



Faculty of Cognitive Sciences and Human Development

**THE RELATIONSHIP BETWEEN SLEEP QUALITY AND
VERBAL AND VISUAL WORKING MEMORY PERFORMANCE**

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ABSTRACT

The study aimed to identify the relationship between sleep quality and both verbal and visual working memory performance among undergraduate students at the Universiti Malaysia Sarawak (UNIMAS). Utilising a correlational research design, the study involved 30 participants who completed the Pittsburgh Sleep Quality Index (PSQI) to assess their sleep quality, the Reading Span Task (RSPAN) for verbal working memory, and Sternberg's Search Task for visual working memory. The data were analyzed using Pearson correlation to determine the strength and direction of the relationships. Results indicated a significant positive correlation between sleep quality and verbal working memory performance, suggesting that better sleep quality was associated with improved verbal working memory. Conversely, a weaker, though still positive, correlation was observed between sleep quality and visual working memory. These findings highlighted the critical role of sleep in cognitive functions, particularly in verbal memory processes. The study contributed to the broader understanding of how sleep affected different types of working memory and underscored the importance of good sleep hygiene for cognitive health. Future research should explore the underlying mechanisms of these relationships and consider longitudinal designs to examine causal links.

Keywords: Sleep Quality, Verbal working memory, Visual working memory, University students

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter discusses the study's background, problem statement, research objectives, research questions, research hypotheses, conceptual framework, and significance of the study. Furthermore, the present chapter also defines terms and concludes with a summary.

1.1 Background of Study

Sleep is a complex and dynamic process which is the state of decreased reactivity to outside stimuli and relative inactivity, along with a loss of consciousness in humans and other animals (Rasch & Born, 2013). According to Patel et al. (2022), sleep consists of a few stages that are classified into non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep. The first three stages are considered non-rapid eye movement (NREM) sleep, which are stage 1 (light sleep), stage 2 (intermediate sleep), and stage 3 (deep or slow-wave sleep). The last stage is called rapid eye movement (REM) sleep, the stage where most dreaming occurs and is associated with high brain activity, followed by bodily restorative processes and relaxation. Rasch & Born (2013) believed that both REM and NREM sleep are involved in memory consolidation, which is the process of transferring new information from short-term to long-term memory. While memory consolidation occurs during both NREM and REM sleep, different types of memory may benefit from different sleep stages. For instance, they mentioned that declarative memory is mainly consolidated during slow-wave sleep while procedural memory is mainly consolidated during REM sleep.

Additionally, sleep quality is a term that refers to how well you sleep, in terms of both quantity and quality. The concept of sleep quality encompasses an individual's contentment with the overall experience of sleeping or subjective evaluation of how well one sleeps, integrating sleep duration, sleep efficiency, sleep onset latency, sleep disturbances, and daytime functioning (Kline, 2013). Adequate and restorative sleep is known to promote cognitive functioning, whereas poor sleep quality, characterized by difficulties falling asleep, frequent awakenings during the night, or insufficient total sleep duration, can impair cognitive performance. For instance, a study published in the *Journal of Sleep Research* suggests that working memory, an essential cognitive function for rationality and strategic planning, can be significantly compromised after a single night of sleep deprivation (Rångtell et al., 2019). Moreover, Suardiaz-Muro et al. (2023) indicated that working memory is the ability to maintain and manipulate information in a short-term memory buffer for immediate use or further processing. Therefore, it can be inferred that working memory is critical for college students as it is vital for academic achievement.

Working memory can be divided into essential two subsystems. First, is verbal working memory, and the second is visual working memory. Verbal working memory deals with the processing of verbal or linguistic information, such as words, numbers, or letters. Next, visual working memory deals with the processing of visual or spatial information, such as shapes, colours, faces, or locations. Both verbal and visual working memory are influenced by various factors, such as age, gender, education, intelligence, motivation, attention, emotion, and stress (Larrabee & Curtiss, 1995). Working memory, comprising verbal and visual working memory, is particularly significant when it comes to academic achievement since it deals with reading comprehension, mental arithmetic, word problems, language, and other related topics (Alloway & Copello, 2013). For instance, mathematics abilities are

tightly correlated with verbal and visuospatial memory. However, as kids hit puberty, it has less of an impact on their ability to use maths (Alloway & Copello, 2013). Visual working memory involves the temporary storage and manipulation of visual or spatial information, whereas verbal working memory pertains to the temporary retention and processing of linguistic or verbal content (Kawashima & Matsumoto, 2016).

Given the multifaceted nature of academic tasks, which often involve a combination of visual and verbal information, understanding the factors that can impact the functioning of these memory systems among university students is of paramount significance. However, the interrelationship and reciprocity between sleep quality and working memory performance from an alternative standpoint. In other words, poor sleep quality has the potential to negatively impact working memory performance through its influence on memory consolidation, retrieval, and imprinting. Conversely, the quality of sleep may be impacted by working memory performance through its influence on the cognitive and affective regulation of sleep. A high workload on the working memory, for instance, may heighten levels of arousal and tension, both of which can disrupt the initiation and maintenance of brain processes, including sleep (Wang et al., 2022). Moreover, the relationship between sleep quality and working memory performance may also vary depending on the type of working memory. Verbal working memory and visual working memory may have different sensitivity and specificity to sleep quality. For example, verbal working memory may be more affected by sleep deprivation than visual working memory, as verbal working memory relies more on the prefrontal cortex, which is more vulnerable to sleep loss. According to Mu et al. (2005), verbal working memory relies more on the prefrontal cortex, parietal cortex, and other brain regions that exhibit significant sleep-deprivation vulnerability. In addition, sleep deprivation

impaired the performance of the verbal working memory task, as indicated by slower reaction times and more errors.

Overall, sleep quality and working memory performance are intricately intertwined and mutually influential. Sleep quality may be further compromised due to academic demands, irregular schedules, and lifestyle choices among university students. For example, approximately 50% of college students complained of sleepiness during the daytime, and around 70% of college students are sleep-deprived (Hershner & Chervin, 2014). Consequently, numerous psychological processes—including memory, learning, emotion, cognition, and behaviour—may be influenced by sleep and sleep quality. Due to their fundamental nature in information processing, problem-solving, and learning, cognitive processes such as working memory are vital to the academic endeavours of university students as proven by MIT professors who found a positive relationship between sleep and test scores (Okano et al., 2019). One of the most significant advantages of sleep is its capacity to improve cognitive functioning, particularly in the domains of learning and memory (Phang & Man, 2021). Verbal working memory and visual working memory may have different patterns of association with sleep quality. For instance, Rana et al. (2018) found that sleep quality can affect visual-spatial working memory, but no correlation when tested with verbal working memory. Regardless, this indicates that improving sleep quality and working memory performance may have beneficial effects on academic achievement and well-being. However, the relationship between sleep quality and cognitive function has been extensively investigated in various populations, there is a paucity of research that focuses on the specific context of university students, especially within the Malaysian academic setting. Thus, this study aims to address this research gap by examining the relationship between sleep quality

and the performance of both visual and verbal working memory tasks among undergraduate students.

1.2 Problem Statement

Sleep quality is a vital determinant of cognitive performance, especially for students who need to process and retain large amounts of information. Among the various cognitive functions, working memory plays a crucial role in academic performance, as it enables students to manipulate and store information in the short term. However, working memory is also susceptible to the effects of sleep quality, which can vary depending on various factors, such as academic demands, social activities, and lifestyle habits. University students, in particular, face many challenges and opportunities that can affect their sleep quality and, consequently, their working memory performance. Therefore, this study aims to investigate how sleep quality affects the visual and verbal working memory performance of undergraduate students.

Previous research has established the significance of sleep quality and working memory in the context of academic success, but there are still some gaps and limitations in the existing literature. First, most of the studies have focused on Western student populations, which may not reflect the specific socio-cultural and academic conditions of Malaysian students (YX & WY, 2022). Malaysia has a distinct educational environment that may introduce unique variables that can influence the relationship between sleep quality and working memory. Besides, tailoring investigations to this specific demographic which is university students is indispensable for generating insights and interventions. Malaysian university students encounter various factors that can potentially compromise their sleep quality and working memory performance. As demonstrated by YX & WY (2022), some of

these factors include irregular academic schedules, heavy workloads, high competition, social pressure, cultural diversity, and lifestyle habits. These factors can cause stress, anxiety, depression, insomnia, and other sleep disorders, which can impair the functioning of the brain regions involved in working memory. Moreover, these factors can also affect the quality and quantity of sleep, which can influence the consolidation and retrieval of information in working memory. As shown by Paller (2004), sleep cognition has the potential to augment memory consolidation via the establishment of novel connections among memory fragments, integration with pre-existing stored information, and alignment with overarching long-term objectives and strategies. Therefore, there is a need for more Malaysian-centric research that can address the cognitive well-being and academic achievement of Malaysian undergraduate students.

Secondly, most of the studies have not differentiated between the two types of working memory: visual and verbal. Visual and verbal working memory are two distinct subsystems of working memory that process and store different types of information (Cronin et al., 2020). Visual working memory deals with visual information, such as shapes, colours, and spatial locations, while verbal working memory deals with verbal information, such as words, numbers, and sounds. These two types of working memory rely on different brain regions and neural pathways and may have different functions and capacities (Chai et al., 2018). Therefore, sleep quality may possibly have different effects on visual and verbal working memory, depending on the type and duration of sleep, the stage of sleep, and the nature of the information. For instance, some studies have suggested that visual working memory may benefit more from slow-wave sleep, while verbal working memory may benefit more from rapid eye movement sleep. However, there is a lack of empirical evidence to support these claims, especially among Malaysian university students. These two types of

working memory may have different mechanisms and functions and may be affected differently by sleep quality. Therefore, there is a need for a more comprehensive and nuanced analysis of how sleep quality influences both visual and verbal working memory in university students.

As a result, this study aims to fill these gaps and limitations by investigating the direct impact of sleep quality on visual and verbal working memory among University of Malaysia students. By exploring the relationship within this specific academic context, we seek to provide a deeper understanding of the dynamics of sleep quality and its implications for cognitive performance. The outcomes of this study are expected to contribute to the academic and cognitive well-being of university students in Malaysia and may create interventions designed to optimize their educational experience.

1.3 Research Objectives

1.3.1 General Objective

To identify the relationship between sleep quality and working memory performance among UNIMAS undergraduate students.

1.3.2 Specific Objectives

- a. To identify the relationship between sleep quality and verbal working memory performance based on total correct recall.
- b. To identify the relationship between sleep quality and verbal working memory performance based on total time taken.
- c. To identify the relationship between sleep quality and visual working memory performance based on total correct recall.

- d. To identify the relationship between sleep quality and visual working memory performance based on total time taken.

1.4 Research Questions

1. Is there any relationship between sleep quality and verbal working memory performance based on total correct recall?
2. Is there any relationship between sleep quality and verbal working memory performance based on total time taken?
3. Is there any relationship between sleep quality and visual working memory performance based on total correct recall?
4. Is there any relationship between sleep quality and visual working memory performance based on the total time taken?

