pre-night shift) to day five (the third rest day) in PM, PVT, PANAS and PROMIS daily fatigue performance. That is, a rapid decrease in performance from day one to day two, followed by a recovery of scores across days three to five, while scores in the control group remained relatively constant aside from a gradual improvement if skill level increased. Secondly, we expected that performance on day five would be no different from performance pre-night shift on day one.

The Einstein and McDaniel PM paradigm (1990) was used to measure prospective memory function; secondly, the PVT (Dinges & Powell., 1985) measured sustained vigilance. Alongside this, the Positive and Negative Affect Scale (PANAS) and the Patient-Reported Outcomes Measurement Information System (PROMIS) daily fatigue short form were used to measure well-being and self-reported fatigue. The evidence was gathered to ascertain how many rest days should be rostered to enable adequate recovery. This information could then contribute to the knowledge of fatigue hazards and proper rest within the workplace.

The individuals invited to make up the study population of this research were shift workers whose schedules included night shifts. These individuals were eligible if they had three consecutive days off after a night shift to complete the recovery portion of the experiment. Employees with three days off after a night shift are hard to find, which made recruiting participants that fit these criteria challenging. Nevertheless, this highlights the laborious work in the shift work industry and further emphasises why more research is needed. The control group consisted of individuals not currently employed in night shift work. In this chapter, the findings and implications of the research will be discussed, the limitations of the research will be acknowledged, and recommendations for further research will be suggested.

5.1 Findings From The Study

The results from the study demonstrated mixed findings across the domains measured. The PM task displayed increased performance for target hits across the five days of the experiment and improved performance in false alarm errors across the five days for both groups, which may have been the result of a practice effect. For the night shift group, reaction time for responding to targets increased on day two when participants were sleep-deprived and began decreasing on days three and four. At face value this could look like sleep deprivation had an effect on vigilance. However, the same pattern appeared in the control group. The analyses did not find any significant evidence to support the hypothesis that PM performance was impacted by sleep deprivation in the night shift group. As such, no clear pattern or period of recovery time was identified. The lack of findings may be because the PM task was not a sensitive enough tool for measuring the cognitive impacts of sleep deprivation in individuals.

The PVT results showed a very similar pattern for the night shift group and the control group for the first three days of the experiment, after which reaction time decreased for the night shift group and increased for the control group. Increases or decreases in reaction time could be due to a practice effect, or participants getting bored with the task and not maintaining attention. False alarm performance was reasonably stable throughout the five days; the only increase was noted for the control group on day two. As such, no quadratic pattern in performance was found across the five days for the night shift group in the PVT, and no evidence suggests that sleep deprivation affected sustained vigilance. Again, the analyses could not support the hypothesis that three days of rest is required to replenish sustained vigilance.

The self-report PROMIS daily fatigue diary recorded fatigue scores increasing from baseline to day three (the first rest day), where they peaked. The scores then gradually returned to baseline by day five (the third rest day), displaying an inverted 'U' shape in the graph. The quadratic trend analysis conducted on the night shift group for the main effect of 'day' was statistically significant. In contrast, the control group's scores remained relatively consistent throughout the five days. These results indicate that feelings of fatigue in the night shift group increased after returning home from work and continued to increase until they were feeling most fatigued on their first rest day. In many occupations, it would be expected that shift workers would be back at work on this day. The scores indicate that the participants had returned to their baseline fatigue scores by day five. However, equivalence testing could not support the hypothesis that scores on day five are no different from those on day one as the fatigue scores had improved further than baseline.

The results from the self-report PANAS-SF questionnaire illustrated that the night shift group experienced a drop in positive affect compared to day one, after returning home from work on day two. Positive affect then gradually improved over the following three days. The quadratic trend analysis that was conducted was statistically significant, supporting the hypothesis that shift workers' scores would display a 'U' shaped pattern as their positive affect declined after a night shift and then improved over the following three rest days. Equivalence testing demonstrated that scores were statistically equivalent on days five and one, supporting the second hypothesis that full recovery of affect (well-being) would occur on the third day of rest following a night shift. However, this finding is contradicted by the fact that the graphs show the control group displaying a similar pattern of results across the five days. It was not possible during the study to monitor every daily experience that could have affected the mood of a shift worker or a non-shift worker and we do not know what negative or positive things happened to each participant during the study. As such, due to the pattern of results being so similar in both groups it cannot be inferred that the quadratic pattern of positive affect found in the night shift group was due to sleep deprivation and not another unknown variable.

The PANAS-SF for negative affect showed again that the night group and control group rated themselves similarly. Scores in both groups were relatively consistent across the five days, with a spike in negative affect for the night shift group on day two and a spike in negative affect for the control group on day three. Again, it would be easy to assume that the night shift group had an overall increase in negative affect on day two because they were suffering from effects of sleep deprivation but there is no way of knowing why the control group experienced a sudden increase in negative affect on day three which makes the claim that sleep deprivation is causing the spike in night shift workers less plausible. The trend analysis on the night shift group found that no quadratic trend was present, and equivalence testing confirmed that scores were equal to day one on day five, verifying that they did not vary a lot throughout the experiment (aside from the sudden spike). As such, the hypothesis that affect (well-being) would decline and then steadily recover over the three days following a night shift was not supported.

5.2 Exploratory Analyses

5.2.1 Prospective Memory Failures:

Although there was no evidence found that suggested that the night shift workers were suffering from lapses in prospective memory after a night of sleep loss, a consideration is that the night shift workers that were suffering from the most extreme prospective memory lapses forgot to complete day two of the experiment. Remembering to sign on and do the experiment is an example of prospective memory on its own. After examining the data, it was found that 93.3% of the day shift workers remembered to sign on and complete day two, while only 78.12% of night shift workers signed in on day two. Appendix H contains a graph showing dropout rates between the two groups over the five days of the study.

5.2.1 Fatigue and Affect on Day Three

The findings indicate that shift workers are experiencing lower emotions and more fatigue on their first rest day compared to how they feel when they get home from a night shift, as the results found significant differences in PANAS negative affect and the PROMIS fatigue diary between days three and two. This could be due to night shift workers experiencing a rise in body temperature when they return home in the daylight hours, which may be naturally decreasing their drive for sleep and feelings of fatigue. Negative affect may also be low as workers are pleased to have finished their night shift and be home. These feelings of tiredness and negative affect may not come on until the following day as they try to retrain back to the normal day but remain in a state of sleep deprivation. This could have implications for workers who would typically be back at work on this day or are working consecutive night shifts. More research in this area may find evidence as to whether there are long-term effects on well-being after working consecutive night shifts.

5.2.2 Factors that Influenced Recovery

There was a question as to whether any confounding variables may have affected how quickly an individual was able to recover from a night shift, such as day sleeping or a rotating shift system over permanent night shifts. The question also went in the other direction, for example, whether there were any factors slowing recovery, such as having a partner or a dependent child at home. Although this information was obtained during data collection, the small number of participants meant that analyses on these variables would not be meaningful. Further research in this area could be beneficial.

5.3 Study Limitations

There may have been limitations to the current study which introduced weaknesses and could have contributed to the outcome of the research.

5.3.1 Sensitivity of Measures

The instruments chosen to measure the impacts of sleep deprivation in this study were an adaptation of McDaniel and Einstein's (1990) PM paradigm, a five-minute version of the PVT (Dinges & Powell, 1985) the PANAS-SF (Watson et al., 1988) and an adapted version of the PROMIS daily fatigue scale (PROMIS, 2016; Christodoulou et al., 2014). Of these measures, the PM paradigm and the PVT failed to detect any significant changes in cognition throughout the five days. This finding is at odds with other research, which has displayed decrements in performance in the PVT (Basner & Dinges, 2011) and PM tasks (Grundgeiger et al., 2013) after periods of sleep deprivation.

