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The Effects of Sleep Time and Power Napping on Memory and Vigilance

THE EFFECTS OF SLEEP TIME AND POWER NAPPING ON MEMORY AND VIGILANCE

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Abstract

This research investigated the effects of power napping and sleep time on verbal and visual memory performance and vigilance levels. This research was conducted because there is limited prior research that determines the beneficial effects of power napping on both verbal and visual memory performance and vigilance levels. In addition, prior research has concluded that going to sleep early enhances memory and vigilance. However the interaction of sleep time and power napping has not yet been investigated. This research hypothesised that power napping would significantly increase verbal and visual memory performance, as well as vigilance levels. It further hypothesised that participants who go to sleep late (after midnight) would benefit significantly more from a power nap, enhancing verbal and visual memory performance and increasing vigilance levels, in comparison to those who go to sleep early (before midnight). This research drew on the findings of prior research which investigated the impact of circadian rhythms and the stages of sleep on performance.

This experiment included 80 participants, 40 participants engaged in a 20 minute power nap whilst the other 40 participants engaged in a 20 minute rest period which involved reading magazines. In the power napping condition and non-power napping condition, 20 participants went to sleep before midnight and 20 participants went to sleep after midnight the night prior to the experiment. All 80 participants completed a verbal memory test, a visual memory test and a vigilance test. The results of the experiment found that engaging in a power nap did significantly increase verbal and visual memory, and participants who went to sleep after midnight had significantly increased verbal and visual memory performance in the power napping condition, compared to those who went to sleep before midnight. However, there were no significant difference between the power napping condition and non-power napping condition with regards to vigilance levels. There were also no significant difference between the early sleep time condition and late sleep time condition in the power napping condition on vigilance levels.

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Dedications and Acknowledgements

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1 Introduction

1.1.1 Sleep

Sleep is recognised to be a public health priority as it has been found to be an essential physiological process for life. Research into this area is providing evidence for the importance of sleep (Tempaku, Hirotsu & Tufik, 2016). Sleep which is constantly disrupted has been found to induce memory impairment and it is assumed that improving the quality of sleep improves mood, memory and cognitive functioning (Henry, Wolf, Ross & Thomas, 2015). Research has found that for adults to gain the full benefits of sleep they should have between seven to nine hours of sleep per night (eight hours on average), which has reduced from an average of nine hours within the last century to allow increased time for more working and leisure hours (Bonuck, Goodlin-Jones, Schechter & Owners, 2017). As time has gone on, leisure and work hours have taken a priority over sleep time, without any real consideration to the impact this has on health and well-being. Adolescents aged between fourteen to seventeen years old should have between eight to ten hours of sleep per night (nine hours on average) (Bonuck *et al.,* 2017). The suggested amount of sleep that individuals should have per night, is based on the completed cycle of the sleep-wake cycle which fluctuates during the night.

1.1.2 Sleep-wake cycle

In the hypothalamus there is a small group of brain cells known as the Suprachiasmatic Nucleus which controls the circadian changes and the sleep-wake homeostasis (Ramirez-Plascencia, Saderi, Escobar, Salgado-Delgado & Silver, 2017). Experiments carried out during sleep mode suggests that participants go through a sleep-wake cycle which is a biological rhythm that is influenced by the external environment (Fuller, Gooley & Saper, 2006). This sleep-wake cycle is regulated by two processes which includes the circadian rhythm and sleep-wake homeostasis (Fuller *et al.,* 2006). This is known as the two-process model of sleep-regulation (Borbely, Daan, Wirz-Justice & Deboer, 2016).

1.1.3 **Stages of sleep**

There are different stages of sleep which fluctuates from stage one (light sleep) to stage four (deep sleep) and Rapid-Eye Movement Sleep (REM sleep) (Babson & Felder, 2015). Stages one to four are referred to as Non-Rapid Eye Movement sleep (Non-REM sleep) and research has concluded that participants go through Non-REM sleep and then through to REM sleep on numerous cycles during the night (Babson & Feldner, 2015). Using an electroencephalogram (EEG), it has been found that dream sleep occurs most predominately during REM sleep, whereas the recovery of the brain and body occurs most predominately throughout non-REM sleep and dreams generally do not occur within these stages (Babson & Feldner, 2015). Research has used EEGs to analyse the brain waves which occur during different stages of sleep. It has been found that beta waves are prevalent in individuals who are in the state of wakefulness. However, stages one and two are mainly associated with a mixture of alpha and theta waves where the individual is in a relaxed state, whereas stage three and four is mainly associated with delta waves. In addition to this, REM sleep is most associated with erratic beta activity (Figure 1).

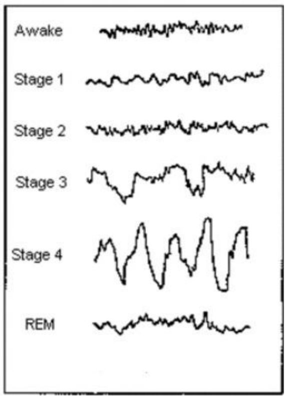

Figure 1: Brain waves during REM and Non-REM sleep (taken from Tuck inc., 2017)

1.1.4 **Physiology of sleep**

Adenosine is a neuromodulator which is an important endogenous, homeostatic factor of sleep. When a molecule known as Adenosine Triphosphate declines, it produces the neuromodulator, Adenosine (Nicolaidis, 2006). Adenosine mediates the sleepiness that follows prolonged wakefulness (Basheer, Strecker, Thakkar & McCarley, 2004). Basheer *et al.* (2004) describe how adenosine mediates the internal energy in the brain during sleep and how stimulants such as caffeine counteract the effects of adenosine by antagonising the adenosine receptors. There are four adenosine receptors: - A1, A2A, A2B and A3. A1 is the receptor well known for mediating "sleep debt" (Basheer *et al.,* 2004). Dijk (2009) found that participants spend more time in stage Slow-Wave Sleep (SWS) at the beginning of the night, and as SWS decreases, REM sleep increases. Moreover, adenosine A2a-receptor agonist increases the amount of NREM sleep because when adenosine increases, the amount of NREM sleep also increases to ensure that when the individual is asleep, the adenosine levels decrease (Dijk, 2009). When an individual experiences sleep deprivation it decreases brain activity which causes the individuals to experience mental, physical and emotional fatigue and struggle to perform high cognitively functioning tasks (Motomura, 2014). This process is known as sleep debt which is a long-term effect of sleep-deprivation (Motomura, 2014).

1.1.5 **Theories of sleep**

Many theories of sleep have been outlined to explain the importance of sleep and the different functions which sleep provides. One of the earlier theories of sleep is the adaptive theory which argues that sleep evolved as a way of saving energy (Jung, Melason, Frydendall, Perreault, Eckel & Wright, 2011). When animals sleep they are out of the way of predators as they are laid still whilst asleep (Capellini, Nunn, McNamara, Preston & Barton, 2008). Research supporting this theory has demonstrated that smaller animals slept for a longer period of time because they needed to conserve more energy (Jung *et al.,* 2011). This theory also suggests that sleep is a way of wasting time (Jung *et al.,* 2011). This demonstrates that wasting time sleeping has evolved to keep animals still whilst out of the way of predators.

In contrast to this, it is argued that this theory is too simple to explain the differences in sleep patterns and the reasons for sleeping (Aristakesyan, 2016). For example, this theory assumes that the function of sleep for every human and animal is to keep safe and sleep evolved when humans were in danger of predators. However, the reasons why humans still sleep for prolonged periods of time, despite not being in danger of predators, cannot be explained by the adaptive theory of sleep. If this theory could explain all sleeping behaviours it would be able to explain the reasons behind why humans sleep for, on average, eight hours per night. Moreover, Aristakesyan (2016) argued that studies which have been used to support this theory have consisted of animal subjects. This suggests that this theory is reductionist and cannot be generalised to the human population, and therefore humans may sleep for different reasons which cannot be explained by the adaptive theory. In turn, research conducted on animal subjects was predominantly observational, and therefore it cannot be argued that it was solely the independent variable which caused the dependent variable because extraneous variables cannot be concluded in observational studies (Coolican, 2014; 2017). In addition, with this theory being deterministic, other theories need to be considered to understand the underlying mechanisms to sleep which the adaptive theory does not consider and / or cannot explain.

The restoration theory of sleep takes a different approach and assumes that individuals need sleep to restore the body and generate energy to allow them to function on a daily basis (Trksak *et al.,* 2010). This theory suggests that sleeping allows the body to restore physiological and mental processes. Trksak *et al.* (2010) has found that SWS sleep (stages one to four) was important for the restoration of physiological functions, whereas REM sleep was vital for the restoration of mental functions. It has been found that after a period of sleep deprivation, the amount of time spent in SWS sleep is increased compared to participants who are not sleep deprived (Dijk, 2009).

The following sections will critically review the research that has investigated the effects of sleep on verbal and visual memory performance and vigilance levels, as well as critically discuss the research that has identified the positive impacts of power napping and sleep time on verbal and visual memory performance and vigilance levels.

1.2 Memory

Memory is the description given to the structures and processes which are involved in the retention and reclamation of information (Macdonald & Cote, 2016). Memory is particularly involved in the storage and retrieval of information and is essential to function in everyday life, as it allows individuals to remember their past, who their friends and family are, and how to function - for example how to cook, get dressed, eat and so on (Nadel, Hupbach, Gomez & Newman-Smith, 2012). It is also vital for individuals to be able to learn new information. Memory is the ability to be able to learn, retain, store and recall information (Nadel *et al.,* 2012). There is a variety of different forms of memory including visual and verbal memory, as well as short-term and long-term memory (Oniz, Inanc, Guducu & Ozgoren, 2015).

An updated view on sleep has concentrated on the benefits of sleep on memory. Some of the well-researched benefits of sleep is the increase in mood, memory and cognitive functioning which individuals experience after a prolonged period of sleep (Ellenbogen, Mulbert, Stickgold, Dinges & Thompson-Schill, 2006). Research on the effects of sleep on memory has gathered research attention. Prior research has investigated the positive effects of sleep on memory performance as well as the adverse effects of sleep deprivation on memory performance. Diekelmann (2013) supports the notion that sleep enhances memory by concluding that sleep consolidates the facilitation of newly acquired information. Therefore, individuals retaining information will recall more information after a period of sleep because sleep increases memory consolidation which means that information is passed from short-term memory to long-term memory. It is clear by reviewing previous research that sleep enhances memory and facilitates memory consolidation, whilst sleep deprivation causes adverse effects on memory performance and attention is a fundamental finding in the research of sleep and cognition (Tripathi & Jha, 2016). With extensive research confirming that sleep enhances memory and has practical applications in real life situations such as preventing road traffic accidents, theories on memory can give insight into the types of memory that sleep enhances (Cetinglu *et al.,* 2015).

Baddeley and Hitch's (1974) Working Memory Model is one theory that has given insight into memory processing. This enhancement of the modal model of memory consists of three components which include: the central executive function, the phonological loop and the visuo-spatial sketch pad (Baddeley & Hitch, 1974). Baddeley and Hitch (1974) suggested that the central executive function drives the whole system by retrieving information and filtering the information through to the relevant component (Baddeley, 1986). This component of memory is responsible for monitoring and co-ordinating the phonological loop and the visuo-spatial sketch pad. The central executive directs attention and decides which tasks to attend to, and which to ignore, and therefore is considered to be the most important component within this working memory model (Baddeley, 1986). This component of short-term memory focuses on individuals' attention and deals with various cognitive tasks including puzzle solving and dual-task paradigms (Baddeley, Allen & Hitch, 2010).

Focusing on working memory and memory consolidation, Kopasz *et al.* (2010) conducted a critical review of the research that has investigated sleep and memory and stated that sleep facilitates working memory and memory consolidation. These researchers concluded that when it comes to, for example, revision for exams which relies on both short and long-term memory function, sleep benefits individuals to remember and recall information (Kopasz *et al.,* 2010). This is in support of Baddeley and Hitch's Working Memory Model (1974), as this theory suggests that the central executive function is able to decide which information is worth attending to and which information is worth restoring in the long-term memory function, as well as which information is less important and therefore can be filtered out and not retained.

Kopasz *et al.'s* (2010) research supports the notion that sleep enhances memory consolidation and promotes working memory. This is in line with the description of the working memory model. In contrast, one criticism of Kopasz *et al.* (2010) study is that their review mainly focused on psychological experiments which recruited children and adolescent samples to investigate memory enhancement and the effects of sleep deprivation on memory. This is a criticism of this research because it is known that children and adolescents require more sleep to gain the beneficial effects of sleep on memory and cognition (Maia, Sousa & Azevedo, 2011). It has also been established that children and adolescents are in their prime period for memory enhancement (Kopasz *et al.,* 2010) and therefore, other biological factors may be influencing the research findings which limits the generalisations of that research.

One component of the modal model of memory is the phonological loop which is known to deal with verbal processing and is implicated in various tasks including verbal memory tasks (Baddeley & Hitch, 1974). The phonological loop is a rehearsal component and circulates the presented information in a loop. For example, when participants are presented with verbal words, their phonological loop will rehearse the words until they are needed to be relayed. Research has demonstrated that one limitation of this component is that participants tend to remember the first and last words significantly better than middle words (Yoo &

Kaushanskaya, 2016). These researchers found that by presenting participants with spoken words, they were able to list the first and last few words significantly more accurately than the words listed in the middle. This is known as the "serial-position" effect which could be due to the phonological loop rehearsing the words presented. This in turn means that the words presented at the beginning of the list of items are remembered easier, as they have been circulated in the phonological loop more frequently than words presented in the middle of the list, whilst the words presented at the end of the list are still present in short-term memory. In addition to the phonological loop, the visuo-spatial sketch pad is suggested to be superior with visual and spatial processing (Baddeley, 1986). This vital component of short-term memory is that it is able to transfer information from long-term memory to adapt the information stored, and therefore is superior at verbal memory tasks.

Moreover, focusing on the phonological loop which is responsible for verbal memory, Horvath, Myers, Foster and Plunkett (2015) found that sleeping for a short period of time during the day enhances vocabulary size in infancy. This can be used in support of the notion that sleeping improves verbal memory in participants. In addition, Barner, Ngo, Diekelmann, Weeb and Schlarb (2016) found that sleep spindles, which are tight repetitive bursts of brain activity, increased after learning verbal words, compared to the control condition where participants did not learn the verbal words prior to the verbal memory test. This further demonstrates that sleep promotes verbal short-term memory. This has practical applications as individuals who revise for an exam verbally is known to enhance sleep spindles the following night, and therefore retain significantly more information (Barner *et al.,* 2016).

In contrast to this, the function of the central executive function is not fully understood and research into the topic cannot directly be tested. Despite this, the central executive function is suggested to be vital in higher-order tasks such as puzzle solving (Ashworth, Hill, Karmiloff-Smith & Dimitriou, 2014). Research into sleep has found that puzzle solving is enhanced with sleep and decreased with sleep-deprivation (Lo, Dijk & Groeger, 2014). Furthermore, using the Tower of Hanoi task, Ashworth *et al.* (2014), supported the notion that sleep is a vital component of higher-order tasks which in turn suggests that sleep does enhance the facilitation of the central executive function. However, Ashworth *et al.* (2014) argued that one disadvantage to this psychological experiment was that participants may have been consolidating declarative aspects of the task to enhance their puzzle solving techniques. With this argument, it could suggest that sleep is actually necessary for the consolidation of declarative memory (Ashworth *et al.,* 2014). Ashworth, Hill, Karmiloff-Smith & Dimitriou (2017; 2015) then researched this area and found that sleep has a more beneficial impact on declarative memory, compared to procedural memory. This demonstrates that sleep is more beneficial on declarative memory such as remembering facts and figures for an exam, compared to procedural memory such as how to do something, (for example, the procedure of how to work a new system at work).

One advantage of the working memory model is that it is a more comprehensive model assuming that there are various stores associated with different memory processes. For example, the phonological loop is responsible for verbal perception and the visuo-spatial sketch pad is responsible for visual information. Moreover, this model is supported by experimental evidence which has measured real life tasks such as revising for exams and it supports the notion that sleep enhances the different components within the working memory model. One experimental design which has been devised to test the different components is the dual task studies. The dual task paradigm is able to distinguish the memory functions which are controlled by the components of the working memory model and it is able to investigate this in terms of the beneficial effects of sleep. Johnsen, Laberg, Eid and Hugdahl (2002) studied twelve sleep-deprived and thirteen non-deprived navy cadets on a sustained attention task. In this experiment, participants were required to focus their attention on the stimulus that was being presented to only the right ear or only the left ear. The findings from this study suggests that sleep deprivation disrupts the ability to sustain attention (Johnsen *et al.,* 2002). Furthermore, Johnsen *et al.* (2002) found that the right hemisphere's top-down processing fails to override the left hemisphere's bottom up processing in participants who are sleep deprived. This indicates that the left hemisphere has superior processing compared to the right hemisphere, which is enhanced by sleep.

In reference to the working memory model, research has shown how sleep can improve memory in the different components of working memory. Focusing specifically on the visuo-spatial sketch pad which is responsible for visual memory, Chuah and Chee (2008) found that posterior cortical activation was significantly reduced for visual memory in sleep deprived individuals, compared to non-sleep deprived participants. Moreover, Tripathi and Jha (2016) found that non-sleep deprived subjects performed sufficiently better on spatial tasks compared to sleep-deprived subjects. This can suggest that sleep enhances visual spatial recognition. This is further support for the notion that sleep promotes visual-spatial memory, and a lack of sleep enhances the amount of errors produced on visual-spatial tasks.

One major disadvantage of the working memory model is that the components cannot be directly examined. The central executive function is suggested to have a limited capacity as it is responsible for short term memory, although this cannot be investigated directly. Moreover, it is impossible to determine whether it does have a limited capacity as the findings of psychological experiments could be a result of deficits in the phonological loop and visuo-spatial sketch pad (Karatekin, 2004). Moreover, Karatekin (2004) also discussed that the findings could also be a result of deficits with attention which is a vital component of the central executive. However these suggestions again cannot be directly tested and therefore definitive conclusions cannot be made. In addition to this, the central executive is also responsible for controlling attention and transfers verbal and visual information to the appropriate component which again cannot be directly tested (Ketelsen & Welsh, 2010).

Overall, the research discussed to support the working memory model suggests that all three of the components including the central executive function, the phonological loop and the visuo-spatial sketch pad can be enhanced by sleep. Research on sleep and these components have found that sleep increases short term memory, for both visual and verbal memory (Horvath *et al.,* 2015; Lo *et al.,* 2014). However, there is more research focused on visual memory as opposed to verbal memory because reviewing the literature it seems that no progress has recently been made in the research of verbal memory and the beneficial effects of sleep.

A further disadvantage of the studies reviewed is that the majority of the psychological experiments have recruited child samples. Prior research suggests that verbal memory is a vital stage of learning in children and therefore investigations have been tested to conclude whether sleep enhances verbal memory at this vital stage in a child's life (Steenari *et al.,* 2003). Therefore, sleep may not be as beneficial on verbal memory amongst the adult population, and generalisations cannot be made. On the other hand, various experimental paradigms were used which suggests that the validation of the research discussed is enhanced because the effects of sleep on memory has been confirmed by various different research paradigms. However, due to the fact that the majority of research has been done on children in their early years, further research is needed to investigate verbal memory on an adult population to distinguish whether sleep is beneficial on verbal memory, or whether this conclusion is only applicable to the younger generation.

In contrast to Baddeley and Hitch's (1974) Working Memory Model, the dual process theory of sleep has been used to explain the function of certain stages of sleep, in particular stage four, slow-wave sleep (SWS) and Rapid-Eye Movement (REM) sleep. Similarly, to the restoration theory of sleep, this view of sleep suggests that different stages of sleep have different beneficial effects on individuals. For example, Slow Wave Sleep (SWS) is beneficial for memory enhancement and restoration, whereas REM sleep is beneficial on the restoration of the body which allows individuals to feel more awake and vigilant (Casey *et al.,* 2016). This theory also argues that REM sleep is vital for the formation of procedural and emotional memories whereas SWS is important for declarative memories. Groch, Zinke, Wilhelm and Born's (2015) research supports this theory. They researched the importance of SWS on emotional memory and conducted an experiment whereby participants were presented with either negative emotional pictures or pictures with neutral emotions before they slept. The pictures were also located in different places and/or in different frames. Groch *et al.* (2015) concluded that SWS is important to the retrieval of context-colour information whereas REM sleep was found to be important in the retrieval of emotional memories. In light of this, this study suggests that REM is vital to item memory with regards to emotions, which is in contrast to SWS which is vital for remembering the context of the emotion. Batterink, Creery and Paller (2016) found that interactions between the hippocampal and cortical networks facilitates memory during SWS.