1.5 Research Hypotheses

- H₁: There is a significant relationship between sleep quality and verbal working memory performance based on the total correct recall.
- H₂: There is a significant relationship between sleep quality and verbal working memory performance based on the total time taken.
- H₃: There is a significant relationship between sleep quality and visual working memory performance based on the total correct recall.
- H₄: There is a significant relationship between sleep quality and visual working memory performance based on the total time taken.

1.6 Conceptual Framework

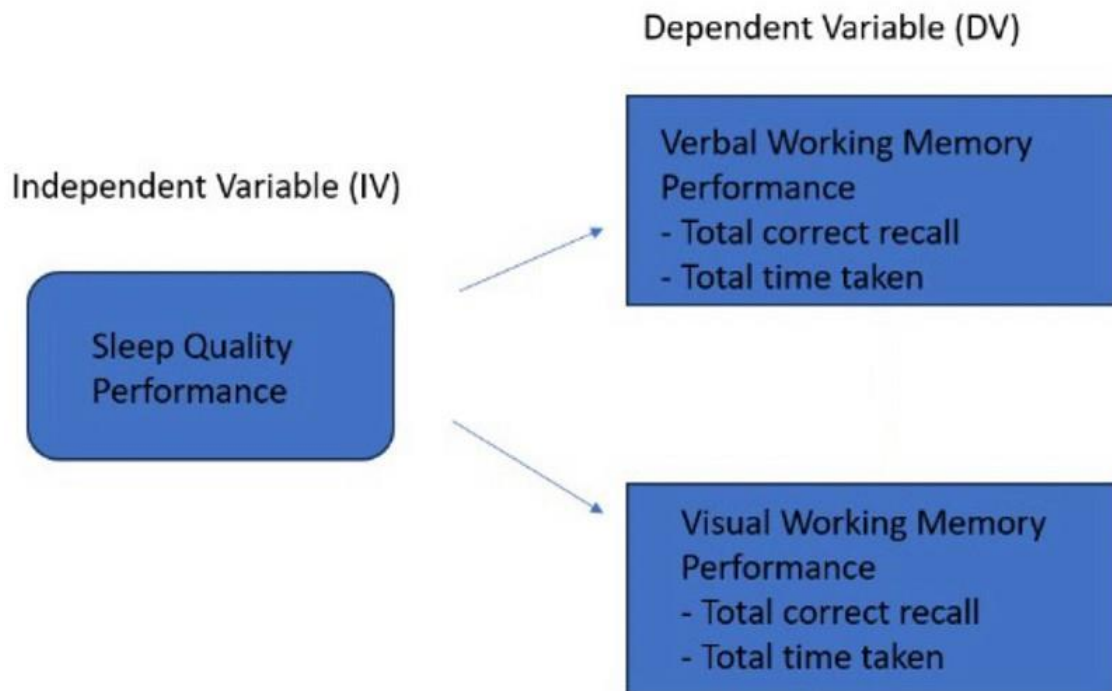


Figure 1. *Conceptual Framework*

The conceptual framework depicted in Figure 1 has been constructed through a comprehensive examination of existing literature, which will assess the relationship between sleep quality and verbal and visual working memory performance through the Reading Span Task (RSPAN) and Sternberg Search Task respectively. It serves as a basis for structuring the ongoing research, while also facilitating the identification and analysis of areas that require further exploration.

1.7 Significance of the Study

The quality of sleep and its effects on cognitive performance are vital topics of research, especially for university students who need to process and retain large amounts of information. However, there is a lack of research on how sleep quality influences the performance of visual and verbal working memory, which are two distinct types of working

memory that process and store different types of information. Moreover, most of the existing studies have focused on Western populations, which may not capture the unique cultural, social, and academic factors that influence the sleep and cognitive patterns of Malaysian students. Therefore, this study aims to examine the relationship between sleep quality and visual and verbal working memory performance among University of Malaysia, Sarawak (UNIMAS) students.

This study has theoretical significance, as it contributes to the existing body of theories in the field of cognitive psychology and educational psychology. By investigating how sleep quality influences the performance of visual and verbal working memory, this study can provide new insights or perspectives on the mechanisms and functions of these two types of working memory, and how they are affected by different factors, such as the type and duration of sleep, the stage of sleep, and the nature of the information. This study can also confirm, refute, or add nuance to the currently accepted theories, or propose new theories that can explain the relationship between sleep quality and working memory.

Moreover, this study also has practical significance, as it has direct implications and applications for real-world contexts, such as improving the cognitive well-being and academic success of UNIMAS students. By identifying the relationship between sleep quality and verbal and visual working memory performance among undergraduate students, this study can offer potential solutions or strategies that can enhance their sleep habits and cognitive capacities. For example, this study can provide personalized recommendations, implement policies and programs, or raise awareness and education on the importance of sleep quality and working memory for academic performance. Furthermore, this study can

also benefit other stakeholders, such as educators, psychologists, and policymakers, who are interested in promoting cognitive health and academic excellence among university students.

In summary, this study has multifaceted significance, as it addresses the specific needs of the Malaysian university student population while also contributing to the broader academic and policy discourse. The outcomes of this study are expected to make a meaningful contribution to the mental health, education, and academic research domains, especially in the Malaysian context.

1.8 Definition of Terms

1.8.1 Sleep Quality

Conceptual Definition:

The term "sleep quality" can encompass a range of sleep metrics, including the degree of fragmentation, total wake time, sleep onset latency (SOL), spontaneous arousals, apnea, and disruptive sleep events like spontaneous arousals (Krystal & Edinger, 2008).

Operational Definition:

The current study will employ the Pittsburgh Sleep Quality Index (PSQI) to evaluate the sleep quality of the participants during the previous month (Buysse et al., 1989). Ten multi-component queries comprise it. The comprehensive index comprises seven subscores, namely Need of Medication to Sleep, Sleep Disturbance, Sleep Latency, Day Dysfunction due to Sleepiness, Sleep Efficiency, and Overall Sleep Quality (for correlations between these subscores and other relevant measures, refer to Supplementary Table S1). As the range of each subscore is from 0 to 3, the total index also spans from 0 to 21. Elevated scores are indicative of poorer sleep quality.

1.8.2 Working Memory

Conceptual Definition:

A few seconds of task-relevant information are stored in working memory (WM), which is accessible to other ongoing mental processes. As a fundamental component of cognition, the quantity of information that can be concurrently retained for a brief duration is significantly constrained by WM (Xie et al., 2019).

Operational Definition:

In this study, WM will be assessed based on verbal WM and visual WM. The verbal WM will be assessed by using the Reading Span Task (RSPAN), while visual WM will be assessed by using Sternberg's Search Task. The performance for both tasks will be based on the total correct recall and total time taken by the participants.

1.9 Summary

This chapter has introduced the topic variables, the background of the study, and the problem statement. Also, the chapter indicates the objectives of the study, research questions, research hypothesis, conceptual framework, and the significance of the study. Last, it also provides the conceptual and operational definitions of the terms.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter provides a concise overview of the basic principles, hypotheses, and empirical findings regarding the correlation between sleep quality and verbal and visual working memory performance. Hence, the objective of this literature review is to investigate and determine whether there is a connection between these two factors. This is done through a thorough analysis of the current research on the relationship between sleep quality and verbal and visual memory. Therefore, this overview is hoped to provide a comprehensive understanding of the issue, identify areas where further research is needed, and set the stage for further examinations of the subject.

2.1 Theories Related to Sleep Quality

2.1.1 Restorative Theory

In the context of sleep quality, the restorative theory is a concept that postulates that sleep is a process of replenishment of the body that allows for the repair and maintenance of biological materials required for bodily functions that are used up from periods of active wakefulness (Brinkman et al., 2023). The basis of the mechanisms behind the idea that sleep is a restorative activity arises from the findings that sleep permits the usage of nutrients consumed for the biosynthesis of essential cellular components. In addition to that, sleep initiates functions of waste removal to be expelled from the body (Vyazovskiy, 2015). In the context of working memory performance, the regenerative processes of sleep refresh the brain's hippocampus, clearing up more space for better memory retrieval and consolidation. Additionally, sleep optimizes neuron connectivity which increases the efficiency of the consolidation and organisation of memories (Newbury et al., 2021). With proper neural

connectivity, the transfer of information to the prefrontal cortex, a brain region essential for working memory, remains intact for the control and manipulation of information that is usually associated with the prefrontal cortex (Verweij et al., 2014).

2.1.2 Brain Plasticity Theory

The brain plasticity theory highlights the significance of sleep in altering the composition and operation of the brain. Sleep facilitates the development and elimination of synapses, the regeneration and maintenance of neurons, and the control of gene activity and protein production in the brain (Kolb & Whishaw, 1998). According to this theory, it elucidates the fundamental role of sleep in consolidating memories, enhancing cognitive function, and learning processes (Sousouri & Huber, 2019). A prominent concept about the impact of sleep on brain plasticity is the synaptic homeostasis hypothesis (Tononi & Cirelli, 2003). In a study by Sousouri & Huber (2019), the synaptic homeostasis hypothesis suggests that the neural network experiences a load-dependent, long-term potentiation (LTP)-like enhancement in synaptic strength (mostly due to synaptic potentiation) during wakefulness, as well as synaptogenesis throughout development. In other words, synaptic potentiation is reflected in the homeostatic regulation of slow-wave activity, which progressively rises as wakefulness duration extends. Therefore, the synaptic homeostasis hypothesis suggests that sleep quality influences synaptic homeostasis, and vice versa. Poor sleep quality may impair the synaptic downscaling process and lead to synaptic overload, impairing cognitive functions such as attention, learning, and memory. Conversely, synaptic overloads may impair sleep quality and increase the need for sleep to restore synaptic balance (Tononi & Cirelli, 2003).

2.2 Sleep Quality

Although the term "sleep quality" is frequently used in academic and medical research, its meaning is still vague and inconsistent. Seven factors are taken into account when evaluating sleep quality by the Pittsburgh Sleep Quality Index (PSQI): sleep latency, duration, habitual sleep efficiency, sleep disturbances, use of sleeping pills, dysfunction during the day, and more subjective measures like feelings of restfulness or depth of sleep (Buysse et al., 1989). Despite this, they acknowledge that it is challenging to quantify the quality of sleep since it varies widely across people and it can be challenging to distinguish between excellent and bad sleep. More recently, sleep efficiency—the ratio of total sleep time to total time in bed—was found to represent one of four distinct elements of sleep quality by Nelson et al. (2021).

Nowadays, sleep has become a widespread concern in the field of public health. The Centres for Disease Control and Prevention (CDC) has published a data brief that offers health information and analysis. In the year 2020, around 14.5% of U.S. adults had difficulty initiating sleep, whilst 17.8% encountered difficulty maintaining sleep regularly or every day throughout the previous 30-day period (Adjaye-Gbewonyo et al., 2022). Other than that, a report published in the Asian Journal of Medicine and Health Sciences revealed that more than half of Malaysian adults suffer from insomnia to varying degrees and some of them (13.6%) have experienced chronic insomnia for more than three months (Nur et al., 2022).

