The Use of Visual Search Tasks to Determine the Effects of Sleep Deficiency on Decision-Making in Civilian and Military Emergency Responders

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Declaration

This thesis is entirely my own work and has not been submitted in full or in part for the award of a higher degree at any other educational institution.

No sections of this thesis have been published and it has not been presented at any conference.

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Abstract

Due to long shifts and difficult working conditions, many emergency responders suffer from poor sleep and long term sleep deprivation, yet they are still required to perform at a demanding level and to make highly important decisions throughout their shifts. It is well known that sleep deprivation has a negative impact on cognitive functions and this is linked to a higher rate of accidents, both in the workplace and in other aspects of life. It is therefore important to understand how the effects of long term sleep deprivation affect decision-making in emergency responders.

The study compared scores from two sleep measures (PSQI and ESS), the cognitive failures questionnaire (CFQ), and a repeated scenes search task, to determine the link between sleep, cognitive failures, and performance in the visual search task. Participants were recruited from St John Ambulance, Search and Rescue, and the Royal Army Medical Corps, with the study sent out online via Qualtrics and Pavlovia. Data were analysed using Pearson Product Moment correlations and repeated measures general liner models.

Results showed that 53% of participants suffered from poor sleep, and that poor sleep correlated with increased cognitive failure scores, suggesting that long term sleep deprivation is linked to an increase in cognitive lapses. Analysis of the task results showed a decrease in sensitivity in participants with poor sleep, which was linked to increased CFQ scores and to an interruption in the learning processes due to variations in the target type.

This study identifies the prevalence of long term sleep deficiencies within the emergency responder community and the effect this has on aspects of decision-making such as cognitive lapses, sensitivity, and learning processes. Further work should focus on detailing models of decision-making and the effects of sleep loss on these models, and on the practical aspect of improving sleep quality in order to reduce negative effects such as lapses and accidents.

1 Introduction

It is well known that medical personnel are often sleep deprived due to long shifts and changing shift patterns, and sleep deprivation is known to increase the risk of human-error related accidents. One study suggests that workers who suffer from poor sleep have a 1.62 times higher risk of being injured than their colleagues who report sleeping well (Uehli et al., 2014). In addition to this, emergency responders face a very different set of risks and requirements from hospital- or clinic-based workers. They are required to assess the patient and decide how to treat them within moments of arriving on scene, a scene which is usually an unknown, fast-paced environment. They are sometimes subjected to violence from either patients or bystanders, and must deal with distractions and disruptions, such as passers-by and concerned relatives or friends. They are often only supported by one other person and have limited medical supplies and treatment options to hand. Emergency workers must be alert and vigilant at all times to prevent errors in protocol and injury to patients or each other, and they must be able to quickly and correctly assess a scene and make decisions in order to save lives.

Volunteer and part-time responders are subject to all of the above, as well as ensuring they stay current in their knowledge despite not using it every day, and working their medical responder schedule around their full-time job, families, and interests. This means they could be more likely to struggle from chronic sleep restriction, rather than acute sleep deprivation which involves no sleep over a shorter period, putting them at increased risk of error and injury. For that reason, it is important to understand the impact of long-term sleep deprivation on cognitive functions, and to understand what other factors could affect the cognitive functions involved in scene assessment and decision-making.

In the introductory chapters to this study, I will review the literature on: sleep deprivation, especially chronic sleep restriction; cognitive failures; and contextual cueing and sensitivity bias in visual search tasks. Sleep deprivation, both acute and long-term, is known to affect cognitive functions such as attention, working memory, and executive control. Whilst lesser known, cognitive failures research, the study of the daily absent-minded mistakes committed by everyone, is gaining more traction within the cognitive psychology community but has not been linked to sleep before. It has been shown to reflect real-world outcomes more reliably than strict, laboratory-based, objective measures, and is best seen as a measure for stress-triggered variations in performance. Using a visual search task provides a dependable framework for measuring cognitive functions such as contextual cueing, in which statistical learning guides attention in repeated scenes. Measuring reaction times and error rates, as well as the contextual cueing effect, provides an opportunity to measure attention and the speed-accuracy trade-off, to understand whether participants favour faster or more accurate responses.

The study includes participants from various volunteer and part-time organisations, and involves the administration of the Pittsburgh Sleep Quality Index (PSQI) and Epworth Sleepiness Scale (ESS) to measure sleep quality and daytime sleepiness, the Cognitive Failures Questionnaire (CFQ) to measure propensity for cognitive failures, and the repeated scenes search task to measure contextual cueing and sensitivity bias. It is hypothesised that poor sleep will negatively affect performance on the visual search task, which would suggest it affects certain functions linked to decision-making. This would be important for real-world applications such as ensuring periods of enforced rest in professions which involve long work shifts and stressful decision-making demands.

1.1 Sleep Deprivation

In 1896, Patrick and Gilbert ran a study examining ‘the physiological and mental effects of enforced abstinence from sleep’ which became the first published experimental study of the effects of sleep deprivation on humans. Three participants were studied during a period of almost 90 hours of enforced wakefulness during which reaction time, discrimination time, sensitivity to pain, motor reaction, and weight were recorded. One participant experienced hallucinations of sight and all participants showed an increase in weight, which is an interesting result regarding physical health. Importantly, significant decreases in attention span, memory, and grip were recorded (Patrick & Gilbert, 1896). With advances in technology and knowledge, much more is known about the effects of sleep deprivation, however this is not exhaustive and more research is always needed.

In 1996, Pilcher and Huffcutt carried out a meta-analysis of the literature so far. They revealed three general types of studies: long-term total sleep deprivation (over 45 hours); short-term total sleep deprivation (equal to or less than 45 hours); and partial sleep deprivation (restriction of sleep to less than 7 hours per 24 hours). They reported hundreds of studies on the effects of total sleep deprivation, far fewer on partial sleep deprivation, and only very few on chronic partial sleep restriction. They also noted that neurocognitive measures vary among studies, however three categories of measurement stand out: mood; cognitive performance; and motor performance.

The effects of sleep deprivation on cognitive abilities have most often been measured using acute sleep deprivation, so that is how they will be reviewed here. However, as chronic sleep deprivation, or sleep restriction, is far more common and is the focus of this research, it will be discussed at the end of the chapter.

1.1.1 Effects of Sleep Deprivation on Performance

1.1.1.1 Mood

It is widely agreed that all forms of sleep deprivation result in increased negative mood states, particularly feelings of fatigue, loss of vigour, sleepiness, and confusion. Although it is believed that inadequate sleep fosters feelings of irritability, anxiety, and depression, there is little evidence of these negative mood states following sleep deprivation in a predictable and comfortable environment. These negative mood states have, however, been observed repeatedly in environments where there is no regard for conditions such as participant comfort, provision of food and water, and entertainment (Van Dongen, Maislin, Mullington & Dinges, 2003).

1.1.1.2 Cognitive Performance

A wide range of cognitive functions are affected by sleep deprivation (see Table 1), although tasks vary in their sensitivity to such deprivation. Across all tasks, cognitive performance generally becomes progressively worse as time on task extends, which is the classic ‘fatigue’ effect that is exacerbated by sleep loss (Kribbs & Dinges, 1994). Brief cognitive tasks that measure attention have also been found to be sensitive to sleep deprivation (Dinges, 1992). Inter-subject variability and intra-subject variability, however, have been found to be confounding factors which can obscure the effects of sleep loss on many cognitive tasks. Van Dongen, Maislin and Dinges (2004) note that one non-sleep-deprived person’s best performance on a task may be worse than a sleep-deprived person’s poorest performance. Similarly, it is possible to be affected by sleep loss but still continue to improve on a repeated task due to the effects of learning. Another problem with many studies on the effects of sleep deprivation is the nature of the dependent variables which are selected for analyses; the effects of sleep loss on cognitive performance can be missed by using less sensitive metrics or data analyses which do not consider the increased variability within subjects and between subjects caused by sleep deprivation (Olofsen, Dinges & Van Dongen, 2004). Table 1 provides a summary of the broad cognitive performance effects of sleep deprivation, according to Durmer and Dinges (2005).

Table 1

Effects of Sleep Deprivation (Durmer & Dinges, 2005)

Involuntary microsleeps occur
Attention-intensive performance is unstable with increased errors of omission and commission
Cognitive slowing occurs in subject-paced tasks, while time pressure increases cognitive errors
Response time slows
Both short-term recall and working memory performances decline
Reduced learning (acquisition) of cognitive tasks
Performance requiring divergent thinking deteriorates
Response suppression errors increase in tasks primarily subserved by prefrontal cortex
Response perseveration on ineffective solutions is more likely
Increased compensatory effort is required to remain behaviourally effective
Tasks may be begun well, but performance deteriorates as task duration increases
There is growing neglect of activities judged to be non-essential (loss of situational awareness)

1.1.1.2.1 Assessing Cognitive Performance

It is important that neurocognitive assessments are valid and reliable reflections of waking functions that can be affected by sleep deprivation in order to provide an accurate and useful measure of performance decrements due to sleep loss. Measures of vigilance, attention, and declarative memory are often used, with reaction time (RT) as the dependent variable. The most used task is the Psychomotor Vigilance Task (PVT), a test of behavioural alertness via sustained attention demands (Dinges & Powell, 1985). It is free of aptitude and learning effects and it is sensitive to sleep loss, sleep pathology, and functioning at an adverse circadian phase, which is functioning according to a cycle which is not one’s natural 24-hour cycle. The task requires continuous attention to detect randomly occurring stimuli. This type of simple but attention-demanding task has proven to be reliable, valid, and a sensitive measure of sleep deprivation; this suggests that the neural mechanisms of attention are among the most susceptible to sleep deprivation (Durmer and Dinges, 2005).

1.1.2 Sleep Restriction

Sleep restriction occurs when an individual is not able to get their optimum amount of sleep for a number of consecutive nights. Adults humans need, on average, 8 hours of sleep each night, so it is widely agreed that sleep restriction occurs when an individual gets 7 hours or less of sleep per night (Frenda & Fenn, 2016).

1.1.2.1 Behavioural Alertness and Lapses

Many different aspects of waking cognitive performance, particularly behavioural alertness, are affected by sleep restriction (Dinges, Rogers & Baynard, 2005). Performance on tasks requiring vigilant attention, such as the psychomotor vigilance task (PVT), is sensitive to sleep loss in general and particularly sensitive to sleep restriction (Dorrian, Rogers & Dinges, 2005). Many experiments, such as stimulus-response experiments, have shown that sleep deprivation leads to increased behavioural lapses during performance (Balkin et al., 2004), which is thought to reflect microsleeps (Dinges & Kribbs, 1991). As sleep loss is extended, lapses can last from 0.5 seconds to over 10 seconds in duration, and sometimes progress into full sleep attacks (where additional stimulation is needed to rouse a subject) (Dinges & Kribbs, 1991). Doran, Van Dongen and Dinges (2001) hypothesised that these lapses caused by sleep loss could originate in sleep-initiating subcortical systems, such as the hypothalamus, thalamus, and brainstem (Saper, Chou & Scammell, 2001). They conceptualised this as "wake state instability" which is described as "moment-to-moment shifts in the relationship between neurobiological systems mediating wake maintenance and those mediating sleep initiation" (Banks & Dinges, 2007, p.522).

1.1.2.2 Controlled Studies

Belenky and colleagues conducted the most strictly controlled experiment on chronic sleep restriction in healthy adults. In their experiment, commercial truck drivers stayed in the laboratory for 14 days and were randomised to seven nights of 3, 5, 7, or 9 hours in bed per night. The psychomotor vigilance task (PVT) was used to measure response speed and number of lapses. Subjects in the 3 hours-in-bed and 5 hours-in-bed conditions displayed growing daytime deficits over the week in response to the PVT, and subjects in the 7 hours-in-bed condition had a significant decrease in PVT response speed by the end of the week, whereas subjects in the 9 hours-in-bed condition displayed stable performance over the week (Belenky et al., 2003). Van Dongen, Maislin, Mullington, and Dinges (2003) ran a similar experiment where healthy adults stayed in the laboratory for 20 days and were randomised to 4, 6, or 8 hours in bed per night for 14 consecutive nights. Every 2 hours, subjects were tested for psychomotor vigilance performance and working memory performance. Cumulative daytime deficits in both the PVT and cognitive throughput were observed for the 4- and 6- hour sleep conditions, but not for the 8-hour sleep condition. The effects of this sleep restriction were compared to 1, 2, and 3 nights of total sleep deprivation in order to quantify the magnitude of the experienced cognitive effects. This showed that both the 4- and 6- hour sleep periods led to the development of impairments of behavioural alertness that increased with time to levels found after up to 3 nights of total sleep deprivation (Van Dongen, Maislin, Mullington & Dinges, 2003). These two controlled experiments on chronic sleep restriction in healthy adults demonstrated that behavioural alertness deteriorates steadily across days when nightly sleep is restricted to between 3 and 7 hours, deteriorating more rapidly as time asleep is reduced.

1.1.2.3 Subjective Reports of Sleepiness and Mood

Total sleep deprivation and chronic sleep restriction show different subjective sleepiness responses, even though the psychomotor vigilance responses may be similar. Total sleep deprivation results in an immediate increase in feelings of sleepiness, fatigue, and cognitive confusion, with associated decrease in vigour and alertness (Dorrian & Dinges, 2006; Harrison & Horne, 2000), whereas chronic sleep restriction presents much weaker changes in these ratings of internal state (Belenky et al., 1993; Van Dongen, Maislin, Mullington & Dinges, 2003). Thus, according to Van Dongen, Maislin, Mullington and Dinges (2003), "in contrast to the continuing accumulation of cognitive performance deficits associated with nightly restriction of sleep <8h, ratings of sleepiness repeatedly made by subjects on standardised sleepiness scales did not parallel performance deficits" (p. 120). Therefore, after 7-14 days of sleep restriction, subjects rated themselves as only moderately sleepy even though vigilance tasks proved they were noticeably impaired and less alert. Studies using driving simulators have yielded similar results, showing subjects are unaware of the effects of sleep restriction on their abilities (Banks, Catcheside, Lack, Grunstein & McEvoy, 2004). This suggests one of the biggest dangers of sleep restriction is that people frequently underestimate the impact of their restricted sleep and overestimate their readiness to perform.

1.1.2.4 Individual Differences

There is substantial interindividual variability in sleep and circadian parameters, and in the subsequent physiological and neurobehavioural responses to sleep deprivation (Van Dongen, Vitellaro & Dinges, 2005; Roehrs, Carskadon, Dement & Roth, 2005; Dorrian & Dinges, 2005). Sleep loss both increases cognitive performance variability within subjects, and reveals marked neurobehavioural differences between subjects, mainly in the form of cognitive performance. Thus, as sleep loss increases over time, intersubject differences related to cognitive deficits also increase noticeably (Russo, Thomas, Thorne et al., 2003; Doran, Van Dongen & Dinges, 2001). This variability has also been shown during experimentally restricted sleep. In both Belenky and colleagues' study and Van Dongen and colleagues' study, sleep restriction of less than 7h per day resulted in cumulative cognitive performance deficits in a majority of healthy adults, however individuals were affected to different degrees. At one end of the scale are those who experience severe neurobehavioural deficits with only limited sleep restriction, and at the other end are those who display few, if any, impairments until sleep restriction becomes severe (Belenky et al., 1993; Van Dongen, Maislin, Mullington & Dinges, 2003). Van Dongen and colleagues also found data to suggest that different cognitive tasks can lead to different cognitive impairments among subjects, for example, subjects experiencing increasing difficulties performing working memory tasks may not experience such difficulties with psychomotor vigilance tasks (Van Dongen, Rogers & Dinges, 2003; Van Dongen, Maislin & Dinges, 2004). Further research into this showed that the neurobehavioural responses to sleep deprivation were stable and reliable within subjects, suggesting these are trait-like effects (Van Dongen, Baynard, Maislin & Dinges, 2004). This is particularly important for future studies researching the possible genetic contributors to differential vulnerabilities to sleep loss, which would help research looking at predicting the effects of sleep loss in individuals.

1.1.3 Measuring Sleep Deprivation

1.1.3.1 Sleep Propensity

Sleep propensity is defined by Bes, Jobert and Schulz (2009) as 'the probability to fall or to remain asleep at a given point in time'. It is increased by sleep deprivation and linked to sleep latency, which is the amount of time it takes for a person to fall asleep. Sleep latency is considered a physiological measure of sleepiness and has been standardised in the multiple sleep latency test (MSLT) (Thorpy, Westbrook, Ferber & Fredrickson, 1992), which is often considered the gold standard of sleep disturbance testing. It is, however, a laboratory-based study, which makes it expensive and which requires considerable time commitment from both subjects and researchers. As this method of studying sleep is not practical, self-reported sleep questionnaires are often favoured by researchers. The two used in this study and described below are the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS).

1.1.3.2 Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) was developed in 1988 by Buysse, Reynolds III, Monk, Berman and Kupfer. It is a self-report instrument designed to measure sleep quality and disturbances over the prior month and to discriminate between ‘good’ and ‘poor’ sleepers (Buysse et al., 1989). It is a widely used measure of sleep quality with high acceptability, reliability, and validity (Omachi, 2011). It is widely agreed that the main strength of the PSQI is its broad range of coverage in measuring multiple aspects of sleep quality and combining these into one global score. This, however, is also a drawback, as there is disagreement about whether the scores of the PSQI represent a single factor and whether it should be used as such or whether it should be used to draw attention to certain factors for further investigation (Backhaus, Junghanns, Broocks, Riemann, Hohagen, 2002; Cole, Motivala, Buysse, Oxman, Levin, Irwin, 2006; Carpenter, Andrykowski, 1998).

1.1.3.3 Epworth Sleepiness Scale (ESS)

The Epworth Sleepiness Scale (ESS) was developed in 1991 by Johns. It was designed to measure daytime sleepiness and the propensity of subjects to fall asleep in different situations (Johns, 1991). The ESS is a widely used measure of sleep quality with high acceptability, reliability, and validity, the last being assessed as its correlation with the mean sleep latency on the multiple sleep latency test (MSLT) (Omachi, 2011). It is important to note that the ESS is a measure of sleepiness, not fatigue, and that it cannot distinguish between sleepiness caused by disturbed sleep and sleepiness caused by other factors, such as medication effects.

1.1.4 Chapter Summary

From the first published sleep deprivation study in 1896 until now, much has been learned about the effects of reduced sleep on the human brain, but there is still further to go. Most sleep deprivation studies use acute total sleep deprivation, although the most common type of sleep deprivation encountered in today’s society is chronic sleep restriction. Studies comparing the two have shown that cognitive abilities are impaired differently by the two different types of sleep deprivation, but that the cognitive effects after long periods of sleep restriction come to resemble the cognitive effects after acute total sleep deprivation. This suggests that it is not just the amount of sleep one gets which has an effect, but the length of wakefulness compared to the length of sleep that has been had.

Sleep deprivation is often measured using sleep propensity, with the Multiple Sleep Latency Test (MSLT) being the gold standard, however the expensive and time-demanding nature of the test means it is often unpractical. Instead, the PSQI and ESS are often used. They are both self-reported questionnaires measuring sleepiness and propensity to fall asleep (both) as well as sleep quality and disturbances (PSQI only). It is important to note, however, that in sleep restriction studies, participants report lower subjective reports of sleepiness, indicating they feel less sleepy and are less aware of their sleep-related cognitive deficits. This could indicate less reliable self-reported measures on the sleep questionnaires. On the other hand, these questionnaires do not directly ask participants how sleepy they feel but probe measures and situations surrounding sleepiness, and they have been shown to be valid and reliable. They will therefore be considered to accurately measure sleepiness and sleep quality in this study.

Cognitive performance has been shown to be greatly affected by acute sleep deprivation, with abilities such as attention, memory, and learning incurring deficits. Sleep restriction has been shown to affect behavioural alertness by increasing the number of lapses during performance, as well as affecting attention, memory and learning.

Importantly, sleep restriction has been shown to both affect subjects differently and affect cognitive abilities differently within subjects. Whilst one person may be heavily impaired by a small amount of sleep restriction, another may not show many, if any, impairments until the restriction is severe. Similarly, one person’s working memory may suffer from extended wakefulness, whilst their attention remains largely unaffected, and vice-versa for someone else. Overall, however, neurobehavioural responses to sleep restriction have been shown to be stable and reliable within-subjects, suggesting these are more trait-like than state-like. Although so much is known about sleep deprivation and sleep restriction, it is still unknown what makes certain people more susceptible to cognitive deficits caused by sleep restriction, or how to measure this other than restricting their sleep.

1.2 Cognitive Failures

Cognitive failures are experienced on a daily basis by everyone, these include walking into a room only to forget why you were there, replacing the orange juice in the cupboard instead of the fridge, or repeatedly pushing a door whilst staring at the ‘pull’ sign. Although these are irritating, they are usually quite minor, however some people experience them far more often than others. For these people who experience them often, cognitive failures can become a serious concern as they become a barrier to safely and successfully carrying out routine responsibilities. It is still not clearly understood what factors increase proneness to cognitive failures and, although they have been compared to performance in different cognitive domains, this has done little to explain why these errors occur and how they might be prevented (Carrigan & Barkus, 2016). “Cognitive failures” was first used as a term by Broadbent, Cooper, FitzGerald, and Parkes in 1982 to describe the minor slips which disrupt the normally smooth flow of intended action, be it physical or mental. They are thought to reflect one’s proneness to frequent lapses in cognitive control. Although several measures have been developed to attempt to quantify this proneness to cognitive failures, the most widely used and accepted is the Cognitive Failures Questionnaire (Broadbent, Cooper, FitzGerald, & Parkes, 1982).

1.2.1 Cognitive Failures Questionnaire (CFQ)

The CFQ is a subjective measure and raises the same concerns as other measures of cognitive functioning which rely on subjective reporting. Certain authors, such as Herrmann (1982), suggest that in order for self-reports to be considered valid, they must match up with performance on objective, laboratory-based tasks. As there is yet to be a link between the Cognitive Failures Questionnaire and the outcome of an objective task, there is some concern as to the validity of the CFQ. Another concern regarding self-reports of cognition is the high importance placed on the participants’ memory by requiring the recall of specific experiences over a significant time period (Myin-Germeys, Delespaul & Van Os, 2003), such as the CFQ asking participants to remember how many times a certain lapse has happened over the previous 6 months.