The dual process hypothesis assumes that different stages of sleep enhance different types of memory. Further research has implemented a split-night design to distinguish which stages of sleep are beneficial for which types of memory functions (Casey *et al.,* 2016). The split-night design involves participants undergoing partial deprivation either early or late in the night. Studies which have implemented this split-night paradigm have suggested that if performance on memory tasks is significantly better after sleeping for the first half of the night then it is SWS that is the vital component of sleep that enhances memory consolidation (Casey *et al.,* 2016). In contrast, studies that have found that memory enhancement occurs after the second half of the night have concluded that REM sleep is the vital stage of sleep which benefits memory consolidation (Casey *et al.,* 2016).

Fogel, Smith and Cote (2007) found that completing a visual-motor task such as the Pursuit Rotor Learning test is consolidated after a period of SWS. This means that performance on visual-motor tasks is significantly increased after individuals have experienced SWS, compared to individuals who have not experienced SWS. Moreover, in line with previous findings, it has been found that SWS was beneficial for the enhancement of visual memory (Chuah & Chee, 2008). Barner, Ngo, Diekelmann, Weeb and Schlarb (2016) examined sleep spindles and verbal memory. These researchers concluded that sleep spindles increased during SWS to promote improvement in learning verbal words. These studies present evidence for the notion that SWS enhances both visual and verbal memory.

Due to the benefits of sleep on memory, recent research has focussed on the effects of sleep deprivation (Bebek, Gürses, Baykan & Gökyiğit, 2015; Gaultney & Collins-McNeil, 2009). Research has found that deprivation of sleep adversely effects individuals' cognitive function (Kopasz, Loessl, Hornyak, Riemann, Nissen, Piosczyk & Voderholzer, 2010). Sleep deprivation is where individuals have a reduced amount of sleep which results in feelings of sleepiness, fatigue and reduced memory and vigilance functions. Gaultney and Collins-McNeil (2009) found that attention within the workplace can be negatively affected by individuals gaining less than the average of seven to eight hours of sleep per night. The researchers' findings provide evidence for the effects of sleep and the functioning in real world scenarios such as the workplace.

In addition to this, Mednick *et al.* (2013) found that sleep spindles during REM sleep increases while the new information is being stored into long-term memory. However, sleeping less than six hours a night can have adverse effects on the sleep spindles by blocking them and stopping information from entering long-term memory. Further research into the effects of sleep deprivation in the real world, conducted by Sadeghniiat-Haghighi, Nia, Aminian and Esmaeeli (2013) demonstrated that a symptom of sleep deprivation is drowsiness which has been found to cause over 1,500 road traffic accident deaths. These accidents have been found to be caused by a deprivation of sleep because a lack of sleep is known to reduce individuals' attention span (Sadeghniiat-Haghighi *et al.,* 2013). This research on the negative impacts of sleep deprivation is evidence for how important sleep is.

Focusing on sleep deprivation and memory impairment, Aleisa, Alzoubi and Alkadi (2011) concluded that SWS sleep has been found to help the brain retain information throughout the day and transfer it to the long-term memory store. Insight into this has found that SWS sleep helps individuals when they are revising for an exam, or have learnt new information at work. In addition, Groch, Zinke, Wilhelm and Born (2015) found that REM sleep is vital for emotional memories. This research has concluded that sleep is vital for memory and restored information (Groch *et al.,* 2015). This is further evidence to support the notion that sleep is an important element of brain functioning including memory and cognition.

Focusing on sleep and memory, overall, the research literature reviewed demonstrates that there is a strong positive correlation between sleep and memory function. It is assumed that sleep deprivation is a contributor to the impairment in memory functions. Moreover, the majority of studies, which have investigated sleep deprivation and the impact on real-life situations, have primarily used night-shift workers as their sample pool. The common finding is that day-shift workers perform significantly better on memory tests compared to night-shift workers due to the biological circadian rhythm. However, further research is needed to investigate the effects of sleep on the enhancement of memory in an adult population which does not work night shifts, to conclude whether the findings which have been established can be generalised to the wider population. Moreover, with prior research findings suggesting that different stages of sleep are vital for different memory functions, it is crucial to investigate and distinguish between the different memory types studied to conclude whether certain types of memory is enhanced more by sleep, or whether all memory types are enhanced. Therefore, due to the review of prior research, this experiment is going to focus on the effects of sleep on both verbal memory and visual memory.

1.3 Vigilance

Vigilance is the term given to maintaining attention, and it is a behavioural tactic that allows people to access their surroundings so they are able to control what goes on in certain situations which, in turn, can reduce potential risks (Javurkova, Horak, Kreisinger, Klvana & Albrecht, 2011). Research into vigilance tasks were first conducted during World War II by Mackworth (Hays, 2006). Driving a car is one example of a task which requires high vigilance levels because, for individuals to reduce the potential risks of driving, they have to access their surroundings to be able to control which direction the car moves, as well as how fast the car stops (Atchley & Chan, 2011). This in turn reduces potential risks, as humans with high vigilance are able to drive safely as they can effectively predict what is likely to happen as their reaction times are faster, which in turn allows them to think more clearly and respond faster, than those who are less vigilant (Javurkova *et al.,* 2011). In an experimental design, participants with high vigilance levels are able to see the problem more clearly and solve the task or puzzle quicker in comparison to participants with low vigilance levels (Javurkova *et al.,* 2011).

Vigilance tasks usually require participants to stay vigilant by responding to certain stimulus. In more recent investigations, the procedure of responding to all stimuli and withholding when presented with one stimulus has been formulated to measure vigilance levels (Killgore, Rupp, Grugle, Reichardt, Lipizza & Balkin, 2008). For example, the Sustained Attention to Response Task (SART) is an example of a vigilance task and this test requires participants to withhold their response to a certain stimulus. This task requires participants to respond to numbers one to nine, excluding the number three, in which the participants are required to withhold their response and, the errors made when failing to withhold from the stimulus is used to assess participants' vigilance levels (Helton, 2009). By using experimental research to examine vigilance levels in humans, it has been found that individuals who sleep for seven to eight hours a night have higher vigilance levels compared to those who sleep less than seven to eight hours a night (Lim & Dinges, 2008). This has been analysed in terms of the amount of errors made on a single puzzle and the participants with fewer errors have higher vigilance levels (Van Schie *et al.,* 2012).

Research has found that high vigilance is an important requirement in the work-place as it reduces the risk of faults, errors and misinterpretations (Signal, Gander, Anderson & Brash, 2009). High levels of vigilance also means that individuals in the work place can also be more alert, make conscious decisions and complete jobs and tasks to a high satisfaction level (Signal *et al.,* 2009). Furthermore, there has been research conducted that has specifically focussed on the impact of sleep deprivation on vigilance. The typical findings from these earlier studies were that sleep deprived participants made significantly more errors on the vigilance task, in comparison to non-sleep deprived participants (Hays, 2006). It is well established that sleep deprivation negatively impacts on vigilance levels in the work-place. For example, Ruggiero, Redeker, Fiedler, Avi-Itzhak and Fischetti (2012;2011) found that sleep deprivation, sleepiness and irregular sleep patterns negatively impacts on levels of vigilance on nurses that work irregular and long shift patterns. Ruggiero et al., (2012; 2011) found that both night-shift workers and mixed shift-workers had decreased vigilance after a shift, despite whether they were working on the day shift or the night shift. These researchers concluded that this was because irregular shift patterns led to tiredness and sleep deprivation, in comparison to regular shift patterns. This therefore suggests that general tiredness and sleep deprivation has a negative impact on vigilance levels (Ruggiero *et al.,* 2012; 2011).

In addition, night-shift workers are required to sleep during the day which interferes with the circadian and homeostatic regulation of sleep (Akerstedt & Wright, 2009). The circadian and homeostatic changes of sleep, due to working night-shifts, have been found to impact negatively on the benefits of sleep (Akerstedt & Wright, 2009). These findings indicate that night-shift workers engaging in a period of sleep will not gain the same beneficial effects on vigilance levels, compared to individuals who are not required to sleep during the day. These findings suggest that further research is needed to investigate participants who work regular shift patterns due to the extensive research that has been conducted on night-shift population. These findings also cannot be generalised amongst the population of day-shift workers, nor individuals who are not involved in workplace setting, for example full time parents, unemployed individuals and students.

In addition, low vigilance levels in night-shift workers may be a consequence in the circadian rhythm of sleep, instead of sleep deprivation itself and therefore, examining individuals who sleep during the night will give a deeper insight into the overall effects of sleep on vigilance. The circadian rhythm means that sleep is optimal during the internal biological night, and therefore the benefits of sleep are gained through sleeping during night-light, whereas cognitive functioning and memory is optimal during the internal biological day (Akerstedt & Wright, 2009). This demonstrates that during day light, the human body and brain is the most active, and is at its highest peak due to the internal biological clock, whereas at night, the circadian rhythm enhances the quality of sleep, and therefore benefits of sleep are improved (Akerstedt & Wright, 2009). Moreover, night shift workers experience a higher homeostatic sleep drive which results in decreased memory and cognition due to the interaction between the circadian and homeostatic regulation of sleep (Goel, Basner, Rao & Dinges, 2013). This in turn implies that individuals who sleep during the day will not gain the full benefits of sleep such as memory and alertness, and therefore cannot be compared or generalised to individuals who sleep in night light when the full benefits of sleep is gained.

Along with night-shift workers being extensively studied, Galioto *et al.* (2015) has investigated sleep deprived students and it was found that poor sleep quality is positively related to omission errors on a vigilance task which requires participants to sustain their attention to certain stimulus within a task. With use of a student sample, this demonstrates that findings on sleep and vigilance can be generalised to the wider population, given the variety of samples the experiments on sleep and vigilance have recruited. Moreover, another confounding variable that is considered to be important to control for when investigating sleep and the impact on vigilance levels are sleep disorders. Sleep disorders, such as sleep apnoea and insomnia, result in poor sleep and sleep deprivation. In line with findings on sleep and vigilance, individuals with sleep disorders have a decreased level of vigilance (Altena, Van der Werf, Strijers & van Someren., 2008; Karimi *et al.,* 2013). There is extensive research on the effects of sleep disorders, sleep deprivation and night shift workers on vigilance levels but there is limited research on individuals who experience healthy sleeping patterns and their vigilance levels.

Whilst studying vigilance levels, researchers have also controlled for experimental settings which have been found to effect the results. Warm, Parasuraman and Matthews (2008) examined the effects of the sleep deprivation and vigilance and found that sleep deprived individuals had high vigilance levels in noisy settings. Warm *et al*. (2008) noted that noisy settings keep sleep deprived individuals alert, and therefore not controlling the setting in which the vigilance task is being completed may impact on the results. From these results, it can be suggested that the experimental room in which participant's complete the vigilance task needs to be silent to ensure that the experimental room is not aiding sleep-deprived individuals to complete the vigilance task. This is another clear explanation as to why controlling extraneous variables is very important to determine whether it is solely the independent variable that causes the dependent variable.

In addition, the most common finding on reviewing the literature which has examined the impact of sleep on vigilance is that participants' performance and reaction time declines overtime (Hays, 2006). It has been found that participants’ vigilance significantly decreased after each half an hour of engaging with the vigilance task. For example, in a task which requires being vigilant whilst detecting certain stimulus, participants tend to have faster reaction times and a more accurate response at the beginning of the task, compared to responses and reaction times towards the end of the task. This decrease of detection performance is known as the "vigilance decrement" (Warm, Parasuraman & Matthews, 2008). One theory which began to explain the effects of vigilance decrement on vigilance investigations is the mindlessness theory of vigilance (Helton & Warm, 2008). This theory was devised by Robertson, Manly, Andrade, Baddeley and Yiend (1997) and the theory is used to explain why individuals may experience low vigilance levels in everyday situations in which they engage with every day. For example, individuals who are learning how to drive will have more awareness and higher vigilance levels compared to someone who has driven for a prolonged period of time. This is due to the supervisory attentional system which loses focus and awareness of the stimulus overtime. Instead, the response of the task becomes 'thoughtless' and automatic (Robertson *et al.,* 1997). In terms of engaging in a vigilance task, participants are required to direct their attention to a signal stimulus.

Using a sustained attention task as an example, vigilance tasks require the participants to respond to all but one stimulus whilst sustaining attention to the one specific stimulus. Due to the repeating action of responding to signal stimulus, the mindlessness theory of vigilance suggests that the automatic and repeated nature of the task makes it effortfull for the participant to withhold their response once presented with the stimulus that they are required to not respond to (Robertson *et al.,* 1997). This creates the notion that the participant disengages from the task and this theory assumes that the participant engaging in the task becomes distracted by unrelated thoughts (Epling, Russell & Helton, 2016).

However, this theory has been challenged by an opposing theory, the resource theory of vigilance which was devised by Helton and Russell (2011) which assumes that failure to respond to signal stimulus is a result of a decline in available attentional resources. Extensive research has concluded that attentional resources are limited for information processing and it is assumed that this is the cause for lower vigilance results whilst the participant is completing the task (Helton & Russell, 2011). Helton and Russell (2011) suggested that due to the extensive task demands within vigilance tests, which requires the participant to repeatedly respond to stimuli without rest, this continuous attentional concentration does not allow for the resources to replenish, and instead depletes. This theory is used to explain performance decrement because the resource of energy is at its upmost peak at the beginning of the vigilance task and then decreases, which results in an increase in failure in response (Helton & Russell, 2011).

It has been found that despite vigilance decrement, which is a result of task unrelated thoughts, it is still evident that sleep-deprived individuals have significantly lower vigilance levels (Piantoni *et al.,* 2013). These findings suggests that, even though the task unrelated thoughts impact on the results, it is significantly harder for sleep-deprived individuals to maintain concentration throughout the vigilance tasks, despite task unrelated thoughts being evident in both conditions.

Therefore, the findings conclude that sleep-deprived individuals have lower vigilance scores than non sleep-deprived participants. Taking these findings into account allows researchers to control for decrement of vigilance, however decrement of vigilance is caused by the type of test applied and therefore if all participants in the experiment complete the same vigilance test and a significant difference is found between the two conditions then it can be reasonably inferred that the independent variable is causally related to variations in the dependent variable, because using the same vigilance test for all participants is a control of decrement of vigilance.

To summarise, researchers have considered useful measures of vigilance which are reliable and valid measures of vigilance. It has been found that the decrease of vigilance across a prolonged time scale typically arises within the first fifteen minutes for lower cognitive demanding tasks and five minutes for high cognitively demanding tests (Tiwari, Singh & Singh, 2009). This suggests that using the SART test, which is a cognitively engaging task as opposed to a cognitively demanding task, could be considered a useful test to measure vigilance levels. This is because the cognitively engaging task lasts between four to five minutes and does not require participants to maintain concentration for a prolonged length of time which have been concluded to impact on decrement of vigilance. Moreover, investigations into the effects of sleep on vigilance has been considered important in real world settings due to the amount of workplace errors as a result of sleep deprivation which has caused decrease vigilance, such as road traffic accidents.

1.4 Sleep time

Along with research on sleep and the positive effects on verbal and visual memory performance and vigilance levels, research has also investigated the time in which participants go to sleep. When an individual is sleep-deprived they will begin to feel mentally, physically and emotionally fatigue and this is known as "sleep deprivation" (Dijk, 2009). Research has found that SWS is experienced at a prolonged period of time at the beginning of the night, which then decreases whilst REM increases (Muzur, 2005). Dijk (2009) stated that the amount of time spent in SWS is related to the amount of time spent awake. This is known as "sleep pressure" as the pressure to sleep increases, and so does the amount of time spent in SWS. Dijk (2009) also stated that sleep deprived individuals will spend an increased amount of time in SWS due to being awake for a prolonged time period and the increased amount of SWS is a result of the accumulated sleep debt. Thus, when individuals go to sleep late, they miss time in SWS, and therefore the next time the individual goes to sleep, they will spend more time in SWS as a result of sleep deprivation, and in turn sleep debt will diminish (Dijk, 2009).

In addition to this, Dijk (2009) discussed that sleep time is crucial to one's development as the shift from SWS to REM sleep happens at certain times during the night, irrespective of the time in which you go to sleep. SWS is known to be the restorative part of sleep, however individuals that go to sleep after midnight tend to experience a reduction in SWS and an increase in REM sleep (Dijk, 2009). Therefore, to gain the full benefits of sleep, individuals need to go to sleep before midnight as individuals who go to sleep after midnight may not restore or gain any enhancements in memory due to a reduction in SWS. Dijk (2009) further discussed that sleep time should be between 8:00pm and 12:00 midnight to allow the body and brain to gain all the benefits from both SWS and REM sleep. Moreover, going to sleep between this time can also allow individuals to function at optimal levels. This research suggests that due to the different timings of SWS and REM sleep regulated by the Circadian Rhythm, the time in which individuals go to sleep is crucial for body functioning and memory enhancement.

Kelly, Kelly and Sacker (2013) found that children who had a set sleep time had greater memory and cognitive performance, compared to children who had an irregular sleep time pattern which again provides further evidence that sleep time is crucial for memory enhancement. Regular sleep time is seen to be very important in children’s brain development. Moreover, Diekelmann, Biggel, Rasch and Born (2012) found that more time spent in SWS, compared to REM sleep was positively correlated with memory enhancements. These researchers concluded that memory consolidation, which is reliant on the hippocampus, is dependent on the sleep time, and particularly with the duration of SWS.

Focusing on the impact of sleep time on memory, Gold and Trauner (2014) discussed that the left and right hippocampus is primarily associated with memory, in particular long term memory. These researchers further discussed that the hippocampus preferentially supports both verbal and nonverbal memory. Gold and Trauner (2014) found that children who experienced a stroke had a volume reduction in the hippocampus. This investigation found that a reduction in hippocampus volume resulted in impairments in certain aspects of declarative memory, which suggests that reduced hippocampal volume is associated with a weaker memory. Therefore, when participants have a volume reduction in the hippocampus, it can be suggested that this impacts on memory. However, Gold and Trauner (2014) studied the effects of hippocampal reduction on memory impairment in children with focal brain injury, not healthy participants and therefore these findings cannot be generalised as the reduced hippocampal volume was caused by brain injury.

In contrast, Kuperczko *et al.* (2015) investigated hippocampal volume and the effects on memory in healthy participants, in relation to sleep time. Kuperczko *et al.* (2015) found that participants who go to sleep late had significantly smaller hippocampal volumes, compared to participants who went to sleep early. Kuperczko *et al.* (2015) categorised sleep time before 11:00pm as early, medium sleep time as between 11:00pm and 12:00 midnight and late sleep time after 12:00 midnight. Wake up times were also controlled to investigate whether the time spent asleep also effected hippocampal volumes. It was found that wake up times did not significantly change hippocampal volumes.

In addition to this, Kuperzcko *et al.* (2015) reported that their research was the first study which assessed the relationship between the time in which participants go to sleep and the alterations in brain structure in healthy participants. In conclusion, sleep time is significantly related to hippocampal volume, with sleep time, age and sex being controlled. Due to this research investigating healthy participants and the effects of sleep time on memory, it is argued that their findings can be generalised to the general population. However, it is suggested that more research into the effects of going to sleep after midnight on memory needs to be researched further before any definitive conclusions can be drawn.

To summarise, the research reviewed on the effects of sleep time on memory has mainly focussed on participant samples who work night-shifts, as they are typically more sleep deprived than individuals who work regular day-shifts. It has been found that because night-shift workers are required to sleep during the day, their sleep pattern significantly changes which impacts on the duration spent in each stage of sleep (Carmona, 2011). In addition, there has been research conducted on different populations which suggests that sleep time impacts on memory functioning (Kang & Chen, 2009). Despite this, more research is needed to investigate the effects of sleep time on memory in participants who are adults and do not work night-shifts.

1.5 Power napping

Although napping is considered to be related to babies and young children, there is an increase in young adults and adults who engage in a nap on a daily basis (Mednick, 2013). The recommended nap time is around twenty minutes and is referred to as a power nap (Milner & Cote, 2009). The practical application of sleep research is vital in terms of opening times for schools and workplace settings, as well as institutions such as businesses and schools implementing nap times (Mednick, 2013).