In the context of university students, upon entering college, students often undergo a significant change in their sleep patterns due to a newfound level of personal autonomy. Students encounter new obstacles, including assuming personal accountability, adapting to foreign timetables and surroundings, fulfilling social commitments, and managing academic

pressure, causing them to alter their irregular sleeping patterns in response to these expectations. Hence, college students are acknowledged as a demographic that is largely impacted by sleep problems and is considered one of the most sleep-deprived age groups (Wolfson & Carskadon, 2003). In a study conducted by Suardiaz-Muro et al. (2023), the researchers investigated that students experienced insufficient sleep and accumulated a significant sleep deficit weekly. The majority of studies conducted in various nations indicate that university students commonly experience poor sleep quality. One study found that 54.7% of the 4318 incoming university students were categorized as having poor sleep quality (Cheng et al., 2012). In Malaysia, research reveals that a substantial majority of Malaysian undergraduate students, specifically 62.3%, experienced substandard sleep quality during the COVID-19 pandemic (YX & WY, 2022). Moreover, empirical evidence indicates that over 50% of university students in Malaysia exhibit substandard sleep quality (Wong et al., 2021). Consequently, the majority of research unambiguously demonstrates that university students are facing the problem of sleep and sleep quality.

2.3 Working Memory Performance

2.3.1 The Baddeley and Hitch Working Memory Model

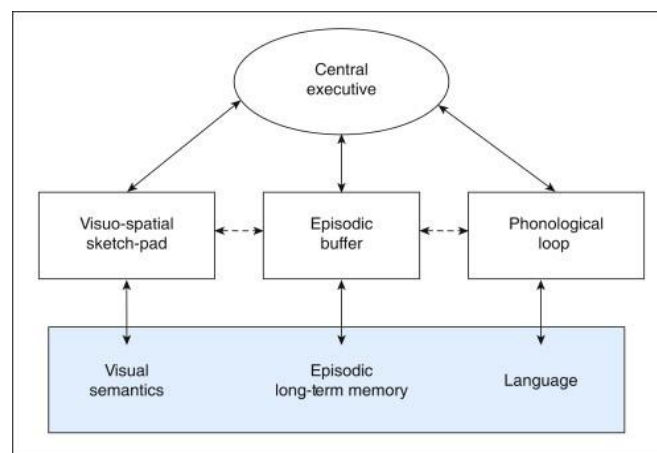


Figure 2. *Baddeley and Hitch's Proposed Model of Working Memory (Baddeley, 2010).*

Baddeley and Hitch's Working Memory Model encompasses the processes that are essential for retaining information during the execution of cognitive functions, such as understanding, logical thinking, and acquiring knowledge (Baddeley, 2010). The proposed model consists of a centralized attentional control system that is termed the central executive, which controls working memory processes. The central executive obtains its information from the two temporary storages, one called the visuo-spatial sketchpad responsible for spatial and visual working memory, and the phonological loop that handles auditory information and verbal working memory. The episodic buffer supplements the visuo-spatial sketchpad and phonological loop. The episodic buffer is said to be a temporary store that is limited to storing about four items or units. It is important for combining and chunking information between the two storage systems, holding them long enough for the integration of other components in working memory processing such as long-term memory, perception, and even olfactory & gustative information (Baddeley, 2010).

2.3.2 Background of Working Memory Performance

Working Memory is defined as a brain system that temporarily stores and manipulates information needed for complex cognitive activities like understanding language, thought processing, and learning (Baddeley, 1992). According to Karlsgodt (2015), working memory performance can be related to the measure of its functional activation. These functional activations can be measured in terms of neuroimaging such as fMRI, BOLD, or encephalopathy. Despite that, functional activation may also be measured through working memory tasks that produce results that can be inferred concerning the participants' working memory performance.

2.4 Previous Findings

2.4.1 Sleep Quality and Working Memory Performance

Studies on how sleep quality affects working memory performance are conflicting, with most research citing detrimental effects on working memory performance due to poor sleep quality while there are a few that observe no relation between sleep quality and working memory. Firstly, research conducted by Karmaker & Akter (2020) was consistent with the notion that sleep quality can degrade visuospatial working memory performance. The study included university students who were asked to complete the Dual n-back test to assess their visuospatial working memory. Before that, they were asked to provide their perceived quality of sleep by filling in the Pittsburgh Sleep Quality Index (PSQI). The findings show that sleep quality was negatively correlated with visuospatial working memory performance, meaning that the poorer a person's sleep quality is, the worse they will perform in visuospatial working memory-related tasks. Furthermore, van Dijk et al. (2020) investigate the cognitive consequences of non-clinical burnout, a chronic stress response with mild symptoms, in a working population. They use online questionnaires and neuropsychological tests to measure burnout, cognitive functioning, sleep quality, and work performance. They summarize the evidence for cognitive impairment in clinical burnout, especially in the domains of attention, memory, and executive functioning. They reveal that the relationship between cognition, work performance, and sleep was inconclusive and unclear. They point out the gaps and inconsistencies in the literature and propose their own hypotheses and research questions.

Next, Zavecz et al. (2020) presented their case of sleep quality effectively not having an impact on a person's working memory. The study was done among young adults who were given tasks related to working memory and executive functions, which were measured against their perceived quality of sleep. Their analysis proved that the difference in sleep quality among the participants did not necessarily correlate to a change in task performance,

indicating that participants with poor sleep performed similarly to those with better sleep. However, Zavecz et al. (2020) reasoned that the reason for this may be due to the demographic of the studies' participants, who were young healthy adults. Young healthy adults may not be as impacted by poor sleep as much as other age groups such as children or elderlies as they are in their golden eras of cognitive performance, explaining the reason why the study's participants' performances were not affected by sleep quality. However, that may not be the accurate reasoning as it has been recorded that young adults do indeed show declines in working memory due to poor sleep as previously stated. Walsh et al. (2016) provided a more accurate representation that perhaps sleep quality matters less to those who already have chronic sleep disturbances, especially in young adults. Peng et al. (2020) back this idea up as they found that working memory is particularly sensitive specifically to acute sleep deprivation.

2.4.2 Sleep Quality and Verbal and Visual Working Memory Performance

Some studies have found that poor sleep quality affects verbal working memory and visual working memory, while others have found the opposite or no difference. A study conducted by Nakagawa et al. (2016) investigated how different sleep habits affect verbal and visuospatial working memory in healthy young adults. The authors measured the working memory capacity of 779 participants using digit span and spatial span tasks and assessed their sleep habits using a self-report questionnaire. They found that nap duration was positively correlated with Visual-spatial working memory capacity (VSWMC) in all subjects, whereas sleep duration was positively correlated with Verbal Working Memory Capacity (VWMC) in all subjects. They also found sex-related differences in these associations, such that nap duration was more beneficial for males, while sleep duration and dream content recall frequency were more beneficial for females. Thus, the authors suggest that the different neural correlates of verbal and visuospatial working memory, and the effects of sleep habits

on stress, anxiety, and cognitive function may explain these findings. Also, a study conducted by Steenari (2003) involving participants of a different age group, children aged six to 13 years old, had their sleep quality measured against their performance in auditory and visual working memory performance through the n-back task paradigm. The participants who had poorer sleep were observed to have a higher frequency of providing incorrect responses in the task, showing that sleep quality harms audio-visual working memory.

Other than that, Drummond et al. (2012) discovered that complete sleep deprivation hampered the ability to ignore distracting stimuli in a visual scenario, but it did not lower Visual Working Memory capacity. This study looked at how two elements of visual working memory—the capacity to store many things and the capacity to weed out irrelevant information—are affected by one night of complete sleep deprivation and four nights of partial sleep deprivation. The researchers discovered that the storage capacity of visual working memory was unaffected by any kind of sleep deprivation. Even Nevertheless, complete sleep deprivation reduced the effectiveness of filtering, particularly when the objectives and distractions were same. These findings suggest that different types of sleep deprivation have different impacts on visual working memory and that filtering efficiency is more sensitive to sleep loss than storage capacity. Additionally, the authors discussed the implications of these results for various occupations that require visual working memory and attentional control. In addition, In a research published in 2018, Pasula et al. examine the effects of complete sleep deprivation on the working memory component processes of both younger and older persons. The effects of sleep deprivation on attention-driven encoding, updating and maintenance, and episodic encoding of verbal and visuospatial stimuli were measured by the authors using a computer model. They proposed that when comparing the verbal and visuospatial domains of Working Memory in younger and older persons, Total

Sleep Deprivation (TSD) may have distinct effects on each component. For example, following a 32-hour sleep deprivation, younger persons had higher deficits in these functions than older adults. The authors suggest that these findings may help explain the inconsistent results in the literature on the impact of sleep deprivation on working memory and cognitive ageing. They also highlight the importance of examining working memory at a more nuanced level to better understand the sleep-cognition interaction in ageing.

2.5 Summary

This literature review investigates how sleep quality affects verbal and visual working memory. It draws on the restorative and brain plasticity theories to explain how sleep facilitates cognitive recovery and memory consolidation. It also discusses the concept and measurement of sleep quality and the high prevalence of sleep problems among university students. Moreover, it refers to the Baddeley and Hitch Working Memory Model to describe how working memory processes and stores different types of information. The review summarizes the empirical evidence on the negative influence of poor sleep quality on working memory across various age groups but also notes some contradictory findings that suggest a need for more research. Therefore, this literature review critically examines the existing literature on the relationship between sleep quality and working memory and calls for further exploration of this important topic in cognitive science.

CHAPTER 3

METHODOLOGY

3.0 Introduction

Chapter 3 describes the complete methodological process in studying the relationship between sleep quality and verbal and visual working memory performance. This chapter explains the research design, focus population and sample, research instruments, research procedures, and the possible pilot study. Following that, the ethics of the study will be explained to maintain academic integrity and protect participants. Lastly, data collection and analysis procedures also will be examined in this chapter.

3.1 Research Design

This study used a correlational research strategy, which is a sort of research design that uses statistical techniques to investigate the associations between two variables—-independent and dependent variables (Curtis et al., 2016). The dependent variables in this study include verbal and visual working memory performance, for which sleep quality is an independent variable. The purpose of this study is to determine whether two (2) observable variables are associated and to gauge how strong that link is. It is possible to determine the direction and intensity of a correlation between variables using a correlational design, but causation cannot be established (Ling & Kenny, 1982; Schober et al., 2018). The Pearson product-moment correlation is a widely used metric to assess the linear relationship between two continuous variables that is generally referred to as "correlation". According to Schober et al. (2018), data that are jointly distributed using a bivariate normal distribution are frequently subjected to the Pearson correlation coefficient analysis.

Schober and Vetter (2020) state that a correlation coefficient ranging from -1 to 1 can be used to determine the correlation's magnitude. The correlation is stronger as the coefficient's absolute value gets closer to 1. Positive correlation, negative correlation, and zero correlation are the three different forms of correlation. When the correlation coefficient is near to 1 and both variables vary in the same direction, there is a positive correlation. On the other hand, when there is a negative correlation, the correlation coefficient is near to -1 and the two variables change in separate directions. According to Herzog et al. (2019), a zero correlation indicates that there is no association between the variables and the data appears as a diffuse cloud of dots.