The lack of a relationship in this study between sleep deprivation and these traditional measures of cognitive performance could have been due to the adapted measures being neither sensitive enough nor used effectively. Secondly, there is the possibility that they were not long enough to detect the decrements they were measuring. As mentioned above, similar studies to the present research have found correlations between sleep deprivation and a decline in PM performance.

Grundeiger et al. (2013) compared non-sleep deprived and sleep-deprived participants on McDaniel and Einstein's (1990) PM paradigm and found that the sleep-deprived participants performed significantly worse than the non-sleep deprived individuals. However, the study had stricter criteria for what was classed as sleep deprivation than the present research. Grundeiger et al. (2013) constantly monitored participants under laboratory conditions to ensure they had 25 hours of sleep deprivation. In contrast, the current study utilised a range of shift workers returning home from a night shift where sleep deprivation varied from person to person.

Another study conducted by Esposito et al. (2015) also found a significant relationship between sleep deprivation and compromised performance on a PM task. The research was similar to the current study in that it compared a non-sleep-deprived control group and a sleep-deprived experimental group in measures of cognitive performance. The study differed in some of the measures used, which could explain why this study found evidence to support the hypothesis while the current study did not. The PM measure was a time-based PM task conducted under laboratory conditions and administered to a group of participants suffering from 24-hours of sleep deprivation. The current study used an event-based PM task under online conditions on a group of participants that did not have an equal number of sleep-deprived hours. Research suggests that time-based prospective memory tasks are more cognitively demanding than event-based prospective memory tasks (Einstein et al., 1995) and thus may yield a higher level of sensitivity when measuring cognitive deficits from sleep deprivation. This is thought to be because time-based tasks are more cognitively demanding in self-initiated retrieval (Einstein et al., 1995).

Further, concerns have been raised that online experiment conditions may produce poorer quality data compared to a controlled laboratory environment. This could be because the participants are not as motivated or pay as much attention as they would if they were in laboratory conditions

(Chandler et al., 2014). Finally, when participants are completing experiments online, they can take photographs of the target stimuli to assist in remembering and thus could perform better.

5.3.2 Self Report Scales

As discussed in the introduction, fatigue is a complex construct to measure. In the current study, some effects of fatigue were measured using self-report questionnaires. However, research suggests that when sleep deprivation is prolonged, self-ratings of sleepiness can be rated lower than they actually may be. A study by van Dongen et al. (2003) assessed the effects of sleep deprivation using a combination of self-report, behavioural and medical monitoring on a total sleep deprivation group and a chronic sleep restriction group. Their results found that participants who had their sleep restricted to four or six hours or less each night for 14 days displayed performance-based cognitive deficits equal to those who had not slept at all for one or two days. However, when their ratings of tiredness were assessed using self-report sleepiness scales (Stanford Sleepiness Scale and Karolinska Sleepiness Scale), the ratings of participants in the sleep restriction group spanned one unit on the scale, while the total sleep deprivation group spanned two units. This made the profile of subjective sleepiness almost linear for the total sleep deprivation group, while the curvature for the sleep restriction group was close to horizontal and lower on the scale, suggesting that these participants were only rating themselves as ‘slightly sleepy’. The authors suggested that chronic sleep restriction may lead to feelings of adaptation when actual cognitive performance has declined, meaning that individuals may have an impaired ability to reliably assess their fatigue level. In the current study while the self-report scales that were used were different to the scales used in van Dongen’s (2003) study, if the theory of adapting to sleep deprivation is correct there is a chance that this could have impacted the self-report scores taken and recorded a lower than an accurate measure of fatigue in the participants. This could be especially relevant in the shift workers that often work night shifts if they are used to the feeling of being tired.

5.3.3 Number of Participants

A significant shortcoming of this study was the low number of participants that completed the five days of the experiment. The target number of participants calculated for this study to yield significant and reliable results was 100 individuals. During the study, 142 participants signed up to participate in the research. However, the actual number of individuals that completed all five days was 39. Other research that has found a relationship between sleep deprivation and PM, sleep deprivation and sustained vigilance or sleep deprivation and well-being has often had a higher participation rate. Scullin and McDaniel (2010) found a relationship between sleep delays (administering the delay with sleep) and improved prospective memory performance with a participant number of N=121. Fabbri et al. (2014) found a positive sleep effect on prospective memory with a participant number of N=254. Basner et al. (2011) found they were able to reliably assess fatigue-related changes in vigilance using a PVT with a participant number of N=74, and Akerstedt and Torsvall's (1978) longitudinal study found an association between the abolition of night shift work and improved well-being in a data set of N=400 shift workers.

A possible reason for the lack of engagement from the study population of this research was the presence of COVID-19, a pandemic that began at the start of 2020 and continued throughout the research. The pandemic forced the world into an era of lockdowns, sickness, travel bans, job losses and uncertainty. One of the industry's most severely impacted by the pandemic was the aviation industry. The virus acted as a catalyst that sent the aviation world into a decline. The demand for international and domestic travel completely dropped off, resulting in many job losses and well-being issues for those involved. This research initially planned to focus on aviation crew; however, after a large proportion of the participants were terminated from their place of work, they could no longer participate in the night shift group. The workplace culture had changed for those remaining, and a new culture of caution had emerged. Many crew expressed that they no longer felt comfortable completing research that they felt could potentially expose a degree of incompetency and preferred not to be involved in the research.

Following the initial impact of COVID-19, a second phase of recruiting began, and the potential study population was widened to include a variety of night shift workers from all industries. This helped increase the number of sign-ups, but as other industries were also heavily affected by COVID-19, there was still a lack of engagement which has been attributed to stress in the workplace, worry of job loss and a focus on the pandemic over other things.

5.3.4 Covid-19 Pandemic Effects

The COVID-19 pandemic may have also caused limitations in other areas of the study aside from the recruitment challenges. As mentioned above, occupations outside of airline crew were included in the study to help increase participation. The inclusion of the other occupations may have introduced another variable that was not able to be controlled. Research suggests that aircrew may take longer to recover from shifts than other individuals engaged in night shift work due to "too much adjustment of the biological clock" (Akerstedt et al., 2000). The suggested increase in recovery time is because international flight crew are constantly changing time zones and beginning the readjustment phase before returning home again. In ideal conditions, the night shift group could have remained a static group of only international flight crew which would have helped to control this limitation. However, current conditions did not allow it.

The other limitation involving COVID-19 is that well-being scores may have been influenced by factors other than sleep deprivation. The pandemic has been a dynamic and changing environment that was impossible to control for within the study. For some of the population, job losses due to business closures were possible, creating an unprecedented level of stress (Bhattacharjee & Acharya, 2020). For some employees working from home was an option which gave job security and helped to avoid getting sick. However, many shift workers had no option to work from home or participate in lockdowns as their jobs involved working on the frontline. This may have increased pressure on these workers who had to keep going to work, causing stress and worry about going to the workplace or resentment toward other workers who got to stay home (Sumner & Kinsella, 2021). Shift workers such as nurses and doctors who continued going to work may have also felt ostracized by their household bubbles and friends as others wanted to avoid them (Taylor et al., 2020). Additionally, research conducted on a group of nurses during the pandemic found that they experienced worse sleep than usual, experienced psychological problems, worked more hours than they usually would per week and often skipped their breaks (Sagherian et al., 2020).