1.5.1 Power napping and vigilance

There has been research which has investigated the effects of power napping on vigilance and it has been found that engaging in a short power nap does increase vigilance (Perrier *et al.,* 2016). These researchers then stated that power naps are beneficial for those who are in highly cognitive demanding jobs such as driving. It is recommended in the UK that within a four and a half hour period of driving, drivers should have a break of at least 45 minutes and research into power napping demonstrates that short power nap would boost their vigilance (gov.uk, N.D). Furthermore, China has implemented a half an hour power nap during working hours and since this has been implemented, the Chinese government has seen a 30% increase in work flow productivity (Shears, 2014). This research demonstrates that the impact of power napping on vigilance has practical applications on real-world situations.

Focusing on the workplace, individuals are required to have high vigilance levels in the workplace to ensure that they are able to do the job to high satisfaction levels. Signal *et al.* (2009) studied the effects of vigilance in the workplace, and found that a power nap during a shift at work significantly improved alertness, performance at work and vigilance. This demonstrates that, even though a power nap may be short and of relatively poor sleep quality at work, it is still able to improve the overall vigilance levels of the individual at work. This study demonstrates that vigilance levels significantly increase following a power nap.

However, most of the research conducted on this have used samples of night shift workers, Smith, Kilby, Jorgensen and Douglas (2007) and Ruggeriero and Redeker (2014) found that a power nap is effective in reducing sleepiness and increasing vigilance in night-shift workers. This sample pool is very popular in the area of sleep and power napping research because these participants tend to be more sleep-deprived than those who work throughout the day. However, there is limited research focusing on the impact of power napping on participants who work during the day. Hence, research on healthy participants who sleep within the recommended hours of sleep, which is between seven to eight hours a night, should be examined to investigate whether their vigilance levels are enhanced. However, focusing on day-shift workers, research has further supported the assumption that individuals can gain further benefits on vigilance when engaging in a power nap, compared to individuals that do not take a power nap (Ficca, Axelsson, Mollicone, Muto & Vitiello, 2010; Smith, Kiby, Jorgensen & Douglas, 2007; Watling, Smith & Horswill, 2014).

1.5.2 **Power napping and memory**

In addition to the effects of power napping on vigilance, research has also focused on the effects of power napping on memory. A power nap is known to restore wakefulness and promote and aid learning and performance on tasks. Milner and Cote (2009) found that power napping for around twenty minutes a day has been found to significantly improve performance on tasks such as addition, reaction time, symbol recognition and logical reasoning. In addition, recent studies have found that prolonged naps of over 30 minutes result in feelings of sleep inertia and reduced performance on memory tasks, because participants who engage in prolonged naps are more likely to wake up during deep sleep (Asaoka, Masaki, Ogawa, Murphy, Fukuda & Yamazaki, 2010). This demonstrates that a twenty minute power nap is considered the most beneficial for improving memory (Milner & Cote, 2009).

Focusing on the stages and the impact of sleep stages on memory, Milner and Cote (2009) found that the sleep spindles in stage two are positively correlated to performance improvements in declarative memory tasks. This research demonstrates that power napping significantly increases functions that are related to stage two. With the literature reviewed on the effects of sleep and memory, it has been suggested that the early stages of sleep are related to declarative memory, as well as verbal and visual memory.

Despite research initially focusing on the importance of stage two sleep whilst engaging in a power nap on memory, it has been found that individuals who have had the recommended amount of sleep do enter stage two sleep. However individuals who experience feelings of sleep deprivation and/or go to sleep after midnight will enter SWS (Dijk, 2009). As already discussed, it has been extensively found that SWS is directly linked to memory and vigilance enhancements and therefore, individuals who enter SWS will have significantly higher memory functions and vigilance levels, than those who have entered stage two. Dijk

(2009) stated that sleep deprived individuals will spend an increased amount of time in SWS due to being awake for a prolonged time period and therefore, the increased amount of SWS is a result of the accumulated sleep debt. Moreover, when individuals go to sleep late, they miss time in SWS so the next time the individual goes to sleep, they will spend more time in SWS as a result of sleep deprivation which results in sleep debt diminishing (Dijk, 2009).

Due to these findings, it can be assumed that those who go to sleep for seven to eight hours a night will spend a considerable amount of time in SWS each night. However, those who are sleep-deprived will have initially spent less time in SWS until they next engage in sleep. With literature relating SWS to increased memory and vigilance performance, it can be suggested that individuals who sleep for the recommended amount of time each night will have increased memory and vigilance levels in comparison to those who are sleep deprived (Dijk, 2009). However, if the sleep deprived individuals engage in a power nap, they will have increased time spent in SWS compared to those who had an average amount of time asleep (Dijk, 2009), and therefore it can be assumed that participants who go sleep after midnight will spend less time in SWS but make up for the loss during the power nap. This suggests that participants who go to sleep after midnight and then engage in a power nap will have higher memory and vigilance levels, compared to those individuals who go to sleep before midnight. Moreover, Dijk (2009) reviewed that participants who are sleep deprived experience SWS significantly more intensely. This again suggests that individuals who go to sleep considerably later will have had reduced time in SWS, so that when they engage in a power nap they will enter SWS at a more intense rate than those who went to sleep considerably early, and therefore should have increased memory and vigilance levels after the power nap.

In support of these findings Cox, Talamini and Hofman (2012) found that a night's sleep that promotes certain benefits on memory and cognition involves participants entering SWS where there is an increased amplitude of delta waves. Lo, Dijk and Groeger (2014) also found that taking power naps during the day improves declarative verbal memory, perceptual learning and procedural motor skills. In addition, Lovato, Lack and Wright (2014) supported the notion that power napping does have significant beneficial effects on memory because they found that participants who engaged in power naps during the day had significantly increased verbal memory scores, in comparison to participants who did not power nap during the day.

In summary, despite research demonstrating that the time in which individuals go to sleep is crucial for memory and vigilance, little research has examined the effects of power napping in relation to sleep time and the effects on both memory and vigilance. Dijk (2009) found that if participants go to sleep late, having a power nap is a useful way of decreasing the effects of sleep debt. Sleep debt has been found to be relieved by having a power nap, or going to sleep earlier than the night before to catch up on the lost stages from the prior night. This has been found to have benefits on memory and vigilance levels because one of the causes of sleep debt is to immediately fall into the stages lost in the night before (Dijk, 2009). Therefore, due to these assumptions, individuals who go to sleep after midnight should benefit more from a power nap because they are more likely to enter SWS, which has been extensively concluded to improve memory and vigilance, compared to participants who go to sleep before midnight.

2 Rationale

Research has found that sleep is crucial for the enhancement of memory and vigilance (Galioto *et al.*, 2015; Gaultney and Collins-McNeil, 2009; Sadeghniiat-Haghighi *et al.,* 2013). It has been established that different stages of sleep are beneficial for different types of memory (Talamini & Hofman, 2012). Sleep research has found that SWS is particularly crucial for verbal and visual memory (Casey *et al.,* 2016), and sleep enhances vigilance levels, despite no investigations being made into the stages of sleep and the impact it has on vigilance levels.

A power nap is known to restore wakefulness and promote and aid learning and performance on tasks and Milner and Cote (2009) has found that power napping for around twenty minutes a day has been found to significantly improve performance on tasks such as addition, reaction time, symbol recognition and logical reasoning. Focusing on the time length of a power nap, recent studies have found that prolonged naps of over 30 minutes are related to sleep inertia and reduced performance on memory tasks due to participants waking up during deep sleep (Asaoka, Masaki, Ogawa, Murphy, Fukuda & Yamazaki, 2010). Due to these findings, this research will be controlling the length of time that participants engage in a power nap for, which will be twenty minutes.

Focusing on the best sample pool to use, most of research which has investigated the effects of sleep on memory and vigilance has been conducted on night-shift workers, individuals with sleep disorders and / or people who are sleep deprived (Campbell, 2014; Ruggiero *et al.,* 2012; 2011). This literature review establishes that further research which investigates the effects of power napping on verbal and visual memory performance and vigilance levels in healthy participants who do not work night-shifts, are not diagnosed with sleep disorders and do not take any medication which impacts directly on engaging in natural sleep is crucial to determine whether power napping is effective for the enhancement of verbal and visual memory performance and vigilance levels. Due to this, this experiment will be using a sample pool of healthy participants and will be excluding any participants who work night-shifts or are diagnosed with sleep disorders and/or take any medication which may impact on their natural sleeping patterns. This sample pool will provide further evidence on the effects of power napping and sleep time on memory and vigilance levels which can be generalised further than previous studies, because only a minority of past research have not investigated night-shift workers or participants with sleep disorders.

Sleep time has been the main focus of recent studies as investigations into sleep time has suggested that the time in which participants go to sleep is also a crucial factor to the investigation on whether sleep enhances memory and vigilance (Kuperczko *et al.,* 2014). This literature review has analysed research which has found that participants who go to sleep after midnight experience feelings of sleep deprivation (Dijk, 2009). With Dijk (2009) demonstrating that when individuals are experiencing sleep-deprivation, their time spent in SWS is increased, which is known to increase memory and vigilance levels. Moreover, Dijk (2009) stated that participants who go to sleep late experience a more intense SWS period during a power nap compared to the SWS experienced by those who went to sleep early. Therefore, even though participants who went to sleep early will have completed the vital stages for the enhancement of memory and vigilance, during the power nap participants who went to sleep late will experience at a more intense rate SWS. Hence, the power nap should enhance memory and vigilance significantly more than those who experienced SWS less intensely (participants who went to sleep early). Due to this, it can be suggested that participants who go to sleep after midnight will benefit significantly more from a power nap, due to them being more likely to enter SWS, in comparison to those who go to sleep before midnight. Due to the effects of sleep time on the beneficial effects of power napping not being researched previously, this investigation is going to distinguish whether participants who go to sleep after midnight do benefit significantly and perform significantly better on memory and vigilance tasks, compared to participants who went to sleep early after engaging in a twenty minute power nap.

In summary, despite the extensive research on sleep and the beneficial effects on both memory and vigilance, there is limited research that has investigated the beneficial effects of power napping on both memory and vigilance. However, from the assumptions of sleep research, which has demonstrated that memory and vigilance are both increased by sleep, this research aims to investigate whether a power nap has the same effects that sleep has on memory and vigilance levels. Moreover, research on power napping so far have benefitted organisations to promote a more efficient team. For example, China has implemented a half an hour power nap during working hours and since this has been implemented, the Chinese government has seen a 30% increase in work flow productivity (Shears, 2014). In addition, even though sleep time cannot be controlled by organisations, if this research does provide evidence that going to sleep after midnight and engaging in a power nap is more beneficial on memory and vigilance levels, compared to going to sleep before midnight, then it may benefit organisations to have a later start time for work to allow employees to go to sleep later. Therefore, with research on power napping and sleep time demonstrating practical applications within the workplace as more organisations are now implementing a daily power nap to promote performance at work, this research aims to investigate the interaction between power napping and sleep time.

3 Hypotheses

This research analyses the effects of a power nap and sleep time on verbal and visual memory performance and vigilance levels in healthy participants.

- **Hypothesis 1**: Participants who have engaged in a twenty minute power nap will have significantly increased scores on the verbal memory test, compared to participants who have not engaged in a twenty minute power nap.

- **Hypothesis 2:** Participants who go to sleep late (after midnight) will have significantly increased verbal memory scores in comparison to participants who go to sleep early (before midnight), in the power napping condition.

- **Hypothesis 3:** Participants who have engaged in a twenty minute power nap will have significantly increased scores on the visual memory test, compared to participants who have not engaged in a twenty minute power nap.

- **Hypothesis 4:** Participants who go to sleep late (after midnight) will have significantly increased visual memory scores in comparison to participants who go to sleep early (before midnight), in the power napping condition.

- Hypothesis 5: Participants who have engaged in a twenty minutes power nap will have significantly fewer errors on the vigilance task, compared to participants who have not engaged in a twenty minute power nap.

- Hypothesis 6: Participants who go to sleep late (after midnight) will have significantly fewer errors on the vigilance task in comparison to participants who go to sleep early (before midnight), in the power napping condition.

4 Method

4.1 Participants and Recruitment

A sample of 80 participants were recruited through opportunity sampling. Opportunity sampling is a sampling technique whereby any participants who are available to take part in this experiment and meet the criteria can take part in the experiment (Howitt & Cramer, 2016; 2017). This sampling method was applied due to the time constraints of this research. There were 32 males and 38 female participants recruited, their ages ranged from 18 to 45 and they were of mixed ethnicity. Participants were recruited through the University of Huddersfield's SONA participation site, to allow undergraduate students to gain course credits for taking part in the experiment. The majority of students recruited were undergraduate Human and Health Professional students at the University of Huddersfield. The social media platform Facebook was also used to recruit participants, allowing friends and family members of the researcher to also participate.

Any participant under the age of 18 or over the age of 45 years old were excluded from the experiment. The reason for this was that there were ethical complications with including participants under 18 in terms of receiving parental consent and research has found that individuals over 45 start to have decreased memory performance (Boseley, 2012). Furthermore, any participants who worked night shifts were excluded from the experiment, as well as those that have been diagnosed with sleep disorders, such as insomnia, or have been diagnosed with mental disorders which required them to take medication, such as antidepressants, that could affect their normal sleeping pattern and task performance. The participation inclusion and exclusion criteria were stated on the briefing statement on SONA, as well as on the participant information sheet (Appendix A).

An email reminder was sent 24 hours prior to the time of taking part in the experiment to ensure that participants were fully prepared and remembered their timeslot (Appendix B). Prior to taking part in this experiment all participants were required to go to sleep at their normal times. Questions in the beginning questionnaire distinguished the time in which participants went to sleep. This was vital to determine which condition the participants would be in, which included 'before midnight' and 'after midnight'. 'Before midnight' involved participants who went to sleep before midnight prior to the experiment and 'after midnight' which involved participants who went to sleep after midnight prior to the experiment. The time in which participants woke up was controlled as each participant was required to wake up between 6:00am and 9:00am the morning of the experiment to ensure that the length of sleep did not influence the data collected.

4.2 Materials

This experiment included one verbal memory test, one visual memory test and a vigilance task.

These were:

Word List Recall - Verbal memory test (Appendix C).
Pelmanism Task - Visual memory test (Appendix D).
Sustained Attention to Response Task (SART) - Vigilance task (Appendix E).

Verbal Memory Test - Word List Recall (Appendix C)

The word list recall test was used to measure verbal memory (Green & Helton, 2011). This involves participants listening to an audio recording which verbally listed 20 words with 15 seconds between each word. Verbal instructions were given at the start of the task to ensure that each participant understood the requirements of the completion of the task and they were informed that they were able to ask any questions before the task started (Green & Helton, 2011). The words used in the audio all had two syllables and involved between five to seven letters. The word lists were recorded using a studio condenser micro-phone and the programme used to record the list of words was Ableton Live (Green & Helton, 2011). After the audio clip finished, each participant were given three minutes to write as many words as they could remember on a blank sheet of paper. The number of correct words recalled were recorded for analysis purposes. The words were randomly chosen from the Paivio (1968) Word Pool and the words were presented in a random order and with the same gap in between each word to ensure that extraneous variables were controlled. Moreover, each word was generated to ensure that each word was as memorable and they all had two syllables and between five to seven letters. This was to control for the extraneous variable that shorter words are recalled easier, and words which are more memorable than others are also recalled easier (Katkov, Romani & Tsodyks, 2014).

This test is extensively used to test short-term verbal memory and has been found to be a reliable measure due to it being easily replicated. Using an audio clip to present a word list to participants is suggested to be a useful way to minimise any differences within the test which could have occurred if the researcher themselves said the words out loud because the pitch, tone and speed would have not been controlled. Due to the audio clip controlling for the type of words, the length of the words and the timing of the words being relayed to the participant it demonstrates that this test is a valid measure of verbal memory.

Visual memory test – Pelmanism Task (Appendix D)

The visual memory test was called 'the pelmanism game' (Doorway Online, n.d.). This test is effectively a game of pairs where each participant was given verbal instructions on how the task needed to be completed. Each participant was told that they had to find all pairs on the computer screen as fast as they could, and the time that they took to complete the task was recorded. Each participant were presented with 18 faced down cards on a computer. On the other side of each card was an image including a cat, a book, a hat, a fan and various other recognisable images. Each image were presented on two different cards and were sequenced randomly. The reveal time of each image was one second. The aim of the task was to find all nine pairs of images, which included nine different images altogether, as fast as they could. Each participant were timed and the amount of pairs found in the first 30 seconds were recorded, and the total time taken to find all nine pairs were numerically recorded in seconds.

This is a good measure of visual memory as it can be used for all ages and because the majority of participants are familiar with this test, it suggests that experience levels would not impact on the data. Wilsom, Darling and Sykes (2011) used this method of testing visual memory and found that using this familiar game tested a hypothesis in a novel way. Moreover, due to using a pelmanism game online it ensured that variables such as the positioning of each card, the time in which the card appeared for and the space between each card were controlled. Each image presented on the card was a recognisable image and they were sequenced randomly.

Vigilance Performance - The Sustained Attention to Response Task (SART) (Appendix E)

The Sustained Attention to Response Task (SART) was used to test vigilance levels (Robertson, Manly, Andrade, Baddeley & Yiend, 1997). This test was computer generated which required participants to respond to numbers one to nine, excluding number three. The response was measured by pressing the space bar on the computer keyboard. The task which was presented on the laptop automatically produced written instructions on how to complete the task, and participants were required to read the instructions and press the space bar once they were ready to start the trial period, and after they asked any further questions that they may have had. The trial period then began. Once completed, participants would be presented with a different set of written instructions which reminded the participants of what to do to complete the task. Participants again then pressed the space bar to start the real test. Numbers one, two, four, five, six, seven, eight and nine are classed as 'Go Stimulus', whereas number three is classed as the No-Go stimulus. The SART duration was 4.3 minutes and it consisted of 225 trials (Robertson et al., 1997). On each trial, a single digit between one and nine were presented on the computer screen for 250ms which was followed by a ring with a diagonal cross in the middle which gave the participants a 900ms time frame to respond to the stimuli (Robertson et al., 1997). The number stimuli were all presented in Arial font but varied randomly in font sizes, including 48, 72, 94, 100 and 120. The height of the number stimuli ranged between 12 and 29 m (Robertson et al., 1997). The results were generated by the computer which gave relevant information to aid analysis of the results, including the number of "commission" errors which means that participants failed to withhold the response to number three, "omission" errors which are errors for responding to numbers one, two, four, five, six, seven, eight and nine as well as the reaction time for both Go stimulus and No-Go stimulus. This test was chosen to measure vigilance in this experiment because it has been extensively used to measure vigilance levels across different domains of research and Dillard et al. (2014) measured the validity of SART and found that this test is a valid measure vigilance.

This experiment involved hiring a room on the University of Huddersfield’s campus which had a bed situated in the room, as well as a computer desk with a chair. All three tasks were on a portable university laptop which was borrowed from the University's technicians for the use of this experiment. A university laptop was used because of license reasons and E-Prime was required for the use of the SART test. Each information sheet (Appendix F and G), consent form (Appendix H), participant questionnaire (Appendix I) and debriefing form (Appendix J) were printed out to allow participants to fill them out. There were 80 copies of each one to ensure that each participant had one copy of each form. Moreover, for the participants who did not engage in a power nap, they had a choice between the following magazines which they were required to read for twenty minutes. The magazines used in this experiment was: Cosmopolitan, Woman’s Own, Match and Men’s Health. Also, a stop-watch to time the participants was always required.

4.3 Design

This experiment involved an independent groups design which involved 80 participants. The 80 participants were divided into two conditions which included 40 participants in the power napping condition and 40 participants in the non-power napping condition. The power napping condition was then further divided into two sub-conditions which analysed the effects of sleep time. These conditions involved an early sleep time condition (before midnight) and a late sleep time condition (after midnight), (Figure 2).