The traditional approach of cognitive psychology also reflects reservations about subjective experiences of cognition, as the former focuses only on objectively assessed ‘trait’ intellect, not subjective measures (Horn, 1972). There are several relatively stable factors, such as genetics, which are known to predict traits like intellect (Davies et al., 2011), therefore changes in performance produce specific well-documented cognitive profiles, and occur only in response to biological processes such as injury, disease, and aging (Hildebrandt, Fink, Kastrup, Haupts & Eling, 2013; Gonzáles-Blanch, et al., 2007). This predictability and stability of trait cognitive ability is appealing to both researchers and clinicians as it can be formally assessed and recorded. Most people, however, naturally feel that mood, environment, and time affect their cognitive functioning, some days they feel more focussed than others, some days they just cannot concentrate. However, objective cognitive tasks only capture cognition at a single point in time, in an idealistic environment (most often a laboratory). Measures of cognitive failures, therefore, could further the understanding of how cognitive processes vary in real life and improve the ecological validity of research into human cognition (Carrigan & Barkus, 2016).

1.2.2 Key Features of Cognitive Failures

1.2.2.1 Dimensions

In their review, Carrigan and Barkus (2016) detail that although CQF scores were found to be distributed normally throughout the healthy population, women tend to report more failures than men (Boomsma, 1998; Kanai, Dong, Bahrami & Rees, 2011). Boomsma (1998) conducted a large-scale genetic study of Dutch families to determine the influence of heritability on CFQ scores. The results suggest that 50% of variability in scores is due to familial heritability, but no evidence was found for effects of shared environment, therefore it is suggested that the non-genetic variance is shaped not by factors linked to the family unit, but rather by external factors specific to the individual.

Two studies have used MRI to further the understanding of the biological component of cognitive failures, one by Kanai et al. (2011) and one by Sandberg et al. (2014). Both studies found that greater distractibility in everyday life was predicted by increased parietal grey matter, with Kanai et al. (2011) also suggesting that high neural density may be a sign of inadequate synaptic pruning during development. Sandberg et al. (2014) further found that reduced GABA in the occipital lobe was associated with increased risk of cognitive failures, they suggested that low GABA levels may limit one's ability to selectively suppress sensory information. Together, the organic differences of GABA levels and parietal grey matter volume were shown to explain about 50% of interindividual variation in failures, according to Sandberg et al. (2014).

1.2.2.2 Relationship with Real World Performance

Researchers have often tried to link measures of cognitive failures with real-world performance, such as spousal ratings, academic tests, and standard intelligence tests, with varying degrees of success. After developing the CFQ, Broadbent et al. (1982) developed a CFQ-for-others, to see whether one's subjective view of proneness to cognitive failures was shared by another person close to them who was in a good position to judge, in this case, a spouse. Both spouses were asked to fill out the CFQ for themselves, and after analysis it was discovered there was only a very weak relationship between the CFQ scores within each couple. The CFQ-for-others completed by the spouse, however, was more highly correlated with each persons' own CFQ, showing that one's subjective measure of cognitive failures was shared by the people close to them. CFQ scores have also been shown to correlate moderately with the Scholastic Aptitude Test (SAT) in the US, which measures academic outcomes

(Unsworth, Brewer, & Spillers, 2012), and with the incidence of at-fault traffic accidents (Larson & Merritt, 1991), suggesting CFQ scores can predict important real-life performances. Both Broadbent, Cooper, FitzGerald, and Parkes (1982) and Larson and Merritt (1991) have measured the correlation between CFQ scores and standard tests of intelligence, finding no significant relationship between these. Following this, Larson and Merritt (1991) suggested that the CFQ assesses different aspects of cognition than the usual ones assessed by traditional testing methods, such as IQ testing.

1.2.2.3 Relationship with stress

Parkes (1981) conducted a study of student nurses and their CFQ and Middlesex Hospital Questionnaire scores. The Middlesex Hospital Questionnaire (MHQ; Crisp, Jones, & Slater, 1978) is a brief self-report mental health questionnaire. The nurses in Parkes' study completed the CFQ before beginning work on hospital wards which provided different levels of stress. It was found that nurses who had spent the previous six weeks on a medical ward reported significantly different MHQ scores to the nurses who had spent the previous six weeks on the surgical wards, but there was no significant difference in the CFQ scores. Out of the 101 nurses who were studied, 48 spent their first six weeks on a relatively low stress ward and 53 spent their first six weeks on a relatively high stress ward. Both groups completed the CFQ and MHQ again after those initial six weeks. In neither situation was there a significant change in CFQ scores and in the low stress ward, previous CFQ and subsequent MHQ showed no correlation, however in the high stress ward, previous CFQ and subsequent MHQ produced a highly significant correlation. This suggests that mental health symptoms can be linked to CFQ scores, but only when higher levels of stress are involved. Subsequently, it is thought that a high CFQ score is a vulnerability factor making the individual less able to resist the effects of stress and therefore experiencing more cognitive failures under high pressure.

A study by Jónsdóttir, Adólfsdóttir, Cortez, Gunnarsdóttir and Gústafsdóttir (2007), however, which asked healthy individuals to report perceived stress levels and number of slips experienced over the period of a week, found no link between the two. According to Carrigan and Barkus (2016), it is possible that this is due to perceived stress being only one aspect of stress, not an acute measure. They suggest that more affective and acute measures of stress may be more closely associated with cognitive failures experienced in everyday life, which is backed up by the following studies. McVay, Kane and Kwapil (2009) found that participants who reported high levels of mind wandering found that their everyday cognitive failures were exacerbated by negative mood states; and Kane, Brown, McVay, Silvia, Myin-Germeys and

Kwapil (2007) found that individuals with good control capacity were likely to experience increased cognitive failures when faced with distracting environments such as chaos or unpleasant tasks, whereas individuals with poor objective control experienced a heightened level of cognitive failures regardless of context. This suggests that the CFQ may not be useful for measuring stable neurological deficits, but rather for measuring stress-triggered variations in performance (Carrigan & Barkus, 2016).

1.2.3 Objective Cognitive Tasks

1.2.3.1 Attention

Several studies have looked at the links between attention and cognitive failures, however the results are inconsistent. This variability in outcomes could be due to the studies measuring different components of attention (e.g. sustained or divided). Broadbent et al. (1986) found that although cognitive failures did not correlate with any measure of attention, a higher CFQ score was associated with a performance advantage on a search task compared to a focused attention task. Later studies found a moderate correlation between more frequent cognitive failures and high distractibility in the lab, such as the study by Tipper and Baylis (1987) which found that individuals who reported higher cognitive failures demonstrated longer reaction times than those who reported fewer failures, both in the presence of distractors and in the absence of negative priming. Murphy and Dalton (2014) found that individuals who reported more cognitive failures were also more likely to succumb to auditory distractors. These results would suggest that an individual's frequency of slips is influenced by both their attentional abilities and their capacity to ignore distractions.

Unsworth et al. (2012) used lab-based tasks such as operation span tasks and the psychomotor vigilance task to measure aspects of working memory capacity and attentional control, which was compared with number of reported failures over the previous week, finding initially that reports of failures correlated with attentional control performance. Further analysis of the data found a relationship between intra-individual variations in attentional control, measured by changes in reaction times between trials, and everyday failures (Unsworth, 2015). This suggests that concurrent to the trait-like components of cognitive failures there is also a state-like element, and shows the importance of making useful comparisons between existing objective assessments and cognitive failures.

1.2.3.2 Inhibition

According to Aron (2007), inhibition is the ability to suppress actions that interfere with goal-driven behaviour. In a behavioural inhibition study, Roche, Garavan, Foxe and O'Mara (2005) measured performance in a Go/No Go task and compared it between the high and low cognitive failure groups, in which they found no differences. They did find, however, that individuals who scored higher on the CFQ demonstrated larger and earlier N2 and P3 components, which are event-related brain potentials thought to reflect activity of the cortical inhibition system. Furthermore, Berggren, Hutton and Derakshan (2011) used eye-tracking to measure physiological inhibition. They found that individuals with higher cognitive failures showed increased latency of antisaccade in an eye-movement inhibition task, which suggests poorer inhibition and greater distractibility. Barkus and Carrigan (2016) suggest that while those who are prone to cognitive failures may show no objective differences in behavioural inhibition, "they may possess a global cortical inefficiency in the physiological mechanisms which underpin behavioural and perceptual inhibitory responses" (p.14).

1.2.3.3 Working memory and executive control

Baddeley (1992) defines memory as the ability to concurrently store and manipulate information, and Kiefer (2012) defines executive control as organising and maintaining actions and thoughts according to goals. These are often grouped together as working memory is supported by control of attention and resource allocation (Lara & Wallis, 2014), and they are essential for processing relevant information and successfully carrying out daily activities. In two separate studies, cognitive failures were found to be associated with objective working memory capacity (Kane et al., 2007) and lapses in executive control indicated by task-unrelated thoughts (McVay et al., 2009). In their study, Kane et al. found that the association was dependent on cognitive load, as participants with high working memory ability reported more failures when they felt less challenged by the tasks. This has been linked to the anecdotal view that boredom causes mind-wandering, which increases the likelihood of mistakes, although limited scientific evidence is available to support this supposition. Despite these studies reporting positive findings, Barkus and Carrigan (2016) report that, overall, correlations between working memory, executive control and cognitive failures are inconsistent.

1.2.4 Biological Factors

1.2.4.1 Sleep-wake cycle

Little research has been conducted into the relationship between sleep and cognitive failures, with most of it looking into the sleep-wake cycle and daytime sleepiness rather than sleep deprivation itself. Wallace, Vodanovich and Restino (2003) examined the link between cognitive failures, daytime sleepiness, and proneness to boredom in military and university populations. They found that higher daytime sleepiness and proneness to boredom were predictive of higher cognitive failure scores. They also found that the military had both higher daytime sleepiness scores and higher cognitive failure scores, which is likely due to the larger workload and therefore higher stress placed on them.

Furthermore, Wilkerson, Boals and Taylor (2012) used a large sample of undergraduate students to investigate the relationship between insomnia and cognitive failures. Regression analyses showed that severity of insomnia predicted cognitive failures score, with further analyses showing this relationship was significant even after controlling for possible confounding variables such as depression, negative affect, stress, and anxiety. This suggests that there is a relationship between amount and quality of sleep and proneness to cognitive failures.

Looking at daytime preferences, Mecacci, Righi and Rocchetti (2004) found that individuals who preferred morning hours reported variable levels of cognitive failures throughout the day, with a notable peak in the evening hours, whereas individuals who preferred evening hours reported their cognitive failures were stable throughout the day with no noticeable peak. This suggests that circadian rhythms interact with the time of day to influence cognitive failures and, more generally, cognition.

1.2.4.2 Age

Although it is accepted that age-related cognitive decline is relatively common (Hanninen et al., 1996), a number of studies found little difference between the number of cognitive failures reported by younger and older people (Kramer, Humphrey, Larish, Logan & Strayer, 1994; Reese & Cherry, 2006; Lange & Süß, 2014), and one study by Mecacci and Righi (2006) found that older people reported fewer slips than younger people. Hohman, Beason-Held, Lamar, & Resnick (2011) conducted a longitudinal study in which they found that higher cognitive failures were predictive of cognitive change over 11.5 years, and were associated with steeper rates of cognitive decline, especially in verbal memory function.

There is some uncertainty surrounding the reliability of self-report measures in older people, as the following two studies showed that whilst older people make more errors in daily life, they are less competent at monitoring and reporting these, therefore under-reporting their cognitive failures (Mecacci & Righi, 2006; Harty, O'Connell, Hester & Robertson, 2013). This limitation can be extended to others as well, as it is possible that highly distractible or forgetful people under-report the amount of slips they experience whilst highly conscientious people are overly aware of cognitive failures and may over-estimate how many they experience in a certain time period.

1.2.5 Chapter Summary

Cognitive failures are experienced on a daily basis by everyone, and although these are irritating, they are usually quite minor. Some people, however, experience them far more often than others which can become a serious concern as they become a barrier to safely and successfully carrying out routine responsibilities. Proneness to cognitive failures is most often measured using the Cognitive Failures Questionnaire first developed by Broadbent in 1981. Brain imaging has shown that greater distractibility in everyday life was predicted by increased parietal grey matter and that reduced GABA in the occipital lobe was associated with increased risk of cognitive failures, suggesting that imaging technology could help to explain why certain individuals experience more cognitive failures than others. This is important as CFQ scores have been shown to correlate with real world outcomes, such as employability and at-fault accident rates. When related to stress, it is thought that a high CFQ score is a vulnerability factor making the individual less able to resist the effects of stress and therefore experiencing more cognitive failures under high pressure. In this case, it would be important to be able to recognise early individuals who may be more prone to errors due to stress and work with them on coping strategies to reduce errors and accidents.

Whilst cognitive failures have been studied in relation to objective cognitive tasks, results are inconclusive. Previous research hints at relationships with attention, inhibition, and working memory and executive control, however more research is needed to further understand how these aspects of cognition interact. Some research has shown that insomnia and preference for time of day is related to proneness for cognitive failures, however more research in these fields is also needed to further understand the interactions. This would be particularly interesting for people who work long hours, changeable shifts, and unsociable hours such as healthcare professionals and drivers, where cognitive failures and accidents are particularly dangerous.

It is still unsure how age affects proneness to cognitive failures, with some studies reporting more errors in older age and some reporting less. This could be due both to a slower pace of life for most elderly people (less chance for errors and these will be less important) and to the misreporting of errors that do occur (due to declining memory).

Research into cognitive failures is an interesting topic that was initially quite slow to gain traction, with most scientists preferring objective measures that can be conducted in strict laboratory settings. It has become obvious, however, that these strict objective tasks do not always reflect real-life outcomes, and that studying subjective, personal outcomes such as cognitive failures can provide more insight into how an individual would react in real life to changes such as stress and sleep deprivation.

1.3 Visual Search Task and Decision-Making

When attending a medical emergency, responders must first analyse the scene and assess the patient before deciding which course of action to take in order to treat the patient. In other words, before the decision-making process can be initiated, responders must use visual search methods to learn what they can from the scene before them. In order to make this process quicker, well-trained emergency responders will use previously acquired knowledge to direct their attention towards the areas that are most likely to display signs of injury or illness and require treatment, such as the neck and back for falls from height, or the chest and airways for breathing difficulties. Using this previous knowledge to direct their attention makes the process faster and means they are more likely to quickly assess and treat a patient than if they followed the same search pattern on every patient, for example, starting at the toes and moving upwards, which would be a laborious and time-consuming method. Furthermore, responders must quickly but accurately diagnose the patient in order to provide treatment as quickly as possible. This means they must decide how much time to dedicate to the diagnosis whilst not compromising the accuracy of the diagnosis, which is known as the speed-accuracy trade off. This chapter focusses on the use of the contextual cueing paradigm to understand implicit statistical learning mechanisms, which are vital in directing attention during visual search, and on the speed-accuracy trade off and its consequences in decision-making.

1.3.1 Contextual Cueing Paradigm

1.3.1.1 Statistical learning

Statistical learning is the term given to an unconscious cognitive process in which repeated patterns and regularities are extracted from sensory inputs (Turk-Browne, 2012). Although it was first identified and used in the field of language acquisition (Saffran et al., 1996), statistical learning is now recognised in various fields of psychology to help explain how humans detect and use statistical regularities found in the environment (Turke-Browne et al., 2005; Thiessen et al., 2013). Statistical learning helps humans to structure the world and to make it understandable and even predictable. It plays an important part in language acquisition, object recognition, scene identification, attentional guidance, and navigation in dynamic and complex environments (Goujon, Didierjean, & Thorpe, 2015). Various approaches from different fields of psychology and linguistics exist to study statistical learning and how humans become sensitive to structured properties within their environment. In the cognitive world, the contextual cueing paradigm is the most popular way to understand how learning mechanisms can detect contextual regularities during visual search and therefore accurately direct attention and optimise basic visual processing (Chun & Jiang, 1998; Chun, 2000).

1.3.1.2 Contextual Cueing

First coined in 1998 by Chun and Jiang, the term ‘contextual cueing’ refers to the type of visual learning where one associates spatial configurations with target positions (Chun & Jiang, 1998). It has been shown that even with little attention paid to the task, participants rapidly learn numerous target-context associations, and that this memory is mostly immune to interference and decay (Mednick, Makovski, Cai & Jiang, 2009). The principle of the paradigm is to present regularities within search displays throughout the course of the task that allow participants to begin to predict target locations based on these regularities. In the original - and the standard - contextual cueing paradigm, participants are tasked with searching for a ‘T’ target within a set of ‘L’ distractors. Half of the configurations are repeated across many blocks of trials while others are only presented once. The repeated configurations lead to faster search times compared to the new configurations, this is what is known as the contextual cueing effect. These faster search times are explained by the learning of associations between spatial configurations and target locations, which then guide the attention to the target location. This usually occurs without formal instruction, intention to learn, or evidence of conscious memory, which has led to the conclusion that contextual cueing results from implicit learning (Chun & Jiang, 2003). Contextual cueing has been shown to remain strong throughout one’s lifetime

(Merrill, Conners, Roskos, Klinger & Klinger, 2013) and has been recognised in young normally developed children (Dixon, Zelazo, & De Rosa, 2010), in children with autism spectrum conditions (Brown, Aczel, Jimenez, Kaufman & Grant, 2010), in young adults with intellectual disabilities (Merrill, Conners, Yang, & Weathington, 2014), and in non-human primates and pigeons (Goujon & Fagot, 2013). It has been concluded that contextual cueing is a universal phenomenon with a constant effect on behaviour, and therefore that it is a robust tool for studying visual learning (Goujon, Didierjean, & Thorpe, 2015).

1.3.1.3 Implicit learning and contextual cueing

Implicit learning is typically defined as an unintentional and automatic adaptation to information present in the world without any clear awareness of what has been learned (Reber, 1967). It is different to explicit learning which is the more formal and aware acquisition of skills or knowledge where the student can explain how they gained the skills or knowledge. Rather than being linked to a set moment in time, implicit learning emerges slowly over practice, becoming robust over time. It is resistant to most psychiatric and neurologic disorders and age effects, it is not linked to IQ, and it is driven by primitive mechanisms shared with other species. Considering what is known about contextual cueing, it is clear that implicit learning plays an important role and is likely to be the driving force behind the contextual cueing effect (Reber, 2013; Zellin et al., 2014).

It is important to note that although the above remarks suggest that implicit learning is stable across all humans, 30% of participants commonly fail to display contextual cueing (Lleras & Von Mühlenen, 2004). More in depth research showed that contextual cueing is not available to patients with major damage to medial temporal lobe structures (Chun & Phelps, 1999; Manns & Squire, 2001), which contradicts the theory that implicit learning is independent of the medial temporal lobe (Geyer et al., 2012; Manelis & Reder, 2012). Despite previous research into implicit and explicit learning suggesting that the medial temporal lobe and hippocampus are not involved in the neural mechanisms of implicit learning (Reber, 1992) but rather are only involved in the mechanisms of explicit learning, more recent literature concludes that the medial temporal lobe does play a crucial role in implicit contextual cueing and that the hippocampus may be engaged even when the knowledge remains implicit (Geyer et al., 2012). These diverging and seemingly contradictory reports do come together to explain the variety of mechanisms involved in contextual cueing and the different statistical learning phenomena which are revealed by the contextual cueing effect.

1.3.1.4 Mediating factors in contextual cueing

The formation and consolidation of perceptual units in both memory and associative learning are strongly influenced by different types of interference, for example a non-target set of distractors being present in the display greatly reduces contextual cueing effects. Another important aspect is the spatial and featural organisation of the items in the display, for example contextual cueing is improved when grouping processes of the items are increased, which is likely to favour extraction of global configurations (Feldmann-Wüstefeld & Schubö, 2014). Attention is also likely to determine the strength of contextual cueing effects, as although both implicit learning and statistical learning can take place with minimal attention being paid, learning effects are usually stronger when attention is fully available for the task (Turke-Browne, 2012; Thiessen et al., 2013). In a dual-task condition requiring significant spatial and concurrent spatial working-memory resources, contextual cueing was shown to be reduced under high working-memory load (Maginelli et al., 2012; Travis et al., 2013). Furthermore, contextual cueing depends heavily on the repeated contexts being attended by the subject (Jiang & Leung, 2005), and it would seem that when surface features become task-relevant, they are automatically integrated into the context representations, therefore showing the importance of attention being oriented towards those features (Jiang & Song, 2005).

1.3.1.5 Contextual cueing in real-world scenes

Brockmole and Henderson (2006) were the first to investigate contextual cueing in real-world scenes. Just like the artificial stimulus arrays first used by Chun and Jiang and still often used to measure contextual cueing effects, real-world scenes have stable structures (Henderson & Hollingworth, 1999). Walking through one's neighbourhood, for example, one will recognise houses, cars, letterboxes, road signs, and more, which are the same objects arranged in the same spatial configuration. Even when some objects move, such as cars, they will appear in regular spatial arrangements, either parked in driveways or along the side of the road. They are not expected to be abandoned in the middle of the road or a garden, and this will cause alarm if it is the case. In their study, Brockmole and Henderson (2006) examined how regularities within real-world environments are used to guide visual attention to behaviourally relevant targets. In order to do this, observers were tasked with searching for and identifying a target letter arbitrarily embedded in scene photographs. Congruent with Chun and Jiang's study, search times across novel scenes stayed constant throughout the experiment and search times for letters appearing in a consistent position in repeated scenes decreased across repetitions. As opposed to Chun and Jiang's study where learning was implicit, however, Brockmole and Henderson discovered that memory for scene-target covariation in real-world scenes was explicit. Subjects reported recognising repeated scenes more often than scenes which were only presented once, and displayed superior recall of target position within the repeated scenes. Moreover, the researchers decided to invert the repeated scenes to increase difficulty in recognition and this resulted in a significantly reduced rate of learning. This suggests that information concerning object and scene identity is used to guide attention, and that paradigms using non-scene stimuli can only partially characterise contextual cueing within the real-world.