5.3.5 Differences in Shift Patterns

This study included participants that were on permanent night rosters, as well as participants that worked rotating day and night shifts. Research suggests that those on permanent night shifts sleep better throughout the day (Akerstedt & Wright, 2009) than participants who only work rotating night shifts. If the permanent night shift workers were more rested, they might have had an advantage during the tasks in the study, thereby making their recovery period shorter than those who work rotating shifts.

5.3.6 Task Difficulty Fluctuations

The PM task involves a trivia quiz and a target-identifying task. During the trivia quiz, patterned backgrounds appear behind the quiz questions, and the participant must identify the target background from six different backgrounds instead of answering the quiz question. On day one of the study, this task may be more complicated than on future days because the backgrounds have never been seen before, and the participant may not fully realise that they are picking the background out of a series of backgrounds that are all very similar. By day two, the participant knows it is hard to remember the background and may rehearse the image more than they did the first time, improving their performance. It may also help that they have seen all the different backgrounds by day two, and due to retrospective memory, they might be better at recognising and storing the target. This may have been the reason for the target hits gradually increasing for both groups in the current study.

5.3.7 Delay in Starting Day Two

To record day one, shift workers must have been absent from night shift work five days before beginning the experiment. Additionally, day two was to be completed on a day followed by three days off. Potential participants with five days scheduled in this pattern were challenging to find, so it was decided that days one and two would not have to be completed consecutively. This meant that participants could complete their day one baseline measure when they had been absent from night shift work for five days and then come back to complete day two when they had a night shift that was followed by three days off. Comparatively, the control group were asked to complete the five days consecutively. The different rules about when participants could start day two meant that some of the individuals in the night shift group ended up completing day one and day two as much as 28 days apart, while others in the night shift group did it one or two days after. This could have implications for performance on the day two tasks because if a practice effect does exist, the participants who experienced a delay in starting day two may have had a disadvantage compared to those who completed it on the day following day one.

5.4 Implications and Recommendations

5.4.1 Most Tired Day

The fatigue and wellbeing scores recorded on the self-report scales on day three of the study indicate a high level of fatigue and a low level of wellbeing is being experienced by these workers even after having one night of sleep back at home. This would suggest that they are feeling worse on their first day off than they did when they arrived home after working all night. This finding suggests that employees that are rostered back to work even after one day and night of recovery still feel substantially impacted by the fatigue they incurred on their last night shift. However, this cannot be accurately claimed without further research.

5.4.2 Long Term Effects of Night Shift Work

The long-term effects of shift work and whether they could be sustained post-retirement is not well understood (Akerstedt & Wright, 2009). Research in this area has identified several adverse health issues that correlate with long-term circadian rhythm disrupting shift work. Some of these health issues are cancer (Hansen, 2017; Papantoniou et al., 2018), cardiovascular disease (Akerstedt et al., 1984; Torquati, 2018), diabetes (Monk & Buysse, 2013) as well as long-term sleeping difficulties (Drake & Wright, 2011; Jehan et al., 2017). Of the shift workers in the current study, 73% have been working night shifts for four or more years. Research that compares experienced and inexperienced shift workers on cognitive deficits or coping mechanisms of shift work is limited. The existing literature suggests that experienced shift workers may have a greater range of strategies for taking care of themselves post-night shifts, which may aid in recovery (Gifkins et al., 2018) and thus could improve cognitive performance. Contrary to this, other research suggests that the longer individuals are engaged in shift work, the higher the impairments in cognitive performance. A study by Cho et al. (2000) compared cabin crew that had been employed for four years or above with crew who had worked three or less years found that the more experienced crew displayed weaker cognitive performance in tests of working memory and reaction time. The authors suggest that this could be due to prolonged cortisol exposure, which they found to be higher in aircrew undergoing frequent time zone changes than ground crew who were not. Another study by Rouch et al. (2005) found that male shift workers displayed a decrease in memory performance as years of shift work increased. The study compared a group of workers who had worked in shift work for one to four years and a group that had worked for 10 to 20 years on memory tests involving immediate free recall. The results indicated that performance was worse in the participants who had worked longer in shift work and had no interaction with age. Their study also considered the long-term effects, if any, once an employee had retired from shift work. The results found that after a four-year delay from shift work, some participants' memory scores improved. This finding suggests that the effects of shift work might be reversible under some conditions. Future research should investigate why some individuals can maintain adequate cognitive performance in the absence of sleep while others cannot and consider whether this could be due to the number of years of shift work employment or developed compensation strategies.

5.4.3 Adequate Days of Following a Night Shift

This research could not find significant evidence to support the claim that three days' rest should be provided to shift workers after completing a night shift. However, this could be due to the study's previously discussed limitations. Similar research to the present study has found evidence to support the view that sleep deprivation does impair both PM and sustained vigilance performance. To re-cap, Grundgeiger et al. (2013) had a consistent dosage of sleep deprivation (25 hrs) under laboratory conditions given to each participant in the sleep deprivation condition. Esposito et al. (2015) used a time-based prospective memory task under laboratory conditions which have been suggested to be more sensitive to detecting impairments in cognitive performance (Einstein et al., 1995). Furthermore, both of the above experiments were conducted in laboratory conditions, while the present study was conducted online. Research suggests that online conditions may not yield as high-quality data as laboratory conditions (Chandler et al., 2014). These examples and the other limitations discussed could be why no significant associations were found between sleep deprivation and cognitive impairment.

The question of how many rest days companies should provide their staff to recover from a night of sleep deprivation remains a valid concern, and further research that addresses the current study's limitations could be useful.

5.4.4 Extra Checks in the Workplace

Although this study was not able to conclude that PM errors occur more frequently while experiencing feelings of fatigue, many other studies have found links between PM lapses/sustained vigilance detriments and sleep loss (Diekelmann et al., 2013; Esposito et al., 2015; Grundgeiger et al., 2013; Hansen, 2019; Neri et al., 2002; Scullin & McDaniel, 2010; van Dongen & Dinges, 2005). This research, as well as the current study highlighting that feelings of fatigue are at their highest on the day following a night shift, is enough reason for workplaces and individuals to take caution. Workplaces that employ staff to work back-to-back nights should consider including extra safety measures in daily tasks. Extra safety measures should come in the form of distinctive external cues (Dismukes, 2012), checklists (Guwande, 2010), reminders (McDaniel & Einstein, 1990) and a second person to check over their work (Douglass et al., 2018).

5.5 Conclusion

In conclusion, this research project aimed to find evidence to support the notion that night shift workers should be rostered adequate rest, allowing them to fully recover following a night shift. Specifically, it looked to see whether three days of rest would be enough time for shift workers' scores in PM, sustained vigilance, self-reported fatigue and self-reported well-being (affect) to recover to their pre-night shift scores. The study's results had varied findings based on the domain that was tested. Self-reported fatigue levels increased on day two when the night shift workers were deprived of sleep, peaked on their first rest day and returned to baseline levels on their third rest day. These findings were in line with the hypothesis that a 'U' shaped pattern of decline and recovery would occur over the five days and supported the notion that two to three rest days should be provided post-night shift. Ratings of positive and negative affect showed that the night shift workers experienced a drop in positive affect immediately after a night shift (day two) and a sudden increase in negative affect on their first rest day (day three). Positive affect followed a 'U' pattern of recovery, supporting the hypothesis that it would take three days for a decrease in well-being to recover from a night shift. However, similar findings in the control group mean that it cannot be inferred that the changes in positive affect were due to sleep loss and subsequent rest. There were no significant findings in PM performance and PVT performance; therefore, the hypothesis that sleep loss would result in a drop in cognitive performance followed by a gradual three-day recovery to baseline function could not be supported. These results illustrate a possible contradiction between feelings and cognitive performance. While the shift workers experienced a pattern of increased fatigue followed by recovery and a drop in positive affect followed by recovery, their cognitive performance did not move in the same pattern. This could suggest that fatigue does not impair cognitive performance, that the measures were not sensitive enough or that some shift workers can compensate and adapt to feelings of tiredness that allow them to function adequately on laboratory-style tests of cognition.