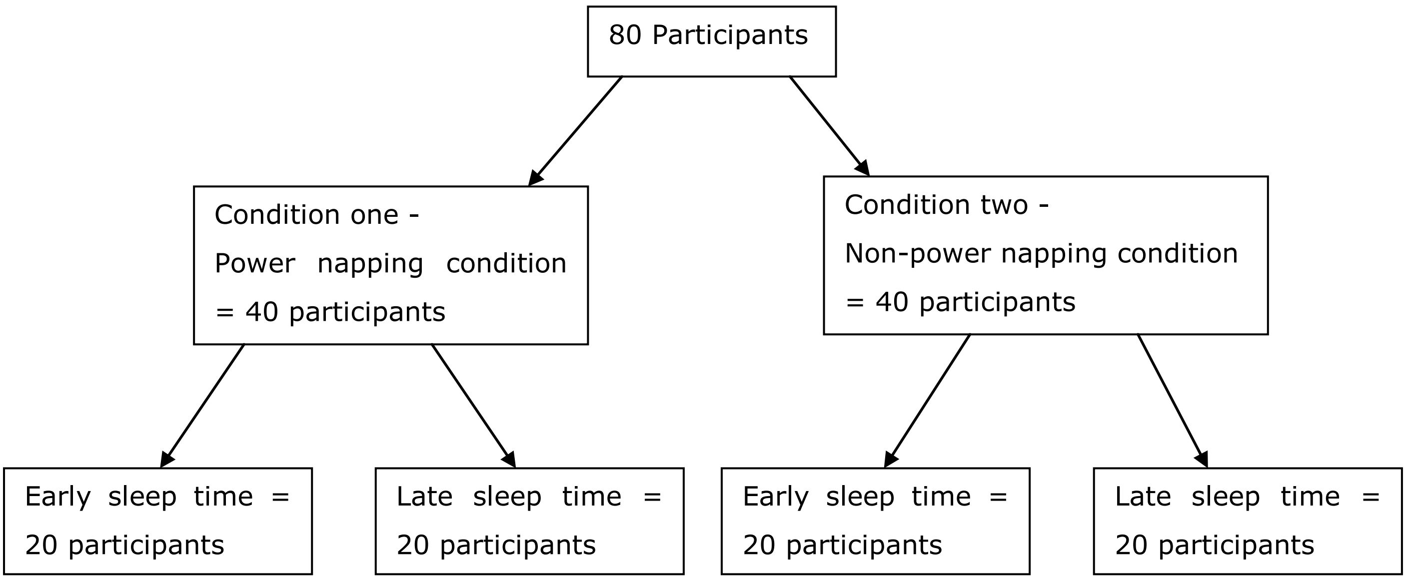

Figure 2: Flow chart of the conditions.

Condition one and two were compared to investigate hypotheses one, three and five and the sub-conditions of condition one were analysed to investigate hypotheses two, four and six. For hypothesis one the independent variable (IV) was power napping and the dependent variable (DV) was verbal memory. The IVs for hypothesis two were power napping and sleep time, and the DV was also verbal memory. The IV for hypothesis three was power napping and the DV was visual memory. The IV for hypothesis four was power napping and sleep time and the DV was visual memory. In addition, the IV for hypothesis five was power napping and vigilance performance and finally the IVs for hypothesis six were power napping and sleep time and the DV was vigilance performance (Please refer to page 35 for the hypotheses).

4.4 Procedure

On entry to the room each participant was seated and they were given a specific information sheet (Appendices F & G) based on which condition they were randomly allocated to, which they were asked to read at the beginning of the experiment. Each participant was randomly allocated to either a power napping condition or a non-power napping condition. Every participant was then given an informed consent sheet which they were asked to read and sign if they agreed to consent to taking part in the experiment (Appendix H). After this, participants were then given a participant questionnaire which determined what time they went to sleep, how long they slept for on average and if they usually engaged in power naps or not (Appendix I). Each participant who met the necessary criteria were allocated to the power napping condition or the non-power napping condition, and participants who stated that they went to sleep before midnight were allocated to the 'early sleep time' condition, and the participants that stated that they went to sleep after midnight were allocated to the 'late sleep time' condition. After each participant answered the participant questionnaire they were able to ask any questions that they had, and they were also given a chance to ask any questions at the beginning of each task.

Participants in the power napping condition then engaged in a twenty minute power nap, lying on a bed provided in the experiment room, whereas participants in the non-power napping condition engaged in a relaxation period which involved twenty minutes relaxing whilst reading a selection of provided magazines. After this twenty minute period, all 80 participants were then required to complete all three tasks including one verbal memory task (Appendix C), one visual memory task (Appendix D) and one vigilance task (Appendix E). All participants were given verbal instructions prior to completing each task.

Finally, after the tests were completed all participants read through a debrief statement which explained the reasons for the use of each test, the purpose of the experiment and the hypotheses tested (Appendix J). At the end of the debrief form, participants were able to state whether they wanted to receive the overall results of the experiment, and if they did want to receive the results they stated their email address on the debrief form which was securely scanned and saved on the computer. This was used for collecting the data and was saved in a password protected folder. Moreover, the numerical scores for all memory and vigilance tests were recorded on an Excel spreadsheet to ensure that all the data was secured in the same area and the scores received from each participant was kept together. Furthermore, the scores on the SART test were automatically generated by the test, and the data collected was kept in individual folders depending on what condition the participant was in. The scores from each test were then entered individually into SPSS to investigate the research hypotheses, which distinguishes whether power napping is significantly beneficial on both verbal and visual memory performance and vigilance levels, and whether power napping is significantly more beneficial for those who have a late sleep time on a verbal memory test, a visual memory test and a vigilance task.

5 Ethical Consideration

Before the research took place, an ethics form was submitted (Appendix K) and ethical approval was gained from the School of Human and Health Sciences Research Ethics Committee (Appendix L) before recruiting any participants. Also, a risk analysis and management form was completed prior to recruiting participants to ensure any risks were identified and minimised (Appendix M). All participants were given an participant information sheet prior to starting the experiment which explained the procedure of the experiment, the exclusion criteria and the information relating to ethics, such as informing them that they have the right to withdraw from the experiment at any section of the experiment, without any given reason. All participants were then given a consent form which required each participant to agree to the terms and conditions and agree that they understood their ethical rights, such as withdrawing from the experiment at any time without an explanation. This was then signed by each participant before the experiment commenced.

In addition to this, each participant's anonymity was maintained as no names or identifying features were recorded during data analysis. Each participant was given a number. Each signed consent form was kept in a secure folder on a personal laptop. In light of this, the experiment was confidential and participants were made aware of this at the beginning of the experiment. Moreover, only 'healthy' participants were allowed to take part in this experiment. Any participants who were deemed to have sleep disorders, work night shifts or took any medications that may impact on the experiment were excluded. Efforts were made to ensure there was no risk to psychological well-being, physical health, personal values or participant dignity throughout this experiment. This was in line with BPS Code of Ethics (2009).

Finally, all participants were given a debrief form at the end of the experiment which explained the experiment and the reasons for taking part. The debrief form also stated the contact details for the University of Huddersfield's counselling services and the research supervisor's contact details. These details were given to participants so they could access if they had any queries or wanted to raise any concerns. This was also in line with BPS Code of Ethics (2009).

6 Results

To distinguish which test is the most appropriate test to use, a normality test was conducted using the Shapiro-Wilks test because there were less than 50 participants in each condition. Focusing on the effects of power napping on verbal memory, the Shapiro-Wilk's test indicates that the data for the power napping condition is normally distributed ($p = .227$), whereas the data for the non-power napping condition is not normally distributed ($p = .002$). In terms of the effects of power napping on visual memory, the Shapiro-Wilk's test indicates that the data for the power napping condition is normally distributed ($p = .262$), whereas the data for the non-power napping condition is not normally distributed ($p = .006$). Focusing on the Shapiro-Wilks test for the effects of power napping on vigilance levels, the data for the power napping condition is not normally distributed ($p < .001$), and the data for the non-power napping condition is also not normally distributed ($p < .001$). (Table 1).

Table 1: The normally distributed p values of the data by participants in the power napping and non-power napping condition for each test in the experiment.

	Verbal Memory	Visual Memory	Vigilance Levels
Condition			
Power nap	.227	.262	< .001
Non-power nap	.002	.006	< .001

However, the Shapiro-Wilk's test for sleep time in the power napping condition for verbal memory demonstrated that the data for the early sleep time condition is normally distributed (p = .750), and the data for the late sleep time condition is normally distributed (p = .260). Moreover, the data for sleep time, in the power napping condition, for visual memory was also normally distributed for the early sleep time condition (p = .224) and late sleep time condition (p = .940). However, the Shapiro-Wilk's test for the sleep time in the power napping condition on vigilance levels demonstrates that the data for the early sleep time condition is not normally distributed (p = .001), whereas the data for the late sleep time condition is normally distributed (p = .232), (Table 2).

Table 2: The normally distributed p values of the data by participants in the early and late sleep time condition for each test in the experiment.

	Verbal Memory	Visual Memory	Vigilance Levels
Condition			
Early sleep time	.750	.224	.001
Late sleep time	.260	.940	.232

Due to the data collected not being normally distributed, the outliers were analysed. The outliers which were more than 3 interquartile ranges were temporarily removed and means for each condition were recalculated. The outliers which were originally removed were then replaced with the recalculated means and further normality tests were conducted which demonstrated that the data was still not normally distributed for verbal memory in the non-power napping condition (p = .001), visual memory in the non-power napping condition (p = .006) and vigilance levels in the non-power napping condition (p < .001). However, all test scores in the power napping condition were normally distributed. In addition, verbal memory in the late sleep time condition was not normally distributed (p = .026), visual memory in the early sleep time condition was not normally distributed (p = .046) and vigilance levels scores were not normally distributed in the early sleep time condition (p = .002) and late sleep time condition (p < .001).

Due to removing the outliers which still produced data which was not normally distributed, a log transformation was conducted however this still demonstrated that the data was still not normally distributed. Due to this, the ANOVA was found to be robust to violations to normality of errors assumptions and type 1 error only has a little effect on the data (Schmider, Ziegler, Danay, Beyer & Buhner, 2010) and therefore the following investigations were conducted in terms of assuming that the data is normally distributed. Three 2x2 ANOVA's were conducted to analyse the interaction between power napping and sleep time on verbal memory, visual memory and vigilance levels.

6.1 Verbal Memory

Hypotheses one and two investigated the effects of power napping and sleep time on verbal memory. The descriptive statistics (Table 3) for hypothesis one, focusing on power napping, revealed that a twenty minute power nap appeared to be more beneficial on verbal memory compared to not having a twenty minute power nap. This was evidenced by the power napping condition scoring, on average, higher on the verbal memory test (M = 8.13, SD = 2.50) compared to the non-power napping condition (M = 6.90, SD = 2.43). These results indicate that there was a difference between verbal memory scores obtained from participants that engaged in a twenty minute power nap prior to the experiment, when compared to those who did not engage in a twenty minute power nap. However, this difference may occur because of the after midnight condition in the power napping condition scoring significantly better than any other sub-condition, and therefore the difference between the power napping condition and non-power napping condition may be because of the interaction between power napping and sleep time.

Furthermore, focusing on hypothesis two, this investigation analysed whether engaging in a twenty minute power nap after going to sleep late (after midnight) was significantly more beneficial on verbal memory than engaging in a twenty minute power nap after going to sleep early (before midnight). The descriptive statistics (Table 3) for hypothesis two revealed that engaging in a twenty minute power nap after going to sleep late did increase verbal memory scores (M = 9.10, SD = 2.45), in comparison to those who engaged in the same twenty minute power nap after going to sleep early (M = 7.15, SD = 2.21).

Table 3: Mean and standard deviation of verbal memory scores gained by participants in the power napping, non-power napping condition and mean and standard deviation of verbal memory scores gained by participants, who engaged in a power nap, in the early sleep time condition and late sleep time condition.

	M	SD	N
Condition			
Power nap	8.13	2.50	40
Non-power nap	6.90	2.43	40
Early Sleep time in the power napping condition	7.15	2.21	20
Late Sleep time in the power napping condition	9.10	2.45	20

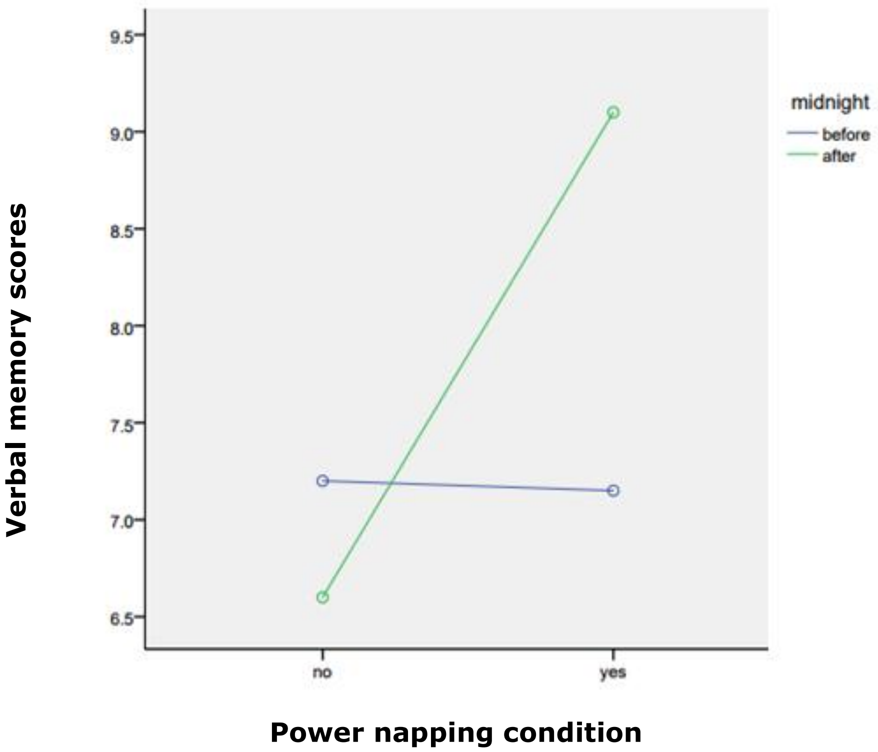

Figure 3: The interaction between power napping and sleep time on verbal memory performance, (y-axis starts at 6.5).

A 2x2 ANOVA was then conducted to investigate the interaction between power napping and sleep time, and the beneficial effects these have on verbal memory scores. A statistically significant interaction was found between the effects of power napping and sleep time on verbal memory test scores, $F(1, 76) = 5.72$, $p = .019$. Figure 3 displays the significant interaction between sleep time and power napping, and demonstrates that the participants who went to sleep after midnight in the non-power napping condition produced lower verbal memory scores ($M = 6.60$), compared to those who went to sleep before midnight in the non-power napping condition ($M = 7.20$). Moreover, it also presented that participants who went to sleep after midnight in the power napping condition ($M = 9.10$) scored higher than those who went to sleep before midnight ($M = 7.15$) in the power napping condition. However, there was not much difference between the scores between participants who went to sleep before midnight in the power napping condition ($M= 7.15$) and participants who went to sleep before midnight in the non-power napping condition ($M=7.20$). These results indicated that engaging in a power nap after going to sleep after midnight was more beneficial on verbal memory than going to sleep before midnight and / or engaging in a power nap and there was not much difference in the beneficial effects of power napping for those who went to sleep before midnight.

Analysing the 2x2 ANOVA for power napping, the main effect analysis demonstrated that verbal memory scores were significantly increased after a power nap compared to participants who did not engage in a power nap ($p = .024$), and therefore engaging in a twenty minute power nap significantly increases verbal memory scores, in comparison to those who did not engage in a twenty minute power nap $F(1, 76) = 5.28$, $p = .024$. In addition, analysing the main effect analysis for sleep time found that there were no significant difference between the 40 participants who went to sleep early and the 40 participants who went to sleep late across both the power napping and non-power napping condition on verbal memory scores $F(1, 76) = 1.60$, $p = .210$.

The main effect for sleep time from the 2x2 ANOVA demonstrated that the time in which participants went to sleep did not significantly affect the verbal memory scores. In addition to this, hypotheses two focuses on the beneficial effects of sleep time on verbal memory in the power napping condition only. Due to this, an independent t-test was conducted to investigate if there was a significant difference between going to sleep early and going to sleep late on verbal memory in the power napping condition. The data collected from the independent t-test, to investigate whether engaging in a twenty minute power nap had significant beneficial effects on verbal memory after going to sleep late compared to going to sleep early, revealed a significant simple main effect of sleep time in the power napping condition, t = -2.65, df = 38, p = .012. Using the Cohen's d test of effect size, the results have suggested a large effect size of d = - .84. These results indicated that engaging in a twenty minute power nap after going to sleep late on the prior night was significantly beneficial on verbal memory, in comparison to engaging in a power nap after going to sleep early on the prior night. Therefore, hypothesis two was accepted and the null hypothesis that predicted that there will be no difference in the verbal memory scores achieved by those who engaged in a twenty minute power nap after going to sleep late compared to those who engaged in a twenty minute power nap after going to sleep early, was rejected.

These results demonstrated that power napping overall does significantly improve verbal memory scores compared to participants who did not engage in a power nap, and therefore hypothesis one is accepted. Moreover, these results also found that the time in which participants go to sleep impacts significantly on the beneficial effects of power napping on verbal memory scores. Moreover, because sleep time across both the power napping and non-power napping revealed a non-significant main effect, it can be concluded that it was the power nap which significantly benefitted participants who went to sleep after midnight, compared to those who went to sleep before midnight on verbal memory scores and therefore hypothesis two is accepted.

6.2 Visual memory

Hypotheses three and four investigated the beneficial effects of power napping and sleep time on visual memory. The descriptive statistics (Table 4) for hypothesis three, focusing on power napping, revealed that a twenty minute power nap was more beneficial on visual memory compared to not having a twenty minute power nap. This is evidenced by participants in the power napping condition scoring, on average, higher on the visual memory test ($M = 6.80$, $SD = 2.02$) compared to the non-power napping condition ($M = 4.68$, $SD = 1.46$). These results demonstrate that there was a difference between the visual memory scores obtained from participants that engaged in a twenty minute power nap prior to the experiment, when compared to those who did not engage in a twenty minute power nap (Figure 4). However, this difference may only occur because of the after midnight condition in the power napping condition scoring significantly better than any other sub-condition, and therefore the difference between the power napping condition and non-power napping condition on visual memory may be because of the interaction of sleep time.

Furthermore, the analysis of descriptive statistics (Table 4) for hypothesis four revealed that engaging in twenty minute power nap after going to sleep late improved visual memory because participants who went to sleep late ($M = 7.60$, $SD = 2.23$) had slightly increased visual memory scores compared to those who went to sleep early ($M = 6.00$, $SD = 1.41$) in the power napping condition (Figure 4). This demonstrated that there is a difference between visual memory scores obtained from participants that engaged in a twenty minute power nap after going to sleep late and those engaged in a twenty minute power nap after going to sleep early, however conducting a 2x2 ANOVA will distinguish whether the difference between both conditions is significant.

Table 4: Mean and standard deviation of visual memory scores gained by participants in the power napping and non-power napping condition and mean and standard deviation of visual memory scores gained by participants, who engaged in a power nap, in the early sleep time condition and late sleep time condition.

	M	SD	N
Condition			
Power nap	6.80	2.02	40
Non-power nap	4.68	1.46	40
Early Sleep time in the power napping condition	6.00	1.41	20
Late Sleep time in the power napping condition	7.60	2.23	20

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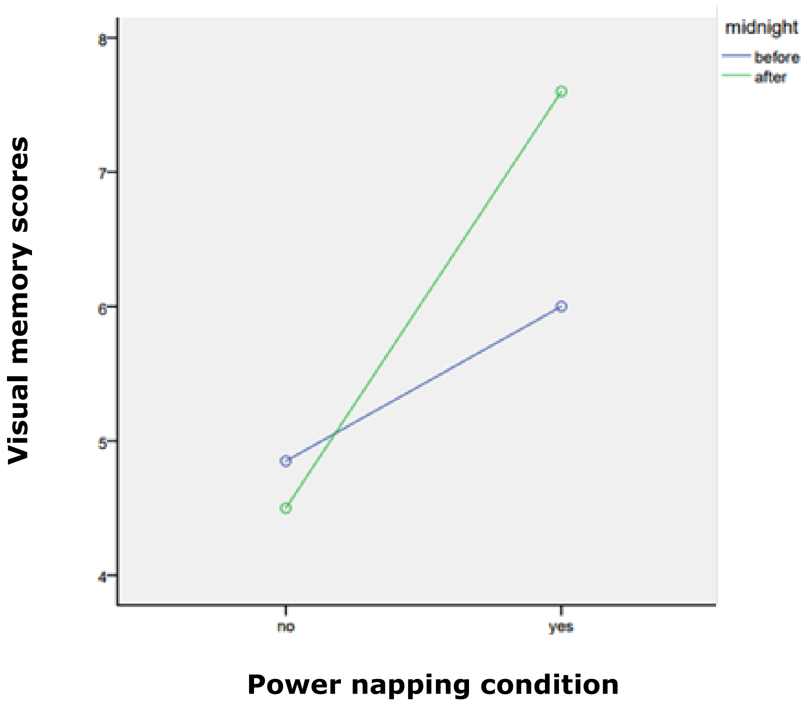

Figure 4: The interaction between sleep time and power napping on visual memory scores, (y-axis starts at 4).