An important issue with contextual cueing in scenes is understanding the nature of the information that is used to reference the target position. Previous studies which used non-scene stimulus arrays, such as a set of ‘L’ letters, found evidence that the target is associated with a small number of nearby items, known as the local area, rather than with the overall pattern, known as the global area. This was shown by Jiang and Wagner (2004) who found that context-target associations transferred to new contexts with different global arrangements created by the items as long as the local aspects from the previously learned context were preserved within this new global context. They found this effect to be so strong that even when the global context was highlighted by a line connecting all the distractors to make a global shape, subjects still used local cues to identify the location of the target. Another study by Olson and Chun (2002) showed that variation in the local area immediately surrounding the target prevented cueing, but that as long as this local area remained unchanged, cueing would occur even in new global contexts that had never been repeated. Brockmole, Castelhano and Henderson (2006) ran a study to examine the degree to which search targets within naturalistic scenes are associated with the immediate local context versus the global context of the scene. Real-world scenes have a degree of coherence which is absent from non-scene stimulus displays and, according to Henderson and Ferreira (2004), the identity of a scene can be identified at a basic categorical level within the first 100ms of viewing. This provides certain expectations about spatial layout and component objects and drives the viewer’s attention to task-relevant scene regions (Henderson, Weeks, & Hollingworth, 1999).

In their experiment, Brockmole, Castelhano and Henderson (2006) presented subjects with a sequence of trials composed of an arbitrarily located target letter within computer simulations of realistic scenes. They clarify that they used computer simulations in order to better manipulate the local and global contexts separately, however these did appear as realistic scenes. They found that once subjects had learned the location of a target in a naturalistic scene, changes in the local context surrounding the target had no impact on contextual cueing when the global scene remained the same, this was shown through the preservation of the search time advantage that had been achieved at the end of the learning phase. A change in the global scene with preservation of the local scene, however, eliminated the effects of contextual cueing that had been achieved, suggesting that during the learning phase, the target was located relative to the global scene information, not the local scene information. Overall this shows that contrary to random non-scene arrays, real-world scenes provide expectations about layout and component objects as these must comply with physical and semantic constraints within the scene (Henderson & Ferreira, 2004). Observers are also more likely to recognise a real-world scene, such as a certain room or a certain crossroads, than a random arrangement of symbols, which may provide a better retrieval cue for past searches and locations. Furthermore, searching for a letter within an arrangement of other letters provides more similarity between the target and the background than searching for a letter within a real-world scene, which could lead to differences in how the targets are associated with the visual information that is presented and more than likely leads to different learning strategies. This shows that contextual cueing in real-world scenes is an explicit memory phenomenon, as opposed to an implicit learning phenomenon as in non-scene arrays, and that in real-world scenes global information, rather than local information, guides the attention to known search targets (Brockmole, Castelhano, & Henderson, 2006).

1.3.2 Signal Detection Theory and Sensitivity Bias

Signal detection theory (SDT) was introduced to psychology by Green and Swets in 1966, and it can be applied whenever a participant must discriminate between two possible stimulus types. The theory was first applied to perception studies, where participants were asked to discriminate between signals (stimuli) and noise (no stimuli). Although signal detection theory has now been applied to many different areas of psychology, the ‘signal’ and ‘noise’ labels remain. Examples of studies involving signal detection theory include recognition memory (old and new items), lie detection (lies and truths), and medical diagnosis (diseased and well patients), among others (see Swets, 1973; Hutchinson, 1981). The three most common tasks to measure performance in signal detection theory are yes/no, rating, and forced-choice tasks. Due to its relevance to the visual search task used, only the yes/no task will be discussed here.

As described above, a yes/no task contains signal trials, presenting one or more signal stimuli, and noise trials, presenting one or more noise stimuli. In the auditory task example, a yes/no task may present a tone during signal trials and nothing at all during noise trials. After each trial, participants indicate whether a signal was presented (‘yes’) or not (‘no’). On signal trials, ‘yes’ responses are correct and are called hits, and on noise trials, ‘yes’ responses are incorrect and are called false alarms (thinking one heard a signal when there was none). The hit rate is the probability of responding ‘yes’ on signal trials and the false-alarm rate is probability of responding ‘yes’ on noise trials. Together, these accurately describe a participant’s performance on a yes/no task.

In order to decide whether a signal is present or not, participants must decide on their criterion, the level at which they decide if a signal is present. In auditory studies, for example, this may be a certain loudness for the signal. If the signal exceeds their criterion, the response is ‘yes’, and if it does not, the response is ‘no’. Participants with a lower criterion are more likely to answer yes both on signal trials and on noise trials, this is a liberal response. It is characterised by a high hit rate and a high false-alarm rate as the participant is biased towards responding ‘yes’ despite the type the stimulus. Participants with a higher criterion are more conservative, and therefore more likely to respond ‘no’, both on signal and on noise trials. This will lead to a lower false-alarm rate, but also a lower hit rate, as the signal must exceed a higher level before it is accepted as a signal. This tendency towards more liberal or more conservative responses is known as the response bias. Signal detection theory also measures sensitivity, which is the degree of overlap between the signal and the noise distributions. It is easily explained using the auditory task, as participants with more sensitive hearing are more likely to detect a signal than less sensitive participants. Participants with low sensitivity are more likely to make errors but will not display a response bias, whereas participants with higher sensitivity will make fewer errors but will display a response bias, either more conservative or more liberal (Stanislaw & Todorov, 1999).

1.3.3 Speed-Accuracy Trade-Off

The speed-accuracy trade-off (SAT) is a fundamental and long-established behavioural phenomenon that can be found across species (Heitz, 2014). It dictates that when actions are performed faster, they are less accurate (Fitts, 1966), and this applies both across motor and cognitive performance. Current theories suggest that reward may increase the speed of actions but decrease accuracy, however more recent studies have reported that reward increases both the speed and accuracy of motor control (Takikawa, Kawagoe, Itoh, Nakahara, & Hikosaka, 2002) and can reduce reaction times and error rates in cognitive tasks (Hübner & Schlösser, 2010; Krebs, Boehler, Egner, & Woldorff, 2011). In cognitive control theory, models of decision-making predict a speed-accuracy trade-off by assuming that faster responding implies less time to weigh up evidence and thus more errors in decision-making (Bogacz, Wagenmakers, Forstmann, & Nieuwenhuis, 2010). Measuring the speed-accuracy trade-off displayed on a task by comparing reaction times to error rate provides a sensitivity threshold. Subjects with a more conservative sensitivity threshold display slower reaction times and a smaller error rate, they favour accuracy over speed. Subjects with a more liberal threshold will display faster reaction times and an increased error rate, they will favour speed over accuracy. In medical decision-making, it is important for a diagnosis to be reached speedily, however it is also important for it to be accurate. Measuring the speed-accuracy trade-off in visual search tasks could provide an insight into the types of decisions and compromises that first responders are willing to make when faced with a task in which they must display both speed and accuracy.

1.3.4 Chapter Summary

Visual search tasks provide a dependable framework for measuring different cognitive functions in a controlled manner. This chapter focussed on the contextual cueing phenomenon, where implicit and statistical learning serve to guide attention in repeated scenes. Statistical learning is the term given to an unconscious cognitive process in which repeated patterns and regularities are extracted from sensory inputs. It helps humans to structure the world and to make it understandable and even predictable. Contextual cueing refers to the type of visual learning where one associates spatial configurations with target positions. It has been shown that even with little attention paid to the task, participants rapidly learn numerous target-context associations, and that this memory is mostly immune to interference and decay. The principle of the paradigm is to present regularities within search displays throughout the course of the task that allow participants to begin to predict target locations based on these regularities. This paradigm is the most popular way to understand how learning mechanisms can detect contextual regularities during visual search and therefore accurately direct attention and optimise basic visual processing. Contrary to random non-scene arrays, real-world scenes provide expectations about layout and component objects as these must comply with physical and semantic constraints within the scene. Observers are also more likely to recognise a real-world scene, such as a certain room or a certain crossroads, than a random arrangement of symbols, which may provide a better retrieval cue for past searches and locations. By guiding attention to the expected location of a target, contextual cueing decreases search time and therefore results in faster reaction times and smaller error rates.

Signal detection theory measures a participant's sensitivity and response bias in a yes/no type of task. To do so, it uses the hit rate (probability of responding 'yes' on signal trials) and the false-alarm rate (probability of responding 'yes' on noise trials). It is a reliable method of measuring how likely one is to recognise signals (sensitivity) and to decide whether these are signals (liberal response bias) or whether they are noise (conservative response bias).

The speed-accuracy trade-off is a behavioural phenomenon that dictates that there is a threshold where one must choose speed or accuracy, and that faster response times result in more errors. This means humans must decide whether they value accuracy over speed. It would seem logical that subjects who value accuracy over speed and take the time to search a scene for a target will be quicker to display statistical learning and contextual cueing, compared to subjects who favour speed over accuracy and may or may not be aware of the presence of a target in repeated scenes.

1.4 Research Plans

1.4.1 Previous Research into Medical Decision-Making

In order to decide what kind of study to use and how to measure decision-making in emergency medical responders, a literature search was conducted to identify previous studies investigating the topic. The search focussed on medical visual search tasks, the link between cognitive failures and medical decision-making, and the impact of sleep on medical decision-making. These findings helped to shape the study and reinforce that more research into these topics is needed.

The vast majority of visual search tasks used to investigate medical topics involve the use of eye-tracking and medical images such as x-rays and scans to look for abnormalities related to pathologies (e.g. Manning, Ethell, & Donovan, 2004; Crawford, Litchfiled, & Donovan, 2017), and to analyse and provide training for trainees (e.g., Litchfield, Ball, Donovan, Manning & Crawford, 2010; Manning, Ethell, Donovan, Crawford, 2006). These studies use measures such as fixation points, saccades, time-to-first-hit, and areas of interest to analyse the way medical professionals and students look at medical images and how they decide whether there are one or more abnormalities present, and whether these abnormalities are related to certain pathologies. This is not directly linked to the study at hand as it relates to visual search in static images which are almost always presented in the same way, whereas this study is investigating emergency medicine, which is composed of changeable, real-world scenes. Emergency responders will rarely attend two identical scenes and must therefore use what they have previously learned to direct their attention to relevant areas of the scene in front of them. A literature search provided no previous instances of research into this area.

Previous research has been conducted into the differences in search patterns between novices and experts in medical fields; for example, Donovan and Litchfield (2013) analysed the ability to detect lung nodules in chest x-rays in medical professionals with different levels of expertise, finding different patterns of visual search based on expertise-level. However, no studies were found which analysed the effects of sleep on visual search tasks in medical professionals. The finding of the effect of expertise on visual search tasks, however, led to the decision to use neutral, non-medical related stimuli to ensure it was not this finding of expertise that was creating an effect.

No literature was encountered which linked cognitive failures to medical-decision making. Other than the early study on student nurses by Parker (1981) which linked CFQ scores to a mental health questionnaire score, suggesting that a high CFQ score is a vulnerability factor to stress, no further research has been conducted in this area. If a link were to be found between cognitive failures and aspects of decision-making it would provide an interesting topic for future research.

Previous studies have shown that poor sleep and both acute and chronic sleep deprivation lead to increased errors and incidents both in non-medical settings (e.g., Belenky et al., 2003; Van Dongen, Maislin, Mullington, & Dinges, 2003), and in medical settings (e.g., Kramer, 2010; Parry, Oeppen, Amin, & Brennan, 2018), but again these studies are often conducted in laboratory or clinical settings, which are very different to the real-world settings emergency responders operate in. This is why it is important to understand the basic factors involved in emergency medical decision-making, such as implicit learning and sensitivity bias, and to study the effect of sleep on these factors.

Although a number of studies have researched areas similar to the topic of this study, no literature could be found that linked directly to the use of visual search tasks to understand the effects of sleep on emergency medical decision-making. Previous studies have, however, helped to shape the study, such as avoiding the effect of expertise by using neutral, non-medical stimuli.

1.4.2 Hypotheses

Conducting a review of the published literature on sleep deprivation and restriction, cognitive failures, and contextual cueing and response bias in visual search tasks has brought to light certain expectations and hypotheses about the results from this study. Although there is no research looking at the combination of these three topics, they are linked by the cognitive functions that are involved or affected by each topic.

It is expected that around 50% of participants report a high PSQI score, signifying poor sleep. It is also expected that poor sleep leads to daytime sleepiness, yielding a positive correlation between PSQI scores and ESS scores. It is hypothesised that daytime sleepiness is linked to increased cognitive failures, and therefore that CFQ scores will correlate positively with ESS scores.

The visual search task is expected to display the contextual cueing effect with faster reaction times occurring in each subsequent block on trials where the target is present and in the same location. Trials with no target ('absent' trials) are expected to show slower reaction times than 'present' trials, but these are also expected to decrease as participants learn which trials contain targets and which do not. We hypothesise that sleepiness will have an effect on attention and therefore reaction times, and also possibly on learning. This will manifest itself through slower reaction times, higher error rate, and a less noticeable learning effect. We also hypothesise that there will be a link between the contextual cueing effect and cognitive failures, with a high CFQ score being linked to a smaller learning effect, due to higher distractibility.

It is not known how fatigue or cognitive failure scores will affect sensitivity and response bias, but it would be a very interesting topic if significant results were obtained.

2 Methods

2.1 Participants

Participants were recruited from the following medical response organisations: Lowlands Search and Rescue; Lancaster Area Search and Rescue; East Croydon and Addiscombe St John Ambulance; London Borough of Sutton St John Ambulance; Lancaster St John Ambulance; 208 Field Hospital, Royal Army Medical Corps; 156 Regiment RLC; and Lancaster Medical School. Potential participants were contacted by an email forwarded by their chain of command (see Appendix A) explaining the study and inviting them to read the Participant Information Sheet (appendix B) and consent form (appendix C). Participants who agreed to take part were provided with a link to the online study.

Based on their sleep score (see Materials), participations were assigned to either the good quality sleep group or the poor quality sleep group. A power calculation was carried out using a study by Jackson et al. (2013) looking at the effects of sleep loss on simulated driving performance and hazard perception. The mean reaction time in the normal sleep group was 231. 2 (SD 21.6) ms compared to 256.2 (42.4) ms in the poor sleep group. The means and SDs were entered into G*Power to calculate the sample size needed to replicate this effect size using an independent sample t-test. At power set at 0.80, to find an effect at the 5% level, it would require a sample of 26 people per group (good sleep quality vs poor sleep quality), with a total sample of 52 participants. It was anticipated that ~50% of all participants would report lower sleep quality as it is well documented that emergency medical workers suffer from poor sleep. A study by Patterson et al. (2012) found that 55% of the 547 Emergency Medical Services (EMS) workers that they surveyed were classified as fatigued by the Pittsburgh Sleep Quality Index (PSQI). This anticipation was correct, as 23 participants (53% of the sample) were classified as having poor sleep quality and 20 participants (47% of the sample) as having good sleep quality.

2.2 Task and Materials

2.2.1 Questionnaire

The questionnaire comprised of four parts: demographic questions, the Cognitive Failures Questionnaire (CFQ), the Pittsburgh Sleep Quality Index (PSQI), and the Epworth Sleepiness Scale (ESS).

2.2.1.1 Demographic Questions

Demographic questions included the participants age and gender, the organisation they worked for, years of experience, their role, employment status (full time, part time, volunteer), the type of shifts most commonly worked in that role, and the total hours worked over the previous week (view Appendix E). These questions were based on the 15-item demographic survey used by Patterson et al. (2012) in their study looking at the association between poor sleep, fatigue and safety outcomes in emergency responders. Questions about general health and drinking and smoking habits which were included by Patterson et al. were not deemed necessary for this study as not potential predictors of interest, however may be of interest for future research.

2.2.1.2 Cognitive Failures Questionnaire (CFQ)

The propensity for cognitive failures was measured using the 25-item Cognitive Failures Questionnaire (CFQ) (view Appendix F). It measures self-reported failures in perception, memory, and motor function over a six-month time interval. The 25 items are various types of "minor mistakes" which most humans commit from time to time and which represent lapses in perception, memory, and motor function. Subjects are asked to report from 0 – 4 (0 = never, 1 = very rarely, 2 = occasionally, 3 = quite often, 4 = very often) how often they made these 'mistakes' in the last six months. With an overall possible score ranging from 0 – 100, higher scores signify higher cognitive failure, which is thought to make a person more vulnerable to showing the effects of stress (Broadbent, Cooper, FitzGerald & Parkes, 1982).

2.2.1.3 Pittsburgh Sleep Quality Index (PSQI)

Sleep quality was measured using the 19-item Pittsburgh Sleep Quality Index (PSQI) (view Appendix G). It is a self-rated questionnaire which assesses sleep quality and disturbances over a one-month time interval. The 19 items form seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Each component is rated from 0 – 3 (0 = not during the past month; 1 = less than once a week; 2 = once or twice a week; 3 = three or more times a week) with an overall possible score ranging from 0 – 21. A score above 5 indicates poor sleep quality. It is considered to be reliable; in the original study the 7 components had an overall Cronbach's alpha of α = 0.83 and individual items correlated strongly with each other also with α = 0.83, and subsequent studies replicate these findings. Test-retest reliability for the PSQI at a four-week interval was 0.85 ($p < 0.001$) (Buysse, Reynolds III, Monk, Berman, Kupfer, 1989; Omachi, 2011).

2.2.1.4 Epworth Sleepiness Scale (ESS)

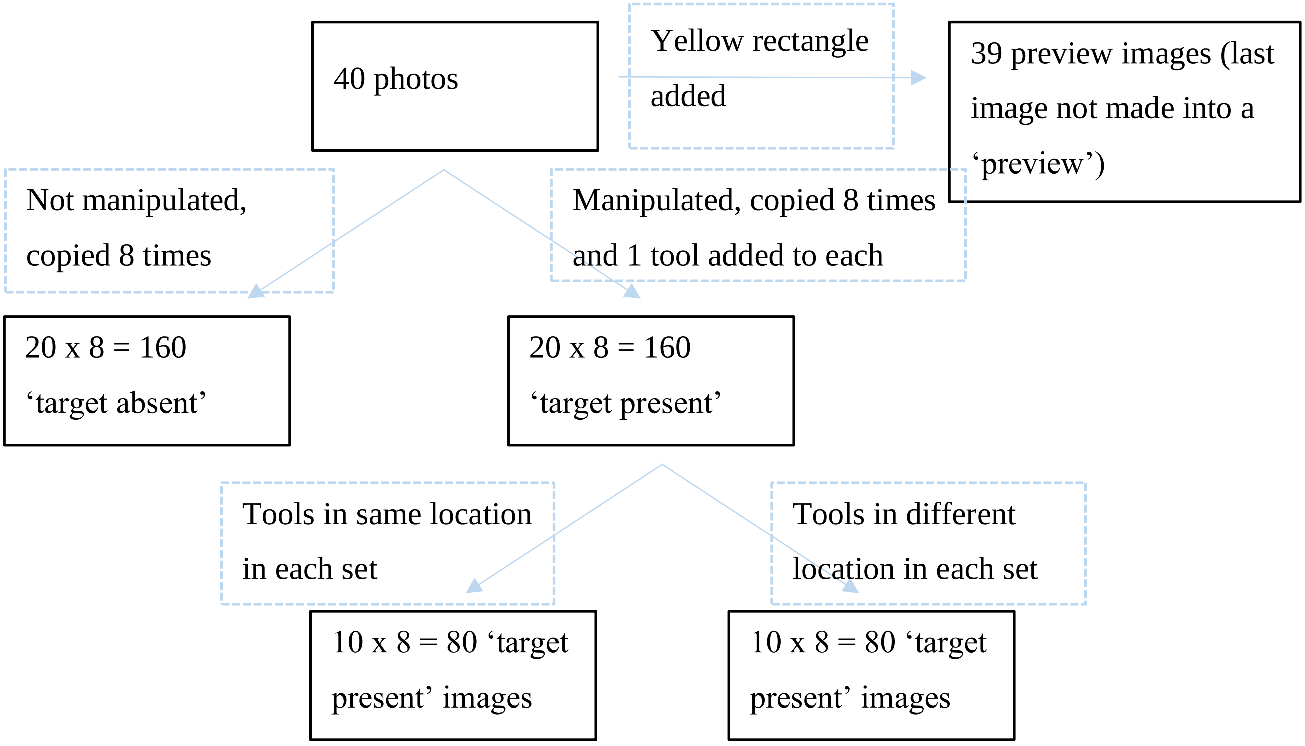
Fatigue was measured using the 8-item Epworth Sleepiness Scale (ESS) (view appendix H). It is a self-rated questionnaire which assesses a subject's general level of daytime sleepiness. The eight items refer to eight situations, some of which are known to be very soporific. Subjects are asked to rate from 0 – 3 how likely they would be to fall asleep or doze off in each situation (0 = would never doze, 1 = slight chance of dozing, 2 = moderate chance of dozing, 3 = high chance of dozing), with an overall possible score ranging from 0 – 24. A score equal to or above 11 indicates high daytime sleepiness (Johns, 1991). It is considered to possess strong reliability, due to adequate internal consistency with Cronbach's alpha (range α = 0.74 – 0.88). Test-retest reliability is reported to be high based on tests 5 months apart in healthy subjects (r = 0.82, $p < 0.001$) (Johns, 1992). The validity of the ESS has been assessed as its correlation with the multiple sleep latency test (MSLT), with studies showing positive correlations of between 0.30 and 0.37, and as its ability to predict the presence of narcolepsy (a condition defined by excessive daytime sleepiness) better than the MSLT (Omachi, 2011; Olson, Cole, Ambrogetti, 1998).

2.2.2 Repeated Scenes Search Task

A visual search task measuring contextual cueing and bias was used. The stimuli were constructed from 40 photographs of street scenes taken along a route in a suburban neighbourhood. The 40 photographs were taken so that they formed a spatially and temporally defined sequence and so that the contents and perspective of the current scene was visible from the preceding scene, though from a more distant perspective. Twenty photos remained un-manipulated and were used as the 'target absent' stimuli and 20 photos were manipulated to contain a target and become the 'target present' stimuli. Each of the 'target present' images were altered eight times, so the same image had eight versions, each with a different tool from a selection of five different threat-related objects; axes, hammers, pliers, saws, and screwdrivers. There were four exemplars of each type of target, resulting in 20 targets used over the whole experiment. Of these 20 sets of manipulated images, 10 sets contained a different tool in the same location and 10 sets contained a different tool in a different location. Every image except the last one was also manipulated to contain a yellow rectangle showing the area depicted in the following image, these are known as 'preview' images. The last image was not given a corresponding 'preview' image as there was no following portion of route for it to be a preview of. The image manipulation is shown in figure 1, below.