Based on the study's results, there is an indication that two to three days could be scheduled as set days off following a night shift to allow for recovery in feelings of fatigue and positive affect. Regarding cognition, there is no evidence provided in this study to support the notion that PM or sustained vigilance is affected by a night of sleep loss; therefore, no number of days can be suggested for recovery, and future research is encouraged.

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Appendices

Appendix A: Email to Employers

To the Employer or Company that this may concern,

My name is Lucy Hudson, I am a student at Massey University doing my masters year in psychology. I am currently searching for individuals who might be interested in taking part in my research.

My study is looking at individuals who stay up for one full night without sleep (night shift workers) and then looking at how long it takes for the body to recover from that night of sleep deprivation.

I am also looking for a control group of workers who do not work nights at all.

The research is all done on a website so it can be done in their personal time. However to be eligible the individual must have an opportunity within the next 1 to 2 months where they have a night shift, followed by three consecutive days off – or two consecutive days but with enough time to complete day 3 before work starts. (This is so they can complete the online game and questionnaires daily without their work impacting their fatigue). The experiment days around 20 minutes each day, for 5 days.

If you are participating in the control group, to be eligible you just need to be getting full night sleeps (7-9 hours) every night during the experiment.

The outline of the research is as follows:
1. When the individuals have not just worked a night shift they will sign into the website and play a trivia game, then a reaction time task followed by some questionnaires about their general wellbeing. This will collect baseline measures.

2. When the individuals have completed a night shift, as soon as they are home they will sign into the website and repeat the same task.

3. On the first of their three days off they will again sign into the website and again complete the same task

4. Same again on their second day off.

5. And finally same again on their third day off (or before work on the third day).

For the control group, the 5 days should just be completed consecutively.

I am also offering a small token of appreciation for participating in the study which will be a $20 voucher emailed to each participant.

If this is something that you think any of your employees would be interested in, or if you have any questions please get in touch.

At this stage I am collecting email addresses from individuals who are interested via this sign up link:

https://psychlab.massey.ac.nz/lucy3/signup.html

From here I will individually contact potential participants with more information or to answer any questions they have.

Thank you for your time,

Kind Regards
Lucy Hudson

Appendix B. Study Information Sheet

Will night shift workers ratings of well-being and performance on prospective memory tasks return to baseline after three nights rest?

INFORMATION SHEET

Introduction:
Thank you for your interest in my project. My name is Lucy Hudson, and I am undertaking this project as part of my Master of Science degree in Psychology, at Massey University. I am being supervised by Dr. Stephen Hill from Massey University in Palmerston North.

Project Description:
This research is aiming to discover how many rest days are required after working a night shift. We are looking to see how many local night's sleep, and days away from work an individual requires in order to be fully restored in terms of their wellbeing, and their cognition. I invite you to take part in this research (if after reading the information sheet you feel that it is something you are interested in). Please note, if you do decide to enroll in the study and at a later date you would like to leave the study you are welcome to do so without giving me any justification.

Recruitment:
Recruitment will be done via word of mouth, and via contacting companies who have employees working night shifts.

Selection Criteria:

- In order to participate in the experiment, you need to currently be working a job where you are always, or sometimes rostered a night shift.
- Following this night shift, you will need three days off work, for many of you this may mean that you will need to do the experiment prior to having rostered days off, or a vacation.
- I am also looking to recruit a group of individuals who do not work night shifts to participate as controls for the study. These individuals will need to be getting an average of 8 hours sleep every night to be eligible.
- As the experiment involves some reading of basic English, you will need to be fluent in reading English Language.
- You will need to have access to a computer as the trial and questionnaires are completed online.
- You cannot be taking any medication that effects your ability to concentrate.
- You cannot be under the influence of alcohol or drugs while participating in the study.
- You cannot be suffering from any jetlag or other sleep condition while participating in the study.

I am aiming to recruit 120 participants for the experiment, the reason for this is to get enough data to be able to draw an accurate as possible conclusion from the data.

Recognition of your time:
As recognition for your valuable time, after completing the experiment you will receive a small voucher via email.
Risks to participants as a result of participation:
There are no risks to you as a result of participating in this research, however as you are working a night shift and potentially driving home to complete the experiment I ask that you maintain caution when driving after completing a night shift, take every measure to ensure you are fit to drive, and do not feel any obligation to hurry home to complete the task if you need to take time to sleep or rest first.

Project Procedure:
The experiment is in five parts over five days.

Part One (day one) of the experiment will record your baseline level of wellbeing and fatigue, so we ask that you complete this when you have not worked a night shift for at least four days and are feeling like your normal self. This will be done in your own home, on your own computer in a quiet area where you can concentrate.

Part two (day two) will need to be completed when you return home from your night shift). Also completed at home on your own computer,

Parts three through to five (days three to five) will need to be completed over the following three days after your night shift, at home on your own computer.

I ask if you could please attempt to complete each part at around the same time every day, not too long after you have woken up - for example, 10am every day. However please ensure you have given yourself time to wake fully before starting the experiment.

Format of the experiment:
On each day you will visit a website, enter your unique code and begin the experiment. The computer will know which day you are up to, so it will direct you to the correct part.

The first part of the experiment will require you to carefully follow the instructions and complete a general knowledge/trivia quiz. The second part will be two questionnaire's which will ask you about your mood and your fatigue levels. Finally, there will be a reaction time test.

Data Management:
The data I collect from you will be analysed to look for patterns that show whether there is a trend in the number of days of rest a shift worker requires after working through the night. I will collect and download the data from the experiment and it will be kept in my locked computer, with your subject number as the only identifier. Your name paired with your subject number will only be accessible by me, which I will retain to ensure I can remove your data from the experiment if you wish to no longer be involved. None of your personal details will be published in the thesis. Following the completion of the experiment the grouped results will be published, and available through Massey university or through myself. I will personally contact each participant at the end of the study to share with them the general findings of the research.

Participants Rights:

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- *decline to answer any particular question;*
- *withdraw from the study (specify timeframe);*
- *ask any questions about the study at any time during participation;*
- *provide information on the understanding that your name will not be used unless you give permission to the researcher*
- *be given access to a summary of the project findings when it is concluded*

Project Contacts:

If you have any questions at all, please do not hesitate to get in contact with me via my email [redacted] or my phone number [redacted] / [redacted]

If you would like to contact my supervisor with any questions or queries, his contact details are below.

Dr. Stephen Hill, phD, MA, BA
Phone: +64 (06) 356 9099 ext 85083
Email: S.R.Hill@massey.ac.nz

Committee Approval Statement:

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 19/56. If you have any concerns about the conduct of this research, please contact Dr Negar Partow, Chair, Massey University Human Ethics Committee: Southern A, telephone 04 801 5799 x 63363, email humanethicsoutha@massey.ac.nz.