A 2x2 ANOVA was then conducted to investigate the interaction between power napping and sleep time, and the beneficial effects these have on visual memory scores. A significant interaction was found between the effects of power napping and sleep time on visual memory test scores, $F (1, 76) = 6.74$, $p = .011$. Figure 4 clearly displays that there is a difference between early and late sleep time, and power napping and non-power napping as well as the significant interaction between the two. It also presents that participants in the power napping condition who went to sleep late produced the highest visual memory scores, followed by participants who went to sleep early in the power napping condition. In addition, graph 2 also indicates that participants who went to sleep early in the non-power napping condition had higher visual memory scores ($M = 4.85$) compared to participants who went to sleep late in the non-power napping condition ($M = 4.50$). These results demonstrate that sleep time does have an impact on visual memory as well as power napping.

Analysing the 2x2 ANOVA for power napping, the main effect analysis demonstrated that engaging in a power nap significantly increased visual memory scores compared to participants who did not engage in a power nap ($p < .001$), and therefore engaging in a twenty minute power nap significantly increases visual memory scores, in comparison to those who did not engage in a twenty minute power nap $F (1, 76) = 32.02$, $p < .001$. In addition, analysing the main effect for sleep time found that there were no significant difference between the 40 participants who went to sleep early and the 40 participants who went to sleep late, $F (1, 76) = 2.77$, $p = .100$, across both the power napping and non-power napping condition on visual memory scores.

The main effect from the 2x2 ANOVA demonstrated that the time in which participants went to sleep did not significantly affect the visual memory scores however, hypothesis four focuses on the beneficial effects of sleep time on visual memory in the power napping condition only and therefore to investigate hypothesis four an independent t-test was conducted. The data collected from the independent t-test, to investigate whether engaging in a twenty minute power nap had significant beneficial effects on visual memory after going to sleep late compared to going to sleep early, revealed a significant simple main effect of sleep time, $t = -2.71$, $df = 32.12$, $p = .011$. Using the Cohen’s d test of effect size, the results have suggested a large effect size of $d = - .90$. These results indicated that engaging in a twenty minute power nap after going to sleep late on the prior night was significantly beneficial on visual memory, in comparison to engaging in a power nap after going to sleep early on the prior night. Therefore, hypothesis four is accepted and the null hypothesis that predicted that there will be no difference in the visual memory scores achieved by those who engaged in a twenty minute power nap after going to sleep late compared to those who engaged in a twenty minute power nap after going to sleep early, is rejected.

These results demonstrated that power napping overall does significantly improve visual memory scores compared to participants who did not engage in a power nap, and therefore hypothesis three is accepted. Moreover, these results also found that the time in which participants go to sleep impacts significantly on the beneficial effects of power napping on verbal memory scores, and therefore hypothesis four is accepted. Also, because sleep time across both the power napping and non-power napping revealed a non-significant main effect, it can definitely be concluded that it was the power nap which significantly benefitted participants who went to sleep after midnight, and not just the sleep time overall, compared to those who went to sleep before midnight on verbal memory scores.

6.3 Vigilance Levels

Hypotheses five and six investigated the beneficial effects of power napping and sleep time on vigilance levels. The analysis of descriptive statistics (Table 5) for hypothesis five revealed that a twenty minute power nap appears to result in fewer commission errors being made compared to not having a twenty minute power nap. Commission errors were calculated by the number of times the participants failed to withhold their response to number three. This is evidenced by the power napping condition scoring, on average, fewer commission errors on the vigilance task (M = 11.40, SD = 5.01) compared to the non-power napping condition (M = 14.23, SD = 11.89). These findings demonstrate that there is a difference between the commission errors made on the vigilance test from participants that engaged in a twenty minute power nap prior to the experiment, when compared to those who did not engage in a twenty minute power nap (Figure 5). However, the before midnight condition in the power napping condition made fewer commission errors than the other sub-conditions, whilst the after midnight non-power napping condition made relatively more commission errors compared to any other sub-conditions and therefore the difference between the power napping and non-power napping condition may be due to the interaction of sleep time, rather than the power nap itself.

Furthermore, this investigation is going to analyse whether engaging in twenty minute power nap after going to sleep late (after midnight) is significantly more beneficial on vigilance levels than engaging in a power nap after going to sleep early (before midnight). The descriptive statistics (Table 5) for hypothesis six revealed that engaging in a twenty minute power did not make a difference to the commission errors made by participants who went to sleep late (M = 11.60, SD = 5.17), in comparison to those who also engaged in the twenty minute power nap after going to sleep early (M = 11.20, SD = 4.98).

Table 5: Mean and standard deviation of commission errors made by participants in the power napping and non-power napping condition on the vigilance test and mean and standard deviation of commission errors made by participants, who engaged in a power nap, in the early sleep time condition and late sleep time condition.

	M	SD	N
Condition			
Power nap	11.40	5.01	40
Non-power nap	14.23	11.89	40
Early Sleep time in the power napping condition	11.20	4.98	20
Late Sleep time in the power napping condition	11.60	5.17	20

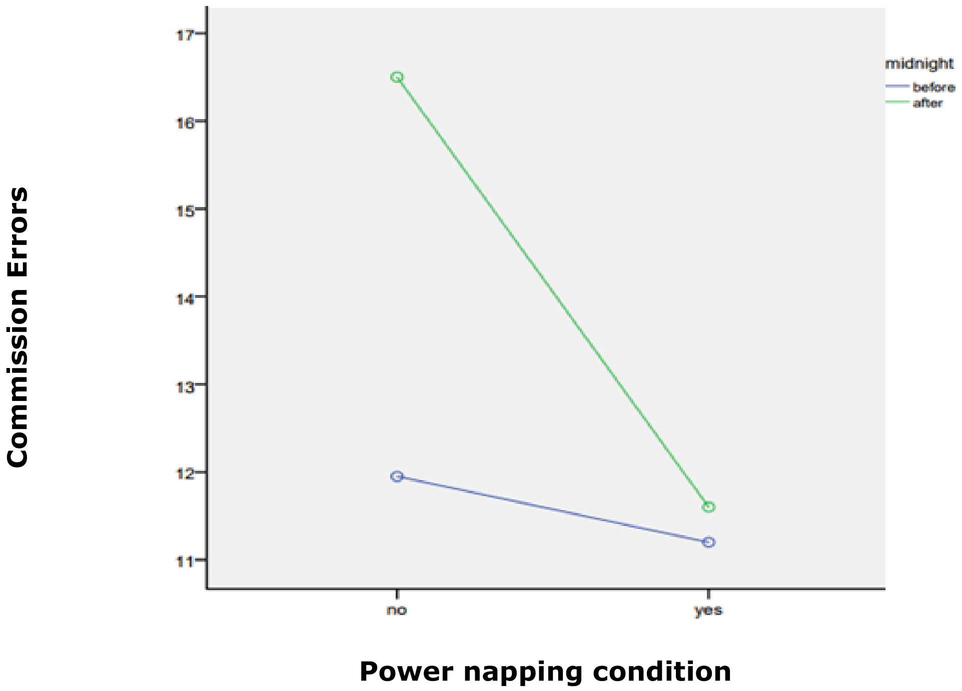

Figure 5: The interaction between sleep time and power napping on errors of commission made on a vigilance task, (y-axis starts at 11).

A 2x2 ANOVA was then conducted to investigate the interaction between power napping and sleep time, and the beneficial effects these have on vigilance levels, which was analysed in terms of how many errors were made on the vigilance task. The higher the errors, the least vigilant the participants were and, the less errors which were made displayed higher vigilance levels. No significant interaction was found between the effects of power napping and sleep time on the commission errors on the vigilance task, $F(1, 76) = 1.04$, $p = .311$. Figure 5 displays that there is an interaction between sleep time and power napping on the errors made on the vigilance task. This is because the results reveal that participants who went to sleep after midnight in the non-power napping condition made more errors than those who went to sleep before midnight in the non-power napping condition. Moreover, participants who went to sleep after midnight in the power napping condition made slightly more errors than those who went to sleep before midnight in the power napping condition. In addition to this, due to the relatively large amount of commission errors made by the after midnight non-power napping condition, there is a difference between the amount of commission errors made on the vigilance task between the power napping and non-power napping condition.

Analysing the 2x2 ANOVA, the main effect analysis for power napping demonstrated that there were no significant difference between those who engaged in a power nap and those who did not engage in a power nap $F(1, 76) = 1.93$, $p = .17$, and therefore hypothesis five was rejected. In addition, analysing the main effect for sleep time found that there were also no significant difference between the 40 participants who went to sleep early and the 40 participants who went to sleep late across both the power napping and non-power napping condition on the errors made on the vigilance task $F(1, 76) = 1.48$, $p = .23$.

The main effect from the 2x2 ANOVA demonstrated that the time in which participants went to sleep did not significantly affect participants vigilance levels. However, hypothesis six focuses on the beneficial effects of sleep time on vigilance levels in the power napping condition only and therefore to investigate hypothesis six an independent t-test was conducted. The results of the independent t-test, to investigate whether engaging in a twenty minute power nap had significant beneficial effects on vigilance levels after going to sleep late compared to going to sleep early, revealed no significant effect of sleep time, $t = -2.49$, $df = 38$, $p = .804$. These results indicated that engaging in a twenty minute power nap after going to sleep late on the prior night did not significantly increase vigilance levels, in comparison to engaging in a power nap after going to sleep early on the prior night. Therefore, hypothesis six was rejected and the null hypothesis that predicted that there will be no significant difference in vigilance levels achieved by those who engaged in a twenty minute power nap after going to sleep late compared to those who engaged in a twenty minute power nap after going to sleep early, was accepted. Overall, these results demonstrated that there is no significantly beneficial effects of sleep time in the power napping condition and power napping on vigilance levels and therefore hypothesis five and six was rejected.

7 Discussion

This research aimed to investigate whether power napping significantly improves memory, as well as analysing whether power napping has beneficial effects on both visual memory and verbal memory. It also aimed to investigate whether power napping significantly increased vigilance levels because the research on sleep and vigilance would suggest that it does. Moreover, this analysis aimed to investigate whether a power nap is significantly more beneficial on both visual and verbal memory and vigilance levels when going to sleep late (after midnight) compared to going to sleep early (before midnight).

This investigation stemmed from research findings which concluded that sleep-deprived participants who went to sleep considerably late (after midnight) will enter SWS during a power nap, compared to participants who go to sleep early who enter stages 1 and 2, and SWS has been found to improve cognitive functions such as memory and vigilance (Batterink *et al.,* 2016; Lau, Tucker & Fishbein, 2010). Moreover, Dijk (2009) stated that participants who go to sleep late experience a more intense SWS period during a power nap, compared to the SWS experienced by those who went to sleep early. So even though participants who went to sleep early will have completed the vital stages for the enhancement of memory and vigilance, during the power nap, participants who went to sleep late will experience SWS more intensely and therefore a power nap should enhance verbal and visual memory performance and vigilance levels significantly more than those who went to sleep early because their SWS on the previous night will have been less intense.

Overall, this investigation found that a twenty minute power nap does significantly increase both verbal and visual memory and therefore, engaging in a power nap, despite what time participants go to sleep, does have beneficial effects on memory. This investigation also found that participants who went to sleep late had significantly increased verbal and visual memory after engaging in a twenty minute power nap, compared to participants who went to sleep early. Therefore, even though a power nap significantly enhances memory for all participants in comparison to participants who did not engage in a power nap, this research also demonstrated that a power nap benefits participants who went to sleep after midnight significantly more than those who went to sleep early, in the power napping condition. This demonstrates that a power nap does promote memory, and analysing the interactions between power napping and sleep time it has been found that there is a statically significant interaction between power napping and sleep time for verbal and visual memory. In addition to this, there were no significant difference between the 40 participants who went to sleep early and the 40 participants who went to sleep late across both the power napping and non-power napping condition. This means that it was the power nap which enhanced verbal and visual memory for those that went to sleep late, because sleep time alone does not impact on verbal and visual memory.

On the other hand, this research analysis also found that there is no significant difference in vigilance levels between those individuals who engaged in a twenty minute power nap, and those who did not engage in a twenty minute power nap. Furthermore, these findings also suggest that there is no significant difference on vigilance levels between individuals who engaged in a twenty minute power nap after going to sleep late, compared to engaging in a twenty minute power nap after going to sleep early as well as no significant interaction between sleep time and power napping. Overall, this confirms that hypotheses one, two, three and four are accepted, whilst hypotheses five and six are rejected. The discussion below will critically analyse these findings.

7.1 Memory

In relation to hypothesis one, this research found that participants who engaged in a twenty minute power nap had significantly increased verbal memory performance, compared to participants who did not engage in a twenty minute power nap. This supports the findings of Horvath, Myers, Foster and Plunkett (2015) who found that power napping during the day improves verbal memory in participants. In addition, Barner, Ngo, Diekelmann, Weeb and Schlarb (2016) found that sleep spindles during a power nap increased after learning verbal words, compared to the control condition which further demonstrates that sleep promotes verbal short-term memory. Therefore, the findings from this experiment support prior research findings demonstrating that power napping does enhance verbal memory.

In relation to hypothesis three, this investigation into the effects of power napping on visual memory has found that participants who engaged in a twenty minute power nap had significantly increased visual memory, compared to participants who did not engage in a twenty minute power nap. These findings are again consistent with prior research which has found that non-sleep deprived subjects performed sufficiently better on visual memory tasks compared to sleep-deprived subjects (Chuah & Chee 2008; Tripathi & Jha, 2016). However, these findings can only be compared to prior research which has analysed the effects of sleep on visual memory, or the effects of power napping on memory because prior research has not distinguished the different beneficial effects that power napping could have on visual and verbal memory. In light of these current findings, however, it can be suggested that power napping does enhance visual memory as well as verbal memory.

Hypotheses one and three are accepted and this may be because power napping helps to stimulate the brain, lifting mood and increasing alertness (Halson, 2008). Therefore, participants who did engage in a power nap may have felt more alert and aware of the task, than those who did not engage in a power nap. Moreover, Autumn *et al.* (2016) found that a twenty minute power nap, which is what participants in this experiment engaged in, helps enhance alertness, creativity and memory.

In relation to hypotheses two and four, it was found that participants who went to sleep after midnight benefited significantly more from a power nap by scoring significantly higher on the verbal and visual memory tasks, compared to those who went to sleep before midnight. These results are consistent with previous research findings that acknowledge that those who go to sleep considerably late (after midnight), start experiencing feelings of sleep deprivation (Kang & Chen, 2009). Due to the feeling of sleep deprivation, as soon as the participant next falls asleep, they will experience an increased amount of time spent in SWS (Dijk, 2009). It has been intensively discussed that SWS has significant beneficial effects on memory, and therefore those participants who spend more time in SWS will score significantly higher on memory tasks (Molle & Born, 2009). Lau, Tucker and Fishbein (2010) found that the duration of SWS obtained during a power nap was positively correlated with memory. This suggests that when SWS is entered during a power nap it has similar beneficial effects on memory than what sleep does. This therefore indicates that participants who go to sleep after midnight, due to them experiencing feelings of sleep deprivation, will enter intense SWS during the power nap. This is in comparison of those who went to sleep before midnight, who are more likely to reach stage two within the 20 minutes power nap, which has not been associated to any beneficial effects on memory. This can be explained from past research findings because the participants who went to sleep after midnight will experience more sleep deprivation compared to those who went to sleep before midnight (Barnes & Hollenbeck, 2009) and therefore are more likely to enter SWS and this enhances both verbal and visual memory performance (Dijk, 2009).

Further support that it is the power napping that improves verbal and visual memory for those that went to sleep late in the power napping condition, compared to those who went to sleep early in the power napping condition, is the insignificant findings between the 40 participants who went to sleep early and 40 participants who went to sleep late across both power napping and non-power napping condition. This means that it can be concluded that it was the power napping which enhanced the verbal and visual memory scores for those who went to sleep late, compared to participants who went to sleep early. This is can be concluded because there was not a significant difference between the participants who went to sleep before midnight and participants who went to sleep after midnight across both the power napping condition and non-power napping condition which suggests that memory performance scores are not impacted by the time in which participants go to sleep. Instead, sleep time only has an impact on memory performance scores if participants engage in a power nap as well.

Despite the current findings being consistent with prior research findings, one limitation of this research is that it cannot be definitively concluded what stages of sleep the participants entered during the power nap in this experiment. Due to these research findings being discussed in terms of participants who go to sleep considerably late entering SWS during the power nap, and therefore are significantly more likely to have increased scores on memory, it cannot be fully confirmed that this has been the case. Prior research which investigates the beneficial effects of sleep has used EEG to distinguish which stages are beneficial for different aspects of memory (Marshall, Kirov, Brade, Molle & Born, 2011). Due to this, it is recommended that future research would need to use an EEG to determine what stages of sleep are entered during the power nap and which stages are responsible for impacting on verbal and visual memory. Therefore, although it can be concluded that engaging in a power nap does significantly increase verbal and visual memory, it cannot be concluded whether it is because of the nature of the stages entered. However, based on prior research is can be assumed that participants who go to sleep later are the ones who are more likely to enter SWS which is associated with the enhancement of verbal and visual memory, and hence it may be suggested that it was SWS that impacted on performance.

Focusing on verbal memory, this experiment used the word recall list. This requires participants to write down as many words down as they can remember from a list of words that were verbally relayed to them. This test involved participants listening to an audio which presented words in a specific order and with the same gap in between each word and therefore, all the participants were presented with the same test. Using an audio clip to present a word list to participants is suggested to be a useful way to minimise any differences within the test which may occur if the researcher themselves said the words out loud (Green & Helton, 2011). Due to the audio clip controlling for the type of words, the length of the words and the timing of the words being relayed to the participant it demonstrates that this test was a reliable measure of verbal memory, which is a strength of this research (Green & Helton, 2011).

Furthermore, it has been found that when the words presented to the participants have a meaning or are similar to each other, the participant can link the words together and remember more words in comparison to words which do not have any meaning to participants (Katkov, Romani & Tsodyks, 2014). This is one factor which is difficult to control because individual differences between each participant means that some words may have more meaning to some participants than to others. To control for this as best as possible, twenty words were selected from Paivio *et al.* (1968) word pool and an audio was used. This means that the words in the word pool were equally rememberable, and all had 2 syllables and between 5-7 letters. Therefore extraneous variables, such as word length and meaning of the words were controlled in this experiment, so this test was considered to be a reliable measure of verbal memory.

In addition to this, an uncontrolled variable which may have impacted on the amount of words recalled in this experiment is the "serial position" effect. Even though this is across all conditions, it is still viewed as a limitation of the test used, and implies that a more reliable and valid verbal memory test could have been chosen. The serial position effect is when words that are presented to the participants at the beginning of the list are recalled significantly better than words in the middle of the list (Laming, 2010). This is known because the words at the beginning of the list is stored in LTM and the words being rehearsed for a longer period of time (Yoo & Kaushanskaya, 2016). Moreover, words at the end of the list has been found to be recalled significantly more than words in the middle of the list because they are stored in the STM (Laming 2010; Yoo & Kaushanskaya, 2016). STM has been found to hold on average seven words (Caplan, Waters & Howard, 2012).

The test used for visual memory was the pelmanism game, also known as pairs. This has been found to be a good measure of visual memory as it can be used for any ages and it is easy to engage in. All participants in this experiment completed the game and the time completed was recorded. Using this test it was found that power napping has increased visual memory, and participants engaging in a power nap whilst going to sleep late had significantly increased scores on this test compared to participants who went to sleep early. However, one extraneous variable in this test that may have manifested and impacted on the results were individual differences. For example, each participant's experience levels on this test may have differed and participants with higher experience levels may have been over represented in the power napping condition and/or after midnight condition, and those with less experience at the task may have been over represented in the non-power napping condition and/or before midnight condition). (Wilson, Darling & Sykes, 2011). Therefore, this test may have been a measure of experience levels, compared to the effects of power napping and sleep time. On the other hand, to control for this, participants were given full instructions on the test at the beginning of the experiment and had an opportunity to ask any questions they may have had, however no practise session was included. They were showed an example to ensure that they all fully understood how to complete the game, and all participants were clear that they had to be as quick and precise as possible. Moreover, another control put in place to ensure that this extraneous variable had as little impact on the results as possible was that participants were randomly assigned to either the power napping or non-power napping condition, and therefore it can be assumed that it is unlikely that everyone in the power napping condition will have had significantly more experience than participants in the non-power napping condition, and the same for sleep time.