Figure 1

Chart explaining creation of stimuli and preview images



The route, or block, contained 20 'target absent' images, 20 'target present' images and the 39 corresponding 'preview' images, giving a total of 40 stimuli and 39 'preview' images for the route. Eight versions of the route were created, making eight blocks, using one of each manipulation of the 'target present' images, giving a total of 320 stimuli and 312 'preview' images for the task. Route progression consisted of each stimulus image followed by the corresponding 'preview' image until the route was completed. As stated above, the last stimulus image did not have a corresponding 'preview' image as there was no following image to preview. There was a 'break' screen in between each block in case participants wished to take a break.

Time to key press and type of key pressed ('A' or 'P') were recorded. Time to key press gave a reaction time for each stimulus and type of key pressed was compared to the correct answer to give the error rate. Feedback (correct/incorrect) was not provided. The first block counted as a practice block considering there was no opportunity for learning. Subsequent blocks provided the opportunity for learning whether the target would be absent or present and whether it would be in the same or a different location.

The task was programmed using PsychoPy3 (Open Science Tools Ltd) and uploaded to pavlovia.org for sharing and running.

2.3 Procedure

A senior training member from each organisation was contacted at the beginning of the research programme to discuss the study and potential involvement from their organisation. They were all eager to provide support with the study and to provide an opportunity to recruit participants. They have been consulted throughout the creation of the final questionnaire and tasks to ensure openness and collaboration, and have asked for a report and a presentation of the findings as a result of their participation.

Potential participants from each organisation were contacted by email, forwarded by their chain of command (see Appendix A), explaining the study and inviting them to read the Participant Information Sheet (Appendix B) and consent form (appendix C). Potential participants were encouraged to contact the researcher with any questions regarding the study or their participation. Participants who agreed to take part were asked to follow the link provided for the online study. The first link directed participants to the Qualtrics questionnaire (see Appendix E) which included the consent form. Participants were only able to access the questionnaire once they had provided consent by ticking 'I agree' for each statement. Participants who did not agree with one or more statements or who no longer wished to participate were instructed to close the browser window in order to terminate their participation in the study. After providing informed consent, participants were asked to input the last 4 digits of their mobile phone number as their Unique Identification Number (UIN). This enabled the data from both tasks to be linked whilst providing anonymity to the participants, and providing the opportunity for them to withdraw their data following participation if they so wished. Participants were then presented the questionnaire, with demographics questions first, followed by the CQF, followed by the PSQI and ending with the ESS. Participants were given the opportunity to take a break between the CFQ and the PSQI.

Upon completion of the questionnaire, participants were provided with a link to the online task and reminded of the instructions. They were asked to input their UIN again before starting the visual search task. During the task, participants were shown sequential images forming a route through the suburbs. For each image, they were asked to search for a target (a type of tool) and to indicate whether the target was present, by pressing the 'P' key, or absent, by pressing the 'A' key. Following the key press, a yellow rectangle appeared on the image to indicate a preview of the following portion of route. Participants were asked to press the 'space bar' to move on to the next portion of route. Participants viewed the same route eight times, with the opportunity for a break in between each viewing. Once they had completed the task, a screen appeared thanking them for their participation and encouraging them to contact the researcher if they had any further questions or if they wished to withdraw their data.

2.4 Experimental Design and Statistical Analyses

The experimental design was repeated measures with two within subjects factors (Trial Type and Block) and a between subjects factor (Sleep Group). The approach to statistical analyses involved the calculation of descriptive statistics and an independent samples t-test to compare the two groups who of those who completed the task (N = 19) and those who only completed the Qualtrics survey (N = 43). Relationships between the questionnaire measures were analysed using Pearson Product Moment correlations. Reaction times, error rates, and sensitivity (d') were analysed using a repeated measures general linear model (GLM) with trial type (present, absent) and block (2 to 8) as within subject factors and sleep group (high quality, poor quality) as the between groups factor. The Greenhouse Geisser correction was applied where appropriate and all pairwise comparisons were Bonferroni adjusted. The analyses were followed with Pearson Product Moment correlations to assess the relationships between the sensitivity bias and the PSQI, ESS and CFQ scores. Block 1 was not included in the analysis as it was a practice block.

2.5 Ethics Statement

Ethical approval was granted on May 6th 2020 by the Faculty of Health and Medicine Research Ethics Committee (FHMREC), reference: FHMREC19019 (see Appendix I), and May 28th 2020 by the Ministry of Defence Research Ethics Committee (MoDREC), reference: 1026/MoDREC/19 (see Appendix J). The study was not considered to carry any risk to participants, however some participants might have felt uncomfortable after reporting their sleep quality and sleeping patterns. Participants were encouraged to contact their GP, or the Independent Medical Officer in the case of serving personnel, if they felt such discomfort. Furthermore, participants were given the opportunity to end the study at any moment and to have their data removed from the study for up to two weeks after participation if they no longer wished to participate, however, no participants requested this.

3 Results

3.1 Attrition Rate

One hundred and twenty-three potential participants opened the link, with 61 immediately leaving the study and 19 quitting the questionnaire before completion, leaving 43 participants who provided full questionnaire data. Of these, 24 quit the task before the end therefore only 19 participants provided complete data. No participants asked for their data to be removed after taking part in the study.

3.2 Questionnaire Only Results

The final sample for the questionnaire part of the study comprised of 43 participants (29 males, 14 females), aged 18 –63 years (*m* = 34.88; *SD* = 13.87). Distribution of participants across organisations was 20 *(46.5%)* from Search and Rescue, 7 *(16.3%)* from the Armed Forces, 7 *(16.3%)* from St John Ambulance, and 9 *(20.9%)* from Lancaster Medical School. Most participants reported being volunteers (21*; 48.8%*), with 8 *(18.6%)* working part-time in that role, and 5 *(11.6%)* working full time. 14 *(32.6%)* reported feeling more alert in the morning, 9 *(20.9%)* at lunchtime, 7 *(16.3%)* in the afternoon, 10 *(23.3%)* in the evening, and 3 *(7%)* reported feeling more alert at night-time. Participants reported working between 0 – 120 hours over the previous week (*m* = 35.88; *SD* = 25.18). The PSQI results ranged from 3 – 16 (*m* = 6.72; *SD* = 3.4), the ESS results ranged from 0 – 20 (*m* = 8.56; *SD* = 4.93), the CFQ results ranged from 20-80 (*m* = 45.23; *SD* = 13.36).

The results of the correlations between the PSQI, ESS and CFQ questionnaire responses found there was a significant relationship between PSQI scores and ESS scores, $r = .597$, $p < .001$, suggesting that in this population, poor sleep quality was associated with higher daytime fatigue. There was also a significant correlation between PSQI scores and CFQ scores, $r = .426$, $p = .004$, and between ESS scores and CFQ scores, $r = .576$, $p < .001$. This suggests that both poor sleep quality and daytime fatigue are linked to an increase in daily cognitive failures.

3.3 Visual Search Task Results

3.3.1 Questionnaire

The final sample for the task part of the study comprised of 19 participants (13 males, 6 females), aged 21 – 62 years (*m* = 32.63; *SD* = 12.32). Distribution of participants across organisations was 7 (*36.8%)* from Search and Rescue, 5 (*26.3%)* from the Armed Forces, 5 (*26.3%)* from St John Ambulance, and 2 (*10.5%)* from Lancaster Medical School. This smaller sample of participants reported working between 0 – 120 hours over the previous week (*m* = 38.05; *SD* = 29.69). The PSQI results ranged from 3 – 16 (*m* = 6.37; *SD* = 3.30), the ESS results ranged from 0 – 16 (*m* = 8.05; *SD* = 4.70), and the CFQ results ranged from 23 – 65 (*m* = 42.63; *SD* = 29.68). Further analysis showed that there were no systematic differences in age, gender, sleep and CFQ measures, and number of work hours in those who completed the task and those who did not.

3.3.2 Error Rate (ER)

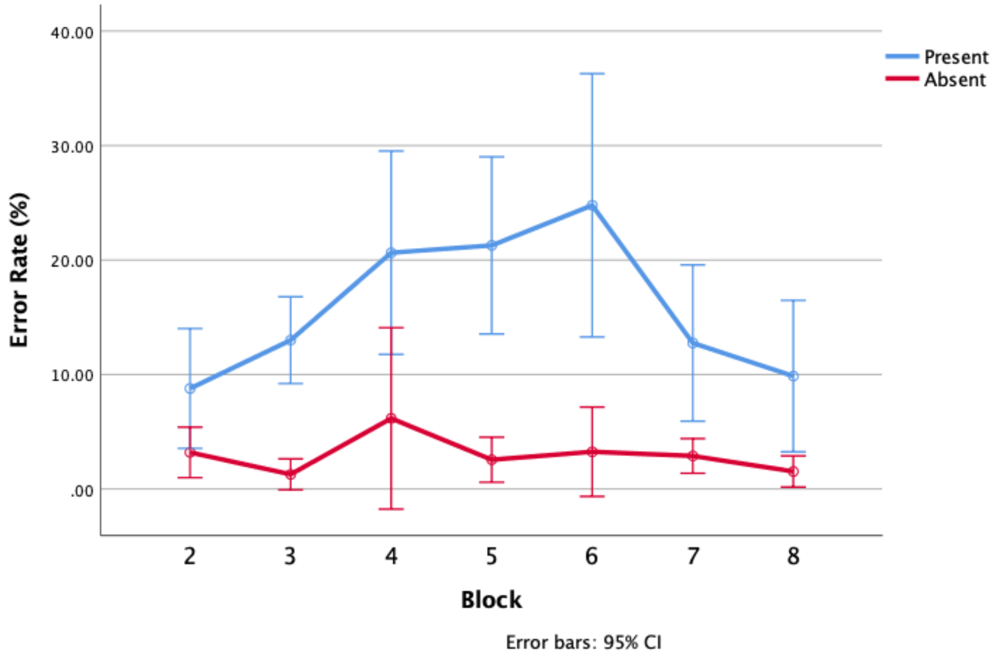
3.3.2.1 Present vs Absent

The repeated measures GLM on type of trial demonstrated a significant main effect of Trial Type F (1, 17) = 18.87, p <.001, η^2_p = .53 (Present = 15.87 (3.08) and Absent = 2.98 (.72)) and Block F (2.81, 47.86) = 6.31, p = .001, η^2_p = .27 (all Present higher than Absent, all *p*s < .05) that was qualified by a significant Trial Type x Block interaction F (3.06, 51.95) = 5.70, p = .002, η^2_p = .25. Figure 2 displays the mean (SE) error rate per block in Present and Absent trials. In Present trials, Block 2 yielded a significantly lower error rate than Block 4 (p = .003), Block 5 (p < .001), and Block 6 (p = .015). Block 8 also yielded a significantly lower error rate than Block 4 (p = .025), Block 5 (p = .003) and Block 6 (p = .003). In Absent trials, there were no significant differences in the error rates across blocks.

The main between subjects effect of Sleep Group was nonsignificant (F (1, 17) = .88, p = .36, η^2_p =.05) and no further significant interactions were found.

Figure 2

Error Rate of Trial Type (Present/Absent) in %



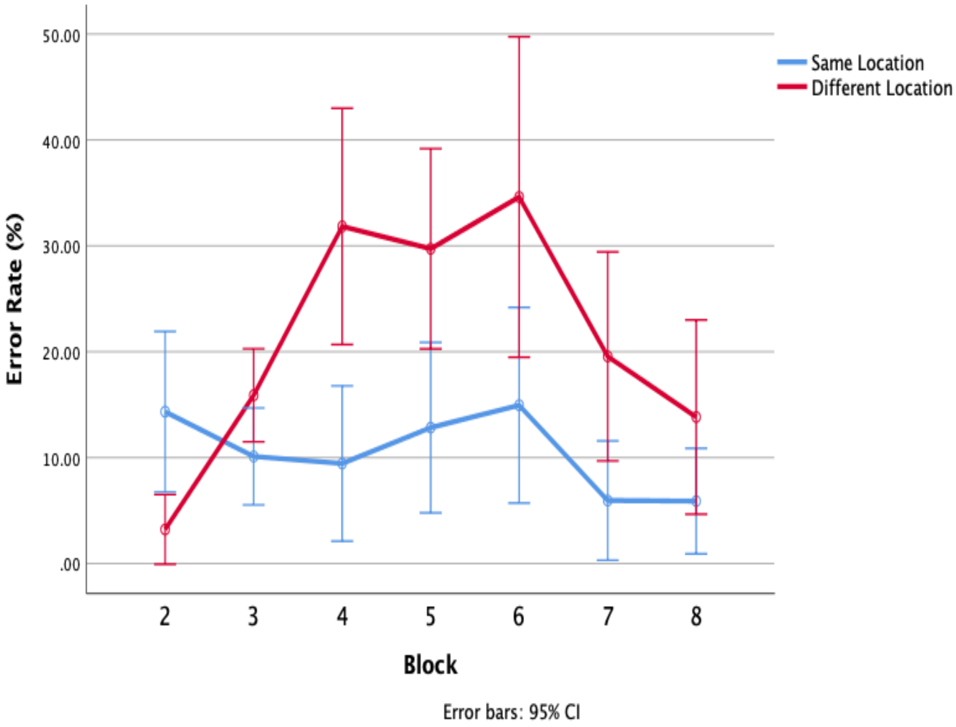
3.3.2.2 Same Location vs Different Location

The repeated measures GLM on the error rates demonstrated a significant main effect of Location F (1, 17) = 36.83, p <.001, η^2_p = .68 (Same = 10.5 (2.78) and Different = 21.24 (3.57)) and Block F (2.96, 50.34) = 9.72, p < .001, η^2_p = .36 (all Same lower than Different, all *p*s < .05) that was qualified by a significant Location x Block interaction F (3.64, 61.87) = 12.38, p < .001, η^2_p = .42. Figure 3 displays the mean (SE) error rate per block for Same and Different location conditions. In Same location trials, only Block 7 yielded a significantly lower error rate than Block 2 (p = .036), all others were non-significant. In Different location trials, Block 2 yielded a significantly lower error rate than Block 3 (p < .001), Block 4 (p < .001), Block 5 (p < .001), Block 6 (p = .002) and Block 7 (p = .004). Block 7 yielded a significantly lower error rate than Block 6 (p = .02), and Block 8 yielded a significantly lower error rate than Block 4 (p = .002) and Block 6 (p = .01).

The main between subjects effect of Sleep Group was nonsignificant (F (1, 17) = .91, p = .35, η^2_p =.05) and no further significant interactions were found.

Figure 3

Error Rate of Location (Same/Different) in %



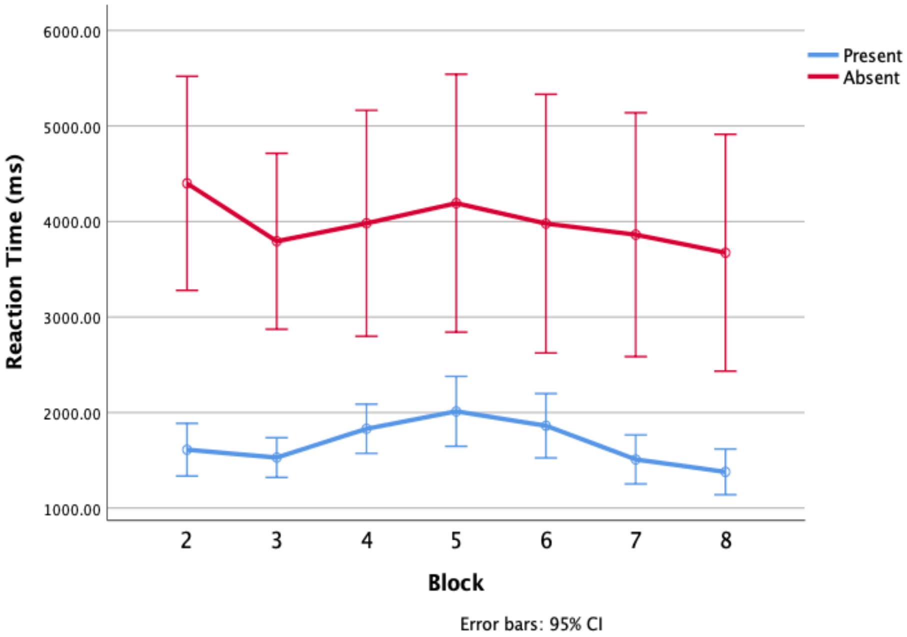
3.3.3 Reaction Times (RT)

3.3.3.1 Present vs Absent

The repeated measures GLM on type of trial demonstrated a significant main effect of Trial Type *F* (1, 17) = 24.03, *p* <.001, η^2_p = .59 (Present = 1676.26 (109.08) and Absent = 3982.81 (539.46)), as seen in figure 4. The main between subjects effect of Sleep Group was nonsignificant (*F* (1, 17) = .14, *p* = .71, η^2_p = .008) and no further significant interactions were found.

Figure 4

Reaction Time of Trial Type (Present/Absent) in ms



3.3.3.2 Same Location vs Different Location

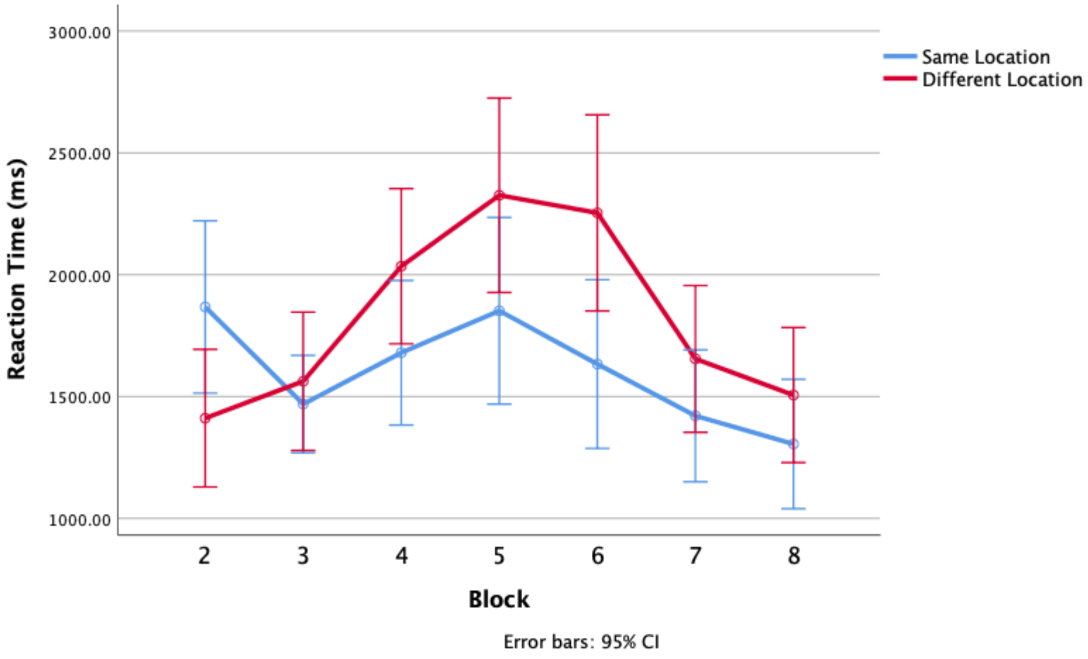
The repeated measures GLM on location demonstrated a significant main effect of Location *F* (1, 16) = 16.15, *p* = .001, η^2_p = .502 (Same = 1603.93 (119.65) and Different = 1821.27 (109.08)) and Block *F* (3.54, 56.69) = 8.59, *p* < .001, η^2_p = .35 (Block 2 Same slower than Different, *p* = .001, Blocks 4, 5, 6, 7 and 8 Same faster than Different, all *p*s< .05) that was qualified by a significant Location x Block interaction *F* (3.73, 59.64) = 8.66, *p* < .001, η^2_p = .35. Figure 5 displays the mean (SE) reaction time per block for Same and Different location conditions. In Same location trials, Block 5 yielded significantly slower reaction times than Block 7 (*p* = .04) and Block 8 (*p* < .001), all others were non-significant.

In Different location trials, Block 2 yielded significantly faster reaction times than Block 5 (*p* = .003) and Block 6 (*p* = .003), Block 3 yielded significantly faster reaction times than Block 5 (*p* = .04), Block 7 yielded significantly faster reaction times than Block 5 (*p* = .05) and Block 6 (*p* = .03), and Block 8 yielded significantly faster reaction times than Block 5 (*p* = .006) and Block 6 (*p* = .004).

The main between subjects effect of Sleep Group was nonsignificant (*F* (1, 16) = .038, *p* = .85, η^2_p =.002) and no further significant interactions were found.