Appendix C. Enrolment information

Recovering from a night shift

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What is the experiment about?

Thanks for taking the time to participate in my experiment! As you will hopefully know by now this research is aiming to discover how many rest days are required after working a night shift. We are looking to see how many local night's sleep, and days away from work an individual requires in order to be fully restored in terms of their wellbeing, and their cognition.

The experiment is made up of two parts, the first part is looking at your cognition. It will involve completing a trivia quiz, and a vigilance test. The second part is looking at your wellbeing and I will be giving you two questionnaires which will ask questions about your mood, and your fatigue levels.

Can I do the experiment?

In order to participate in the experiment as a **night shift worker**, you **need** to be currently working a job where you are either always or sometimes required to work a **night shift**. For this experiment a night shift is defined as "time spent at work during the night, where you are unable sleep, that lasts at least 7 hours and takes up the majority of your night." The experiment will ask you further questions on the next page to clarify your shift – however please read the following examples to determine whether you are a suitable candidate or not.

Suitable: You begin work in the evening, or later at night and do not finish your shift until sunrise or just prior to sunrise.

Not suitable: You begin work in the late afternoon and finish by midnight.

In the second example you finish work with time to still get some sleep during the night, so you would not be suitable for this experiment.

It's normal practice for some occupations to be able to take a break during their night shift. During this break some people are able to sleep. To be eligible to participate in the experiment you can not have had more than 3 hours of sleep or rest during your night shift. You will be asked on day two of the experiment to record how much sleep you had during your night shift. It's important that you record to the best of your ability how much of this break was spent fully asleep.

You will also need to have *three days* off work after your night shift.

To participate as a **day worker** you **cannot** be a worker who ever works during the night, you must get a full night's sleep (7-9 hours) every night and not be recovering from any jet lag.

Next

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When do I do this experiment?

This experiment lasts for a duration of **five** days.

Night Shift Worker

Day One: This should be completed when you are feeling your best. This will record your baseline levels, so it needs to be done when you are not fatigued. We ask that you complete this after having **4 days of *full 8-hour night time sleeps.***

Day Two: This should be completed as soon as you get home from your night shift.

Day Three: This should be completed on rest day one.

Day Four: This should be completed on rest day two.

Day Five: This should be completed on rest day three.

We ask that you do your best to complete this at the same time of the day each day. During these three days you need to be resting and aiming to get 8 hours sleep each night. *Please try to refrain from doing anything that may impact your ability to recover physically and mentally.*

Day Worker

Day One: This can be completed on any day that you have had a full 8 hour sleep and are feeling good and well rested, and have had at least 4 full night sleeps prior to this day.

Day Two: This should be completed the following day.

Day Three: This should be completed the next day.

Day Four: This should be completed the next day.

Day Five: This should be completed on the final day.

We ask that you do your best to complete this at the same time of the day each day. During these five days you need to be resting and aiming to get 8 hours sleep each night. *Please try to refrain from doing anything that may impact your ability to recover physically and mentally.*

Final Details about the experiment:

- Each day of the experiment will take approximately 20-30 minutes to complete.
- The task requires you to use a keyboard so please ensure that you are using a device with one.
- Please remember to do this task somewhere that you can focus without interruptions.
- You should not consume any alcohol in excess during the period of the experiment.
- You should not be taking any medication that will affect your alertness or concentration.
- You should not have consumed any coffee or alcohol in the past 5 hours before doing the experiment - the only exception to this is for night shift workers during their night shift or night shift workers before driving home from a night shift.
- Night shift workers are permitted to have a nap before safely driving themselves home if this is what they normally do.
- Give yourself time to wake up naturally before starting the experiment each day.
- Please try to do the task at the same time every day (except for day 2 - the one directly after your night shift).
- Please complete day 2 as soon as you finish or arrive home from your night shift.
- You should be fluent in English to complete the experiment.
- You should not have any diagnosed or suspected sleep disorder.
- You should not be suffering from any jet-lag while completing the experiment.
- You cannot have more than 3 hours rest during your night shift if you are a night shift worker.
- You cannot be working during your three rest days (if you are in the night shift worker condition).
- If for any reason you do not wish to continue with the experiment, please let me know so I can take you off the reminder email list.

Click the button below to proceed to the consent form.

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Night shift worker

Please indicate below if you are or are not a night shift worker:

- ○ I work night shifts
- ○ I do **not** work night shifts

Consent

If you are willing to participate in this research, please check the boxes below confirming that you understand and agree with each statement and then click the button below.

- ☐ I confirm that I have read and understand the experiment information page for this study, and I have had the opportunity to ask any questions which have since been answered fully.
- ☐ I understand that my participation is voluntary, and I am free to withdraw at any time without giving any reason.
- ☐ I understand that the results from the questionnaires and cognition tasks will be looked at and analysed by the researchers and published as a thesis which will be available through Massey University. My specific personal information including my name and the company I work for will be kept anonymous.
- ☐ I agree to take part in the above study.

Confirm Consent

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Day One

Welcome to **Day One** of the experiment. You should be completing this day when you are feeling your best.

Have you had **5** *days of full 8-hour night time sleeps?* ○Yes ○No

(You must be able to answer yes to proceed with this experiment)

Was this because you have been away from work for the previous 4 days? ○

Was this because you have been on day shifts for the previous 4 days? ○

Was this because you have had a mixture of days off and day shifts for the previous 4 days? ○

Demographic Information

Are you: ○ Male ○ Female ○ Identify as neither of the above

Age: [ ]

Do you have a partner at home? ○ Yes ○ No

Do you have any dependent children at home? ○ Yes ○ No

How many years have you been doing shift work for? [ ]

Your Shifts: ○ I only ever work night shifts ○ I work a mixture of day and night shifts

What is the nature of your work? (Optional Question) ○ Security ○ Aviation ○ Hospital ○ Emergency Response ○ Food and Beverage ○ Other

Do you take sleep aids to help you fall asleep at night, even when you have not been doing night shift work? ○ Yes ○ No

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Appendix D. Multi-Choice Quiz Questions for the Prospective Memory Game

Prospective Memory Game:

General knowledge/trivia quiz
Background changes with each question, when you see this background show up you need to press the button, when a question is asked about an animal you need to press this button.

First Day:
1. Who invented the telephone
a) Thomas Edison
b) **Alexander Bell**
c) Albert Einstein
d) Nikola Tesla