It is argued that this test is a good measure of visual memory because it requires individuals to process various different images and remember where they are placed to be able to match them. This indicates that those participants who do have increased visual memory functions will be able to complete this test in a significantly faster time in comparison to those who with a lower visual memory function. This suggests that the verbal and visual tests having various strengths and limitations in regards to what the test being reliable and valid. The randomly assigned conditions and the controls which were put in place increased the validity of this experiment and the tests used, and prior research which have used these tests to measure verbal and visual memory increases the validity (Uguccioni, Pallanca, Golmard, Leu-Semenescu & Arnulf, 2015; Wilson *et al.,* 2011). Therefore, it can be concluded that these tests do have high validity and reliability and this then suggests that these results can conclude that participants who engaged in a power nap did have significantly increased verbal and visual memory in comparison to those who do not engage in a power nap, and those who went to sleep after midnight did benefit more from the power nap in comparison to those who went to sleep before midnight.

7.2 Vigilance

In relation to hypothesis five, it was found that there were no significant differences between the power napping condition and the non-power napping condition based on the scores achieved on the vigilance test. In relation to hypothesis six, it was found that there were no significant difference between participants who went to sleep late and participants who went to sleep early in the power napping condition on vigilance levels. Despite prior research demonstrating that sleep does enhance vigilance levels, this research suggests that engaging in a power nap does not have the same beneficial effects on vigilance than what sleep does.

It has also been found that power napping has been implemented in jobs which require high vigilance levels, such as prolonged driving (Campagne, Pebayle & Muzet, 2004). The UK government now recommends that drivers should have at least a 45 minute rest every four and a half hours to improve their vigilance levels on the road (Gov.uk, n.d.). Moreover, due to research finding that sleep-deprivation causes road traffic accidents, it is suggested that a power nap can decrease the chance of road-traffic accidents as vigilance levels would be increased (Eoh, Chung & Kim, 2005). However, the findings of this research do not support that engaging in a power nap will improve individuals vigilance levels. This is an interesting finding because drivers are encouraged to engage in power naps, however this research indicates that power napping does not increase vigilance levels which could potentially lead to road traffic accidents.

However, the results of this experiment can be explained by drawing on different theories of vigilance and many researchers have attempted to explain why findings within laboratory settings cannot be applied to real-world settings. Some prior research which has found the benefits of power napping on vigilance has been conducted in real life settings. One theory that has attempted to explain the results of vigilance tasks is the mindlessness theory of vigilance (Helton & Warm, 2008). This theory was devised by Robertson, Manly, Andrade, Baddeley and Yiend (1997) and the theory is used to explain why individuals withdraw attention in everyday situations. This mindlessness theory of vigilance assumes that individuals that are engaging in vigilance tasks that require the need to respond repeatedly to the same group of stimulus, and withhold to a chosen stimulus of the task have a decreased level of attentional focus (Robertson *et al.,* 1997). This is due to the supervisory attentional system which loses focus and awareness of the stimulus. Instead, the response of the task becomes 'thoughtless' and automatic (Robertson *et al.,* 1997). For example, whilst engaging in a vigilance task, participants are required to direct their attention to a signal stimulus. Using a sustained attention as an example, vigilance tasks require the participants to respond to all but one stimulus whilst sustaining attention to the one specific stimulus. Due to the repeating action of responding to signal stimulus, the mindlessness theory of vigilance suggests that the automatic and repeated nature of the task makes it effortful for the participant to withhold their response once presented with the stimulus that they are required to not respond to (Robertson et al., 1997). This creates the notion that the participant disengages from the task and this theory assumes that the participant engaging in the task becomes distracted by unrelated thoughts (Epling, Russell & Helton, 2016).

Despite the mindlessness theory assuming that all participants who engage in the vigilance task will become thoughtless, and actions will be automatic, and therefore make it harder to sustain from responding to a stimulus, research has found that sleep deprived participants still find it significantly harder to sustain responding, in comparison to non-sleep deprived participants (Lim & Dinges 2008; Ross, Russel & Helton, 2014). In the light of this theory, it is assumed that the analysis of errors made throughout the vigilance task is the actual analysis of the disengagement of conscious awareness. It could be argued that the findings can be attributed to a disengagement of conscious awareness throughout the task hence finding that there was no significant difference between participants who engage in a twenty minute power nap, compared to those who do not engage in a twenty minute power nap.

In addition to this, Helton and Russell (2011) concludes that the mindlessness theory suggests that the decrease of detection performance throughout the vigilance task is due to the primary mechanism which is the disengagement of awareness from the task. Robertson *et al*. (1997) discusses that the disengagement of awareness throughout the task is a result of task unrelated thoughts which produce an automatic response to the task.

Robertson, Manly, Andrade, Baddeley and Yiend (1997) supported their own mindlessness theory of vigilance by using the Sustained Attention to Response Task (SART). Individuals which engaged in the SART task in this experiment displayed the typical features of mindlessness which is where participants lapse in attentional focus and automatic responses which is a result of being in a routine whilst completing the task, and the repetition of the SART test produces task unrelated thoughts (Helton & Warm, 2008). This is a further limitation of the task used to investigate vigilance levels within this experiment as participants are likely to have thought about task unrelated thoughts or become automatic in their response, even if they did have high vigilance levels. Due to this, the validity of this measure is low, because it cannot be concluded that the SART task truly measured vigilance levels. Despite the support of this theory being predominately from the SART test, the theory can explain the results of sustained attention across various other vigilance tasks. Moreover, with the support of the theory using the SART test, it demonstrates that this explanation of findings can be directly related to the current study.

Cheyne, Solman, Carriere and Smilek (2009) have presented supporting evidence for the mindlessness theory of vigilance by discussing the three-state attentional model of engagement and disengagement of vigilance. This model demonstrates that there is three states of mindlessness, which involves occurrent task inattention, generic task inattention and response disengagement (Cheyne *et al.,* 2009). Inattention is the term given to the inability to direct and maintain attention to a certain task. Testing these three stages of mind-wandering have been used in various experimental designs which consist of GO / NO-GO tests, the SART task as well as real-world stimulus tests which enhances the validity of the research (Cheyne *et al.,* 2009). These researchers analysed the errors, reaction times and anticipations on the SART test, whilst the errors and success rates were analysed on the NO-GO trails. These results demonstrate that both mindlessness does cause a decrease in vigilance levels, and thus provides further support for the mindlessness theory of vigilance. This suggests that whilst participants were completing the SART test throughout this present experiment, they were actually demonstrating increased mindlessness, not increased vigilance levels.

Despite the strengths of the mindlessness theory of vigilance and the fact that it can explain the non-significant findings of the results, this theory has been challenged by the opposing theory, a resource theory of vigilance. This theory can also be used to explain why non-significant findings may arise when using the SART test to measure vigilance. The resource theory of vigilance was devised by Helton and Russell (2011) which assumes that failure to respond to signal stimulus is a result of a decline in available attentional resources. With extensive research concluding that attentional resources are limited for information processing, it is assumed that this is the cause for lower vigilance results whilst the participant is completing the task (Helton & Russell, 2011). Helton and Warm (2008) discussed that due to the extensive task demands within vigilance tests, which requires the participant to repeatedly respond to stimulus without rest, this continuous attentional concentration does not allow for the resources to replenishment, and instead depletes. This theory is used to explain performance decrement because the resource of energy is at its upmost peak at the beginning of the vigilance task, and then decreases in time which results in an increase of failure to the responses throughout (Helton & Russell, 2011).

Despite this theory challenging the mindlessness theory of vigilance, numerous challenges have been made about the resource theory of vigilance. Ariga and Lleras (2011) argues that because these researchers used SART tests to provide support for their theory, this is using sensory stimulus which is different to other vigilance tasks used. A SART test is a cognitively engaging task which is known to involve cognitive stimulus. However, Ariga and Lleras (2011) argues that this is the opposite to cognitively demanding tasks which imposes a higher demand on working memory, and therefore using high cognitively demanding tasks provide supporting evidence for the resource theory of vigilance. This indicates that participants in this current study will have had reduced attentional resources because the test used was not a cognitively demanding task. It therefore may be assumed that the non-significant findings were a result of both conditions demonstrating reduced attentional resources, instead of the SART test measuring vigilance. However, if future research investigates the effects of power napping on vigilance levels whilst using a different vigilance task, the result may produce different findings. This means that recommendations for future research is to use a more cognitively demanding task.

Supporting evidence for these predictions have found that high cognitively demanding tasks involves an overload in working memory, which results in more failures due to the resource overload and participants decrease throughout the experiment (Epling, Russell & Helton, 2016). This is further support for vigilance decrement and it demonstrates that high cognitively demanding tasks are more valid measure of vigilance. In despite of this, it is argued that the resource theory of vigilance does not provide an explanation as to why individuals still have decreased performance on cognitively engaging tasks which are not cognitively demanding like the SART test, and therefore this theory cannot explain all aspects of vigilance and the reasons as to why participants' attentional resources decreases in lower demanding experiments (Warm, Parasuraman & Matthews, 2008). In despite of this, this current experiment has found a non-significant finding on the SART test, however it cannot be concluded whether there is no difference between vigilance levels between those who engage in a power nap and those who do not engage in a power nap, or whether it is due to vigilance decrement, disengagement and reduced attentional resources that is the product of these results.

Moreover, research that measures the vigilance levels of participants such as this current study which has used the SART test does not last more than five to ten minutes (Epling, Russell & Helton, 2016). Ariga and Lleras (2011) discussed that cognitively engaging tasks, such as the SART test, usually results in vigilance decrement after fifteen minutes, whereas high cognitively demanding tasks which are used to test vigilance usually demonstrates vigilance decrement within the first five minutes. This again suggests that reduced vigilance levels in participants will not be evident in this research because the cognitively engaging task only lasted approximately five minute. This demonstrates that further research either needs to investigate the effects of power napping on vigilance levels by using a more cognitively demanding task which lasts approximately five to ten minutes, or a cognitively engaging test which lasts more than approximately fifteen minutes. This is because these are the usual times that participants demonstrate a decrease in vigilance levels (Ariga & Lleras, 2011). However, it is argued that if power napping really did increase vigilance levels then a difference still should have been demonstrated on the vigilance task no matter what the period of time was.

Moreover, this current study cannot be generalised to real world situations because individuals who require high vigilance levels throughout their daily lives, such as driving for a job, will require high vigilance levels for a prolonged period of time (Epling, Russell & Helton, 2016). However, the task used in this experiment only lasted five minutes which suggests that this test is not a true measure of vigilance because tasks which require high vigilance levels usually lasts for a prolonged period of time. However, the mindlessness theory suggested that an individual’s vigilance decreases once they have a pattern of repetition and start to think about task unrelated thoughts which is more likely to happen once individuals are required to have high vigilance levels for a long period of time (Ariga & Lleras, 2011). The mindlessness theory can therefore be, to some extent, generalised outside of laboratory settings because it explains how individuals can decrease their vigilance levels across a long period of time. For example, individuals who drive for a living will drive automatic, without conscious thought so they will no longer need high vigilance levels to drive. However, this experiment cannot be generalised outside of laboratory settings which is still a limitation of this study because the SART lasted approximately five minutes which is not a true reflection of vigilance level performance required in the real world.

Despite these criticisms of this current experiment and the use of SART, Ariga and Lleras (2011) discussed that SART, despite the short period of time that it takes to complete the task, it is a reliable measure of the perceived mental workload which is imposed on the participants who are engaging in the tasks. Moreover, analysing neurological studies, it has been found that there is a temporal decline in signal detections which has been used to investigate vigilance performance and vigilance decrement (Cheyne, Solman, Carriere & Smilek, 2009). Earlier studies conducted by Hitchcock *et al*. (2003) have found that there is a parallel decline in cerebral blood flow which suggests that this is positively correlated to the cognitive demands which are imposed on participants whilst engaging in the vigilance tasks (Helton & Warm, 2008). This demonstrates that further research into the effects of power napping on vigilance levels would need to take into account the cerebral blood flow to demonstrate whether this is linked to the decrease or increase in vigilance levels, and if so, is this improved by a power nap.

Furthermore, another reason why the results of this experiment may not have been significant may be explained by the goal habituation theory. This theory is known to assume similar points to the mindlessness theory of vigilance, however this theory assumes that tasks, such as SART, requires participants to maintain a goal, for example to sustain their attention from number three for a prolonged period of time which is what results in the decrement of vigilance performance, and therefore this test does not measure vigilance levels (Helton & Russell, 2011). This theory can be applied to explain the findings as it suggests that there will be no difference in vigilance levels across two conditions as the prolonged period of maintaining the same goal would produce the same findings across both conditions.

The goal habituation theory assumes that instead of task unrelated thoughts that results in the decrement in vigilance tasks, it is instead 'goal habituation' that causes participants to have decreased vigilance levels across time. In support of this goal habituation theory, Ariga and Lleras (2011) conducted an investigation to support their theory and found that when they activated a different goal after various time intervals, participants' vigilance levels enhanced. This implies that it is the habituation of goal that leads to decrement of vigilance. This is in comparison to the mindlessness theory which assumes that the automatic response which is required for completing a vigilance task results in a decrease of vigilance over a prolonged period of time, but instead, the goal habituation theory assumes that it is maintaining the same goal for a prolonged period of time that results in the decrement of vigilance. Therefore, it is argued that by slightly changing the goal of the task, this is enough to enhance vigilance levels and prevent the decrease of vigilance levels across the length of the task. With this assumption, it is recommended that further research which uses SART should change the aim of the goal, for example, after two minutes of sustaining the response to number three, change to sustaining the response to a different number, for example number eight. According to this theory, this will then be enough to increase vigilance levels throughout the test. This indicates that the non-significant findings of this experiment may be a product of the extraneous variables such as the disengagement of the task, the goal habituation and the reduced attentional resources, and therefore, it cannot be certain if there is a non-significant difference in vigilance levels until these extraneous variables have been controlled.

Warm, Parasuraman, & Matthews (2008) also described vigilance tasks as under stimulating and mentally undemanding and in turn means that these are resource demanding because participants have to ensure that they do not become automatic in their response. This again suggests that the task used to measure vigilance may be the cause of non-significant results. However, there has been prior research which has concluded that vigilance levels have been significantly increased whilst using the SART test as a measure of vigilance. This suggests that other factors may be able to explain the non-significant findings. In summary, these findings do contradict prior research findings which did find that a power nap and sleep time did significantly increase vigilance levels.

8 Limitations and further recommendations

This research found that engaging in a power nap increases both verbal and visual memory performance and power napping is significantly more beneficial for those who went to sleep after midnight, in comparison to those who went to sleep before midnight. However, this research has also found that power napping and sleep time did not have a significant beneficial effect on vigilance.

These results can be explained in terms of individual differences in power napping because some participants may have been habitual nappers, whilst other may have not been habitual nappers prior to taking part in this experiment. Milner, Fogel and Cote (2006) found that power napping significantly increased memory levels, but only in those who are habitual nappers. Li *et al.* (2017; 2016) also found that there was a difference in memory performance in those who do not nap, moderately nap or extensively nap. In this research it was found that participants who moderately napped had significantly increased memory levels compared to participants who did not nap or who extensively nap, and it was found that those who moderately and extensively napped had more beneficial effects on memory compared to those who did not nap. In this experiment, the extent to which participants power napped in their daily lives was unknown and the extent to which each participant engages in a power nap on a daily basis could have skewed the results. Therefore, further research would need to be conducted which would control for whether participants were non-power nappers, moderate power nappers or extensive power nappers. Moreover, researching the beneficial effects of power napping on memory would be more validated if all participants taking part in the experiment were not habitual nappers so then it could be definitively concluded that the increased memory scores can be attributed to the beneficial effects of power napping under experimental conditions.

McDevitt, Whitehurst, Duggan & Mednick (2014) found that habitual nappers engage in power naps easier than non-habitual nappers and therefore those who engage in power naps during the day on a frequent basis were more likely to have actually engaged in a power nap than those who are not used to taking power naps during the day. Habitual nappers are those who incorporate a power nap into their everyday lives, whereas a non-habitual napper is individuals who only engage in a power nap every so often, for example, once a week when the individuals is really tired (McDevitt *et al*., 2014). Moreover, McDevitt *et al.* (2014) discussed that habitual nappers experience the significant benefits of power napping such as increased visual memory, motor learning and verbal memory, compared to non-habitual nappers. However, it was unknown in this experiment as to whether the participants were habitual nappers or not, as this was not controlled for. Therefore, whether participants were non habitual nappers or not could have impacted on the results of this experiment and this was another limitation of this experiment. Future research into this area would need to distinguish whether participants were habitual or non-habitual nappers and control for this by excluding one of the groups (habitual or non-habitual nappers) to ensure that it is that one off power nap which is increasing memory and vigilance, and the findings are not a result of whether the participants are habitual power nappers or non-habitual power nappers. Moreover, further research may benefit into the investigations of the effects of power napping on memory and vigilance by recruiting habitual nappers because they are more likely to fall asleep during the power nap in the experiment.

Despite obtaining significant results for the effects of power napping and sleep time on memory, many extraneous variables may have impacted on these results. Kamimori *et al.* (2015; 2014) found that a daily dose of caffeine (5mg), when there were no opportunity to engage in a power nap, was a significantly effective way to maintain cognitive functioning and memory. These findings demonstrate that caffeine can impact significantly on memory. Smith (2013) also found that caffeine increased cognitive performance and memory. This investigation found that individuals demonstrated an increase in memory functioning and vigilance levels after a single dose of caffeine (5mg) (Smith, 2013). This suggests that caffeine has beneficial effects on memory and vigilance. Research has also found that consuming caffeine prior to engaging in a power nap increases the beneficial effects of power napping (Smith, 2013). This experiment did not control for the intake of caffeine prior to participants taking part in this experiment. This was a limitation of the experiment and in turn further research would need to determine whether power napping and sleep time does increase both memory and vigilance levels when caffeine ingested is controlled for, as prior research has found that the intake of caffeine prior to a power nap does increase memory and vigilance levels (Hayashi, Masuda & Hori, 2003, Smith, Kilby, Jorgensen & Douglas, 2007).

Another extraneous variable which may have impacted on the results of this experiment is the time of day that the power nap occurred. Milner and Cote (2009) discussed that taking a power nap at the time when the circadian rhythm causes a dip in alertness results in an increased amount of time in SWS, as well as the power nap promoting benefits on memory and vigilance over a shorter period of time. The time in which power naps are more beneficial on memory and vigilance is within the peak time of 15:00 and 17:00 (Milner & Cote, 2009). This means that a twenty minute power nap in the afternoon, when there is a dip in alertness (between 15:00 and 17:00), is significantly more beneficial on memory and vigilance levels, than what a twenty minute power nap would be in the early afternoon or evening. In addition to this, it has been found that prolonged sleep causes sleep inertia and engaging in a power nap at the wrong time can lead to prolonged sleep inertia, and therefore would not have any beneficial effects on memory and vigilance (Gorgoni, 2015). This is because, if the participant woke up from the prior night at 8:00am and engaged in a power nap at 10:00am, this could cause sleep inertia because the participant is not feeling symptoms of sleep deprivation. Therefore the participant does not need the beneficial effects of a power nap, so instead a power nap could cause symptoms which is the opposite of the beneficial effects of a power nap such as feeling tired and impaired performance. In this current experiment, the times in which participants engaged in a power nap varied between 09:00am and 17:00pm and therefore, participants who engaged in a power nap between 15:00 and 17:00 may have demonstrated an increase on memory and vigilance levels due to the time of day they had the nap, in comparison to those who engaged in a power nap between 09:00 and 15:00. This was another limitation of the experiment. Despite this, significant findings were found between the power napping and non-power napping condition, and therefore engaging in a power nap outside of peak times of 15:00 and 17:00 did not impact on the results. This indicates that engaging in a power nap, no matter what time of day it was taken, had a significant effect on verbal and visual memory performance, and engaging in a power nap after going to sleep after midnight significantly increased verbal and visual memory, suggesting that the time of day in which participants engaged in the power nap did not affect the results.