Figure 5

Reaction Time of Location (Same/Different) in ms



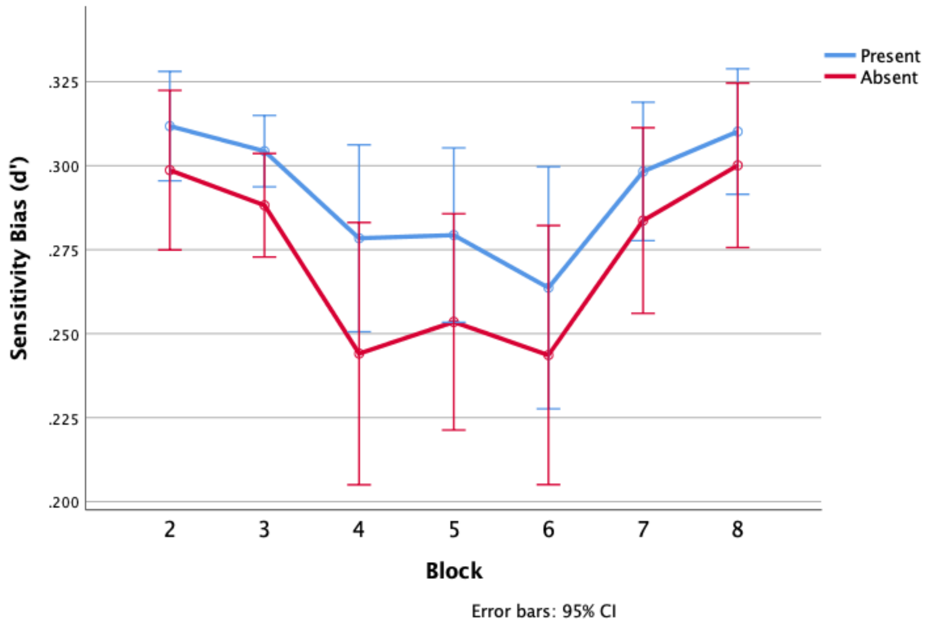
3.3.4 Sensitivity Bias (d')

3.3.4.1 Present vs Absent

The repeated measures GLM on type of trial demonstrated a significant main effect of Trial Type F (1, 17) = 38.83, p <.001, η^2_p = .70 (Present = .29 (.01) and Absent = .27 (.01)) and Block F (3.50, 59.56) = 10.09, p = .001, η^2_p = .37 (all Present higher than Absent, all *p*s < .05) that was qualified by a significant Trial Type x Block interaction F (1.99, 33.8) = 3.57, p = .04, η^2_p = .17. Figure 6 displays the mean (SE) sensitive bias per block in Present and Absent trials. In Present trials, Block 2 yielded a significantly higher sensitivity bias than Block 4 (p = .003), Block 5 (p = .013), and Block 6 (p = .013). Block 8 also yielded a significantly higher sensitivity bias than Block 5 (p = .02) and Block 6 (p = .007). In Absent trials, Block 2 yielded a significantly higher sensitivity bias than Block 4 (p = .02), Block 5 (p = .002) and Block 6 (p = .002). Block 7 yielded a significantly higher sensitivity bias than Block 6 (p = .02), and Block 8 yielded a significantly higher sensitivity bias than Block 4 (p = .03), Block 5 (p = .004) and Block 6 (p = .001).

Figure 6

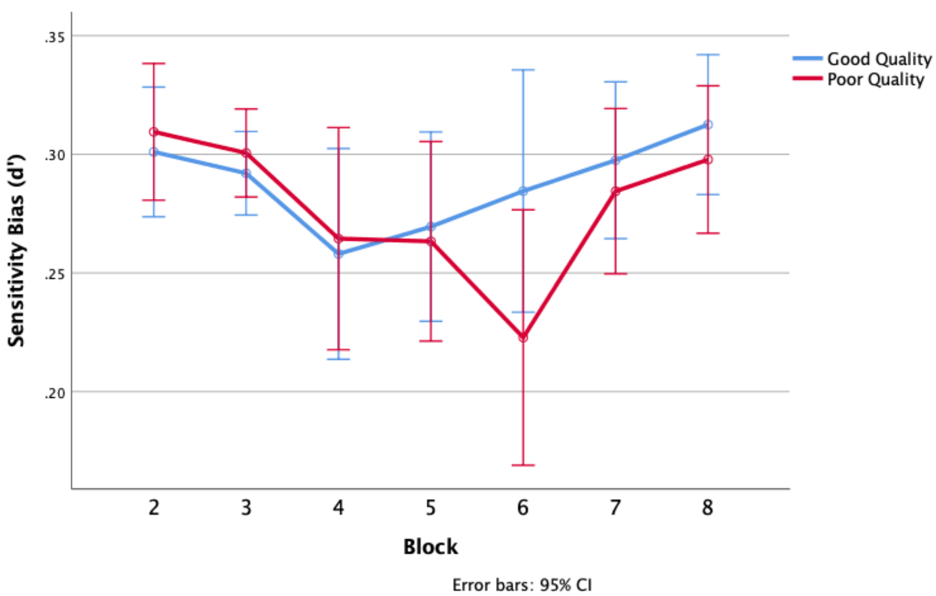
Sensitivity Bias by Trial Type (Absent/Present)



A further significant Block x Sleep Group interaction *F* (3.50, 59.56) = 3.27, *p* = .02, η^2_p = .16 was found, figure 7 displays the mean (SE) sensitive bias per block in the good sleep quality and poor sleep quality groups. In the good sleep quality group, there were no significant differences in sensitivity bias across the blocks. In the poor sleep quality group, Block 2 yielded a significantly higher sensitivity bias than Block 5 (*p* = .004) and Block 7 (*p* = .004), and, notably, Block 6 yielded a significantly smaller sensitivity bias than Block 2 (*p* = .001), Block 3 (*p* = .03), Block 7 (*p* = .01) and Block 8 (*p* = .002).

Figure 7

Sensitivity Bias by Sleep Group (Good/Poor)

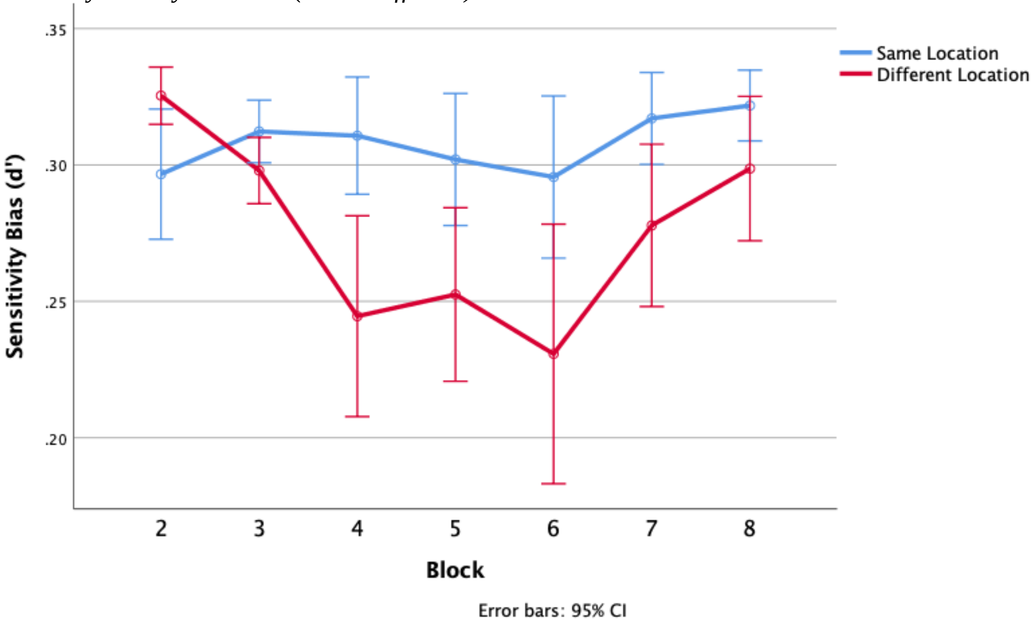


3.3.4.2 Same Location vs Different Location

The repeated measures GLM on location demonstrated a significant main effect of Location F (1, 17) = 36.78, p < .001, η^2_p = .68 (Same = .31 (.01) and Different = .27 (.01)) and Block F (.08, .15) = 9.33, p < .001, η^2_p = .35 (Block 2 Same had a smaller sensitivity bias than Different, p = .002, Blocks 3, 4, 5, 6, 7 and 8 Same higher sensitivity bias than Different, all ps< .05) that was qualified by a significant Location x Block interaction F (.06, .09) = 11.55, p < .001, η^2_p = .40. Figure 8 displays the mean (SE) sensitivity bias per block for Same and Different location conditions. In Same location trials, there were no significant differences in sensitivity bias across the blocks. In Different location trials, Block 2 yielded a significantly higher sensitivity bias than Block 3 (p = .002), Block 4 (p < .001), Block 5 (p = .001), Block 6 (p = .003) and Block 7 (p = .008). Block 7 yielded a significantly higher sensitivity bias than Block 6 (p = .02), and Block 8 yielded a significantly higher sensitivity bias than Block 4 (p = .004) and Block 6 (p = .004).

Figure 8

Sensitivity Bias by Location (Same/Different)

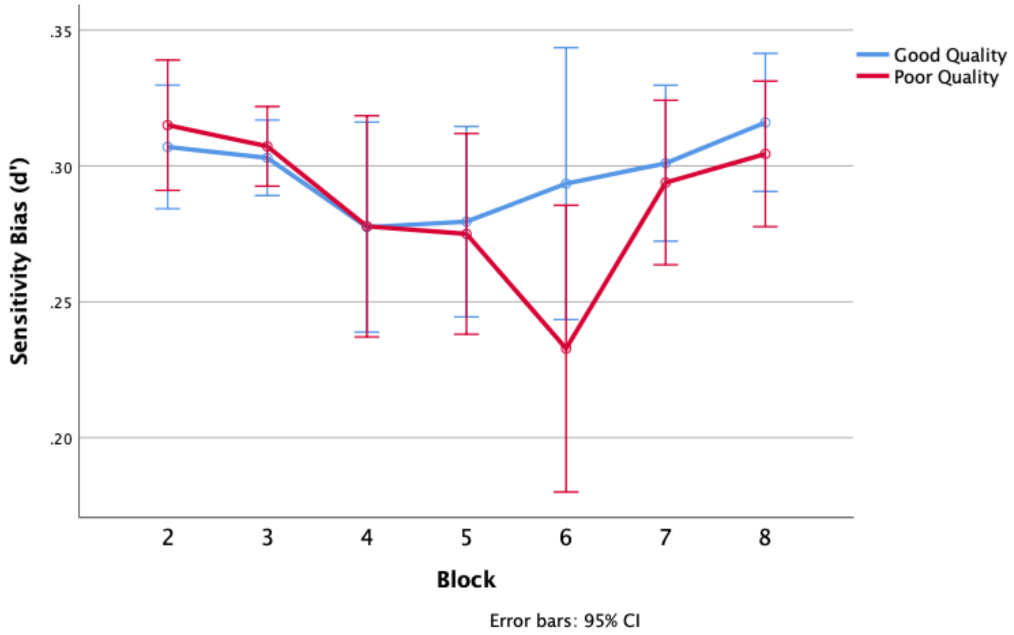


A further significant Block x Sleep Group interaction F (.03, .15) = 3.52, p = .02, η^2_p = .17 was found, figure 9 displays the mean (SE) sensitive bias per block in the good sleep quality and poor sleep quality groups. In the good sleep quality group, there were no significant differences in sensitivity bias across the blocks. In the poor sleep quality group, Block 2 yielded a significantly higher sensitivity bias than Block 4 (p = .04) and Block 5 (p = .04), and, notably, Block 6 yielded a significantly smaller sensitivity bias than Block 2 (p = .003), Block 3 (p = .048), Block 5 (p = .04), Block 7 (p = .02) and Block 8 (p = .004).

The findings show that sleep group is unrelated to location in terms of sensitivity bias, F (1, 17) = 2.49, p = .13, η^2_p =.13.

Figure 9

Sensitivity Bias by Sleep Group (Good/Poor)



3.3.4.3 Additional Analysis

3.3.4.3.1 ESS

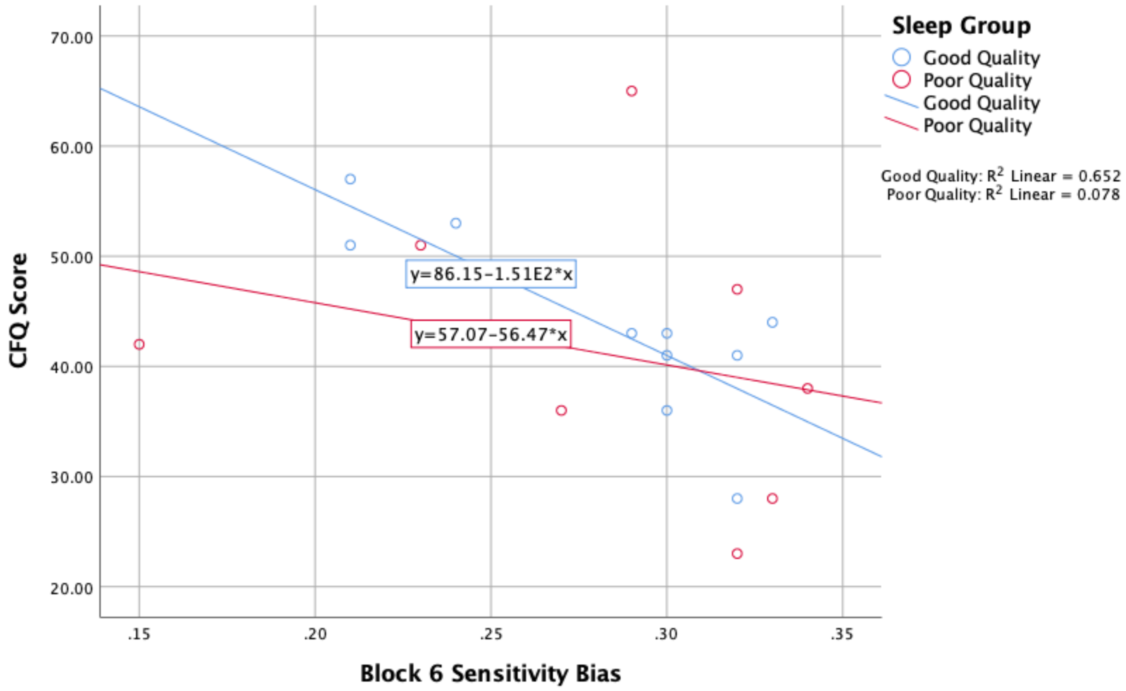
The repeated measures GLM was re-run using the ESS to qualify groups as fatigued and non-fatigued and the main between subjects effect of Fatigue Group was nonsignificant (F (1, 17) = 1.75, p = .20, η^2_p =.09) suggesting that the effect from Sleep Group noted above is due to the sleep quality measure within the PSQI and not due to daytime fatigue.

3.3.4.3.2 Sensitivity Bias Decrease in Block 6

Pearson correlations were calculated between the questionnaire measures and the sensitivity bias derived from Block 6. A significant relationship was found between the sensitivity bias in Block 6 and CFQ scores, r = -.458, p = .048 [-.8, -.18], signifying that the decrease in sensitivity bias during the task was related to an increase in CFQ scores, as seen in figure 10.

Figure 10

Pearson's Correlation – CFQ Score and Block 6 Sensitivity Bias



4 Discussion

The aim of this study was to investigate the effects of chronic sleep deprivation on emergency medical decision-making in civilians and the military. It used an online repeated scenes search task to measure contextual cueing and sensitivity bias, two important effects linked to decision-making. Relationships between task performance and the following measures were assessed: sleep quality, measured by the Pittsburgh Sleep Quality Index (PSQI), daytime fatigue, measured by the Epworth Sleepiness Scale (ESS), and propensity for cognitive failures, measured by the Cognitive Failures Questionnaire (CFQ). The population was made up of part-time and volunteer emergency responders recruited from St John Ambulance (SJA), Search and Rescue (SAR), and the Royal Army Medical Corps (RAMC), as well as students from Lancaster Medical School (LMS). Results from the questionnaire are discussed first, followed by results from the visual search task. The attrition rate and other methodological aspects are discussed at the end to understand any limitations of the study and to look forward to future research.

4.1 Questionnaire Results

It was hypothesized that 50% of participants would be classified as having poor sleep quality. Considering that a PSQI score above 5 is indicative of poor sleep, 20 participants (47%)

reported good quality sleep and 23 participants (53%) reported experiencing poor quality sleep. This supports the finding by Patterson et al. (2012) that at least 50% of emergency responders are classified as suffering from poor sleep and are more likely to suffer from the cognitive effects of sleep restriction. Interestingly, considering an ESS score of 11 or more is indicative of high daytime sleepiness, only 14 participants (33%) reported experiencing high daytime fatigue, however there was a positive correlation between PSQI scores and ESS scores. Although some may expect the PSQI and ESS to be correlate positively, this is not always the case. In their study, Buysse et al. (2008) found a weak relationship with a small effect size between the PSQI and ESS and concluded that these two questionnaires measure orthogonal dimensions of sleep-wake symptoms. Another study by Mondal, Gjevre, Taylor-Gjevre, and Lim (2013) found a weak correlation with a small effect size between the ESS and the PSQI, although they did report that participants with an abnormal ESS score were more likely to have an abnormal PSQI score. This suggests that the higher correlation found between the ESS and PSQI in this study is unusual and that in this population, contrary to others, poor sleep quality and daytime fatigue are linked.

There was also a positive correlation between PSQI scores and CFQ scores, and between ESS scores and CFQ scores, suggesting that both poor sleep quality and high daytime fatigue were linked to higher instances of cognitive failures. This is interesting as little research has previously been conducted into the link between sleep and cognitive failures. Previous research shows that proneness to boredom was linked to higher daytime sleepiness, and both were predictive of higher CFQ scores (Wallace, Vodanovich & Restino, 2003). It also showed that individuals preferring morning hours reported a peak in cognitive failures in the evening hours, whereas individuals who preferred evening hours showed no such peak at any time of day (Mecacci, Righi & Rocchetti, 2004). The results from these studies combined suggests more complex interactions between sleep-wake cycles and time-of-day preferences and their impact on cognition than is currently known. Cognitive failures have been linked to similar cognitive processes as those affected by lack of sleep, notably attention, inhibition, and working memory and executive control, which may be reflected in the CFQ, PSQI, and ESS scores. This would be an interesting avenue for further research as cognitive failures are already known to have a strong relationship with real-world performance and stress, so an additional relationship with poor sleep and fatigue may provide further understanding of these underlying mechanisms.

4.2 Visual Search Task Results

4.2.1 Error Rate (ER)

The error rate on absent trials was significantly lower than on present trials, indicating that participants were more likely to make a mistake by thinking there was no tool present when there was one, known as errors of omission, than thinking there was a tool present when there was not, known as errors of commission, and this was consistent throughout all trial blocks. Results show that there were no significant differences in error rate across blocks in the absent condition, indicating that there was no learning of when to expect absent trials taking place in the absent condition. In the present condition however, the error rate started low in block 2 before rising significantly in blocks 4, 5 and 6 and then dropping significantly in block 8. The error rate for block 8 was not significantly different than in block 2, indicating that although learning may have occurred between blocks 6 and 8, it was not significant enough for the error rate to drop lower than it was at the beginning of the task. The inverted U-shaped nature of the error rate trend was further analysed by looking at the Same Location and Different Location conditions.

In order to understand whether there was a contextual cueing effect taking place, target-present trials were further divided into two sub-categories: same location and different location. In the same location condition, tools in certain settings were always in the same location across blocks (e.g. always under the tree in front of the red car), whereas in the different location condition, the tools were always in a different location across blocks. This demonstrated the contextual cueing effect, as participants learn where to expect the tools in certain settings and guide their attention to that location, therefore recognising the target faster and more accurately, compared to the different location condition where participants are required to search for the target in every block. This showed that participants were learning when and where to expect a tool to be present based on the previous trials they had completed. With a tool being located in the same place on every previous trial, they learned that, statistically, it would be in the same place again in the current and in future trials.

Interesting effects in error rates were observed for the same/different location manipulation in the study. In block 2, the error rate was significantly lower in the different location condition than in the same location condition, but this then reversed in the following blocks, with the same location condition yielding a significantly lower error rate than the different location condition. The results from block 2 were unexpected, whereas the rest of the blocks appear to demonstrate a stronger contextual cueing effect in the same location condition, as was expected. This is further compounded by the significant drop in error rate at block 7, suggesting that learning has taken place and attention is being directed to the expected location of the tool, therefore providing more accurate responses. This is not the case in the different location condition, which follows the same inverted U-shaped as the present condition, suggesting it is the different location condition creating that rise in error rate before it drops off, as learning cannot take place and therefore attention cannot be directed and more mistakes are likely to be made. The significant drop from block 6 to blocks 7 and 8 suggests some learning is taking place, perhaps the participants learn to expect a target in certain settings even if they cannot learn where that target is likely to appear. Arsenio, Oliva and Wolfe (2002) found that observers who are presented with a scene they have previously searched but where objects have been removed still direct their attention to where the objects had been, as if they are searching for the 'ghosts' of the objects. Considering that in the Different Location condition, the objects were in a different location in every repeated scene, this 'searching for ghosts' could explain how attention was directed in the scene even if there was no contextual cueing effect taking place.

There was no effect of sleep group on the error rate measure, suggesting that reported sleep quality did not explain error rates in the visual search task. As there was an effect of sleep group on sensitivity, is it likely that poor sleep affected different component processes between those in overall error rates and those in the more specific sensitivity bias.

4.2.2 Reaction Times (RT)

Reaction times were significantly faster in the present condition than in the absent condition. This is because participants were told that it was a single target task, therefore once the target was located the search was ended, whereas it takes longer to decide to end a search when there is no target present for fear of missing said target. This is known as the satisfaction of search paradigm (Berbaum et al., 1990) and it is encouraging that there was no effect of sleep group on this measure as this would indicate that poor sleepers abandon visual searches quicker than good sleepers. There were no significant differences in reaction times across blocks in each condition.

There were mixed results from the analyses of the Same Location and Different Location conditions. In the same location condition, there were few significant differences found, despite the initial decrease in reaction times from block 2 to 3, followed by a rise to block 5 and another decrease to blocks 7 and 8 (the latter being the only significant change in reaction times). There were more significant changes in the different location condition, with a significant increase in reaction times from blocks 2 and 3 to blocks 5 and 6, followed by a decrease to blocks 7 and 8. There was again no effect of sleep group on reaction times, suggesting that poor sleep did not lead to an increase or decrease in reaction time on the visual search task. It is important to note, however, that reaction times are not a linear measure and produce great variability, and therefore although an analysis of variance on the sample mean can provide an overview of the reaction time data, this method has little power to detect genuine differences between conditions (Whelan, 2008) As there were few significant results, however, it was felt that further analysis was not warranted at this time.