3.2 Population and Sample

The population of this study directly targets undergraduate students who are studying at the Universiti Sarawak Malaysia (UNIMAS). According to Fraenkel and Wallen (2009) on page 335, a correlation research must have a minimum acceptable sample size of thirty. Larger sample numbers, however, will yield correlation coefficient estimates that are more precise and trustworthy. The convenience sample approach will be used in this study to recruit a total of 30 respondents. This type of non-probability sampling technique chooses sample units according to how easily the researcher can reach them (Nikolopoulou, 2023). Gathering information from subjects who are conveniently reachable by the researcher is the primary goal of the convenience sampling approach (Etikan et al., 2016). It is an affordable and convenient method to collect data (Etikan et al., 2016). As a result, 40 respondents will be used by convenience sampling method where the researcher can sample any undergraduate students in UNIMAS.

3.3 Instruments

3.3.1 Google Forms (Demographic information)

The researcher will use Google Forms, a free online survey tool, to collect the demographic information of the participants, such as gender, age, faculty, and race. Google Forms allows the researcher to create and distribute customized forms that can be accessed through various platforms, such as email, social media, or QR codes. The responses will be automatically stored and organized in a spreadsheet, which can be easily exported and analyzed. Google Forms also provides various features to enhance the validity and reliability of the data collection, such as data validation, required questions, and response limits. The demographic information collected by Google Forms will help the researcher to describe the characteristics of the sample and to control for any confounding variables that may affect the results of the study.

3.3.2 Pittsburgh Sleep Quality Index (PSQI)

Participants will fill out the PSQI, an instrument that is patented by Daniel J. Buysse, M.D., after completing the demographic information. Permission had been given to the researcher to duplicate the scale on this. Subjective sleep quality, sleep latency, length, efficiency, disruption, use of sleep medicine, and dysfunction throughout the day are the seven components of sleep quality that are covered by the PSQI. It is also intended to assess the participants' sleep quality alone for the previous month. Ten (10) primary questions will make up the PSQI, of which questions five (5) and ten (10) each feature ten and five sub-questions. Item ten (10), located on the third page of the PSQI questionnaire, inquires about the occurrence of loud snoring, breathing pauses, leg twitching, and episodes of confusion or disorientation during sleep, as reported by the bed partner or roommate.

However, it is important to note that this particular item does not factor into the calculation of the PSQI score.

Moreover, PSQI is a Likert scale questionnaire where each component score varies from zero (0), indicating no difficulty, to three (3), indicating significant difficulty. The individual scores of the components are added together to generate a comprehensive PSQI score, which can vary from 0 to 21. Greater scores correlate with poorer sleep quality. In other words, if the 5 above scores indicated that individuals had poor sleep quality during the past month (Buysse et al., 1989). The PSQI demonstrated strong internal homogeneity, consistency, and validity in effectively distinguishing between individuals with excellent and poor sleep patterns, as well as within various diagnostic categories of patients (Buysse et al., 1989). The PSQI is a viable and accurate tool for assessing sleep quality in different populations and environments, as demonstrated by Manzar et al. (2018).

3.3.3 Reading Span Task (RSPAN)

The reading span task (RSPAN) is a widely used measure of verbal working memory capacity that involves both processing and storage functions. It was first developed by Daneman and Carpenter (1980) to examine the relationship between working memory and reading comprehension. In this task, participants will be required to read aloud a series of unrelated sentences and check if the sentence is correct based on the participant's comprehensibility. In the process, the reading span score, which is the highest set size completed with at least 50% accuracy because it correlated strongly with various measures of reading comprehension (Daneman & Carpenter, 1980). Next, participants need to remember the last word of each sentence in a list. The list length varies from two to six sentences, and the participants have to recall the words in the correct order after each list. The task measures

how much verbal information can be maintained and manipulated in working memory under the interference of reading comprehension. A systematic review by Conway et al. (2005) suggested that more continuous measures, such as the total number of words recalled or the proportion of words per set, are more reliable and valid than the traditional span score, which quantifies the highest set size completed. Therefore, RSPAN will repeat testing the participants including rehearse in advance to ensure participants can understand the rules. It will take around fifteen minutes with a minimum time to complete the RSPAN task which will be provided by the researcher. As a result, the reading span task is a well-established and widely used measure of verbal working memory that has proven to be reliable and valid in various populations and settings (Friedman & Miyake, 2004).

3.3.4 Sternberg's Search Task

The Sternberg task is an extensively utilized instrument in the fields of visual and cognitive science for evaluating working memory performance (Klabes et al., 2021). The approach of this test is straightforward. The participants were instructed to memorize a brief sequence of numbers consisting of one to six items. Participants will be given a few seconds to memorize the set of numbers. Following their storage in memory, a probe number was displayed. Either a new number or one of the numbers in the list constituted the query number. The participant was instructed to provide a prompt response specifying whether the probe number was present or absent from the list.

3.4 Procedures

Before conducting this study, the researcher will prepare an informed consent form that explains the purpose, procedures, and risks of the study and the rights and responsibilities of the participants to obtain written consent from each participant before administering the

instruments. In addition, the researcher promises the participants' data given will be anonymized and stored securely on a password-protected computer. Next, the researcher will start to recruit 40 UNIMAS undergraduate students as the sample for the study, using convenience sampling. To accomplish this objective, the researcher will disseminate online forms which are Google Forms via WhatsApp, Instagram, and Telegram to individuals or groups. The online Google Forms will encompass the demographic information of the participants, an informed consent form, and a hyperlink to a PDF file containing the PSQI questionnaire. The researcher selected to distribute the online form due to easy accessibility, lower costs faced, and higher convenience. In the event of unsatisfactory or unattained results, the researcher will proactively visit several locations on campus to inform and extend invitations to UNIMAS undergraduate students to participate in this study.

Following the completion of the Google Forms, the researcher will promptly invite and schedule a time for participants to complete the Reading Span Task (RSPAN) and Sternberg's Search Task in a controlled environment. The devices utilized by the participants to access the Inquisit (for RSPAN) and CogLap (for Sternberg's Search Task) applications will be supplied by the researcher. Amid the assessments, the researcher will document the number of total correct recalls and the time taken for the respective tasks. The entirety of this procedure will be concluded in one week, commencing with the data of the participants who have fulfilled the PSQI. Upon completion of the tasks, the participants will be permitted to exit the regulated environment and be granted a small present as a gesture of gratitude for their involvement. Lastly, the data will be analyzed once all participants complete the tasks.

3.5 Pilot Study

A pilot study functions as a preliminary examination to assess the viability of the main research endeavour and as a mechanism to improve the design and execution of the main research (In, 2017). In order to conduct a pre-test prior to the distribution of the actual questionnaire and assessments, a pilot study is therefore required. In this study, the researcher will enlist six undergraduate students from UNIMAS who will adhere to the identical protocols outlined in the primary research design.

The pilot study yielded a majority opinion that the procedures, research instruments, and methodologies were suitable and relevant to the study. However, one participant criticized the duration of the verbal and visual working memory tests, indicating that they were too time-consuming. Based on this feedback, the researcher considered adjustments to the test durations to enhance participant comfort and maintain data quality. This process highlighted the importance of pilot studies in refining research tools and ensuring the feasibility of the main study. To sum up, a pilot study enables the researcher to assess the outcomes and methodologies of the preliminary investigation, ascertain any merits and drawbacks, obstacles and resolutions, and necessary adjustments or enhancements for the primary study.

3.6 Ethics of the Study

The main ethical issues for this study were protecting the validity and integrity of the research and giving participants' or research subjects' rights, dignity, and well-being top priority (Resnik, 2020). Before using the equipment on any subject, the researcher will get their signed informed permission. The goal, methods, dangers, and participant rights and duties will all be included in the informed consent form. Thus, the researcher will guarantee

the privacy and anonymity of the information provided by the participants. The researcher and the supervisor are the only people who will have access to the password-protected computer where the data is kept safe. Besides, the researcher will respect the participants' autonomy and freedom to withdraw from the study at any time without any penalty or negative consequences. The researcher also will avoid any harm or discomfort to the participants during the study. Lastly, the researcher will also debrief the participants after the study and provide them with a modest token of appreciation for their involvement.

3.7 Data Analysis Procedures

The Statistical Package for the Social Sciences (SPSS) will be used to analyze all of the data collected for this project. In the first stage, the researcher will analyze demographic data using descriptive statistics.

3.7.1 Descriptive Data Analysis

In the first stage, the researcher will analyze demographic data and PSQI scores of the participants using descriptive statistics. According to Bhandari (2022), descriptive statistics is to summarize and organize each characteristic of the data set. As a result, the demographical characteristics and the PSQI results of the participants will be summarized using descriptive statistics, which will include measures such as means, standard deviations, frequencies, and percentages. In this study, the results will be presented in the form of tables, charts, and graphs to enhance the comprehensibility of the results.

3.7.2 Inferential Data Analysis

The four hypotheses in this study, as shown in Table 1, will be tested using the Pearson Product Moment Correlation Coefficient (PPMCC). The PPMCC is a statistic that measures the strength and direction of the linear relationship between two variables, according to Shieh (2010). It is sometimes referred to as Pearson's r or the Pearson Correlation Coefficient (PCC) (Turney, 2023). The ideal negative linear relationship is represented by a value of -1 in the PPMCC, the ideal positive linear relationship by a value of +1, and the lack of any linear relationship by a value of 0 (Schober et al., 2018). To ascertain the association between verbal and visual working memory performance and sleep quality, the PPMCC or PCC will be utilized in this investigation.

Hypotheses	Statistical Test
H1: There is a significant relationship between sleep quality and verbal working memory performance based on the total correct recall.	Pearson Product Moment Correlation Coefficient (PPMCC)
H2: There is a significant relationship between sleep quality and verbal working memory performance based on the total time taken.	Pearson Product Moment Correlation Coefficient (PPMCC)
H3: There is a significant relationship between sleep quality and visual working memory performance based on the total correct recall.	Pearson Product Moment Correlation Coefficient (PPMCC)

H4: There is a significant relationship between sleep quality and visual working memory performance based on the total time taken.	Pearson Product Moment Correlation Coefficient (PPMCC)
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Table 1. *Statistical Test Used for Hypothesis Testing*

3.8 Summary

Overall, this study aimed to investigate the relationship between sleep quality and verbal and visual working memory performance among UNIMAS undergraduate students. The study employed a correlational design and used the PSQI, RSPAN, and Sternberg's search task as the instruments to measure the variables of interest. The study followed a series of procedures to recruit, test, and debrief the participants, as well as to analyze the data using SPSS. The study also addressed the ethical issues and conducted a pilot study to ensure the validity and reliability of the instruments and methods. The study expected to find significant correlations between sleep quality and working memory performance, which would contribute to the existing literature and have implications for the academic and well-being of the students.

CHAPTER 4

FINDINGS AND DISCUSSION

4.0 Introduction

This chapter outlines the findings derived from the current research, which involved the collection of data through Google Forms. The obtained data is then comprehensively examined, encompassing the demographic profile of participants and exploring the link between the independent variable (sleep quality) and the dependent variables (verbal and visual working memory performance). Furthermore, the analysis utilized the Pearson Product Moment Correlation Coefficient (PPMCC) to derive inferential statistics, assess the proposed hypotheses, and fulfil the research objectives.