In contrast, when considering the hypotheses which concentrate on the effects of sleep time on power napping on memory and vigilance performance, it may have been that those participants who engaged in a power nap in the experiment whilst being in the late sleep time condition (after midnight) may have been over represented in the peak timeslot of 15:00 and 17:00, whereas the early sleep time condition (before midnight) may have engaged in a power nap earlier, before the peak time. If this were the case, focusing on sleep time on memory performance, then the results may be significant due to the timings in which the power naps took place, and not due to the time in which participants went to sleep. Therefore, if further research was to be conducted that would control for the time in which participants engaged in power napping, it may demonstrate different findings with regards to the effects of power napping on memory performance. This is however contradicted by the non-significant results obtained for vigilance because if participants who went to sleep late were over represented in the peak timeslot of 15:00 and 17:00, then the results for the memory performance and vigilance levels should have been similar. Not controlling for the time in which the power nap took place in the experiment is another limitation of this experiment and further research is needed to investigate whether the time in which participants go to sleep does significant impact of memory and vigilance performance, by controlling for whether participants only take part in the power nap before the peak time of 15:00-17:00 or whether participants only engage in a power nap within the peak time of 15:00-17:00.

Despite the limitation of not controlling for the time in which the power nap took place in the experimental conditions, the research into the timing of power naps and the causes of sleep inertia can only be applied to day shift workers and / or people who are awake during daylight and sleep during nightlight (Gorgoni, 2015; Milner & Cote, 2009). This demonstrates that the timing of sleep, wake up time and the timing of power naps cannot be generalised to night-shift workers due to the circadian changes which is experienced when altering sleeping patterns. Moreover, night shift workers are required to sleep during the day and engage in power naps throughout the night, and therefore these power naps may produce findings similar to those who engage in power naps outside of peak times. This current experiment controlled for night-shift workers which were excluded from the experiment. This suggests that the findings discussed on sleep time and power napping can be applied to this experiment due to the participants engaging in 'normal' sleep time routines, and hence sleeping patterns and biological rhythms should not be altered. However, to distinguish the effects of power napping on memory and vigilance for night-shift workers, which are known to have more highly cognitively demanding jobs, would need to consider the time in which a power nap was taken place and more research is needed into this area for conclusions to be generalised to night-shift workers. This means that the findings of this experiment can only be applicable to individuals who are awake during daylight and sleep during nightlight.

It cannot be assumed that participants within the power napping condition actually engaged in a power nap, instead participants may have simply closed their eyes for twenty minutes as a factor of demand characteristics. This means that participants may have simply pretended to engage in a power nap to follow their interpretation of the experiments purpose. Despite this being viewed as a limitation of this study, Littlehales (2016) suggested that when participants close their eyes it is just as beneficial as falling asleep because the participants will not be thinking of anything in particular and they will enter a stage which is midway from being awake and falling asleep. Littlehales (2016) found that even participants who do not fully fall asleep during a power nap still gain all the benefits of resting, which includes memory enhancements and the increase of vigilance levels. However, despite Littlehales (2016) discussing that resting is just as beneficial as power napping, when participants rest they will not enter SWS which has been used to explain these findings. This indicates that the extraneous variables discussed may have impacted on the results and no definitive conclusions can be drawn about the beneficial effects of sleep time and power napping on verbal memory, visual memory and vigilance. If further research were to be conducted an electroencephalogram (EEG) could be incorporated to determine if participants engaged in a power nap.

However, despite the extraneous variables discussed the significant findings of this experiment does support research which used an EEG to measure the effects of power napping on memory. Marshall, Kirov, Brade, Molle and Born (2011) found that participants entering stages of SWS during a power nap in laboratory settings were found to have significantly increased scores on memory, compared to those who either did not engage in a power nap. In addition to this, Moroni *et al.* (2014) found that EEG frequencies in NREM sleep is associated with the increase of visual memory. This suggests that engaging in a power nap which induces NREM sleep enhances visual memory. This current investigation into sleep time and power napping on visual and verbal memory therefore provides further support that power napping does increase both verbal and visual memory and is consistent with prior findings.

This research also found that participants who went to sleep after midnight also benefitted more from engaging in the twenty minute power nap, and this impacted more on verbal and visual memory in comparison to those who went to sleep before midnight. These significant findings bring a new perspective on the beneficial effects of power napping on memory and sets the foundation for future research. However, there were no difference found between participants who engaged in a twenty minute power nap and participants who did not engage in a twenty minute power nap on vigilance levels and there were no significant difference between those who went to sleep before midnight and those who went to sleep after midnight in the power napping condition on vigilance levels. This is, in contrast to the prior assumptions made on the effects of sleep on vigilance, however the type of test used in this experiment may explain the non-significant findings, because the task was cognitively engaging which leads to an automatic response from participants, as opposed to cognitively demanding. This overall suggests that future research needs to control for different variables across the experiment and further research would also benefit by using a different experimental task to measure vigilance.

Another limitation of the experiment was that gender of the participants were not controlled for as there were more females than males in this experiment. Also, despite the age being controlled for to ensure all participants in the experiment were between the age 18-45, the majority of participants were between the age of 18-24 year olds. Focusing on time spent in SWS, which is associated with increases in verbal memory and visual memory, Dijk (2009) found that females have more SWS than males and SWS also decreases with age. This illustrates that these findings may be result of gender and age differences. Furthermore, another limitation that was not controlled for in this experiment was the prior stress levels of the participants. Helena (2014) found that pre-sleep stress reduces the time spent in SWS whilst being asleep. Not controlling for these extraneous variables is a further limitation of this experiment and age, gender and stress levels would need to be controlled in further research to determine whether age, gender and stress levels have an effect on the results found in this experiment.

Despite the extraneous variables of this experiment, there were some control measures put in place. One control measure was that participants who were night-shift workers or experienced any sleep disorders or took any medication which would impact negatively on their natural sleep pattern were automatically excluded from taking part in the experiment. This is due to past research demonstrating the changes in the circadian rhythm for night shift works and individuals who have irregular sleep. Moreover, participants with sleep disorders would have impacted on the results because they have been found to benefit more from a power nap in comparison to participants without sleep disorders, however participants with sleep disorders tend to take a lot longer to initially engage in a power nap.

Overall, there are many limitations and criticisms of this research. Some extraneous variables were not controlled for, such as: the timing of the power nap, individual differences, gender differences and to some degree age, the intake of caffeine, whether the participants were habitual nappers or not and whether the participants actually did engage in a power nap during the experiment and the stress levels of the participants prior to engaging the experiment. However, this experiment did control for the time the participants went to sleep. This experiment also controlled, to some degree, the age of the participant in that all participants were aged between 18 and 45 years old and all participants engaged in a power nap for the same length of time which was twenty minutes. This experiment also excluded participants who worked night-shifts and participants who experienced sleeping disorders.

In summary, for further conclusions to be drawn, future research needs to consider the time in which participants wake up, gender differences, the intake of caffeine and measure whether participants actually fall asleep during the power nap which can be controlled by recruiting habitual nappers or with the use of EEG. However, despite some extraneous variables not being controlled for, this research did find that participants who engage in a twenty minute power nap had significantly enhanced scores on both verbal and visual memory tests which is in support of prior research which has investigated the effects of sleep on memory. In addition, the vigilance theories discussed above can explain the non-significant results for vigilance, and if further research controlled for the above extraneous variables then definitive conclusions could be drawn upon.

9 Conclusion

Overall, to conclude, these findings have demonstrated that power napping is a vital enhancer of verbal and visual memory, particularly in those who go to sleep late, in comparison to participants who go to sleep early. These findings have been discussed in relation to past research. Moreover, the beneficial effects of power napping and sleep time has been discussed in terms of the timing of sleep and the stages of sleep which may be entered. However, to definitively conclude that power napping does enhance verbal and visual memory, due to the stages entered whilst engaging in a power nap, further research is required which uses an EEG to ensure that all participants engage in a power nap and to determine the stages of sleep entered during the power nap. Despite this, due to the control measures put in place and the timing of the power nap, it can be concluded that engaging in a twenty minute power nap is significantly more beneficial for enhancing verbal and visual memory compared to those who have not engaged in a power nap. Furthermore, it can also be concluded that participants who go to sleep later than midnight significantly benefit more from a power nap, in comparison to those who go to sleep earlier than midnight and this finding has been explained drawing on the knowledge of the effects of sleep deprivation.

In addition, these findings have demonstrated that power napping does not significantly increase vigilance levels and the time in which participants go to sleep also does not impact on whether a power nap significantly enhances vigilance levels. This therefore suggests that there are no beneficially effects on vigilance levels when engaging in a power nap. These non-significant findings have been explained, discussing the limitations of the tests used and it is recommended that further investigations do need to use a cognitively demanding task, as opposed to the cognitively engaging task because the change in test would minimise the automatic response within the five minutes of taking part in the test. In addition, further research also would need to control for whether participants are habitual nappers or non-habitual nappers as findings have shown that there is a significantly difference between the two, which could impact on the results if this is not controlled.

In summary, this research has given insight into the importance of the time in which participants go to sleep and the effects that sleep time has on the beneficial effects of power napping. With these findings, this research has practical applications, in particular for those who go to sleep late, as a power nap is significantly more beneficial for participants who go to sleep after midnight. It can also have relevance to the work place and for students. This research has created a platform for future research to determine whether the stages of sleep entered during the prior night, and the stages of sleep entered in the power nap is the vital component needed which enhances verbal and visual memory. Moreover, if further factors are controlled for whilst investigating the effects of power napping and sleep time on vigilance levels, research would be able to distinguish whether power napping and sleep time does enhance vigilance levels.

10 References

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11 Appendices

11.1 Appendix A - SONA Recruitment

Study Name	An investigation into the effects of sleep time and power napping on memory and vigilance
Study Type	**Standard (lab) study** This is a standard lab study. To participate, sign up, and go to the specified location at the chosen time.
Credits	2 Credits
Duration	60 minutes
Description	In this experiment you will be required to complete two simple memory tests and a vigilance test.
Eligibility Requirements	All participants must be above the age of 18 and below the age of 45 and any participants with sleep disorders will be excluded from the experiment.
Researcher	Stephanie Dennison
Deadlines	Deadlines that occur on a Saturday or Sunday will be moved back to Friday Sign-Up: 24 hour(s) before the appointment Cancellation: 24 hour(s) before the appointment

11.2 Appendix B - Email Reminder

The following was emailed to each participant 24 hours prior to their allocated timeslot:

Dear [name of participant]

This email is a reminder for your participation timeslot to take part in the study 'an investigation into the effects of power napping and sleep time on memory and vigilance.

Your allocated timeslot is [date of timeslot] at [time of timeslot] in room HW1/02.

To take part in this experiment you must be over the age of 18 and under the age of 45. Night shift workers, participants with sleep disorders and / or participants who take medication which impact on their natural sleeping pattern will be excluded from taking part in this experiment. All participants are also required to wake up between the hours of 06:00am and 09:00am the morning of taking part in the experiment.

If you have any queries on the above, please do not hesitate to ask.

Thank you for your time and I look forward to seeing you tomorrow,

11.3 Appendix C - Word List Recall

Word List Recall:

These are the 20 words which were verbally presented to participants on an audio clip:

Missile
Mucus
Locker
Leopard
Sunburn
Monarch
Icebox
Infant
Hostage
Pudding
Cowhide
Slipper
Banner
Socket
Piano
Saloon
Bullet
Doorman
Ankle
Sofa

Reference: Green, A. L., & Helton, W. S. (2011). Dual-task performance during a climbing traverse. Experimental Brain Research, 215(3-4), 307-313.

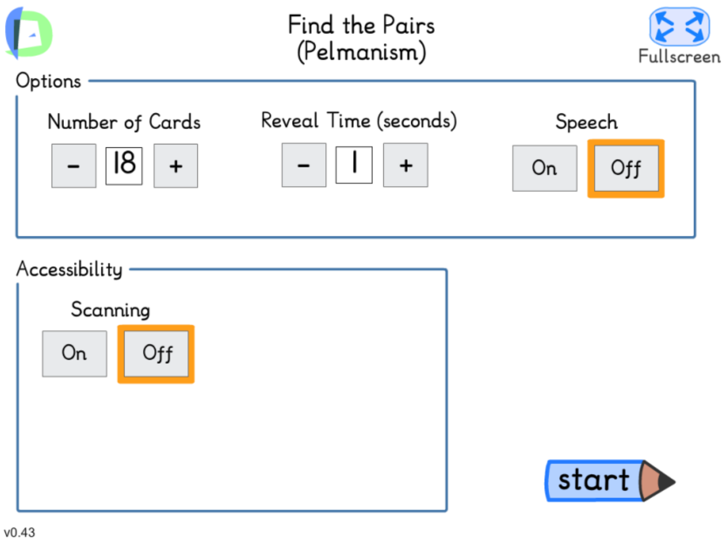
11.4 Appendix D - Pelmanism Task

Pelmanism Task:

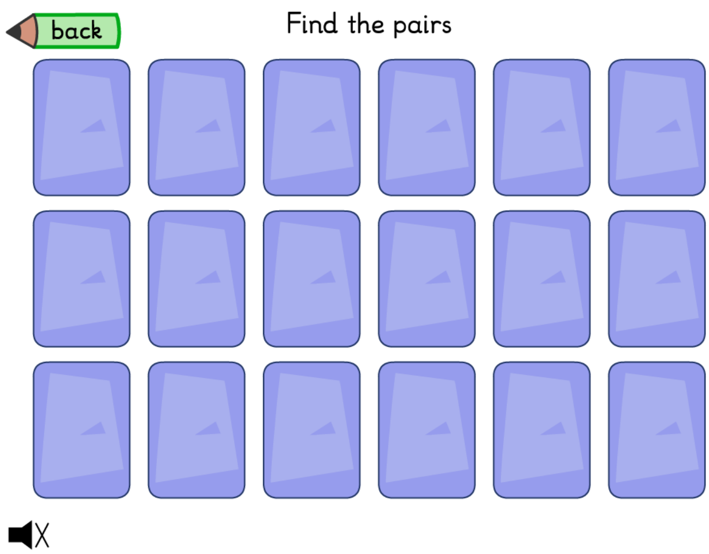
Verbal Instructions given to the participant:

This is the Pelmanism game whereby you will be presented with 18 cards which are faced job and your task is to find the 9 pairs as fast as you can. (An example was then shown to the participant). Do you have any questions?

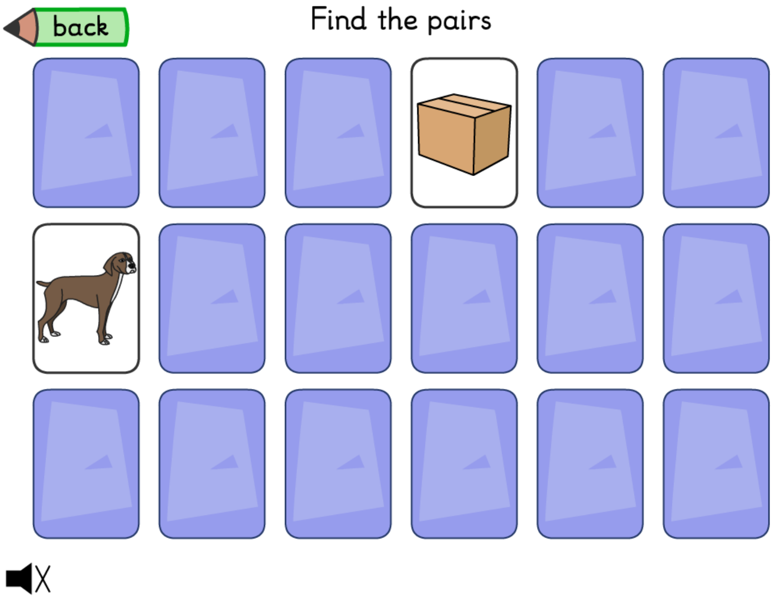
The options to ensure that the number of cards and reveal time was controlled:



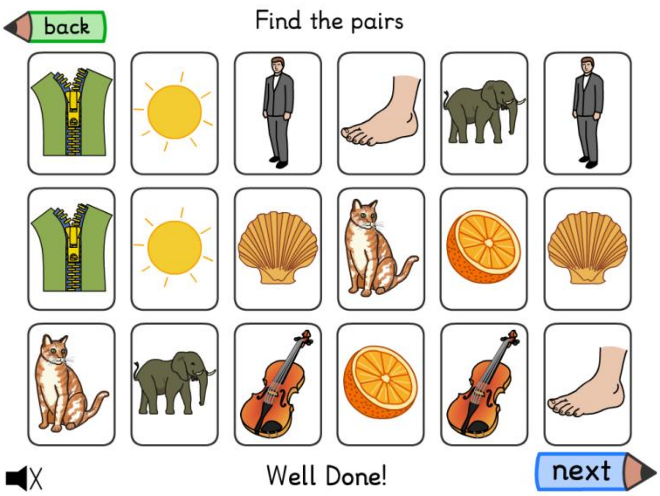
The beginning of the task:



An example of a pair error:



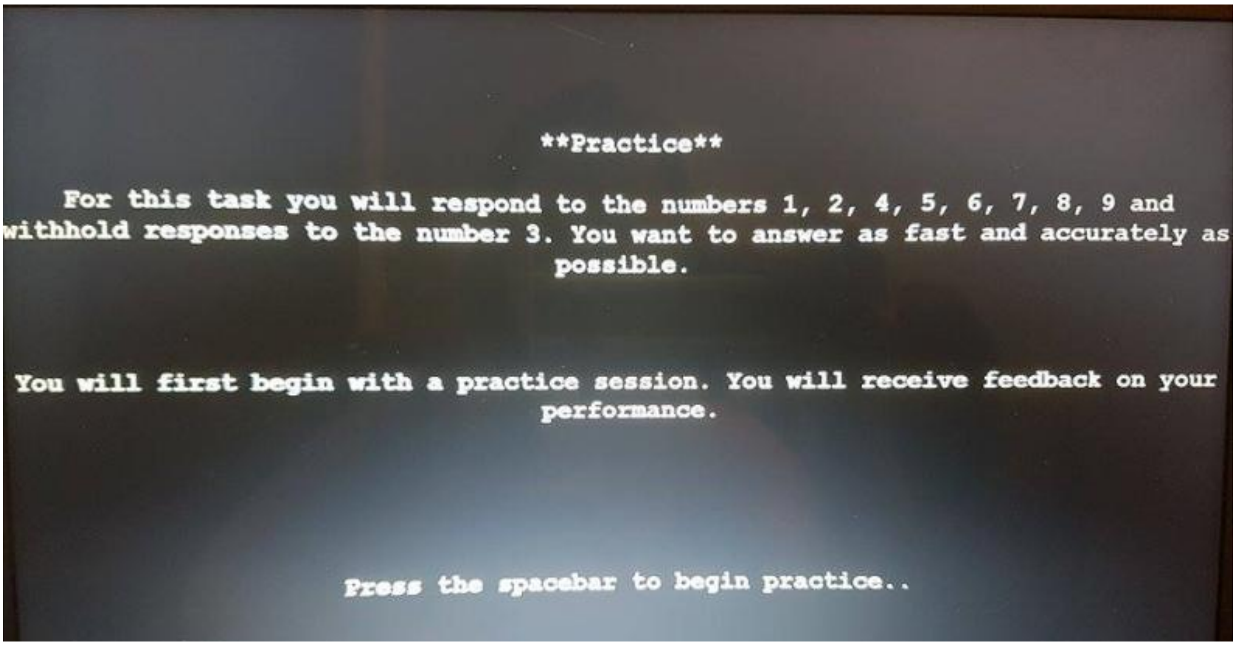
The task once it is complete:



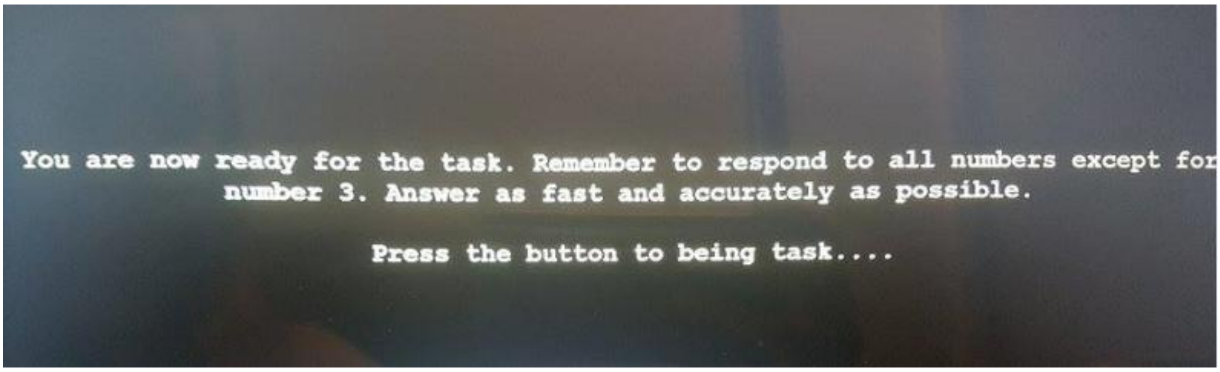
Reference: Doorway Online (n.d.). *Find the Pairs – Pelmanism*. Retrieved from: http://www.doorwayonline.org.uk/memoryandmatching/findthepairs/

11.5 Appendix E - Sustained Attention to Response Task

Instructions for trail:

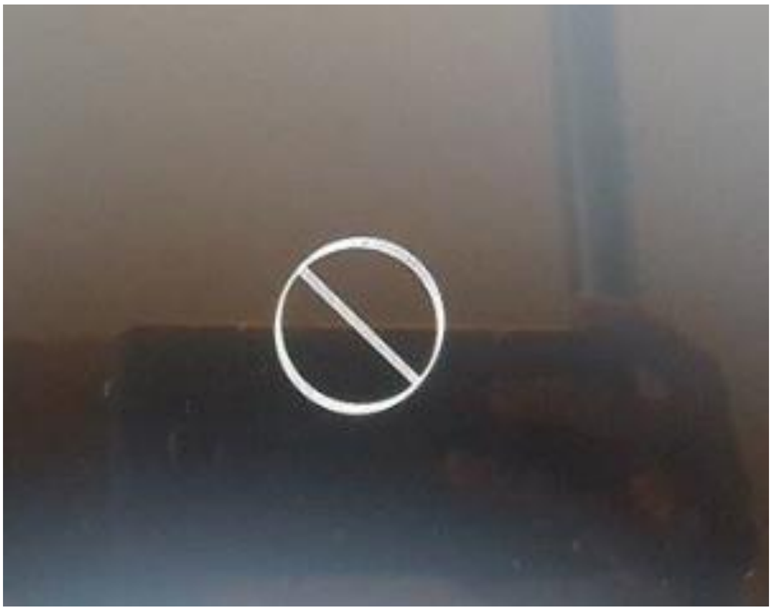


Instructions after the trail:



The numbers are presented to the participant as follows:

The pause in between number is presented to participants as follows:



Reference: Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). Oops!': performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*(6), 747-758.