4.2.3 Sensitivity Bias (d')

The sensitivity bias, measured using d', explores the pattern of responses in each condition and measures how one is likely to respond in that condition and how sensitive they are to the changes in condition (Stanislaw & Todorov, 1999). Results show that across all blocks, participants displayed a significantly higher sensitivity bias in the present condition than the absent condition. This means participants were less likely to respond with a false-alarm in the present condition than in the absent condition, in other words, participants were less likely to respond that a target was present when it was absent (error of commission), and more likely to respond that a target was absent when it was present (error of omission). Participants were better at discriminating in the present condition than in the absent condition, and these findings are consistent with previous research (e.g. Hutchinson, 1981, Stanislaw & Todorov, 1999). In the present condition, there was a significant decrease in sensitivity bias from block 2 to blocks 4, 5 and 6, followed by a significant increase in sensitivity bias in block 8. In the absent condition, there was also a significant decrease in sensitivity bias between block 2 and blocks 4, 5, and 6, followed by a significant increase in sensitivity bias in blocks 7 and 8. This fall and rise in sensitivity bias could be explained by an increase in boredom and distraction as the task goes on, but once again followed by a learning effect which reveals itself as an increase in sensitivity. A further significant interaction of sleep group by block was found, demonstrating no significant differences in sensitivity in the good quality sleep group, but a large decrease in sensitivity in the poor sleep group in block 6. This was not expected, leading to further analyses of the phenomenon.

An analysis of the location conditions shows that aside from block 2 which yields unexpected results because the different location condition showed a higher sensitivity bias, the same location condition provided a higher sensitivity bias than the different location condition. Furthermore, there were no significant differences in sensitivity bias across blocks in the same location condition, however the large decrease reported above is present in the different location condition, with a significant decrease in sensitivity in block 6 compared to blocks 1, 7 and 8. In this case, block 2 also yielded a significantly higher sensitivity bias than almost all other blocks (only block 8 is non-significant). This suggests that although sensitivity is relatively high in block 2, it decreases dramatically to its lowest point in block 6, before increasing in blocks 7 and 8 but still staying below the original sensitivity level, which is unexpected. A further significant interaction of sleep group by block was found, demonstrating again, as above, no significant differences in sensitivity in the good quality sleep group, but a large decrease in sensitivity in the poor sleep group in block 6.

4.2.4 Additional Analysis

In order to attempt to understand the findings discussed above, additional analyses involved replacing the Sleep Group with ESS scores to determine which factor of the PSQI was resulting in these significant effects. No effect of fatigued versus non-fatigued group was found, suggesting that it is not daytime sleepiness, or indeed the fatigue factor of the PSQI, that is causing these effects, but rather a real measure of sleep quality in the PSQI and the ensuing effect of long term poor sleep quality on cognitive functions. This suggests it is not the transient state of fatigue and its effects on attention that are causing these changes in sensitivity, but rather a more trait-like cognitive mechanism caused by long term poor sleep. This result is similar to that of the study carried out by Banks, Catcheside, Lack, Grunstein, and McEvoy (2004) where participants suffering from long term sleep restriction did not report feelings of daytime sleepiness but displayed impaired cognitive functions during attention and vigilance tasks, which were linked to the cognitive effects of long term sleep deprivation.

Correlations were analysed between the various questionnaire measures (PSQI, ESS, and CFQ) and the sensitivity bias derived from block 6. A significant relationship was found suggesting that an increase in cognitive failures predicts the decrease in sensitivity in block 6. This is particularly interesting as it concerns measures that have not previously been analysed together, but could have significant ramifications for real-world decision-making. Cognitive failures are experienced by everyone, although some people experience them more often than others, and they have previously been shown to correlate with real-world outcomes such as employability (Unsworth, Brewer, & Spillers, 2012) and accident rates (Larson & Merritt, 1991), though these are broad measures. Research into cognitive factors has hinted at a relationship between cognitive failures and attention, inhibition, working memory and executive control, although this is still widely inconclusive. This newfound relationship between cognitive failures and sensitivity bias suggests there is a factor affecting sensitivity which could be predicted by one's CFQ score. As a low sensitivity bias is a result of more errors (low hit rate and high false-alarm rate), it would be important to be able to predict this in order to put in place measures to prevent real-world errors from happening. Upon reflection, it seems logical that lower sensitivity is linked to an increase in cognitive failures, as they could be a result of being less aware of the environment and less focussed on one's aims, therefore allowing more slips to happen, which is similar to the study by Murphy and Dalton (2014) which reported a significant correlation between increased cognitive failures and increased distraction. A person with higher sensitivity bias is likely to be more aware of their surroundings and their actions, and therefore less likely to commit slips. Although cognitive failures tend to happen more when one is distracted and less when one is affording their full attention to a task (Unsworth et al., 2012), it is thought that they reflect frequent lapses in cognitive control, which could suggest the possibility of more important lapses happening during more serious, attention-demanding tasks.

Only the poor sleep group presented a decrease in sensitivity bias in block 6, suggesting that poor sleep leads to a decrease in cognitive function which may affect sensitivity. The positive relationships between the PSQI and the CFQ, and between the ESS and the CFQ, suggest that both poor sleep and daytime fatigue predict higher instances of cognitive failures. Following on from this, it is possible that poor sleep lowers one's sensitivity bias, making one more susceptible to frequent lapses in cognitive control which manifests itself as an increase in cognitive failures and, more dangerously, as an increase in mistakes and accidents (Larson & Merritt, 1991). Considering the highly important role carried out by emergency medical responders, it is imperative that they make as few mistakes as possible. If poor sleep is indeed linked to a decrease in sensitivity and cognitive control, it is important to monitor this closely and reduce the risk as much as possible by working with responders to improve their sleep quality and therefore reduce their likelihood of committing errors.

Further analyses of the methodological methods were also carried out to determine whether there were any differences in the stimuli used in block 6 compared to the other blocks. The frequency of the types of tool present in each block was calculated, showing that the different types of tool were not well distributed throughout the blocks, which was a methodological oversight. Block 1, the learning block, contained 18 axes and 2 hammers; block 2 contained 11 axes, 8 hammers and 1 set of pliers; block 3 contained 3 axes, 15 hammers and

3 pliers; block 4 contained 8 hammers, 10 pliers and 2 saws; block 5 contained 12 pliers and 8 saws; block 6 contained 6 pliers, 13 saws and 1 screwdriver; block 7 contained 9 saws and 11 screwdrivers; and block 8 contained 20 screwdrivers (images of each type of tool can be found in Appendix K). It is likely that certain types of tool were easier to recognise than others, and therefore in certain blocks, the stimuli proved harder to locate. Blocks 4, 5, and 6 are the blocks with the highest error rates and reaction times and the lowest sensitivity bias, and these mainly contained hammers, pliers, and saws. Block 6, which showed a large decrease in sensitivity in the poor sleep group, consisted mainly of saws (13 out of 20 images), however, block 7 also contained a large number of saws (9 out of 20 images) yet it did not show the same decrease.

Previous research by Hout and Goldinger (2010) showed that inconsistent information of the target object disrupted learning performance on a repeated scenes search task. Inconsistent information included a change in type of target or a deformation of the target, therefore it is possible that the changes in features in the target images caused an interruption in the statistical learning process. More specifically, the minor variations in the appearance of targets could have caused high decrements in the statistical learning and contextual cueing processes, but only in participants with poor sleep. This would suggest that poor sleep is linked to less adaptation to variability, which could then affect cognitive processes which rely on learning mechanisms. Further research into the effect of target variability on learning mechanisms would provide more insight into this topic and could explain whether the decreased performance measured in block 6 is attributable to the same underlying mechanisms tapped by the cognitive failures questionnaire, and how it is linked to interrupted learning due to variations in the target type.

4.3 Limitations and future research

4.3.1 Attrition

Although it was not originally considered, it feels important to report the attrition rate as from the 123 potential participants who opened the link to the study, only 43 provided full questionnaire answers, and only 19 provided full usable data (questionnaire and task). The low number of people who completed the full study compared to those who completed the questionnaire, and even more so those who followed the original link, is more than likely due to the online nature of the study. It is thought that participants feel less inclined to take part when they do not meet the researcher face-to-face, and it is far easier for them to quit the study before completion when they are carrying it out online rather than in a laboratory with a researcher.

Although it is frustrating that only a small number of participants provided data, significant results were still obtained from a sample of participants that represent the more general part-time emergency responder population. Previous online studies (e.g., SurveyMonkey, 2009; Jones, 2017) reported between 30% and 50% response rate for online studies, with this study yielding a 35% questionnaire completion rate and a 15% task completion rate of the total number who opened the link. It is my belief that had this study been run in-person, the completion rate would have been much higher, and the drop-out rate much lower.

A further interesting point to note is the five participants who completed both the questionnaire and the task but disregarded the instructions in the latter and provided unusable data. It suggests that although they wanted to please the researcher by completing the study, they were not interested enough to follow the instructions and did not realise that this would render the data unusable anyway; it shows good intention on the part of the participant but a lack of understanding of the study. It also reinforces the importance of verifying the data before processing and analysing, as the task would likely have yielded different results and far more incorrect answers if the sets containing these repetitive responses had not been removed.

4.3.2 Demographics

The final sample for the questionnaire part of the study comprised of 43 participants, including 29 males and 14 females, showing an imbalance in gender. The distribution of participants across organisations also showed an imbalance, with almost half of the responses from Search and Rescue and the other half split between a further 3 organisations. Due to the differences in training across organisations this could potentially create a further imbalance in the results, however as this is not the main focus of the study it was not investigated further. It would be interesting to bear this in mind for future research.

It was deemed essential to carry out this research using a sample of the population of interest, which is why the research was focussed on emergency responders, with the majority of participants recruited from Search and Rescue, St John Ambulance and the Army Reserves. A majority of studies make use of undergraduates for their population samples but these cannot be assumed to be representative of the population of interest, therefore although it presented its own difficulties, it was important to recruit from a pool of emergency medical responders. Part-time and volunteer responders were chosen as they often hold down a full-time career as well as carrying out their emergency responder duties, therefore it is important to understand how poor sleep and fatigue could affect their decision-making whilst working.

4.3.3 Methods

This research study was severely limited by the impact of the COVID-19 pandemic, as it affected recruitment, participant engagement, and data collection methods. Eye-tracking was no longer available as a data collection method due to the close physical proximity required to set up, calibrate, and run the study with participants. The study was instead adapted for online distribution, meaning that the wealth of information provided by eye-tracking was no longer available for analysis. It also meant that the researcher had to interact with and recruit potential participants using online methods, which coupled with data protection laws, made establishing a relationship with participants difficult. This is likely to have contributed significantly towards the low study completion rate and the disregarding of instructions during the task.

Due to time pressures caused by the pandemic, the online study was set up rather hastily, without a full analysis of the stimuli set being conducted. The analysis of the targets used in each block shows an uneven distribution of tools throughout the task, which could have affected the learning processes being measured. An initial study measuring the visibility of the tools and analysing whether any proved harder to locate than others, and then ensuring they were distributed evenly throughout the blocks, would likely have led to a more homogenous stimuli set for the visual search task, which may have demonstrated more noticeable contextual cueing effects.

Using an online platform for dissemination of the questionnaire and task was a cause of concern, particularly regarding the reliability of the questionnaire responses. This is more of a concern when using online recruitment platforms such as Amazon Mechanical Turk (MTurk) or Prolific Academic, where anyone with an account has access to the study and there is a reward for participating, as it has been shown that people lie in the demographic questions just to ‘conform’ with the target population in order to make money (Zhou & Fishbach, 2016). As this particular study did not offer compensation and was specifically sent out by email to chosen organisations, it is unlikely that much, if any, data is not from the target population. It is possible that individuals will have passed on the link to others, but it is also highly unlikely as they had nothing to gain from doing so.

Another concern regarding the questionnaire is that the pandemic has affected participants’ sleep schedules. A study by Patterson *et al.* (2012), researching the association between poor sleep, fatigue, and safety outcomes in Emergency Medical Services providers, found that 55% of respondents were classified as fatigued and exceeded the PSQI score for poor sleep, therefore we hypothesised that the study was likely to yield close-to-equal numbers of fatigued and non-fatigued participants. Due to the pandemic, however, most healthcare professionals are likely to be working harder and in more stressful conditions and therefore have poorer sleep than usual, whereas non-healthcare workers and medical school students are likely to have more time on their hands and therefore be able to more readily adapt their sleep schedule to their needs. As the final sample showed that 53% of participants suffered from poor sleep, it appears that the sleep data was not skewed as a result of the pandemic.

Online data collection for tasks such as the one used in this study is a new method of collection, and thus still raises concerns as to the reliability of the data. Running the task in a laboratory means the researcher can ensure the participants' understanding of the task and instructions, limit distractions to the participant, ensure correct functioning of the apparatus and reliability of the reaction times, fix any problems that may arise and ask the participant to restart the task, provide motivation for the participant to actually finish task, and allows the researcher to ensure the data is correctly stored and logged. Although advances in technology allow for more and more types of task to be run online, it is still difficult to ensure that all the above criteria are met.

Instructions for the task were provided in the Participant Information Sheet, along with example images, and were repeated at the end of the questionnaire and on the welcome screen of the task. It is possible, however, that participants rushed through these blocks of text and therefore did not fully understand what was asked of them, resulting in unusable data. Participants were asked to conduct the study in a quiet room and to limit distractions, such as muting phone notifications and ensuring no interruptions, however this is not always possible when participants have jobs requiring instant responses or dependents, such as children.

It is entirely possible that display settings or unreliable internet speed render the presentation times and therefore response times unreliable. To counter this, the Pavlovia platform that was used to run the study requires all stimuli to be downloaded prior to starting the task to ensure no lags in stimuli presentation, and ensures screen refresh rates are set to 60Hz, which is the standard refresh rates for modern screens. Two recent large studies (Bridges, Pitiot, MacAskill & Peirce, 2020; Anwyl-Irvine, Dalmaijer, Hodges & Evershed, 2020) have investigated the timing precision of online and offline stimulus presentation methods, finding good overall precision from the most-used online platforms (up to 26 ms difference). It was noted that using the Safari browser on Mac OS X provided greatly increased stimulus presentation time and is therefore the least preferred browser to use. Another study by

Semmelmann and Weigelt (2017) compared online response times to lab-based response times on various cognitive tasks. They found an additive timing offset of 87 ms in online studies compared to lab-based studies, however this offset was similar across tasks and conditions and, most importantly, the expected task-based effects in the different tasks were reproduced.

4.3.4 Future Research

Time- and resource- permitting, a more in depth analysis of the visual search task results would allow for a more thorough model of medical decision-making, and could serve to direct future research towards further avenues of investigating, which may be more specifically focussed on the medical aspect of decision-making. It is also important to ensure adequate representation of the target population in future research, and the provision of incentives to finish the task as quickly and accurately as possible would likely reduce the amount of aborted task sessions and unusable data. This research has shown that further understanding of the subject is required, and it would be encouraging to provide further knowledge in order to help emergency medical responders to improve their sleep quality and subsequently improve decision-making and reduce errors.

5 Conclusion

This study researched the use of visual search tasks to determine the effects of sleep deficiency on decision-making in civilian and military emergency responders. The Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS) were included to measure sleep quality and daytime fatigue, and the repeated-scenes search task measured contextual cueing and sensitivity bias. The Cognitive Failures Questionnaire (CFQ) was also included to assess any potential relationship with sleep quality and visual search, due to its links with cognitive functions such as attention, inhibition, working memory, and executive control. The target population was part-time and volunteer emergency responders from civilian and military backgrounds, and participants were recruited from St John Ambulance, Search and Rescue, and the Royal Army Medical Corps. Reaction times, error rates, and sensitivity (d') were analysed using a repeated measures general linear model (GLM) with trial type (present, absent) and block (2 to 8) as within subject factors and sleep group (high quality, poor quality) as the between groups factor. The analyses were followed with Pearson Product Moment correlations to assess the relationships between the sensitivity bias and the PSQI, ESS and CFQ scores.

Analysis of the task data found an effect of sleep group on sensitivity bias, with findings showing no difference across blocks in the good sleep group, but an important decrease in sensitivity bias in block 6 in the poor sleep group. Additional analysis showed a relationship between the decrease in sensitivity bias and reported CFQ scores. This suggests that lower sensitivity bias is linked to an increase in cognitive lapses, which manifests itself as an increase in cognitive failures. This suggests that poor sleep leads to a decrease in cognitive function which may affect sensitivity. This is an important finding as it could have a significant effect on real-world outcomes. Further analysis into the methodology of the study showed an imbalance in the distribution of tools across the blocks, and this inconsistency in target type has previously been linked to interrupted learning. The results obtained from this study suggest that good sleepers were not affected by the variance in tool type, whereas poor sleepers showed less adaption to the change in tool type which interrupted their learning processes.

Additional research is needed to further analyse these relationships, both theoretically and practically, in order to understand how poor sleep and cognitive lapses affect functions linked to sensitivity bias and, in a wider area of research, decision-making. If more were known in this area, it could be feasible to provide not only awareness of the issues surrounding poor sleep and long-term sleep restriction, but also to provide mechanisms for people whose roles often involve little sleep and decision-making in contexts of high importance.

The response rate was lower than originally expected, with 43 questionnaire-only responses and 19 questionnaire and task responses. This is thought to be due to the impersonal nature of online recruitment and the busy schedules of the participants, many of which are also full time medical professionals and were involved in the COVD-19 efforts. Data show that more than half of the respondents were classified as having poor sleep quality, which could manifest itself in their daily lives. Analysis of the questionnaire measures found positive relationships between the sleep measures and the CFQ, suggesting further research in this area would be beneficial to enhance knowledge of the possible link between sleep and cognitive lapses, as the latter are known to be linked to higher incident rates and other real-world outcomes.

There were many methodological considerations for this study, many of which were due to the adaptation of study for online distribution. Future research should aim to address and reduce these considerations in order to provide further knowledge on the impact of long term sleep deprivation on decision-making in emergency medical responders.

6 Reflective Piece

Writing a reflective piece was suggested by my supervisors as a way of detailing my learning experience throughout the MSc by Research. I describe how the research area was chosen and how the study was planned, drawing from my own experience and discussions with my supervisors and experts. I detail the impact of the COVID-19 pandemic on my experience and how I adapted my study in order to carry out my research under the new guidelines. I evaluate and analyse the changes made and discuss the impact these had on the study and ensuing results.

6.1 Description

6.1.1 Setting up the research

I discovered during my third year as a psychology undergraduate at Lancaster University that I really enjoyed the research side of psychology, far more than the traditional lectures that are typical of university degrees. This prompted me to search for a MSc by Research programme, which I found at Lancaster Medical School. I began the 12-month course on September 30th 2019, supported by my supervisors, Dr Judith Lunn and Professor Rachel Isba.

In my undergraduate dissertation, I studied the link between alcohol-related attentional bias, alcohol consumption, and sleep quality in university students. I appreciated researching a topic that was relevant to me and my cohort and understood the importance of being motivated to carry out research by feeling that it was relevant to myself and my interests. Being a reservist in the British Army means I have been sleep deprived myself during training exercises yet still required to operate to the same high standards as usual. I have met a number of soldiers who have been out on operations, such as in Bosnia and Afghanistan, where sleep quantity and quality range from poor to non-existent, yet who are relied upon to make snap decisions where the consequences can be deadly. This is what motivated me to look into the effects of chronic sleep deprivation and how it affects cognitive processes, particularly decision-making, in emergency medical responders.

6.1.2 Discussions with Experts

The study was developed through research and discussions with various experts. On October 30th I met with Natalie Smith, founder of SR8 Group, a specialist provider of medical, security, and training services. Natalie herself was a medic in the Navy and now provides training in first aid and trauma medicine. She experienced first-hand the difficulties of operating whilst sleep deprived and recognised the importance of the research I am carrying out. She explained that most often, the initial adrenaline surge from attending an emergency would override the sleep deprivation, but when the adrenaline died down the fatigue would return and that was when mistakes were made. She explained that the post-adrenaline dip was worse during periods of chronic sleep deprivation, which is what prompted me to look into the effects of chronic sleep deprivation rather than acute sleep deprivation. Following the meeting, I decided to include both the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS) to measure both sleep quality over the past month and daytime fatigue. I felt it important to include both scales to capture both aspects of sleep deprivation.

I decided to use eye-tracking technology to measure the cognitive processes involved in decision-making as I had previous experience with this method and there is a large amount of data that can be collected, such as regions of interest, number of saccades, saccadic velocity, and pupil dilation, to name a few. On December 4th I met online with Dr Jessica Ray, a Human Factors researcher with Yale School of Medicine, to discuss the use of simulations and video-based eye-tracking methods. She explained that static images often provided rich enough data in a number of different tasks, whereas videos were harder to code and collect data from. Through her work with the Army Research Institute's Technology-based Training Unit, she discovered that using simulations was time- and effort-consuming and noted the lack of urgency from her participants. Simulations could not provide a translation of real world situations and often required actors to replicate stressors in the environment. Speaking with Jessica helped me decide to use still images to analyse eye movements during decision-making tasks rather than attempting to measure behavioural responses during simulations.

Having created the questionnaire and made the decision to use still images, I was struggling to find an appropriate task and the relevant stimuli that would measure medical decision-making processes. Reading around the literature I discovered that decision-making was best measured in a neutral task, not linked to the participants' expertise, to avoid bias from previous knowledge or bias towards a certain type of medical training (for example military training versus search and rescue training). I therefore decided to conduct a visual search task and contacted Professor Nick Donnelly, Head of Department of Psychology at Liverpool Hope University. We met on February 28th and discussed previous studies he had conducted, both with undergraduates and the army, and the Repeated Scenes Search Task (RSST) caught my attention. One of his students had previously used it to measure the effects of stress on contingency learning, and I thought it would be interesting to research the possible link between fatigue and contingency learning. Furthermore, the RSST measures underlying decision-making processes such as memory, learning, and attention.

6.1.3 Ethical Approval

I initially sought ethical approval for the study from the Faculty of Health and Medicine Research Ethics Committee (FHMREC) and was close to receiving approval when I was made aware of needing approval from the Ministry of Defence Research Ethics Committee (MoDREC) for studies involving military personnel. I began the lengthy application process immediately and it was a steep learning curve. The MoDREC required detailed answers for a number of questions relating to the study, the safety of the researchers, and the wellbeing of the intended participants. Due to the potentially dangerous and often uncomfortable nature of some studies involving serving personnel, they are strict as to the possible outcomes resulting from taking part in the study. They require the Army Scientific Assessment Committee (ASAC) to determine the soundness of the research and the benefits of this research to the MoD before approving the study. They also require a sponsor from the University if applicable, and written consent from the Commanding Officer of the unit to be recruited from. Any amendment must be reviewed by the ASAC before being passed onto the MODREC. Although MODREC approval would cover any non-MoD participants mentioned in the protocol, FHMREC approval was also gained to provide more flexibility both with study timelines and participants.