4.1 Demographic Data

Characteristics		Frequency	Percent (%)
Gender	Male	14	46.7
	Female	16	53.3
Age	18-21	8	26.7
	22-25	20	66.7
	26-29	2	6.7
Race	Bumiputera	9	30.0
	Chinese	12	40.0
	Indian	2	6.7
	Malay	5	16.7
	Siam	1	3.3

	Timor	1	3.3
Year of Study	Year 1	6	20.0
	Year 2	7	23.3
	Year 3	10	33.3
	Year 4	7	23.3
Faculties	FACA	5	16.7
	FBE	1	3.3
	FCSHD	7	23.3
	FCSIT	4	13.3
	FEB	6	20.0
	FENG	4	13.3
	FELC	2	6.7
	FMHS	1	3.3

Table 2. *Demographics: Profile of the Respondents*

The demographic profile of the study participants provides a comprehensive overview of the sample population. The study included 30 participants, with a close gender distribution of 53.3% female and 46.7% male, indicating a slight predominance of female participants. This balanced gender perspective, though slightly female-skewed, ensures a fair representation of both genders, which may subtly influence the outcomes. Moreover, the age distribution of the participants is predominantly skewed towards the younger spectrum, with 66.7% of participants (20 out of 30) aged between 22-25 years. This suggests that the study's insights are particularly reflective of the experiences of young adults in this age range.

Additionally, 26.7% of the participants (8 out of 30) were aged between 18-21 years, while a smaller portion, 6.7% (2 participants), were aged between 26-29 years.

The study also revealed a diverse racial composition among participants. The largest racial group was Chinese, representing 40.0% (12 participants) of the sample. Bumiputera participants accounted for 30.0% (9 participants), and Malay participants made up 16.7% (5 participants). The Indian category accounted for 6.7% (2 participants), while Siam and Timor each comprised 3.3% (1 participant each). This diversity ensures that the study's findings are inclusive of various racial perspectives. Regarding academic standing, Year 3 students had the highest representation, accounting for 33.3% (10 participants). Both Year 2 and Year 4 students were equally represented, each constituting 23.3% (7 participants), while Year 1 students had the lowest representation at 20.0% (6 participants). This distribution indicates a higher involvement of more senior students in the study.

A review of the research participants' sleep quality as determined by the Pittsburgh Sleep Quality Index (PSQI) is also included in their demographic profile. Participants were divided into two groups based on their PSQI scores: those with good sleep quality (SCORE = 0-4) and those with poor sleep quality (SCORE = 5- 21). A thorough explanation of the participants' frequency and percentage within these categories may be found in Table 3.

PSQI Score Range	Frequency	Percentage
1-4 (Better Sleep Quality)	9	30.0%
5-21 (Poor Sleep Quality)	21	70.0%

Table 3. *PSQI Scores Distribution*

Out of the 30 participants in the study, 9 individuals (30.0%) reported PSQI scores between 0 and 4, indicating good sleep quality. This minority proportion of the sample demonstrates that a smaller portion of participants experiences good sleep quality, which is essential for optimal cognitive functioning. On the other hand, 21 participants (70.0%) had PSQI scores ranging from 5 to 21, suggesting poor sleep quality. This majority highlights a prevalent issue of suboptimal sleep among the participants, which could potentially impact various cognitive processes, including working memory performance. This distribution of PSQI scores provides a foundation for analyzing how sleep quality affects cognitive functions, specifically working memory, within this sample population. The significant proportion of participants with poor sleep quality ensures a comprehensive examination of the effects of sleep on cognitive performance in subsequent analyses.

4.1.1 Descriptive Statistic

	<i>N</i>	<i>Minimum</i>	<i>Maximum</i>	<i>M</i>	<i>SD</i>
PSQI Score	30	1	14	6.27	3.18
Total Correct Recall (RSPAN)	30	2	13	8.80	3.01
Total Time Taken (RSPAN)	30	08:07	18:21	12:02	02:32
Total Correct Recall (Sternberg Search Task)	30	25	30	27.97	1.25
Total Time Taken (Sternberg Search Task)	30	03:39	05:53	04:30	00:31

Note. *M* and *SD* represent mean and standard deviation, respectively.

Table 4. Descriptive Statistics Table

Table 4 displays the descriptive data analysis of the variables derived from the responses of 30 participants, emphasizing their sleep quality and working memory performance. This analysis specifically examines verbal and visuospatial domains, measured through total correct recall and total time taken. Firstly, the PSQI scores, representing sleep quality, range from 1 to 14 with a mean (*M*) score of 6.27 and a standard deviation (*SD*) of 3.18. This indicates a moderate variation in sleep quality among the participants.

For verbal working memory performance, measured by the RSPAN task, the total correct recall scores range from 2 to 13, with *M* = 8.80 and *SD* = 3.01. The highest score in

total correct recall is 13, while the lowest is 2. The total time taken for the RSPAN task ranges from 8:07 to 18:21 minutes, with an average time of 12:02 minutes and an SD of 2:32 minutes. The maximum time taken is 18:21 minutes, while the minimum is 8:07 minutes. This suggests considerable variability in both accuracy and time efficiency in verbal working memory tasks among participants.

In the visuospatial domain, measured by the Sternberg Search Task, the total correct recall scores range from 25 to 30, with $M = 27.97$ and $SD = 1.25$. The highest score in total correct recall is 30, while the lowest is 25. This smaller SD indicates less variability and generally high performance in visuospatial working memory tasks. The total time taken for the Sternberg Search Task ranges from 3:39 to 5:53 minutes, with an average time of 4:30 minutes and a SD of 31 seconds. The maximum time taken is 5:53 minutes, and the minimum is 3:39 minutes, suggesting relatively consistent performance times among participants.

4.2 Inferential Data (Main Findings)

4.2.1 Tests of Normality

	Test of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	<i>Statistic</i>	<i>df</i>	<i>Sig.</i>	<i>Statistic</i>	<i>df</i>	<i>Sig.</i>
Total Correct Recall	.129	30	.200	.947	30	.144
(RSPAN)	.157	30	.058	.933	30	.059

Total Time Taken						
(RSPAN)	.211	30	.002	.931	30	.052
Total Correct Recall						
(Sternberg Search						
Task)	.147	30	.098	.939	30	.083
Total Time Taken						
(Sternberg Search						
Task)						

**. This is a lower bound of the true significance.*

a. Lilliefors Significance Correction

Note. *df* and *Sig.* represent degrees of freedom and significance level, respectively.

Table 5. *Test of Normality*

Table 5 presents the results of the Kolmogorov-Smirnov and Shapiro-Wilk tests of normality. Given that the results contain fewer than 50 observations ($N = 30$), the Shapiro-Wilk test will be interpreted. The Shapiro-Wilk test results for the Total Correct Recall (RSPAN) show a p-value of .144, which is greater than the alpha level of 0.05, leading us to fail to reject the null hypothesis and conclude that the data is normally distributed. Similarly, the Total Time Taken (RSPAN) has a Shapiro-Wilk test statistic of .933 and a p-value of .059, just above the 0.05 threshold, again indicating that the null hypothesis is failed to be rejected and an assumption of normal distribution. In contrast, the Total Correct Recall (Sternberg) yields a p-value of .083. Since $p = .083 > .005$, the null hypothesis is failed to be rejected, suggesting a normal distribution and the appropriateness of parametric tests. For the Total Time Taken (Sternberg Search Task), it shows that $p = .083 > .05$, which the null hypothesis is failed to be rejected, showing that the data is normally distributed. As such,

the parametric test of the Pearson Correlation Coefficient was selected for the correlative analysis due to the continuous distribution of all the data.

4.2.2 There is a significant relationship between sleep quality and verbal working memory performance based on the total correct recall

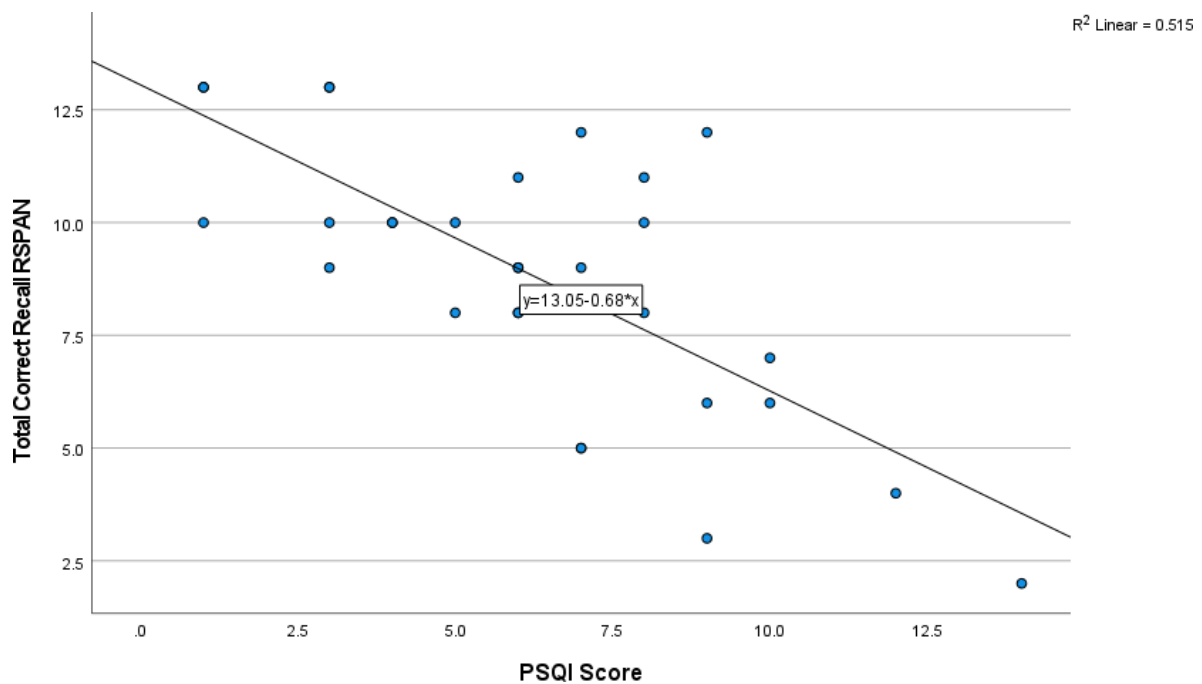


Figure 3. Scatter Plot on the Relationship Between Sleep Quality and Verbal Working Memory Performance Based On the Total Correct Recall (RSPAN)

H₁: There is a significant relationship between sleep quality and verbal working memory performance based on the total correct recall.

Correlations

		Total Correct Recall (RSPAN)	
		PSQI Score	
PSQI	Pearson Correlation	1	-.718*
	Sig. (2-tailed)		<.001
	N	30	30
Total Correct Recall (RSPAN)	Pearson Correlation	-.718**	1
	Sig. (2-tailed)	<.001	
	N	30	30

*. Correlation is significant at the 0.01 level (2-tailed).