2. When did the first world war start?
a) 1912
b) 1913
c) **1914**
d) 1915

3. Where is the smallest bone in the human body?
a) **ear**
b) small toe
c) nose
d) palm

4. Which is the only mammal that can't jump?
a) **elephant**
b) giraffe
c) hippopotamus
d) cow

5. Who painted the Mona Lisa?
a) Pablo Picasso
b) Vincent Van Gogh
c) Michelangelo
d) **Leonardo Da Vinci**

6. What is the name of the big clock in London?
a) big bob
b) **Big Ben**
c) tall tom
d) big bon

7. Which is the largest ocean?
a) Atlantic

b) **Pacific**
c) Indian
d) Arctic

8. How many squares are there on a chess board?
a) 67
b) **64**
c) 68
d) 62

9. How many prongs are there on a fork?
a) 7
b) 6
c) 5
d) **4**

10. What currency is used in Japan?
a) Japanese dollar
b) Japanese yuan
c) Japanese rupiah
d) **Japanese yen**

11. Which two colours make purple?
a) green and orange
b) **blue and red**
c) yellow and pink
d) brown and red

12. Which singers real name is Stefani Joanne Angelina Germanotta?
a) Pink
b) Lorde
c) Cher
d) **Lady Gaga**

13. In Fahrenheit what temperature does water freeze?
a) 0
b) -32
c) **+32**
d) +50

14. What is Chandlers last name in the TV show “Friends”
a) Binn
b) **Bing**
c) Brinn
d) Bling

15. The Statue of Liberty was given to the US from which country?
a) **France**
b) Germany
c) England

d) Australia

16. What city is the capital of Australia?
a) Sydney
b) **Canberra**
c) Melbourne
d) Perth

17. Which of these planets is closest to the sun?
a) **Mercury**
b) Venus
c) Neptune
d) Mars

18. What is the chemical symbol for iron?
a) Ir.
b) In.
c) Oi.
d) **Fe**.

19. Which city has the largest population?
a) Shanghai
b) **Tokyo**
c) Delhi
d) Mexico City

20. Which fruit is the US state of Georgia famous for?
a) **Peach**
b) Plum
c) Apple
d) Apricot

21. What is a baby whale known as?
a) Cub
b) Whalin
c) **Calf**
d) Pup

22. What make was the car in the movie “Back to the Future”?
a) Cadillac
b) **DeLorean**
c) Lotus
d) Dodge

23. If Cats are feline what then are sheep?
a) Avian

b) Lapine
c) Porcine
d) **Ovine**

24. What number does "Giga" stand for?
a) One million
b) **One Billion**
c) One Trillion
d) One Quadrillion

25. What is the smallest country in the world?
A) Monaco
b) Nauru
c) **The Vatican**
d) Marshall Islands

26. What is the first name of Shakespeare?
a) Henry
b) David
c) **William**
d) Arnold

27. Which is the fastest animal in the world?
a) Zebra
b) Lion
c) Tiger
d) **Cheetah**

28. What year was the first model of the iPhone released?
a) **2007**
b) 2008
c) 2009
d) 2010

29. Which country produces the most coffee?
a) United States of America
b) **Brazil**
c) Vietnam
d) Colombia

30. Which name is rapper Sean Combs better known by?
a) Jay-Z
b) Kanye
c) **P-Diddy**
d) Drake

<u>Second Day</u>

1. Which country did the band ACDC originate from?
a) New Zealand
b) **Australia**
c) United States of America
d) Ireland

2. What colour is Absinthe?
a) **Green**
b) Blue
c) Grey
d) Red

3. Which is the largest and densest of the four rocky planets?
a) Mercury
b) Venus
c) **Earth**
d) Mars

4. What country is Prague in?
a) Croatia
b) **Czech Republic**
c) Austria
d) Germany

5. Who recorded the album the dark side of the moon?
a) David Bowie
b) The rolling stones
c) Queen
d) **Pink Floyd**

6.With which sport is Michael Jordan associated?
a) Rugby
b) **Basketball**
c) Golf
d) Football

7. Who plays Rachel Green in Friends?
a) **Jennifer Aniston**
b) Courtney Cox
c) Lisa Kudrow
d) Reese Witherspoon

8. Someone who suffers from oneirophobia is scared of what?
a) The Number One

b) Caffeine
c) Robots
d) **Dreams**

9. “The Twilight Saga” is a series of movies based on novels by…
a) Jodie Picoult
b) **Stephanie Meyer**
c) J.K Rowling
d) Emma Donoghue

10. Which mammal has the longest gestation period?
a) **Elephant**
b) Rhino
c) Giraffe
d) Velvet Worm

11. Which is the hardest substance?
a) Iron
b) **Diamond**
c) Gold
d) Steel

12. What colour is a giraffe’s tongue?
a) Pink
b) Red
c) Grey
d) **Black**

13. Who plays the lead character in mean girls?
a) Vanessa Hudgens
b) Emma Stone
c) **Lindsay Lohan**
d) Amy Adams

14. Who is known as the king of pop?
a) Elvis Presley
b) **Michael Jackson**
c) Prince
d) Freddy Mercury

15. What is the name of the wizard in The Hobbit?
a) **Gandalf**
b) Gollum
c) Frodo
d) Bilbo

16. Where is the world’s tallest building?
a) Shanghai, China
b) **Dubai, United Arab Emirates**

c) Mecca, Saudi Arabia
d) Seoul, South Korea

17. In which country is Machu Picchu located?
a) Chile
b) Bolivia
c) Colombia
d) **Peru**

18. Which is the biggest island in the world?
a) New Guinea
b) Borneo
c) **Greenland**
d) Iceland

19. In the children's book series, where is Paddington bear originally from?
a) India
b) **Peru**
c) Canada
d) China

20. "Nephelococcygia" is the practice of doing what?
a) **Finding shapes in clouds**
b) Sleeping with your eyes open
c) Breaking glass with your voice
d) Swimming in freezing water

21. What bird is gifted to the singer on the sixth day in the song "The 12 days of Christmas?"
a) Turtle Doves
b) French Hens
c) Swans a Swimming
d) **Geese a Laying**

22. How many different breeds of dogs are there in the world?
a) **339**
b) 297
c) 544
d) 601

23. In the TV show "The Simpsons" what is the name of Ned Flanders two children?
a) Fred and Tedd
b) Bill and Bob
c) **Rod and Todd**
d) Phil and Dyl

24. How many planets in our solar system have moons?

a) 2
b) 4
c) **6**
d) 8

25. Are Santa's reindeer male or female?
a) **All female**
b) All male
c) Half are female the other half male
d) One female, and the rest are male

26. How many edges does a cube have?
a) 24
b) 8
c) **12**
d) 10

27. What was Elvis Presley's middle name?
a) Lee
b) Clinton
c) John
d) **Aaron**

28. In which US state would you find Mt Rushmore
a) Colorado
b) West Virginia
c) North Carolina
d) **South Dakota**

29. What is the largest planet in our solar system?
a) Earth
b) **Jupiter**
c) Pluto
d) Saturn

30. The great pyramids of Giza consist of how many pyramids?
a) 2
b) **3**
c) 4
d) 5

<u>Third Day</u>

1. What is the name of a group of porcupines?
a) **A Prickle**
b) A Band
c) A Gang
d) A Troop

2. Which of the following is the lowest prime number?
a) 11
b) 12
c) **7**
d) 4

3. Where is the character superman from?
a) Mercury
b) **Krypton**
c) Kryptonia
d) Orion

4. Who preceded Kim Jong-Un as Supreme leader of North Korea?
a) **Kim Jong-il**
b) Hwang Pyong-so
c) Kim Il-sung
d) Kwak Pom-gi

5. What is the capital city of Nigeria?
a) Abeokuta
b) **Abuja**
c) Warri
d) Lagos

6. Who is the only US president to serve more than 2 terms?
a) Abraham Lincoln
b) George Washington
c) **Franklin D. Roosevelt**
d) Bill Clinton

7. What blood type often known as being “universal” in that it can be transfused to almost any patient?
a) AB-
b) AB+
c) **O-**
d) A+

8. Which element are diamonds made up almost entirely of?
a) **Carbon**
b) Zinc
c) Hydrogen
d) Nitrogen

9. How many hearts does an octopus have?
a) 1
b) 2
c) **3**
d) 4

10. What is Otology?
a) **The study of the ears**
b) The study of the eyes
c) The study of coins
d) The study of coral

11. What country boarders Chad to the North?
a) Sudan
b) Egypt
c) Niger
d) **Libya**

12. Which of the following psychologists is most associated with classical conditioning?
a) Freud Sigmund
b) **Ivan Pavlov**
c) Carl Jung
d) B.F Skinner