6.1.4 The Study

Following the original thoughts about my interest areas, the discussions with my supervisors and with experts, and the requirements and concerns voiced by the MoDREC, the experimental study plan was complete. Participants would be recruited from the local Search and Rescue, St John Ambulance, and Royal Army Medical Corps units. Demographic questions were influenced by a study researching the link between poor sleep, fatigue and safety outcomes in emergency responders. Two validated self-report sleep questionnaires were chosen to measure sleep quality and fatigue; these had previously been shown to be correlated. The Repeated Scenes Search Task run using the eye-tracker would provide insight into the processes underlying decision-making and the recorded eye movements would provide insight into arousal, regions of interest, dwell times, saccades, and search paths. Data would be collected by visiting each participating organisation during an in-house training day and inviting volunteers to participate throughout the day. This would provide easy access to large numbers of potential participants and reduce the requirements from participants themselves as they would not need to travel any further or volunteer any more time than they already had to attend their routine training. Organisation leads were supportive of the research and of the study set-up and asked for a subsequent visit to present the findings and discuss the implications, as these would be directly relevant to their members and would show the importance of their participation.

6.1.5 COVID-19 Pandemic

On March 11th 2020, the World Health Organisation (WHO) officially labelled the COVID-19 outbreak as a pandemic and the UK went into lockdown on 23rd March 2020. On that day, I was called upon through my role as an Army Reservist to provide Military Aid to the Civil Authorities (MACA) with my regiment, 156 Regiment RLC. We were originally tasked for 10 days to support Personal Protective Equipment (PPE) distribution, however, the task was soon extended as the PPE shortages became more apparent. We were working 10-14 hour days, 6 days per week in an attempt to address and reduce the shortages as fast as possible. During this time, I was unable to focus on my research due to the lengthy days working in the warehouse. I contacted my supervisors immediately and we agreed I would take this time to understand how the pandemic would affect my research, including the lockdown and social distancing measures that would be in place for an indeterminate amount of time. After three weeks we were stood down from the PPE tasking, but were asked to remain on call in case future effort was required, this meant that I was able to return my focus to my research.

It was apparent that I would not be able to carry out the original eye-tracking task due to the close proximity required by this method, and with the uncertainty surrounding the duration of the social distancing methods, I was concerned I would not be able to complete my data collection in time to finish my degree. I discussed my concerns with my supervisors and we decided on the following options:

- not carrying out the eye-tracking task for safety reasons and thus providing a detailed literature review and methods section only for the thesis;
- adapting the study to be delivered online in order to provide data to be analysed and to complete the study in the original time period;
- intercalating my degree and resuming only when social distancing methods were removed in order to carry out the original study, with no indication of when this would be or how it would affect funding and future plans.

We decided that adapting the study for online data collection would benefit me most, allowing me to collect data and analyse it as required by the degree scheme without having to worry about lockdown measures. It was noted that this would involve a significant change and extra work which, coupled with the time spent serving with the Army, would result in a highly increased workload in order to complete the research before the deadline.

6.1.6 Contingency Plan

The new study would involve the same demographic questionnaire and both self-report sleep questionnaires, as well as an added cognitive failures questionnaires (CFQ). This was added as cognitive failures reflect proneness to errors in real world planned thought and action, which is linked to attention and decision-making. A range of factors have been linked to increased cognitive failures, but only a small amount of research has been conducted into the effects of fatigue. It was therefore thought to be an interesting addition to the research which could provide directions for future studies.

The original Repeated Scenes Search Task was adapted for online distribution, however, due to limited technology this could no longer be carried out as an eye-tracking task. Instead, reaction times and error rates would be measured and compared to sleep quality, fatigue, and cognitive failures score. It was unfortunate to lose the rich data that would have resulted from the eye-tracking task, however, this contingency plan meant the study could still be carried out and data collected, analysed, and reported.

6.2 Feelings

The initial and over-riding feeling since the pandemic took hold has been uncertainty. Not knowing how long it would last, when we would be able to return to normal academic activities, or if I would be able to run my study as originally planned proved very difficult. I knew I wanted to continue my degree if at all possible and to complete my research project as planned, or as close to that as possible. I was highly interested in the subject to begin with, and the reports of nurses, doctors, and emergency responders working longer hours and under more pressure than before made me realise just how important this research was. Nevertheless, as a reservist, I wanted to do my bit and support the nation when I was called up, helping in the PPE distribution chain. It was very important for me, however, not to jeopardise my degree. The support I received from my supervisors was encouraging, we discussed all the options and how they would affect me both currently and in the future, but they did not pressure me into making a decision. They allowed me to do what I felt was best for myself and for my research, and I am grateful to them for that.

6.3 Evaluation and reaction

After evaluating the circumstances and choosing the best way forward myself, I was aware it would require a lot more work and would prove more stressful than I had originally anticipated when starting the Masters programme, but I knew it was worth it. Although I had agreed with my supervisors that I would work to the original deadline, we discussed the possibility of applying for an extension if the need arose.

The first step to adapt the study for online data collection required me to evaluate what I would maintain from the original study and what needed changing. It required me to familiarise myself with PsychoPy and Pavlovia, the experiment builder and online platform on which it would be distributed. I had to adapt the participant recruitment, information sheet, consent form, and questionnaire for the study to run smoothly without in-person directions.

The new study required updated ethical approval, and thus the MoDREC protocol was amended. This meant it had to be reviewed by the ASAC again before being considered by the ethics committee. The extra time required for this and the lockdown measures in place at the time resulted in slow progression, therefore the amended protocol was also sent to FHMREC for approval in order to carry out the study on non-military participants and to collect data in a timely fashion.

6.4 Analysis

In adapting the study for online distribution rather than using the original eye-tracking method, four major themes stood out: recruitment and participation; reliability of questionnaire responses; reliability of task responses; and the concerns surrounding data analysis. Some of these difficulties were immediately apparent to me, such as the reliability of online reaction time measures, some were brought to my attention during an online conference with the North West Visual Cognition Group, such as the reliability of questionnaire responses, and some were discovered whilst reading the literature surrounding online studies, such as the small participation response to online studies.

6.4.1 Recruitment and Participation

I was aware that online recruitment would be very different to the planned in-person recruitment. On the one hand, online recruitment meant I would be able to share my research with more people without concern for geographical distance, but on the other hand it lacks the personal touch and motivation that comes from in-person recruitment. The original plan was to attend a training evening with each organisation to present the study and distribute Participant Information Sheets and consent forms. This would give potential participants the opportunity to understand the purpose of the study and what they would be asked to do without feeling pressured to participate immediately. I would then return to each organisation on an in-house training day and set up the eye-tracker in a quiet room, giving participants the chance to take part in the study without having to go out of their way to participate. Given the non-invasive nature of the study and the immediate relevance to the participants themselves, I was positive that I would receive a high participation rate.

Regarding the online distribution of the study, in order to comply with the Data Protection Act 2018, I could not ask for potential participants' details to contact them myself but had to ask organisation leads to forward my email to their members. I was initially under the impression that I would still get a high response rate as the study could be completed at a time that most suited the participant and did not require extra equipment or a significant amount of time. Unfortunately, I quickly realised that participant uptake would not be as significant as I had hoped. This was backed up by literature as, according to SurveyMonkey, the anticipated response rate for an online survey using their program is 30% (SurveyMonkey, 2009). An online questionnaire used to collect data relating to nursing research got a response rate of 47.4% (Jones, 2017), which I thought would be similar to this study's response rate due to the similarities in populations and their workloads, and the relevance of the studies.

After sending out the invitation to the two original non-military organisations (Lancaster St John Ambulance and Lowlands Search and Rescue) I closely monitored the response rate. As this was lower than I was expecting, I sent a reminder email and contacted further organisations in order to recruit more participants. The study was then sent to Lancaster Area Search and Rescue, East Croydon and Addiscombe St John Ambulance, London Burrough of Sutton St John Ambulance, and Lancaster Medical School. After MoDREC approval was received, the study was disseminated to 208 Field Hospital, RAMC, and the medical personnel of 156 Regiment, RLC. Participants were given two weeks to complete the study to allow them to find a quiet time to complete it whilst not giving them so long that they put it off and forgot about it.

As well as the distance created by the online nature of the study rather than the more personal face-to-face method, I believe that the COVID-19 pandemic had a more direct effect on the response rate. A lot of the people who volunteer in St John Ambulance or Search and Rescue, or who work for medical regiments, are also full-time healthcare providers. On top of that, volunteers who were not able to work due to the pandemic were asked to work alongside the NHS to provide support to overwhelmed services. Due to this, the target population for the study are likely to have been busier than usual and subject to more stress from difficult work conditions, therefore it is entirely understandable that this may have contributed to a diminished response rate. Whilst it is frustrating to not collect as much data as planned and to not be able to contact participants directly to ask them to participate, I am grateful that I was able to adapt the study to at least collect some data for analysis and complete my research degree as planned.

6.4.2 Reliability of Questionnaire Responses

Although I had some previous knowledge of participant bias and the need to analyse questionnaires for real responses rather than quick repeated answers, it had not occurred to me that distributing a survey online meant people other than the target population might take part. This was brought to my attention during an online conference with the North West Visual Cognition Group, where it was discussed how to ensure only the target population participated in the study. As this study was distributed by email to the population of interest, rather than advertised online in exchange for compensation, I am not concerned that people outside of the target sample may participated.

6.4.3 Reliability of Task Responses

There were 19 aborted task sessions out of a total of 43 attempted tasks and 5 sessions which provided unusable data, which could be due to technological issues (for example, the internet connection failing or the computer unexpectedly shutting down), participants getting bored and quitting the task before completing it (whereas in laboratory studies the presence of the researcher motivates them to complete it), or participants not following the instructions to the end and closing the browser before the data has been saved, even though they may have fully completed the task. Unfortunately, at the time, Pavlovia did not indicate how far along participants get before aborting the task and neither did it save incomplete data sets, issues which have now been addressed. As the issue of closing the browser before the data is saved was also brought up at the North West Visual Cognition Group conference, I followed a suggestion to over-emphasise the importance of following the instructions to the end, and highlighted that participants needed to press ‘space bar’ a final time in order for their data to be saved.

6.4.4 Data Analysis

I do not know the exact number of people on each organisations’ emailing list so I cannot know how many people received the study invitation email, but out of the 123 who opened the link to the study, only 43 provided full questionnaire responses, and 24 completed the online task. Of these, 5 datasets showed disregard for the instructions after a certain number of blocks and just repeatedly pressed the same key to get to the end of the study. This means there were 19 full datasets for me to analyse as originally planned. A power calculation had been conducted to estimate the sample size needed for the study, revealing that 26 participants identified as having good sleep and 26 participants identified as having poor sleep were required, for a total of 52 participants. Despite my best efforts and engagement with various organisations across the country, the issues mentioned above meant I was unable to recruit and collect data from the planned number of participants. I decided to follow the plan and analyse the data that I had, rather than delay the analysis and possibly my degree by beginning a second recruitment drive. As the pandemic is still on-going and many healthcare professionals are still overworked and facing a lot of pressure, it is unlikely that any additional recruitment would have provided significantly more responses. The complete data was analysed as planned, but the higher volume of questionnaire answers encouraged me to analyse that data in more depth. Early analysis showed significant correlations between the PSQI and ESS, as was to be expected, but also between these and the Cognitive Failures Questionnaire. This was a new area for me and one which is not covered much in the literature, so I thought it would be interesting to analyse this data further, as is reported in the results and discussion sections. Although the analysis has changed completely from the original plan of using eye movement data, and even been adapted from the contingency plan analysis, it was important to me to carry out the study until the end and conduct the analyses that I did, it just meant that in an already heavily adapted study I had to adapt a little more.

6.5 Conclusion

I have really enjoyed writing this reflective piece, it has allowed me to look back at how the study was created, drawing on my interests and experience, to reflect how it was affected by the COVID-19 pandemic and the changes that were required, and to analyse how those changes affected the different parts of the study, such as participant recruitment and data analysis. I remember my supervisor, Rachel, telling me “there are two things that never go to plan in life: weddings and research” and I think it is safe to say that I certainly had not planned the path this research would take.

Although it has been frustrating and stressful at times, having to change so much of the study after months of hard work, the uncertainty surrounding the pandemic and what would be allowed by the limitations imposed on us, the distance created by working from home and having to schedule online meetings rather than being able to pop into the office for a chat, I have certainly learned far more about academic research and about my skills and areas I need to improve on than I originally thought when beginning this masters’ programme. I have realised the importance of discussing my research, my plans, and my ideas with a vast number of people, from experts in the field, to other research students, to interested friends and family. Each discussion I had allowed me to see the research from someone else's perspective, and I am grateful for the knowledge and encouragement passed down from my supervisors, Jude and Rachel, the support and sharing of ideas from my peers, and the opportunity to strip back and explain the research to non-academic friends, who allowed me to understand and share my own knowledge and see potential issues from a different perspective.

Although I did not realise it at the time, the weeks I spent deployed with the army distributing PPE allowed me to take a step back and analyse the situation, how it was evolving in those first few uncertain weeks, and what the future was likely to resemble. This meant that instead of feeling the pressure to keep working on a project with such an uncertain future and to immediately adapt it when no-one knew what the limitations would be, I was able to assess the situation once it had stabilised and discuss the various options with my supervisors, coming up with a plan that has suited the current situation and allowed me to complete my research and my degree.

Writing this piece has allowed me to see the importance and the learning benefits of the masters by research programme, rather than worrying about yielding significant results that would change the world. While the data collected and the results of the analyses are important, the skills that I have practised and honed along the way are also of great importance. I have learned to better manage my own time and to organise my work, integrating the reading of literature, completing application forms, contacting organisations and participants, collecting data and analysing it, writing up the literature, and communicating all this with both my supervisors, keeping them up to date and asking for their guidance when needed. I have practiced collecting large amounts of information, understanding it, applying it to my research, and collating it into a report. I have researched seminars, journal clubs, talks, and conferences that I believed to be of interest to my research and integrated my attendance into my workload, to provide ideas I would not necessarily contemplate on my own. Most of all, I have worked on my independence, as although my supervisors have been incredibly supportive over the last 12 months, this has been my project to imagine, put into practice, and to work on, even when times were hard. The pandemic made this even more important to me, as it was up to me and me only to find the motivation to sit down and work, and to reach out to my supervisors for help and guidance when needed. It has been a tough 12 months, filled with unimaginable obstacles, but I am proud of the hard work and motivation that has gone into this research project and I am grateful for the wonderful support of Jude and Rachel.

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Appendices

Appendix A – Participant Recruitment Invitation

Dear all,

My name is Charlie Brown, I am a postgraduate student at Lancaster University and a Reservist in 156 Regiment RLC. As part of my degree in Medical Sciences, I am carrying out research exploring the effects of sleep deficiency on decision-making in emergency medical responders, and I would like to invite you to take part in my study.

The purpose of this study is to determine how chronic sleep deprivation affects decision-making, specifically in trained medics. I am using an online program to measure visual search and decision-making during observation of different images. This will be compared to reported sleep quality and quantity, measured by questionnaires, in order to determine whether sleep deficiency is related to impaired decision-making in emergency responders.

Due to the current situation with the COVID-19 pandemic, I am unable to meet with you in person to discuss the study or to collect any data. As a result, I will be providing all information via this email. I have attached the Participant Information Sheet, containing all the details about the study, and the consent form. I ask that you please read them carefully and, if you are interested in participating, follow the link to the online study. The questionnaire and the program will take no more than 15 minutes each. The study will be available online until **Sunday 31st May 2020**.

https://lancasteruni.eu.qualtrics.com/Charlie_B/Tools_Questionnaire

I would like to thank you in advance for engaging with my study and for volunteering your time in this difficult situation. Please do contact me at c.e.brown1@lancaster.ac.uk if you have any questions or queries about the research or your participation. I will happily discuss the study further by email or video/phone call if you wish.

Best Wishes,
Charlie

Appendix B – Participant Information Sheet

Using visual search tasks to determine the effects of sleep deficiency on decision-making in civilian and military emergency responders

MoDREC Reference: 1026/MODREC/19

Invitation to take part

We would like to invite you to take part in a research study exploring the effects of sleep deficiency on emergency medical decision making. Before you decide whether to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to ask for more information or if you have any questions regarding the study.

What is the purpose of the research?

The purpose of this study is to determine how chronic sleep deprivation affects decision-making in emergency medical situations. Chronic sleep deprivation arises from sleeping less than seven hours per night over a number of consecutive nights and has been found to lead to cognitive deficits, including impaired attention and decision-making. I am using an online program to measure visual search, decision-making and learning patterns during observation of repeated routes. This will be compared to reported sleep quality and quantity, measured by questionnaires, in order to determine whether sleep deficiency is related to impaired decision-making in emergency responders.

Who is doing this research?

My name is Charlie Brown and I am conducting this research as part of my postgraduate degree in the Medical Sciences programme at Lancaster University, Lancaster, United Kingdom.

Why have I been invited to take part?

You have been approached because the study requires information from people who are trained medical responders from both civilian and military backgrounds.

Do I have to take part?

No. It's completely up to you to decide whether or not you take part.

Can I withdraw from the research and what will happen if I withdraw?

If you decide you no longer want to take part after initiating the study, you may withdraw without giving a reason at any time before and during the task by informing the researcher. You may also withdraw up to two weeks after completing the task by contacting the researcher with your Unique Identification Number (UIN). After two weeks, your anonymised data will be included in the statistical analysis and it will no longer be retrievable.

What will I be asked to do?

If you decide you would like to take part, please follow the link in the email. This will take you to the first part of the study where you will be asked to confirm you have read the participant information sheet and the consent form. You will be asked to tick each statement to confirm your consent to participate in this study before you are able to continue. Following this, you will be asked to complete three online questionnaires, including one demographics questionnaire and two sleep-related questionnaires. You will be asked to input your Unique Identification Number (UIN); this is the last 4 digits of your mobile phone number (eg. 7736). It is important that you input the correct number as you will need it for the second part of the study and in case you wish to withdraw from the study. This UIN will provide anonymity to your data, in that it will be identified as coming from the same participant without it being recognised as yours personally.

Once the online questionnaires have been completed, you will move on to the second part of the study, where you will be reminded of the instructions. You will be asked to follow the link to the web-based decision-making task, where you will be required to input your UIN again. This task requires you to imagine you are en-route to a medical emergency and to search for a target (tool) in the images of the route presented to you. For each image, you will be asked to indicate whether a target is present or absent, by pressing the '**P**' key for **present**, and the '**A**' key for **absent**. The route is presented as sequential sets of images, with a yellow rectangle appearing after each image to indicate a preview of the following portion of the route. You will be asked to press the '**space bar**' when you are happy to continue to the next portion of the route. You will view the route 8 times in total, with the opportunity for a break in between each viewing if you wish. When you have viewed the route for the last time, you will be able to close the browser and relax. Both parts of the study will take no more than 15 minutes each to complete.

Please ensure you are in a quiet room and limit any distractions (e.g. switch off mobile phone notifications) before starting the study as this may affect your concentration and reaction times.

Image 1: Example image of route including a target (axe). Press 'P' key for *present.*

Image 2: Example image of the route preview. Press 'Space bar' to move on.

What is the procedure that is being tested?

I am aiming to determine whether sleep deficiency affects participants' abilities for visual search, learning patterns, and decision-making.

What are the benefits of taking part?

There are no direct benefits of taking part in this study.

What are the possible disadvantages and risks of taking part?

There are no risks anticipated with participating in this study. However, if you experience any distress from answering questions about your sleeping patterns, you are encouraged to speak to your GP and the Independent Medical Officer (details below). The NHS also has a support page about sleeping difficulties, with advice of things to try and who to speak to. You can find this website at the following link: https://www.nhs.uk/oneyou/every-mind-matters/sleep/.

Are there any expenses and payments which I will get?

You will not receive any expenses or payments.

Will my taking part or not taking part affect my service career?

Whether you decide to take part or not, or whether you request to withdraw your data after completing the study, will not affect your service career.

What happens if I suffer any harm?

If you suffer any harm as a direct result of taking part in this study, you can apply for compensation under the MoD's 'No-Fault Compensation Scheme.

Will my data be identifiable?

The information you provide is confidential. The data collected for this study will be stored anonymously and securely and only the researchers conducting this study will have access to this data:

- o Your data will be anonymised and you will receive a UIN in case you would like your data to be withdrawn
- o Hard copies of consent forms will be kept in a locked cabinet.
- o The files on the computer will be encrypted (that is no-one other than the researcher will be able to access them) and the computer itself password protected.

What will happen to my results?

Your results will be grouped together with others for analysis and reported in my masters dissertation. The results of this study will be provided to the organisations participating in the study in the form of a technical report. These findings may also be submitted for publication in an academic or professional journal. No individual participant's data will be identified. Anonymised scores will be made available for analysis by other researchers who could use the data to increase the impact of our research. The management of this data will adhere to Lancaster University's Research Data Policy and the Data Protection Act 2018.

Who has reviewed the project?

This study has been reviewed and approved by the Faculty of Health and Medicine Research Ethics Committee at Lancaster University. It has also been reviewed and given favourable opinion by the Ministry of Defence Research Ethics Committee (MoDREC).

Where can I obtain further information about the study if I need it?

If you have any questions about the study, please contact the main researcher:

- Charlie Brown: c.e.brown1@lancaster.ac.uk
- Dr Judith Lunn (supervisor): j.lunn1@lancaster.ac.uk
- Prof Rachel Isba (supervisor): rachel.isba@lancaster.ac.uk

Complaints

If you wish to speak to someone or raise concerns about any aspect of this study and do not want to speak to the researcher, you can contact the Independent Medical Officer:

Lt Col Mike Brownsell
OC Nursing
208 Field Hospital, RAMC
m.brownsell@chester.ac.uk

If you wish to speak to someone outside of the Masters Research Programme, you may contact:

Professor Roger Pickup;
Associate Dean for Research;
Faculty of Health and Medicine
Lancaster University
LA1 4YG
Tel: +44 (0)1524 593746
Email: r.pickup@lancaster.ac.uk

Compliance with the Declaration of Helsinki

This study will be conducted in accordance with the principles defined in the Declaration of Helsinki as adopted at the 64thWMA General Assembly at Fortaleza, Brazil in October 2013.