11.6 Appendix F - Information Sheet for power nappers

Information sheet for participants who engaged in a power nap during the experiment:

Participation information sheet

Study Title
An investigation into the effects of sleep time and power napping on memory and vigilance.

Invitation paragraph
This information sheet will inform you of what the experiment will entail and the reasons for your participation. This experiment is to help me complete my Masters degree at the University of Huddersfield. Please read this information sheet carefully and if you have any questions do not hesitate to ask.

What is the purpose of the study?
I am undertaking this research to investigate the effects of sleep time and power napping on memory and vigilance.

Do I have to take part?
It is entirely your choice if you want to take part in the experiment and you do have the right to withdraw from the experiment at any time.

What will happen to me if I take part?
The study should last no more than one hour and it will just be a one off experiment which will include one questionnaire, a twenty minute nap, two memory tests and an attention test.

What are the possible benefits of taking part?

Taking part in this experiment does not have any direct benefits, however it will give you experience in taking part in a psychological experiment and it will give you the knowledge on how a psychological experiment is conducted.

What is the process of the experiment?

At the beginning of the experiment you will be presented with an informed consent sheet which will allow you to tick whether you agree to take part. At this point you will be given the opportunity to ask any questions. Once you have given written informed consent to take part in the experiment you will be given a short questionnaire which will need to be filled out at the beginning of the experiment. You will then be required to make a twenty minute nap in a quiet and controlled environment to help you relax for the experiment. After the nap you will then complete two memory tests and an attention test which will be fully explained to you before each task, and again you will be able to ask any questions. Finally, you will then be given a debrief form which will include the nature of the experiment and the reasons for your participation. You will also be given another opportunity to ask any further questions that you may have.

If you are wanting a copy of the final results of the experiment, you will be given a chance to provide your email address upon the debrief. The results of the study will be kept in a password protected folder and each participant will be referenced by participant number, and therefore no-one will be able to identify which results have come from which participants.

Will my taking part in the study be kept confidential?

The information that you provide today will be kept confidential under the Data Protection Act 1998. Only the researcher and personal tutor will be able to see the data that is collected and after the write up of the experiment has been completed all the data will be shredded. A final copy of the results will be sent to participants who request a copy, however this will just include the final statistics of the experiment, and will not include any participants' identity being compromised.

Exclusion criteria

All participants must have woke up between the hours of 06:00am and 09:00am this morning, prior to taking part in this experiment. Moreover, all participants be above the age of 18 and below the age of 45 and any participants with sleep disorders will be excluded from the experiment. Also, participants who work night shifts and have mental disorders, for example anyone required to take medicine that could affect sleep will also be excluded from the experiment.

11.7 Appendix G - Information Sheet for non-power nappers

Information sheet for participants who did not engage in a power nap during the experiment

Participation information sheet

Study Title
An investigation into the effects of sleep time and power napping on memory and vigilance.

Invitation paragraph
This information sheet will inform you of what the experiment will entail and the reasons for your participation. This experiment is to help me complete my Masters degree at the University of Huddersfield. Please read this information sheet carefully and if you have any questions do not hesitate to ask.

What is the purpose of the study?
I am undertaking this research to investigate the effects of sleep time and power napping on memory and vigilance.

Do I have to take part?
It is entirely your choice if you want to take part in the experiment and you do have the right to withdraw from the experiment at any time.

What will happen to me if I take part?
The study should last no more than one hour and it will just be a one off experiment which will include one questionnaire, a twenty minutes relaxing period which will involve reading some magazines, two memory tests and an attention test.

What are the possible benefits of taking part?
Taking part in this experiment does not have any direct benefits, however it will give you experience in taking part in a psychological experiment and it will give you the knowledge on how a psychological experiment is conducted.

What is the process of the experiment?

At the beginning of the experiment you will be presented with an informed consent sheet which will allow you to tick whether you agree to take part. At this point you will be given the opportunity to ask any questions. Once you have given written informed consent to take part in the experiment you will be given a short questionnaire which will be filled out at the beginning. You will then have a twenty minute relaxing period which will involve you reading magazines. You will then be required to complete two memory tests and an attention test which will be explained fully to you before each task, and again you will be able to ask any questions. Finally, you will then be given a debrief form which will include the nature of the experiment and the reasons for your participation. You will also be given another opportunity to ask any further questions that you may have.

Will my taking part in the study be kept confidential?

The information that you provide today will be kept confidential under the Data Protection Act 1998. Only the researcher and personal tutor will be able to see the data that is collected and after the write up of the experiment has been completed all the data will be shredded. A final copy of the results will be sent to participants who request a copy, however this will just include the final statistics of the experiment, and will not include any participants' identity being compromised.

Exclusion criteria

All participants must have woke up between the hours of 06:00am and 09:00am this morning, prior to taking part in this experiment. Moreover, all participants be above the age of 18 and below the age of 45 and any participants with sleep disorders will be excluded from the experiment. Also, participants who work night shifts and have mental disorders, for example anyone required to take medicine that could affect sleep will also be excluded from the experiment.

11.8 Appendix H - Consent Form

Consent Form

Material gathered during this research will be treated as confidential and securely stored.

Please answer each statement concerning the collection and use of the research data.

I have read and understood the information sheet.	Yes		No	
I have been given the opportunity to ask questions about the study.	Yes		No	
I have had my questions answered satisfactorily.	Yes		No	
I understand that I can request a copy of the final results of the experiment.	Yes		No	
I understand that I can withdraw from the study at any time without having to give an explanation.	Yes		No	
I understand that my identity will be protected and that all data will be anonymous.	Yes		No	

Participant

Name

____

Signature

____

Date

____

Researcher(s) signature:		Date:	

11.9 Appendix I - Questionnaire

Questionnaire

Do you have any sleep disorders which prevent you from sleeping naturally?

Yes	No

If you stated yes to the above question, please elaborate.

____

____

____

____

How many hours of sleep, on average, do you have per night?

0 hours	1-2 hours	3-4 hours	5-6 hours	7-8 hours	9-10 hours	11 + hours

How many hours of sleep did you have last night?

0 hours	1-2 hours	3-4 hours	5-6 hours	7-8 hours	9-10 hours	11 + hours

What time did you go to sleep last night?

17:00pm-19:00pm	19:01pm-21:00pm	21:01pm-23:00am	23:01am-12:00am	12:01am-01:00am	01:01am-03:00am	03:01am-05:00am	05:01am-07:00am	07:01am or later

Did you wake up between 6:00am and 9:00am this morning?

Yes	No

On average, how many naps do you have per day?

0	1-2	2-3	4+

If applicable, how long do your naps last on average?

0-10 minutes	11-twenty minutes	21-30 minutes	31-40 minutes	41-50 minutes	51-60 minutes	Over 60 minutes

11.10 Appendix J - Debrief Form

Debriefing for a study on the effects of sleep time and power napping on memory and vigilance.

Thank you very much for taking part in this research.

This study was an investigation into the effects of sleep time and power napping on memory and vigilance. It has been found that the time in which individuals go to sleep impacts on memory and vigilance. Specifically, it has been found that individuals who go to sleep before midnight has significantly increased scores on memory and vigilance, compared to participants who go to sleep after midnight. Research has also found that power napping for twenty minutes a day significantly increases memory and vigilance. The beginning questionnaire which you completed was to distinguish the time in which you go to sleep and how many naps you have, on average, on a daily basis, and how long the naps last for. Some of you then went on to have a twenty minute power nap whilst the rest had a twenty minute relaxation period whilst reading magazines. You then went on to complete a verbal recall memory test (the word list recall test) and a visual recognition test (Pelmanism test) which tested visual and auditory memory. After this, you then completed the Sustained Attention to Response Test which measured your vigilance. This was to investigate whether having a power nap does significantly increase memory and vigilance, compared to participants who doesn't have a power nap. Consistent with prior research, this study should find that participants who went to sleep before midnight will have significantly increased scores on both memory tests and the vigilance test, in comparison to participants who went to sleep after midnight. Also, this experiment should find that the participants who have a power nap prior to the experiment should have significantly increased scores on both memory tests and the vigilance test, compared to participants who did not have a twenty minute power nap prior to the experiment. Moreover, this study will also examine whether a twenty minute power nap will increase scores on both memory tests and the vigilance test in participants who go to sleep after midnight, compared to participants who go to sleep before midnight. This will then demonstrate that a power nap can increase scores significantly on memory and vigilance, despite the time that participants go to sleep.

If you would like to receive a copy of the overall final results of this study, please provide your email address below. The results of this experiment will be kept within a password protected folder and will only be used for the benefits of this research. Each participant will remain confidential, and therefore, no-one will receive personal results, instead you will just receive the overall findings of the study.

Email Address ____

If you have any concerns regarding this study please contact the University of Huddersfield counselling services on ipoint@hud.ac.uk or my research supervisor, Dr David Peebles on the following e-mail address (d.peebles@hud.ac.uk) if you have any problems regarding this study.

THANK YOU AGAIN FOR TAKING PART IN THIS EXPERIMENT.

11.11 Appendix K - Ethics Form

THE UNIVERSITY OF HUDDERSFIELD

School of Human and Health Sciences – School Research Ethics Panel

APPLICATION FORM

Please complete and return via email to:

Kirsty Thomson SREP Administrator: hhs_srep@hud.ac.uk

Name of applicant: Stephanie Ann Dennison

Title of study: The effect of sleep time and power napping on memory and vigilance

Department: School of Health and Health Sciences Date sent: 13 December, 2016

Please provide sufficient detail below for SREP to assess the ethical conduct of your research. You should consult the guidance on filling out this form and applying to SREP at http://www.hud.ac.uk/hhs/research/srep/.

Researcher(s) details	Stephanie Ann Dennison Stephanie.dennison@hud.ac.uk
Supervisor(s) details	David Peebles d.peebles@hud.ac.uk Kagari Shibazaki K.Shibazaki@hud.ac.uk
All documentation has been read by supervisor (where applicable)	**YES** This proposal will not be considered unless the supervisor has submitted a report confirming that (s)he has read all documents and supports their submission to SREP
Aim / objectives	To investigate the effects of sleep time and power napping on memory and vigilance.

Brief overview of research methods	This experiment will be an independent groups design with two main conditions involving 80 participants (40 participants who go to bed early (before midnight) and 40 participants who go to bed late (after midnight)). These conditions will be split into a further two sub conditions involving 20 participants who take a 20 minute power nap during the experiment and 20 participants who do not take a 20 minute power nap during the experiment. Participants will be a mixture of males and females aged between 18 to 45.. Participants who work night shifts and participants with mental health and / or sleep disorders will excluded from the experiment. All participants will be given an information sheet outlining what the experiment entails and they will then be required to give informed consent prior to taking part in the experiment. Twenty participants from each condition will then take a 20 minute power nap in the experiment room, whilst the other 20 participants from each condition will be required to read a magazine for 20 minutes. This is to eliminate the confounding variable of the time spent in the experiment room. Participants will then be asked to complete the Sustained Attention to Response Test (SART). The SART involves participants sustaining attention to infrequent and unpredictable stimuli. The procedure involves numbers 1 to 9 appearing 225 times in a random order and in different fonts in a white front, on a black computer screen. Each time a number appears, the participant is required to press a button before the next number appears, except when a number 3 appears. Number 3 appears 25 in total and participants must sustain their attention to ensure that they do not press the button when number 3 is on the screen. Once the SART is completed, participants will then go on to complete two memory tasks. Both memory tests will test for short-term memory with one measuring visual short-term memory and the other one measuring auditory short-term memory. The memory test which will be measuring auditory short term memory will involve the recall memory test, which is where participants will be required to listen to a set of twenty words and will be asked to remember each word in order, and the number of words accurately repeated will be recorded. The second memory test will be measuring short-term visual memory

Project start date	19th September 2016.
Project completion date	18th September 2017.
Permissions for study	Not Applicable.
Access to participants	Through SONA participation online system and friends and colleagues.
Confidentiality	I will not obtain participants' name in any part of the experiment and will not include any personal information in the experiment that can lead to their identity.
Anonymity	I will uphold the anonymity of the participants by not obtaining their name in any part of the experiment and by not including any personal information in the experiment that can lead to their identity. The information gathered will purely be used for research purposes and will not passed on to any third parties.
Right to withdraw	I will be informing the participants at the beginning of the study that they have the right to withdraw from the experiment at any time without giving a reason. They will also be made aware that any data collected from them will be removed appropriately by shredding any paperwork and permanently deleting any files that contain data that has been produced by them on the computer.
Data Storage	All data will be stored on my personal laptop in a work folder which is password protected so no other individual can gain access to the data. However, if a participant withdraws from the experiment, despite the stage that they have withdrawn from the experiment, the data file will be permanently deleted.
Psychological support for participants	I will ensure that there are no potential risks to the psychological well-being, physical health, personal values and dignity of the participants. The participants can also withdraw from the experiment at any time and refuse to answer any questions that they do not want to answer. If any of the participants feel that they have experienced any harm in any way during the experiment then they will be given information about the relevant University services that can help, such as the counselling service.

Researcher safety / support (attach completed University Risk Analysis and Management form)	Attached.
Information sheet	Attached.
Consent form	Attached.
Letters / posters / flyers	Not Applicable.
Questionnaire / Interview guide	Attached.
Debrief (if appropriate)	All participants will be debriefed after the experiment which will include outlining the outcomes of their participation and the nature of the experiment. All results will be made available to all participants upon request. At the end of the debrief form, participants will have the opportunity to request for a copy of the results. If they choose to receive the results they will be asked to provide their email address by which the results will be sent via. The results given to the participants will be a overall analysis of all participants taken part in the experiment, however no information which could lead to participants' identity will be included.
Dissemination of results	If participants withdraw from the experiment, all data will be permanently deleted from the computer file, and all paperwork will be shredded. Furthermore, after the results have been analysed, participants will be able to observe the findings of the study they participated in and all results will be saved in a password protected folder on a personal laptop.
Identify any potential conflicts of interest	Not Applicable

Does the research involve accessing data or visiting websites that could constitute a legal and/or reputational risk to yourself or the University if misconstrued? Please state: No If Yes, please explain how you will minimise this risk	No.
The next four questions in the grey boxes relate to Security Sensitive Information – please read the following guidance before completing these questions: http://www.universitiesuk.ac.uk/policy-and-analysis/reports/Documents/2012/oversight-of-security-sensitive-research-material.pdf	
Is the research commissioned by, or on behalf of the military or the intelligence services? Please state No If Yes, please outline the requirements from the funding body regarding the collection and storage of Security Sensitive Data	No.
Is the research commissioned under an EU security call Please state: No If Yes, please outline the requirements from the funding body regarding the collection and storage of Security Sensitive Data	No.

Does the research involve the acquisition of security clearances? Please state No If Yes, please outline how your data collection and storages complies with the requirements of these clearances	No.
Does the research concern terrorist or extreme groups? Please state No If Yes, please complete a Security Sensitive Information Declaration Form	No.
Does the research involve covert information gathering or active deception? Please state Yes/No	No.
Does the research involve children under 18 or participants who may be unable to give fully informed consent? Please state Yes/No	No.
Does the research involve prisoners or others in custodial care (e.g. young offenders)? Please state Yes/No	No.

Does the research involve significantly increased danger of physical or psychological harm or risk of significant discomfort for the researcher(s) and/or the participant(s), either from the research process or from the publication of findings? Please state Yes/No	No.
Does the research involve risk of unplanned disclosure of information you would be obliged to act on? Please state Yes/No	No.
Other issues	Not Applicable.
Where application is to be made to NHS Research Ethics Committee / External Agencies	Not Applicable.
Please supply copies of all relevant supporting documentation electronically. If this is not available electronically, please provide explanation and supply hard copy	

All documentation must be submitted to the SREP administrator. All proposals will be reviewed by two members of SREP.

If you have any queries relating to the completion of this form or any other queries relating to SREP's consideration of this proposal, please contact the SREP administrator (Kirsty Thomson) in the first instance – hhs_srep@hud.ac.uk

11.12 Appendix L - Ethics Approval

Your SREP Application - Stephanie Dennison (MSc by Res) - APPROVED - The effect of sleep time and power napping on memory and vigilance - SREP/2016/107

SE

SHUM Research Ethics

Wed 01/02, 11:13

Stephanie Dennison (Researcher); David Peebles; Kagari Shibazaki

Reply all |

Inbox

Dear Stephanie,

The reviewers of your SREP application have advised that you have addressed the issues raised to their satisfaction and I can confirm that your SREP application as detailed above has now been **approved outright.**

With best wishes for the success of your research project.

Regards,

Kirsty
(on behalf of SREP)

Ethics 1 of 1

11.13 Appendix M - Risk Analysis & Management

THE UNIVERSITY OF HUDDERSFIELD: RISK ANALYSIS & MANAGEMENT

ACTIVITY: Psychological Research			Name: Stephanie Dennison	
LOCATION: University of Huddersfield			Date: 10/12/2016	Review Date: 30/01/2017
Hazard(s) Identified	**Details of Risk(s)**	**People at Risk**	**Risk management measures**	**Other comments**
Conducting the experiment as a lone worker in an experiment room.	Personal Safety	Researcher	• Log the dates and times of the experiment. • Inform a member of staff at the University of Huddersfield the times that I will be in the experiment room to and from, for example 9am - 17:00pm.	
Display Screen Equipment	Poor posture sat working for prolonged periods resulting in musculoskeletal problems, visual / physical fatigue.	Researcher	• All workstations subject to DSE assessment process.	
Fire Safety	In the event of a fire.	Researcher and Participants	• All participants will be made aware of the fire exists in the building and no materials will be obstructing the exists within the experiment room at any time.	
Loss / theft of data	Security of data.	Participants	• Electronic data will be stored only on password secured computer equipment and storage devises. • Paperwork will be in a folder which will be stored in a lockable case.	All data will be transported in the boot of a car and will not be left unattended at any time.