13. How many years are in a score?
a) 10
b) **20**
c) 30
d) 40

14. What is the fifth element in the Periodic Table?
a) Beryllium
b) Nitrogen
c) **Boron**
d) Helium

15. Which city is the second largest by population in Australia?
a) Sydney
b) **Melbourne**
c) Canberra
d) Brisbane

16. What is the approximate mass of a human brain?
a) 7 pounds
b) 5 pounds
c) **3 pounds**
d) 2 pounds

17. In what year did the Titanic sink?
a) 1908
b) 1910
c) **1912**
d) 1916

18. Who wrote “a brief history of time?”

a) Nikola Tesla
b) Albert Einstein
c) **Stephen Hawking**
d) Isaac Newton

19. In what year did Elizabeth II become Queen?
a) 1942
b) **1952**
c) 1962
d) 1972

20. In which country did the Hindenburg disaster occur?
a) Germany
b) France
c) Switzerland
d) **United States**

21. Florence is the capital of which region of Italy?
a) **Tuscany**
b) Lazio
c) Veneto
d) Sicily

22. Apnea is the inability to…
a) Eat
b) Drink
c) Sleep
d) **Breathe**

23. In the animated film Shrek, who voiced Princess Fiona?
a) **Cameron Diaz**
b) Drew Barrymore
c) Jennifer Aniston
d) Sandra Bullock

24. What was Marilyn Monroe's real first name?
a) Cindy Monroe
b) **Norma Jeane**
c) Marilyn Jeane
d) Marilyn Monroe was her real name

25. What did the crocodile swallow in the 1953 animated feature, Peter Pan?
a) Broomstick
b) Television
c) Radio
d) **Alarm Clock**

26. Bruce Willis played a time traveler in which movie?
a) Back to the Future
b) The time Machine

c) The time Travelers wife
d) **Twelve Monkeys**

27. In what year was the iPad introduced?
a) 2007
b) 2009
c) **2010**
d) 2012

28. Which compound makes up the “majority” of Saturn’s rings?
a) **Water and Ice**
b) Gas
c) Rock
d) Gas and Rock

29. The Angkor Wat is located in…
a) Vietnam
b) **Cambodia**
c) Malaysia
d) Singapore

30. Which of the following naval ranks is the highest?
a) **Commodore**
b) Commander
c) Captain
d) Lieutenant

<u>Fourth Day</u>

1. Which of the following is the currency of India
a) **Rupee**
b) Dollar
c) Peso
d) Dinar

2. The lyrics take my hand, take my whole life too, for I can’t help, falling in love with you” are from which artist?
a) 2 Pac
b) Justin Bieber
c) Bob Dylan
d) **Elvis Presley**

3. Which language is the most widely spoken first language in the world?
a) English
b) **Chinese**
c) Russian
d) Hindi

4. How many hemispheres does the brain have?

a) 1
b) **2**
c) 4
s) 6

5. Roughly what percentage of a jellyfish is water?
a) 75%
b) 80%
c) 90%
d) **95%**

6. What sort of creature is a Barbell?
a) Deer
b) Horse
c) Rabbit
d) **Fish**

7. Who wrote the 1964 novel Charlie and the Chocolate Factory
a) Beatrix Potter
b) C.S Lewis
c) Dr Suess
d) **Roald Dahl**

8. Which country is credited with the invention of chopsticks?
a) Thailand
b) Japan
c) **China**
d) Vietnam

9. Which actor played James Bond in the film Golden Eye?
a) Sean Connery
b) **Pierce Brosnan**
c) Daniel Craig
d) Timothy Dalton

10. Where in the body would you find metatarsal bones?
a) The Hands
b) **The Feet**
c) The Neck
d) The Shoulders

11. Which of the following is a name for the US F16 aircraft?
a) **Fighting Falcon**
b) Fighting Eagle
c) Fighting Hawk
d) Fighting Condor

12. In Greek Mythology, whose elopement with Helen of Troy precipitated the Trojan War?
a) Aeneas

b) **Paris**
c) Agamemnon
d) Hector

13. In terms of media, what does the “H” in “VHS” stand for?
a) **Home**
b) Hue
c) Human
d) House

14. How many stomachs does a cow have?
a) One
b) Two
c) Three
d) **Four**

15. What is another name for Chinese Gooseberry?
a) Passionfruit
b) Strawberry
c) **Kiwifruit**
d) Blueberry

16. Baklava is a dessert pastry typically filled with which of the following ingredients?
a) Fruit
b) Rice
c) **Nuts**
d) Chocolate

17. Which of these birds has the largest wingspan?
a) **Albatross**
b) Pelican
c) Bald Eagle
d) Turkey Vulture

18. Roughly, what percentage of the human brain is water?
a) 40%
b) 50%
c) **75%**
d) 95%

19. What does the flag of Finland look like?
a) **White with a blue cross**
b) Blue with a white cross
c) White with a red cross
d) Red with a white cross

20. Where would you find Mt Erebus?
a) Nepal
b) Arctica
c) **Antarctica**
d) Greenland

21. What is the world’s largest non-polar desert by surface area?
a) **Sahara Desert**
b) Great Victoria Desert
c) Arabian Desert
d) Gobi Desert

22. A lady’s slipper is a type of…
a) Hairstyle
b) **Orchid**
c) Knot
d) Dessert

23. What was Ho Chi Minh City formerly known as?
a) **Saigon**
b) Da Nang
c) Hanoi
d) Minh City

24. Myopia is another name for which of the following medical conditions?
a) Bronchitis
b) **Short sightedness**
c) Asthma
d) Eye Infection

25. How many chromosomes are in a normal human cell?
a) 21
b) 23
c) 42
d) **46**

26. What type of juice is typically added to vodka in a screwdriver?
a) Pineapple Juice
b) Tomato Juice
c) **Orange Juice**
d) Apple Juice

27. What was the Roman name for London?
a) Britannia
b) Leodis
c) **Londinium**
d) Lutetia

28. According to Freuds model of the Human Psyche, which component is most primitive?
a) **Id**

b) Super Id
c) Ego
d) Super Ego

29. Where would you find Doges Palace?
a) **Italy**
b) Poland
c) France
d) Germany

30. What were Walt Disney's Seven Dwarfs looking for in the mines?
a) Silver
b) Gold
c) **Diamonds**
d) Coal

Fifth Day

1. What is the medical term for the symptom of difficulty swallowing?
a) **Dysphagia**
b) Cotards syndrome
c) Prosopagnosia
d) Tachycardia

2. In terms of date order, which zodiac sign is after Sagittarius?
a) Taurus
b) Scorpio
c) Virgo
d) **Capricorn**

3. What type of animal is a drill?
a) **Monkey**
b) Sheep
c) Bird
d) Possum

4. How many moons does mars have?
a) zero
b) one
c) **two**
d) three

5. What letter represents 50 in Roman Numerals?
a) C
b) **L**
c) M
d) R

6. An Obtuse angle is an angle that is…?
a) **More than 90 degrees**
b) Less than 90 degrees
c) More than 45 degrees
d) Less than 45 degrees

7. What is Lincrusta a type of?
a) Cake
b) Spider
c) Paint
d) **Wallpaper**

8. Approximately how many bytes are there in one megabyte?
a) 1000
b) 10,000
c) **1000,000**
d) 1000,000,000

9. who was the Greek goddess of war and wisdom?
a) Persephone
b) **Athena**
c) Aphrodite
d) Leto