Appendix C – Consent Form

Health & Medicine | Lancaster University

Consent Form for Participants in Research Studies

Title of Study: *Using visual search tasks to determine the effects of sleep deficiency on decision-making in civilian and military emergency responders*

MODREC Reference: 1026/MODREC/19

- The nature, aims and risks of the research have been explained to me. I have read and understood the Participant Information Sheet and understand what is expected of me. All my questions have been answered fully to my satisfaction. ☐

- I understand that if I decide at any time during the research and up to two weeks after that I no longer wish to participate in this project, I can notify the researchers involved and be withdrawn from it immediately without having to give a reason. I also understand that I may be withdrawn from it at any time, and that in neither case will this be held against me in subsequent dealings with the Ministry of Defence, St John Ambulance, or Search and Rescue. ☐

- I consent to the processing of my personal information for the purposes of this research study. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 2018. ☐

- I agree to volunteer as a participant for the study described in the information sheet and give full consent. ☐

- This consent is specific to the particular study described in the Participant Information Sheet attached and shall not be taken to imply my consent to participate in any subsequent study or deviation from that detailed here. However, I understand my anonymised data may be used for future studies. ☐

- I understand that in the event of my sustaining injury, illness or death as a direct result of participating as a volunteer in Ministry of Defence research, I or my dependants may enter a claim with the Ministry of Defence for compensation under the provisions of the no-fault compensation scheme, details of which are attached. ☐

Appendix D – Participant Reminder Email

Hi all,

I hope you are all keeping well.

Due to a low level of responses I have extended the participation window for my study into sleep deprivation and decision-making, please do consider completing the study. It will take no more than 30 minutes and will provide vital insight into the effects of sleep deprivation on decision-making. I am unable to collect my data face-to-face so it is really important for me to engage participants remotely, both to complete the research and to complete my degree. Please read the information about the study and follow the link below if you would like to participate, and please ensure you follow the instructions right to the end of the task to ensure your data is successfully saved (closing the browser before the last 'space bar' click will not save any data). The link will now be open for another two weeks, until Tuesday 30th June.

https://lancasteruni.eu.qualtrics.com/jfe/form/SV_difdM8P5zBTb1Wt

Please do email me if you have any questions about the study or the research, I am happy to discuss it (c.e.brown1@lancaster.ac.uk).

Thank you for your help and support,

Best wishes,

Charlie

Appendix E – Qualtrics Questionnaire, including consent and demographics

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Start of Block: Introduction

Welcome **Using visual search tasks to determine the effects of sleep deficiency on decision-making in civilians and military emergency responders**

Thank you for following the link and showing your interest in my research. Please ensure you have read the Participant Information Sheet and you understand what will be asked of you before continuing on with this study.

Thank you,
Charlie

Page Break

Consent **Consent Form**

MODREC Reference: 1026/MODREC/19

Please read the following information before agreeing to participate in the study. If you choose not to participate, please exit the study now. Please tick each statement as you read it to provide consent.

	I Agree (1)
The nature, aims and risks of the research have been explained to me. I have read and understood the Participant Information Sheet and understand what is expected of me. All my questions have been answered fully to my satisfaction. (4)	
I understand that if I decide at any time during the research and up to two weeks after that I no longer wish to participate in this project, I can notify the researchers involved and be withdrawn from it immediately without having to give a reason. I also understand that I may be withdrawn from it at any time, and that in neither case will this be held against me in subsequent dealings with the Ministry of Defence, St John Ambulance, or Lowlands Rescue. (7)	
I consent to the processing of my personal information for the purposes of this research study. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 2018. (8)	
I agree to volunteer as a participant for the study described in the information sheet and give full consent. (9)	
This consent is specific to the particular study described in the Participant Information Sheet attached and shall not be taken to imply my consent to participate in any subsequent study or deviation from that detailed here. However, I understand my anonymised data may be used for future studies. (10)	

I understand that in the event of my sustaining injury, illness or death as a direct result of participating as a volunteer in Ministry of Defence research, I or my dependants may enter a claim with the Ministry of Defence for compensation under the provisions of the no-fault compensation scheme, details of which are attached. (11)

End of Block: Introduction

Start of Block: UIN

UIN Please input your Unique Identification Number (UIN) below - this is the last 4 digits of your mobile phone number (eg. 7736). This will be used to ensure the anonymity of your data, so please ensure you do not enter your entire number. Remember that you will need to input the same UIN in the next part of the study and you will need to provide it to the researcher if you wish to withdraw your data later on, so make sure you input the correct digits.

Please enter your UIN (last 4 digits of mobile phone number):

____

End of Block: UIN

Start of Block: 1 - Demographics and CFQ

NotaQ Part 1 - Demographics

Please tell me a little bit about yourself. This will remain anonymous.

Age Age (in years)

____

Gender Gender

- ◯ Male (1)
- ◯ Female (2)
- ◯ Other (3) ____

Organisation Which organisation are you a part of?

- ◯ St John Ambulance (1)
- ◯ Search and Rescue (2)
- ◯ Armed Forces (3)
- ◯ Other (4) ____
- ◯ Lancaster Medical School (5)

Display This Question:

If Which organisation are you a part of? = Lancaster Medical School

LMS_Year Which year of study are you in?

- ○ Year 1 (1)
- ○ Year 2 (2)
- ○ Year 3 (3)
- ○ Year 4 (4)
- ○ Year 5 (5)

Skip To: Total_hours If Which year of study are you in? , Year 1 Is Displayed

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Display This Question:

If Which organisation are you a part of? = St John Ambulance

And Which organisation are you a part of? = Search and Rescue

And Which organisation are you a part of? = Armed Forces

Year_Qualified When did you first qualify as an emergency medical responder? (Year)

____

Display This Question:

If If When did you first qualify as an emergency medical responder? (Year) Text Response Is Displayed

Role What is your current role?

____

Shift_type Type of shifts most commonly worked in this role

○ 24 hours (1)

○ 12 hours (2)

○ ≤ 8 hours (3)

○ Other (4) ____

Work Are you:

○ Full time (1)

○ Part time (2)

○ Volunteer (3)

Display This Question:

If Are you: != Full time

And Which organisation are you a part of? != Other

Medical_related Is your full time employment medical-related?

○ Yes (1)

○ No (2)

Display This Question:

If Is your full time employment medical-related? = Yes

Full_time What is your full time employment?

____

Total_hours Total hours worked in the past week - both full time employment and part-time/volunteer if applicable.

____

Page Break

NotaQ The following questions are about minor mistakes which everyone makes from time to time, but some of which happen more often than others. Please answer truthfully and remember that all responses are anonymous.

CFQ1 Please tick the box showing how often these things have happened to you in the last 6 months.

	Very Often (4)	Quite Often (3)	Occasionally (2)	Very rarely (1)	Never (0)
Do you read something and find you haven't been thinking about it and must read it again? (9)	○	○	○	○	○
Do you find you forget why you went from one part of the house to the other? (10)	○	○	○	○	○
Do you fail to notice signposts on the road? (11)	○	○	○	○	○
Do you find you confuse right and left when giving directions? (12)	○	○	○	○	○
Do you bump into people? (13)	○	○	○	○	○

Do you find you forget whether you've turned off a light or a fire or locked the door? (14)	○	○	○	○	○
Do you fail to listen to people's names when you are meeting them? (17)	○	○	○	○	○
Do you say something and realise afterwards that it might be taken as insulting? (21)	○	○	○	○	○
Do you fail to hear people speaking to you when you are doing something else? (22)	○	○	○	○	○
Do you lose your temper and regret it? (19)	○	○	○	○	○

Do you leave important letters unanswered for days? (20)	○	○	○	○	○
Do you find you forget which way to turn on a road you know well but rarely use? (18)	○	○	○	○	○
Do you fail to see what you want in a supermarket (although it's there)? (15)	○	○	○	○	○

CFQ2 Please tick the box showing how often these things have happened to you in the last 6 months.

	Very Often (4)	Quite Often (3)	Occasionally (2)	Very rarely (1)	Never (0)
Do you find yourself suddenly wondering whether you've used a word correctly? (16)	○	○	○	○	○
Do you have trouble making up your mind? (23)	○	○	○	○	○
Do you find you forget appointments? (24)	○	○	○	○	○
Do you forget where you put something like a newspaper or a book? (25)	○	○	○	○	○
Do you find you accidentally throw away the thing you want and keep what you meant to throw away - as in the example of throwing away the matchbox and putting the used match in your pocket? (26)	○	○	○	○	○

Do you daydream when you ought to be listening to something? (27)	○	○	○	○	○
Do you find you forget people's names? (28)	○	○	○	○	○
Do you start doing one thing at home and get distracted into doing something else (unintentionally)? (29)	○	○	○	○	○
Do you find you can't quite remember something although it's "on the tip of your tongue"? (30)	○	○	○	○	○
Do you find you forget what you came to the shops to buy? (31)	○	○	○	○	○
Do you drop things? (32)	○	○	○	○	○
Do you find you can't think of anything to say? (33)	○	○	○	○	○

End of Block: 1 - Demographics and CFQ

Start of Block: Break

Break You may now take a break. Please click on the arrow when you are ready to continue.

End of Block: Break

Start of Block: 2 - Sleep Qs

Not_A_Q Part 2 - Sleep-related questionnaires

PSQI 2.1 Sleep Quality Assessment (PSQI)
The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

During the past month,

PSQI1

When have you usually gone to bed? Please use the 24-hour clock (eg. 2300).

____

PSQI2

How long (in minutes) has it taken you to fall asleep each night? (eg. 20)

____

PSQI3

What time have you usually gotten up in the morning? Please use the 24-hour clock (eg. 0600).

____

PSQI4a

How many hours of actual sleep did you get at night? Please round up to the nearest half hour (eg. 7h = 7, 7h30 = 7.5).

____

PSQI4b

How many hours were you in bed? Please round up to the nearest half hour (eg. 9h = 9, 9h30 = 9.5).

____

Page Break

PSQI5

During the past month, how often have you had trouble sleeping because you:

	Please click on the answer			
	Not during the past month (0)	Less than once a week (1)	Once or twice a week (2)	Three or more times a week (3)

Cannot get to sleep within 30 minutes (PSQI5a)	○	○	○	○
Wake up in the middle of the night or early morning (PSQI5b)	○	○	○	○
Have to get up to use the bathroom (PSQI5c)	○	○	○	○
Cannot breathe comfortably (PSQI5d)	○	○	○	○
Cough or snore loudly (PSQI5e)	○	○	○	○
Feel too cold (PSQI5f)	○	○	○	○
Feel too hot (PSQI5g)	○	○	○	○
Have bad dreams (PSQI5h)	○	○	○	○
Have pain (PSQI5i)	○	○	○	○
Other reason(s), please describe, including how often you have had trouble sleeping because of this reason(s): (PSQI5j)	○	○	○	○

PSQI5.10b Reason(s) if applicable:

____

Page Break

PSQI6 During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?

- Not during the past month (0)
- Less than once a week (1)
- Once or twice a week (2)
- Three or more times a week (3)

PSQI7

During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

- Not during the past month (0)
- Less than once a week (1)
- Once or twice a week (2)
- Three or more times a week (3)

PSQI8

During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?

- Not during the past month (0)
- Less than once a week (1)
- Once or twice a week (2)
- Three or more times a week (3)

PSQI9 During the past month, how would you rate your sleep quality overall?

- Very good (0)
- Fairly good (1)
- Fairly bad (2)
- Very bad (3)

Page Break

Not_a-Q 2.2 Sleepiness Scale (ESS)

How likely are you to doze off or fall asleep in the following situations, in comparison to feeling just tired? This refers to your usual way of life in recent times. Even if you haven't done some of these things recently, try to work out how they would have affected you.

ESS How likely are you to dose off or fall asleep when...

	Would never doze (0)	Slight chance of dozing (1)	Moderate chance of dozing (2)	High chance of dozing (3)
Sitting and reading (9)	○	○	○	○
Watching TV (10)	○	○	○	○
Sitting still in a public place (e.g. a theatre, a cinema or a meeting) (11)	○	○	○	○
As a passenger in a car for an hour without a break (12)	○	○	○	○
Lying down to rest in the afternoon when the circumstances allow (13)	○	○	○	○
Sitting and talking to someone (14)	○	○	○	○
Sitting quietly after lunch without having drunk alcohol (15)	○	○	○	○
In a car or bus while stopped for a few minutes in traffic (16)	○	○	○	○

AlertQ During which part of the day do you feel more alert?

- ○ Morning (1)
- ○ Lunchtime (2)
- ○ Afternoon (3)
- ○ Evening (4)
- ○ Night (5)

End of Block: 2 - Sleep Qs

You have now come to the end of the questionnaires and part one of the study.

You may take a small break if you wish.

When you are ready, please follow the link below to complete part two of the study, the visual search task. Please input your UIN (last 4 digitd of mobile phone number) in the box named 'Participant', wait for the study to download, and press 'ok'. You will be shown images from a route, some of which will contain a target (a tool). For each image, using your keyboard, press the '**P**' key if a target is **present** and the '**A**' key if the target is **absent**. After each image, a preview of the next part of the route will appear with a yellow rectangle. Please press the '**space bar**' when you are ready to move forward.

You will be shown the route 8 times, with a break between each viewing. When you are ready to continue to the next viewing, press the '**space bar**'. You will be notified when you have reached the end of the task and can close your browser, that will be the end of the study. Please make sure you follow the instructions right to the end so your data is saved! The task will take no more than 15 minutes.

Please follow the instructions right to the end of the next task before closing your browser or your data will not be saved.

https://run.pavlovia.org/Charlie_B/tools_experiment/html

Thank you,
Charlie

Appendix F – Cognitive Failures Questionnaire

The Cognitive Failures Questionnaire (Broadbent, Cooper, FitzGerald & Parkes, 1982)

The following questions are about minor mistakes which everyone makes from time to time, but some of which happen more often than others. We want to know how often these things have happened to your in the past 6 months. Please circle the appropriate number.

		Very often	Quite often	Occasion-ally	Very rarely	Never
1.	Do you read something and find you haven't been thinking about it and must read it again?	4	3	2	1	0
2.	Do you find you forget why you went from one part of the house to the other?	4	3	2	1	0
3.	Do you fail to notice signposts on the road?	4	3	2	1	0
4.	Do you find you confuse right and left when giving directions?	4	3	2	1	0
5.	Do you bump into people?	4	3	2	1	0
6.	Do you find you forget whether you've turned off a light or a fire or locked the door?	4	3	2	1	0
7.	Do you fail to listen to people's names when you are meeting them?	4	3	2	1	0
8.	Do you say something and realize afterwards that it might be taken as insulting?	4	3	2	1	0
9.	Do you fail to hear people speaking to you when you are doing something else?	4	3	2	1	0
10.	Do you lose your temper and regret it?	4	3	2	1	0
11.	Do you leave important letters unanswered for days?	4	3	2	1	0
12.	Do you find you forget which way to turn on a road you know well but rarely use?	4	3	2	1	0
13.	Do you fail to see what you want in a supermarket (although it's there)?	4	3	2	1	0
14.	Do you find yourself suddenly wondering whether you've used a word correctly?	4	3	2	1	0

		Very often	Quite often	Occasion-ally	Very rarely	Never
15.	Do you have trouble making up your mind?	4	3	2	1	0
16.	Do you find you forget appointments?	4	3	2	1	0
17.	Do you forget where you put something like a newspaper or a book?	4	3	2	1	0
18.	Do you find you accidentally throw away the thing you want and keep what you meant to throw away – as in the example of throwing away the matchbox and putting the used match in your pocket?	4	3	2	1	0
19.	Do you daydream when you ought to be listening to something?	4	3	2	1	0
20.	Do you find you forget people's names?	4	3	2	1	0
21.	Do you start doing one thing at home and get distracted into doing something else (unintentionally)?	4	3	2	1	0
22.	Do you find you can't quite remember something although it's "on the tip of your tongue"?	4	3	2	1	0
23.	Do you find you forget what you came to the shops to buy?	4	3	2	1	0
24.	Do you drop things?	4	3	2	1	0
25.	Do you find you can't think of anything to say?	4	3	2	1	0

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References

Broadbent, D.E., Cooper, P.F., FitzGerald, P., & Parkes, K.R. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology*, *21*, 1-16.

Appendix G – Pittsburgh Sleep Quality Index (PSQI)

Name____ Date_________

Sleep Quality Assessment (PSQI)

What is PSQI, and what is it measuring?

The Pittsburgh Sleep Quality Index (PSQI) is an effective instrument used to measure the quality and patterns of sleep in adults. It differentiates “poor” from “good” sleep quality by measuring seven areas (components): subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction over the last month.

INSTRUCTIONS:

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

During the past month,

1. When have you usually gone to bed? ______________________________
2. How long (in minutes) has it taken you to fall asleep each night? ______________________________
3. What time have you usually gotten up in the morning? ______________________________
4. A. How many hours of actual sleep did you get at night? ______________________________
   B. How many hours were you in bed? ______________________________

5. During the past month, how often have you had trouble sleeping because you	Not during the past month (0)	Less than once a week (1)	Once or twice a week (2)	Three or more times a week (3)
A. Cannot get to sleep within 30 minutes				
B. Wake up in the middle of the night or early morning				
C. Have to get up to use the bathroom				
D. Cannot breathe comfortably				
E. Cough or snore loudly				
F. Feel too cold				
G. Feel too hot				
H. Have bad dreams				
I. Have pain				
J. Other reason (s), please describe, including how often you have had trouble sleeping because of this reason (s):				
6. During the past month, how often have you taken medicine (prescribed or “over the counter”) to help you sleep?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
8. During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?				
9. During the past month, how would you rate your sleep quality overall?	Very good (0)	Fairly good (1)	Fairly bad (2)	Very bad (3)

Scoring

Component 1	#9 Score	C1 __________
Component 2	#2 Score (<15min (0), 16-30min (1), 31-60 min (2), >60min (3)) + #5a Score (if sum is equal 0=0; 1-2=1; 3-4=2; 5-6=3)	C2 __________
Component 3	#4 Score (>7(0), 6-7 (1), 5-6 (2), <5 (3)	C3 __________
Component 4	(total # of hours asleep) / (total # of hours in bed) x 100 >85%=0, 75%-84%=!, 65%-74%=2, <65%=3	C4 __________
Component 5	# sum of scores 5b to 5j (0=0; 1-9=1; 10-18=2; 19-27=3)	C5 __________
Component 6	#6 Score	C6 __________
Component 7	#7 Score + #8 score (0=0; 1-2=1; 3-4=2; 5-6=3)	C7 __________

Add the seven component scores together _________________ ***Global PSQI*** ______________

A total score of “5” or greater is indicative of poor sleep quality.
If you scored “5” or more it is suggested that you discuss your sleep habits with a healthcare provider

Appendix H – Epworth Sleepiness Scale

Epworth Sleepiness Scale

Name: ______________________________________ Today's date: ______________

Your age (Yrs): ____________ Your sex (Male = M, Female = F): ______

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

This refers to your usual way of life in recent times.

Even if you haven't done some of these things recently try to work out how they would have affected you.

Use the following scale to choose the **most appropriate number** for each situation:

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

It is important that you answer each question as best you can.

Situation	**Chance of Dozing (0-3)**
Sitting and reading	___
Watching TV	___
Sitting, inactive in a public place (e.g. a theatre or a meeting)	___
As a passenger in a car for an hour without a break	___
Lying down to rest in the afternoon when circumstances permit	___
Sitting and talking to someone	___
Sitting quietly after a lunch without alcohol	___
In a car, while stopped for a few minutes in the traffic	

THANK YOU FOR YOUR COOPERATION

Appendix I – FHMREC Approval Letter

Applicant: Charlotte Brown
Supervisor: Judith Lunn
Department: Lancaster Medical School
FHMREC Reference: FHMREC19019

06 May 2020

Dear Charlotte

Re: Using eye tracking to determine the effects of sleep deficiency on emergency medical decision-making in military and civilian first responders

Thank you for submitting your research ethics application for the above project for review by the **Faculty of Health and Medicine Research Ethics Committee (FHMREC)**. The application was recommended for approval by FHMREC, and on behalf of the Chair of the Committee, I can confirm that approval has been granted for this research project.

As principal investigator your responsibilities include:

- ensuring that (where applicable) all the necessary legal and regulatory requirements in order to conduct the research are met, and the necessary licenses and approvals have been obtained;
- reporting any ethics-related issues that occur during the course of the research or arising from the research to the Research Ethics Officer at the email address below (e.g. unforeseen ethical issues, complaints about the conduct of the research, adverse reactions such as extreme distress);
- submitting details of proposed substantive amendments to the protocol to the Research Ethics Officer for approval.

Please contact me if you have any queries or require further information.

Tel:- 01542 593987
Email:- fhmresearchsupport@lancaster.ac.uk

Yours sincerely,

Becky Case
Research Ethics Officer, Secretary to FHMREC.

Appendix J – MoDREC Approval Letter

Ministry of Defence
Research Ethics Committee

MODREC Secretariat
Building 5, G02,
Defence Science and Technology Laboratory,
Porton Down, Salisbury, SP4 0JQ

Telephone: 01980 956351
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Email: c.e.brown1@lancaster.ac.uk

Our Reference: 1026/MODREC/19

Date: 28th May 2019

Dear Charlotte,

Using visual search tasks to determine the effects of sleep deficiency on decision-making in civilian and military emergency responders

Thank you for submitting your revised application (1026/MODREC/19) with tracked changes and the covering letter with detailed responses to the MODREC letter. I can confirm that the revised protocol has been given favourable opinion ex-Committee.

This favourable opinion is valid for the duration of the research and is conditional upon adherence to the protocol – please inform the Secretariat if any amendment becomes necessary.

Please note that under the terms of JSP 536 you are required to notify the Secretariat of the commencement date of the research, and to submit annual and final/termination reports to the Secretariat on completion of the research.

Yours sincerely,

Dr Simon Kolstoe
MODREC Chair

Appendix K – Target Examples

Image 1: Example image where target is an axe.

Image 2: Example image where target is a hammer.

Image 3: Example image where target is a set of pliers.

Image 4: Example image where target is a saw.

Image 5: Example image where target is a screwdriver.