Table 6. *Pearson Correlation Coefficient for the Hypothesis 1*

Based on the result of the Pearson Correlation Coefficient, the PSQI scores and total correct recall (RSPAN) were negatively strongly correlated among the undergraduate UNIMAS students, $r(28) = -.718$, $p = < .001$. Thus, the null hypothesis is rejected at ($p = < .001$), meaning that there is a significant relationship between sleep quality and verbal working memory performance based on the total correct recall. Specifically, students with better sleep quality (lower PSQI scores) tend to perform better on the verbal working memory task (higher total correct recall on RSPAN).

4.2.3 There is a significant relationship between sleep quality and verbal working memory performance based on the total time taken.

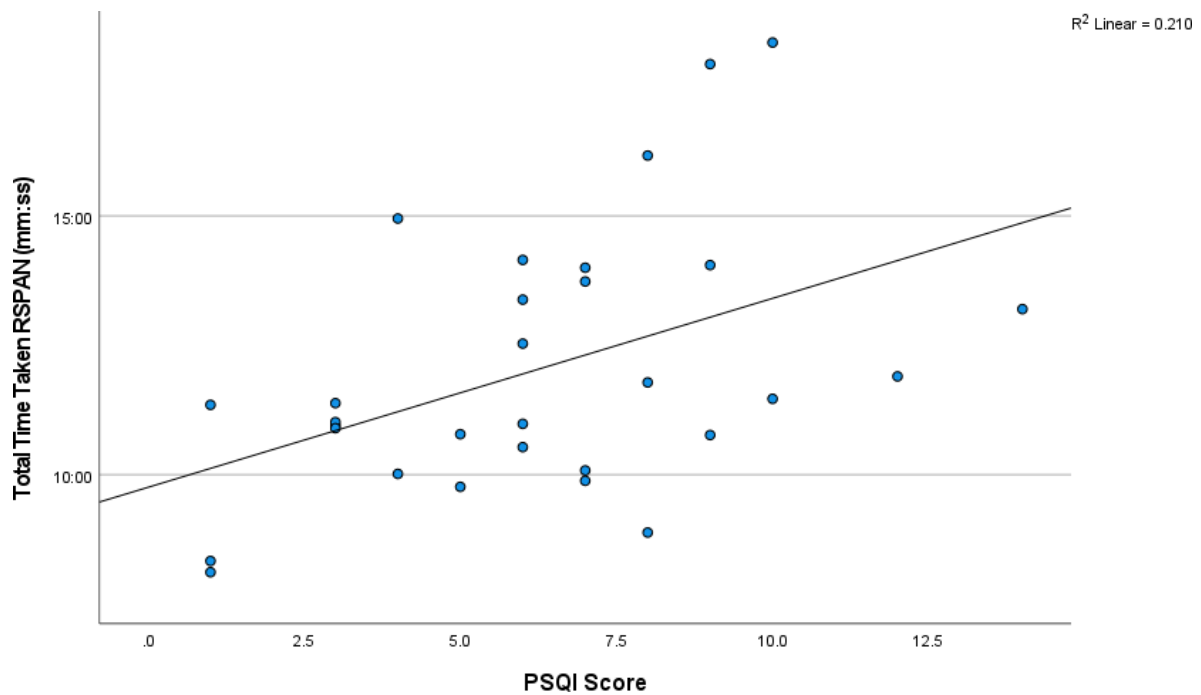


Figure 4. *Scatter Plot on the Relationship Between Sleep Quality and Verbal Working Memory Performance Based On the Total Time Taken (RSPAN)*

H₂: There is a significant relationship between sleep quality and verbal working memory performance based on the total time taken.

Correlations

		Total Time Taken (RSPAN)	
	PSQI Score		
PSQI	Pearson Correlation	1	.458*
	Sig. (2-tailed)		.011
	N	30	30
Total Time Taken (RSPAN)	Pearson Correlation	.458*	1
	Sig. (2-tailed)	.011	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Table 7. *Pearson Correlation Coefficient for the Hypothesis 2*

Table 7 shows there is a weak, positive correlation between the PSQI scores and total time taken (RSPAN) among undergraduate UNIMAS students, $r(28) = .458$, $p = .011$. Since $p\text{-value} = .011 < .05$, the null hypothesis is rejected, showing that there is a significant relationship between sleep quality and verbal working memory performance based on the total time taken. Hence, undergraduate UNIMAS students with poorer sleeping quality will take longer to complete the RSPAN.

4.2.4 There is a significant relationship between sleep quality and visual working memory performance based on the total correct recall.

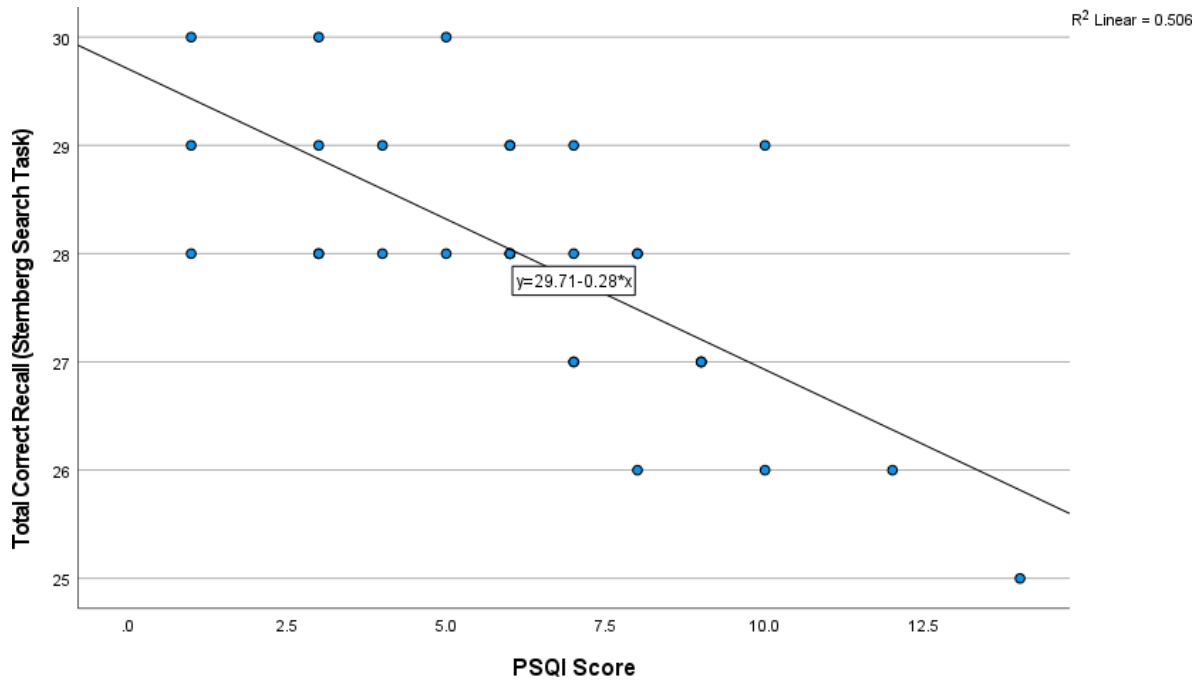


Figure 5. Scatter Plot on the Relationship Between Sleep Quality and Visual Working Memory Performance Based On the Total Correct Recall (Sternberg Search Task)

H₃: There is a significant relationship between sleep quality and visual working memory performance based on the total correct recall.

Correlations

		Total Correct Recall	
		PSQI Score	(Sternberg Search Task)
PSQI	Pearson Correlation	1	-.711**
	Sig. (2-tailed)		<.001
	N	30	30

Total Correct	Pearson Correlation	-.711**	1
Recall (Sternberg Search Task)	Sig. (2-tailed)	<.001	
	N	30	30

*. Correlation is significant at the 0.01 level (2-tailed).

Table 8. *Pearson Correlation Coefficient for the Hypothesis 3*

Among undergraduate UNIMAS students, the PSQI scores and total correct recall (Sternberg Search Task) had a strong negative correlation, $r(28) = -.711$, $p = <.001$. Since $p = <.001$, this data shows that the null hypothesis is rejected, indicating that there is a significant relationship between sleep quality and visuo-spatial working memory performance based on the total correct recall.

4.2.5 There is a significant relationship between sleep quality and visual working memory performance based on the total time taken.

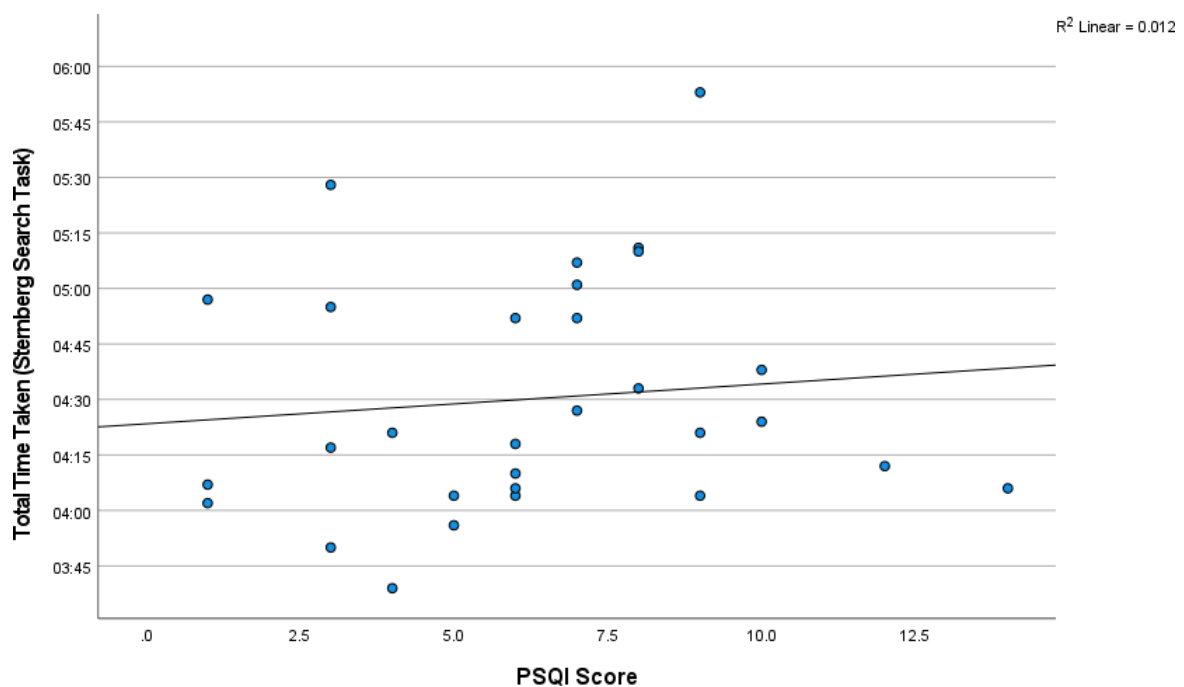


Figure 6. *Scatter Plot on the Relationship Between Sleep Quality and Visual Working Memory Performance Based On the Total Time Taken (Sternberg Search Task)*

H4: There is a significant relationship between sleep quality and visual working memory performance based on the total time taken.