10. Kingston is the capital of which country?
a) Bahamas
b) Cuba
c) **Jamaica**
d) Dominican Republic

11. What type of object is a clevis?
a) **A type of joint**
b) A type of tool
c) A type of spring
d) A type of string

12. Where would you find the ocean of storms?
a) Near California
b) Near Brisbane
c) **On the Moon**
d) On Mars

13. What does the acronym STOL stand for in terms of aviation?
a) Secure Trolleys on Landing
b) Sensitive Tailwind On Left
c) Satisfactory True Oxygen Levels
d) **Short Take Off Landing**

14. Pancit is a type of cuisine most associated with which country?
a) **The Philippines**
b) Malaysia
c) China
d) Vietnam

15. What does the B in ISBN stand for?
a) Business
b) Broadband
c) Binary
d) **Book**

16. What is George W Bush’s middle name?
a) Wilmer
b) Wilson
c) William
d) **Walker**

17. What is the hardest substance in the human body?
a) Bones
b) **Tooth Enamel**
c) Nails
d) Muscle

18. What Mountain gets you closest to the moon?
a) Mt Everest
b) Mt Pandim
c) **Mt Chimborazo**
d) Mt Fuji

19. What Ocean is home to 75% of the Earths Volcanos?
a) **Pacific Ocean**
b) Indian Ocean
c) Atlantic Ocean
d) Arctic Ocean
20. What was the first city to reach a population of one million?
a) London
b) **Rome**
c) Paris
d) New York

21. What was the first sport televised in the United States?
a) Football
b) Golf
c) Rugby
d) **Baseball**

22. Who was the first skin tight costumed superhero?
a) **The Phantom**
b) Superman

c) Batman
d) Arrow

23. What Hawaiian Island is known as Bird Island?
a) **Nihoa**
b) Maui
c) Kauhuula
d) Oahu

24. Who invented Arabic Numerals?
a) Greeks
b) English
c) **Indians**
d) Romans

25. What colour is liquid Oxygen?
a) **Blue**
b) Colourless
c) Red
d) White

26. When was the first fax machine invented?
a) **1840s**
b) 1850s
c) 1860s
d) 1870s

27. What is the largest object in the asteroid belt that lies between the orbits of Mars and Jupiter?
a) Vesta
b) Orcus
c) Salacia
d) **Ceres**

28. What are the bones in your hands called?
a) Meta tarsals
b) Beta carpals
c) **Metacarpals**
d) Beta tarsals

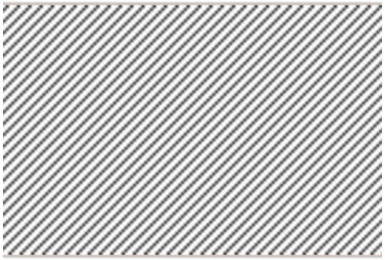
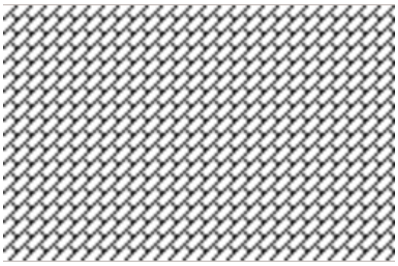
29. How long is a Parsec?
a) 3.14 light years
b) 19.2 light years
c) 8.1 light years
d) **3.26 light years**

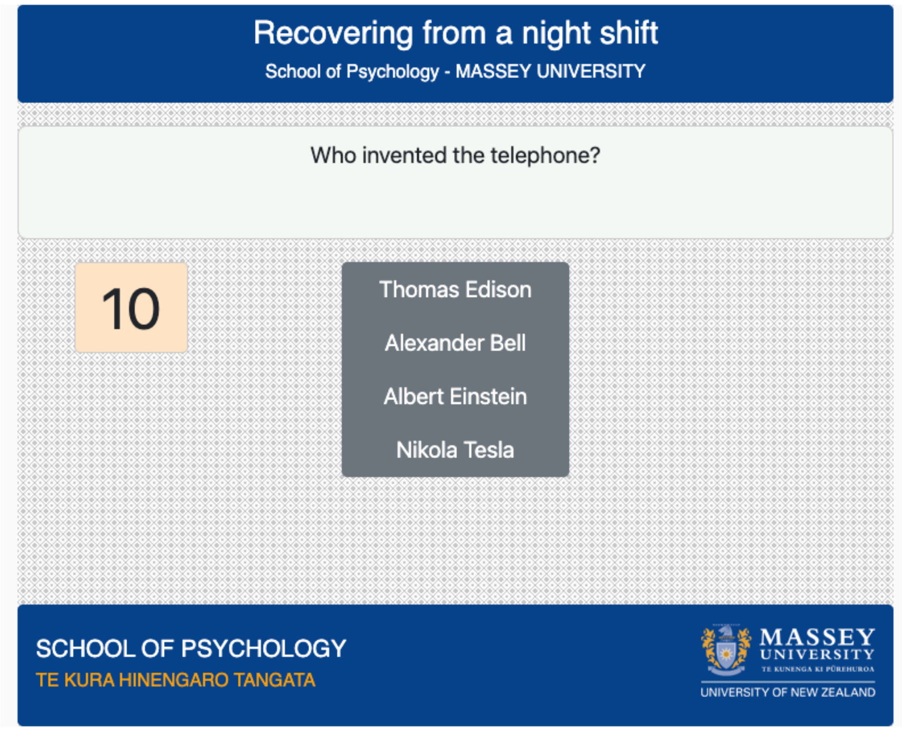
30. Herpetology is the study of what?
a) Flowers
b) Herbs

c) **Reptiles**
d) Insects

Appendix E. Patterned Backgrounds



Appendix F. PANAS Questionnaire

"You will be shown a number of words that describe different emotions and feelings. Your job is to read each word and respond with the sentence that most accurately describes to what extent you are feeling this emotion at this exact moment."

1.**Interested**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

2.**Distressed**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

3.**Excited**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

4.**Upset**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

5.**Strong**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

6.**Guilty**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

7.**Scared**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

8.**Hostile**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

9.**Enthusiastic**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

10.**Proud**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

11.**Irriatable**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

12. **Alert**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

13.**Ashamed**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

14.**Inspired**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

15.**Nervous**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

16.**Determined**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

17.**Attentive**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

18.**Jittery**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

19.**Active**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

20.**Afraid**
- ☐ Very slightly or not at all
- ☐ A Little
- ☐ Moderately
- ☐ Quite a bit
- ☐ Extremely

Appendix G. PROMIS Fatigue Diary Questionnaire

"Thank you for your responses. The second questionnaire is made up of 7 statements about fatigue and will require you to choose an answer that best describes how you are feeling.
Please be assured that your answers are confidential and you can take all the time you need to complete the questionnaire".

1. In the last day, how often did you feel tired?
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

2. In the last day, how often did you experience extreme exhaustion?
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

3. In the last day, how often did you run out of energy?
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

4. In the last day, how often did your fatigue limit you at home?
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

5. In the last day, how often were you too tired to think clearly?
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

6. In the last day, how often did you feel tired even though you hadn't done anything?
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

- ☐ 7. In the last day, how often did you have to push yourself to get things done because of your fatigue?
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

Appendix H. Participant Drop Out Rate

Dropout rate for night shift workers and controls