Correlations			
		Total Time Taken	
		PSQI Score	(Sternberg Search Task)
PSQI	Pearson Correlation	1	.107
	Sig. (2-tailed)		.572
	N	30	30
Total Time Taken (Sternberg Search Task)	Pearson Correlation	.107	1
	Sig. (2-tailed)	.572	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Table 9. *Pearson Correlation Coefficient for Hypothesis 4*

Based on Table 9, there is a weak, positive correlation between the sleep quality and visual working memory test, with $r(28) = .107$, $p = .572$. Additionally, the relationship is not statistically significant at $p = .572$. Since $p\text{-value} = .572 > .05$, the null hypothesis failed to be rejected. Therefore, there is no significant relationship between the PSQI score and the total time taken (Sternberg Search Task).

4.3 Discussion

The findings of this study illuminate the relationship between sleep quality and working memory performance. The significant negative correlation between sleep quality and verbal working memory performance, as indicated by the total correct recall in the RSPAN task at $r(28) = -.718$, $p < .001$, underscores the critical role of sleep in cognitive processes. Specifically, this finding suggests that poorer sleep quality, indicated by higher PSQI scores, is associated with lower performance in verbal working memory tasks. This negative relationship highlights the detrimental impact of inadequate sleep on cognitive functions, particularly on the ability to retain and recall verbal information. It supports the theory that insufficient or poor-quality sleep disrupts the consolidation of verbal information, thereby impairing retention and recall abilities (Guttesen et al., 2024; Puchkova, 2020).

Good sleep quality, reflected by lower PSQI scores, appears essential for optimal performance in tasks requiring verbal working memory. This result is consistent with research by Ma et al. (2020), which suggests that poor sleep quality negatively impacts cognitive functions, including memory consolidation. Therefore, ensuring adequate and high-quality sleep is crucial for maintaining cognitive performance, particularly in verbal working memory tasks. This emphasizes the importance of addressing sleep issues to enhance cognitive functioning and overall academic performance among students.

Moreover, the study identified a weak positive correlation between PSQI scores and the total time taken to complete the RSPAN task at $r(28) = .458$, $p = .011$. This suggests that students with poorer sleep quality tend to take longer to complete verbal working memory tasks. While this correlation is not as strong as the one related to correct recall, it still indicates that sleep quality affects the efficiency of cognitive processing. This is supported by

Dijk et al. (2020), who noted that sleep quality impacts cognitive functions, though the relationship is often complex and multifaceted.

Following that, the relationship between sleep quality and visual working memory performance based on total correct recall measured by the Sternberg Search Task was found to be strongly negatively correlated and significant at $r(28) = -.711$, $p = <.001$. This finding can be attributed to the critical role that high-quality sleep plays in memory consolidation processes. During sleep, particularly during the REM and slow-wave stages, the brain undergoes significant synaptic plasticity and neural reorganization, which are essential for stabilizing and integrating new information (Stickgold & Walker, 2013). These processes enhance the brain's ability to accurately encode, store, and retrieve visual information, leading to improved performance in tasks requiring visual working memory. Nakagawa et al. (2016) suggest that distinct neural pathways underlie verbal and visuospatial working memory, and these pathways may be differentially affected by sleep. Hence, individuals with better sleep quality to remember and accurately recall more visual information.

In contrast, the correlation with the total time taken was weak and non-significant, $r(28) = .107$, $p = .572$. This suggests that visual working memory may be less sensitive to variations in sleep quality in total time taken than total correct recall. This aligns with research by Drummond et al. (2012), who found that while sleep deprivation impairs attention and the ability to ignore distractors, it does not necessarily reduce visual working memory capacity as the differential impact of sleep quality on visual working memory performance can be attributed to various factors depending on the context of the individual. In this case, it could be inferred that sleep quality does not necessarily impact the speed of visual working memory performance among the participants.

Other than that, the practical implications of these findings are significant, particularly for academic and occupational settings. For students and professionals alike, improving sleep quality could enhance cognitive functions critical for performance, such as verbal working memory. Educational institutions and workplaces might consider implementing programs to promote better sleep hygiene, thus potentially improving overall productivity and performance. While the current study provides valuable insights, it is not without limitations. The sample size is relatively small and primarily consists of young adults, which may limit the generalizability of the findings. Additionally, self-reported sleep quality measures might be subject to bias. Future research should aim to include a more diverse sample and explore the mechanisms underlying the relationship between sleep quality and different types of working memory more comprehensively. In conclusion, this study reaffirms the importance of sleep quality for cognitive performance, particularly in verbal working memory tasks. By fostering environments that promote good sleep hygiene, it may be possible to enhance cognitive functions critical for academic and professional success. Future research should focus on elucidating the specific neural mechanisms involved and expanding the demographic scope to validate and extend these findings.

4.4 Summary

This study explored the pivotal role of sleep quality in cognitive performance, with a specific focus on working memory among undergraduate students. Key findings revealed a significant negative correlation between sleep quality and verbal working memory performance, indicating that better sleep quality is associated with improved verbal recall accuracy. Additionally, there was a weak positive correlation between sleep quality and the time taken to complete verbal memory tasks, suggesting that poorer sleep quality may slow cognitive processing speed. In contrast, visual working memory performance showed a

strong negative correlation with sleep quality in terms of recall accuracy, but the correlation with the time taken was weak and non-significant. This implies that while visual memory accuracy is affected by sleep quality, the speed of visual processing is less influenced by sleep variations. Also, the study's limitations, including a small and demographically narrow sample, suggest that further research is needed to generalize these findings across diverse populations and to explore the underlying neural mechanisms in greater depth. Nonetheless, this research reinforces the importance of good sleep quality for optimal cognitive functioning, particularly in tasks demanding verbal working memory.

CHAPTER 5

IMPLICATION, LIMITATION, RECOMMENDATION AND CONCLUSION

5.0 Introduction

This chapter covers the study implications, limitations of the study, and recommendations for future research, before concluding with a concise summary of the entire study.

5.1 Implication of Study

This study investigates the relationship between sleep quality and working memory performance, specifically focusing on verbal and visual working memory among undergraduate students. While existing research has explored the impact of sleep on cognitive functions, more is needed to understand how sleep quality affects different types of working memory. The results of this study highlight several critical implications for practical, theoretical, and social advancement.

5.1.1 Theoretical Implication

This study's results add to the body of empirical research demonstrating the critical impact that good sleep quality plays in cognitive functions, especially working memory. For many higher-order cognitive processes, including learning, reasoning, and problem-solving, working memory—a crucial component of executive functions—is necessary (Cowan, 2014). This study validates and adds to the body of research emphasizing the critical role sleep plays in cognitive functioning by demonstrating a direct correlation between working memory function and sleep quality. In support of the Restorative Theory, for example, which holds that sleep promotes the preservation and repair of cognitive processes and brain functions, is

the negative connection found between verbal working memory performance and poor sleep quality. According to Ellenbogen et al. (2009), sleep is essential for memory consolidation and the best possible operation of the neural networks engaged in verbal working memory tasks. Yoo et al. (2007), for instance, showed that sleep deprivation causes a decrease in brain activity in areas linked to working memory, highlighting the need of sleep for maintaining cognitive function.

Moreover, the positive correlation between sleep quality and visual working memory performance aligns with the Brain Plasticity Theory. This theory highlights the importance of sleep in synaptic plasticity, neuronal regeneration, and the modulation of gene activity and protein synthesis in the brain. The observed relationships suggest that sleep enhances the brain's ability to consolidate visual information, thereby improving performance in visual working memory tasks. According to Stickgold & Walker (2013), their result further elaborated that sleep-dependent memory consolidation processes are crucial for the integration and reorganization of new information, which enhances cognitive flexibility and learning capacity.

To sum up, previous research has shown inconsistent and conflicting results for the association between sleep quality and working memory performance, with most research citing detrimental effects on working memory performance due to poor sleep quality while there are a few that observe no relation between them. The present study aims to find answers to the correlations between these variables and to make a unique contribution to a more nuanced understanding of how sleep quality affects different cognitive modalities by distinguishing between verbal working memory and visual working memory. By incorporating these findings into theoretical models, researchers can better understand the

complex relationship between sleep and cognitive functioning, provide opportunities to develop more targeted and effective strategies, and improve sleep hygiene to enhance cognitive performance.

5.1.2 Practical Implication

First of all, this study stimulated self-awareness and self-reflection in undergraduate students as they completed the questionnaire. Knowing their current sleep quality may increase their awareness which may lead to behavioural changes for better sleep quality as all behavioural changes begin with awareness and intention to change. Therefore, it can be recommended that universities incorporate sleep quality assessment into student health and wellness services. By identifying students with poor sleep quality, targeted interventions such as counselling, stress management resources, progressive muscle relaxation training, and sleep therapy can be provided. This holistic approach can help students achieve better academic performance through improved cognitive functioning (Heissel et al., 2017; Hubbard & Blyler, 2016).

5.2 Limitations of Study

As with any research study, this study contains limitations that should be taken into account when interpreting the results and planning future research. The first limitation of this study is that the sample size and frequency of participants are small and belong only to a specific category of the population such as the study just suitable for the UNIMAS undergraduate students. The sample in the present study is relatively modest and includes only 30 undergraduate students from UNIMAS. Although this number is sufficient for correlation studies, it can be problematic in terms of the statistical power of the study, meaning the amount of evidence available to support the hypothesis of the two variables

being related. Further, a small sample size might not be enough to capture the population in a given study, which in turn may cause problems as regards external validity. The study sample size is 30 participants, though some measures were employed to ensure a more representative sampling of the student population across the faculties. For instance, the researcher tried to find participants who are all from different colleges, rather than participants who are all in the same college. Therefore, participants were selected from various faculties at UNIMAS and balanced the data. It may help to mitigate the effects of a small sample size, thus enhancing the generalizability of the findings.

Next, the current study involved the convenience sampling method that limits its generalization of the results to a certain population and settings. This approach can cause a selection bias whereby the subjects chosen may not represent most individuals because it was easy to get in touch with them or agree to participate in the study. For instance, students who are more diligent or those who have a tight timetable will be able to complete surveys, while more stressed students or those who have an unpredictable timetable will not. This non-randomness may distort the generalizability of the study and fail to show other students' behaviours that should be expected in a real context. However, this study endeavored to have a more even distribution of participants, including participants from different colleges, average gender, race, and so on to ensure a wide representation of academic disciplines and student demographics. By actively seeking a balanced distribution of participants across various fields of study, it was able to mitigate the selection bias inherent in convenience sampling.

Another major limitation is the reliance on self-reported measures to assess sleep quality. This means all of the participants have to complete the PSQI questionnaire on their

own without any assistance from the others. The PSQI in this study is self-reported and may have issues of social desirability and recall bias. Self-report measures can have a number of limitations, including participants failing to remember their exact sleep practices, or reporting only the favorable part of the information. Using self-rating of sleep quality is a limitation because it is a subjective measure, which is different from the actual sleep behaviors or phenomena. This difference may result in confusion when working memory performance is correlated with the quality of sleep. To address this shortcoming of prior studies, the current study incorporated reliability assessments to confirm the accuracy of the PSQI scores. For instance, the internal consistency of the PSQI was verified using Cronbach's alpha, which was greater than 0.70, indicating acceptable reliability. This approach helps to validate the self-reported data, ensuring that the measures used are robust and reliable. According to Buysse et al. (1989), the PSQI demonstrated a Cronbach's alpha of 0.83, which confirms its internal consistency and reliability in assessing sleep quality.

Moreover, the cross-sectional design of the study is a major limitation because it only collects data at one point in time. While this can show a relationship between sleep quality and working memory, it cannot prove that one causes the other. This design misses the chance to observe changes over time and the effects of factors like academic stress and lifestyle changes. Cross-sectional studies are good for spotting correlations but can't show how variables influence each other over time. Without long-term data, we can't know if poor sleep quality causes poor working memory or if other factors affect both. Future research should use longitudinal designs, which track participants over time. This approach would help us understand better how sleep quality affects cognitive functions and academic performance by considering individual differences and developmental changes.

Last but not least, the study did not take into account potential factors that may affect working memory performance. Conducting tasks in a controlled setting may not accurately reflect real-world conditions where numerous external factors influence sleep quality and cognitive performance. Variables such as stress, diet, and physical activity, which can significantly impact sleep and cognitive functions, were not accounted for in the controlled environment of the study (Naveed et al., 2020; Sewell et al., 2021; Zagaria et al., 2022). For instance, a high coffee intake may interfere with cognitive function and sleep patterns, and a high stress level may negatively impact working memory and sleep quality. The results might be skewed since there is no control over these confounding variables, which could have an impact on the connections between working memory and sleep quality that have been identified. Additionally, the results might not be totally relevant to situations in the actual world due to this lack of ecological validity.

5.3 Recommendations

Based on the findings and limitations identified in this study, it is possible to propose several recommendations for future research endeavours. First of all, the researcher should strive to include a larger and more diverse sample to improve the generalizability of the findings. Recruiting participants from various age groups, educational backgrounds, and cultural settings would provide a more comprehensive understanding of how sleep quality affects working memory performance across different demographics. For instance, recruiting participants from different Malaysia's public and private universities such as University Kebangsaan Malaysia (UKM), University Technology Malaysia (UTM), University Tunku Abdul Rahman (UTAR), and so on. It may improve the accuracy of the information gathered about undergraduate students at different universities' sleep quality, verbal working memory performance, and visual working memory performance. This is due to the likelihood that the majority of undergraduate students from the same university may have higher stress and

comparable sleep patterns. Thus, a more heterogeneous sample will also allow researchers to examine potential moderating variables such as age, gender, and cultural factors that might influence the relationship between sleep and cognitive performance. Researchers can ensure that the results are more representative of the broader population by diversifying the sample, thereby enhancing the external validity of the study. Moreover, including a wide range of demographic variables can help identify the potential moderating effects of these variables on the relationship between sleep quality and working memory performance.

Further research ought to include objective measurements of sleep quality in order to overcome the drawbacks of using self-reported sleep data. Metrics like sleep duration, efficiency, and phases may be assessed more precisely and reliably using methods like actigraphy and polysomnography (Kahawage et al., 2019; VAN DE WATER et al., 2011). Actigraphy is a technique where a wrist-mounted device is used to continuously record data that might identify anomalies or inconsistencies in sleep behavior that self-reports could overlook. This data is used to infer sleep-wake patterns over lengthy periods of time. Several physiological parameters, such as brain activity (EEG), eye movements (EOG), muscle activity (EMG), heart rhythm (ECG), and respiratory effort, are recorded during an overnight sleep study in a laboratory setting during polysomnography, which is frequently regarded as research on sleep. Furthermore, it can shed light on particular sleep disorders like periodic limb movement disorder and sleep apnea, which can have a major negative influence on cognitive abilities but are frequently underreported in self-evaluations. According to Ancoli-Israel et al. (2003), this means that objective assessment can increase the efficacy of identifying sleep disorders that participants may have neglected to disclose. By integrating these advanced techniques, researchers can validate self-reported sleep quality scores, reduce measurement biases, and enhance the reliability and accuracy of their findings. This approach

will not only improve the validity of the data but also offer a more comprehensive understanding of participants' sleep behaviours, ultimately leading to more robust conclusions about the relationship between sleep quality and cognitive performance.

Thirdly, future studies should adopt a longitudinal study design to track sleep quality and cognitive performance over extended periods. This approach will provide comprehensive insights into the temporal dynamics and causal relationships between these variables, helping to identify critical periods where interventions might be most needed. Longitudinal studies are essential for capturing the long-term effects of sleep quality on cognitive development and academic success, which are often overlooked in cross-sectional research (Zisapel, 2018). By following participants over time, researchers can observe how changes in sleep patterns influence cognitive functions and academic outcomes, providing valuable data for developing targeted and effective interventions. Additionally, longitudinal designs allow for the control of individual differences and confounding variables, thereby enhancing the reliability and applicability of the findings (Galambos et al., 2009). Such studies can also help to determine whether interventions aimed at improving sleep quality have sustained benefits on cognitive performance, which is crucial for informing educational policies and support programs (Tarokh et al., 2016).

Next, future studies should incorporate controls for environmental factors such as noise levels, lighting conditions, and overall living environments. By standardizing these variables, researchers can minimize the influence of external factors on both sleep quality and working memory performance, leading to more reliable results. Additionally, researchers should consider internal factors that can affect cognitive performance and sleep quality, including stress levels, dietary habits, and physical health. Monitoring participants' stress

levels and diet through surveys or biometric measures can provide a more comprehensive view of how these factors interact with sleep and working memory. To increase the ecological validity of the findings, future studies should aim to simulate real-world conditions as closely as possible. This could involve conducting experiments in naturalistic settings or including a more diverse sample of participants that represents the variability found in real-world environments. As caffeine consumption can significantly impact sleep patterns and cognitive alertness (Aidman et al., 2021), future research should control for this variable by instructing participants to avoid caffeine and other stimulants, such as energy drinks, at least 24 hours before the experiment. Additionally, recording participants' caffeine intake habits can help in understanding its effects on the study outcomes.

5.4 Conclusion

In summary, this study underscores the significant role of sleep quality in enhancing cognitive performance, particularly in verbal working memory tasks among undergraduate students at the Universiti Malaysia Sarawak (UNIMAS). The findings reveal that improved sleep quality correlates with higher accuracy in verbal recall and suggest a possible slowing of cognitive processing speed due to poor sleep. However, the impact of sleep quality on visual working memory accuracy is evident, whereas its effect on processing speed remains inconclusive. These results highlight the necessity of prioritizing good sleep hygiene to foster optimal cognitive functioning, which is crucial for academic and professional success. Future research should expand on these findings by incorporating a more diverse sample and exploring the intricate neural mechanisms at play. By advancing our understanding in this area, we can better inform strategies to improve sleep quality and, consequently, cognitive performance across various domains

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APPENDIX A

GOOGLE FORM QUESTIONNAIRE

The Relationship between Sleep Quality and Verbal and Visual Working Memory Performance

Greetings to all,

I am **ANG XIAN YIE (78812)**, a third-year psychology student from the Faculty of Cognitive Science and Human Development (FCSHD) of University Malaysia Sarawak (UNIMAS). I am currently conducting a **Final Year Project (FYP)** on understanding **THE RELATIONSHIP BETWEEN SLEEP QUALITY AND VERBAL AND VISUAL WORKING MEMORY PERFORMANCE**. Therefore, I would like to request that you dedicate a brief period of time to engage in this investigation. Once the provided assessments have been finished, you are welcome to respond to this questionnaire.

This questionnaire consists of five (5) sections:

SECTION A: Informed Consent

SECTION B: Demographics

SECTION C: The Pittsburgh Sleep Quality Index (PSQI) Questionnaire

SECTION D: RSPAN

SECTION E: Sternberg's Search Task

Please answer ALL the questions and will take approximately 10-15 minutes to complete.

All your information obtained in this study will be kept and handled confidentially, by applicable laws and/or regulations. When publishing or presenting the study results, your identity will not be revealed without your expressed consent.

For inquiries/clarification, please **contact**:

 **Email:** 78812@siswa.unimas.my

 **Phone no:** 012-4344473

Your cooperation and active involvement in completing this questionnaire is much value. Thank you and enjoy the rest of your day.

* Indicates required question

Figure B1. *Introduction to Research's Google Forms*

ELECTRONIC INFORMED CONSENT FORM

*

By clicking on the "agree" button indicates that:

1. I have been read and understood the information for the above study.
2. I have sufficient time to consider participation in the study.
3. Understand that my participation is voluntary, and I can freely withdraw my participation from the study without giving a reason. I understand the risks and benefits related to my participation in the study.
4. While information gained in this study, it may be used in a conference presentation, and may also be published in a journal article, I will not be identified. Information concerning me will remain strictly confidential.
5. I understand that study investigators, qualified monitors and auditors, the sponsor or its affiliates, and governmental or regulatory authorities, have direct access to my record in order to make sure that the study is conducted correctly, and the data are recorded correctly. All personal details will be treated as STRICTLY CONFIDENTIAL.

☐ Agree

Figure B2. *Consent Form*

Section B: Demographics

Nicknames *

Your answer

Gender *

☐ Male

☐ Female

Age *

☐ 18-21

☐ 22-25

☐ 26-29

☐ ≥ 30

Figure B3. *Demographics*

Race *

☐ Malay

☐ Chinese

☐ Indian

☐ Bumiputera

☐ Other: _____

Year of the study *

☐ Year 1

☐ Year 2

☐ Year 3

☐ Year 4

☐ Year 5 and above

Faculties *

Choose ▼

Figure B4. *Demographics (cont.)*

Section C: PSQI Questionnaire

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

Please answer all questions.

1. During the past month, what time have you usually gone to bed at night? (***e.g*** ***10 p.m.***) *

Your answer _____

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night? *

- ☐ ≤15 minutes
- ☐ 16-30 minutes
- ☐ 31-60 minutes
- ☐ >60 minutes

3. During the past month, what time have you usually gotten up in the morning? (***e.g*** ***8 a.m.***) *

Your answer _____

Figure B5. *PSQI Questionnaire*

4. During the past month, how many hours of actual sleep did you get at night? (*
This may be different than the number of hours you spent in bed.) (e.g 7hours)

Your answer _____

5. During the past month, how often have you had trouble sleeping because you... *

	Not during past month	< Once a week	Once or twice a week	≤ 3 times a week
Cannot get to sleep within 30 minutes	☐	☐	☐	☐
Wake up in the middle of the night or early morning	☐	☐	☐	☐
Have to get up to use the bathroom	☐	☐	☐	☐
Cannot breathe comfortably	☐	☐	☐	☐
Cough or snore loudly	☐	☐	☐	☐
Feel too cold	☐	☐	☐	☐
Feel too hot	☐	☐	☐	☐
Have bad dreams	☐	☐	☐	☐
Have pain	☐	☐	☐	☐

Figure B6. PSQI Questionnaire (cont.)

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

- ☐ Not during past month
- ☐ < Once a week
- ☐ Once or twice a week
- ☐ ≤ 3 times a week

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

- ☐ Not during past month
- ☐ < Once a week
- ☐ Once or twice a week
- ☐ ≤ 3 times a week

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

- ☐ No problem at all
- ☐ Only a very slight problem
- ☐ Somewhat of a problem
- ☐ A very big problem

Figure B7. PSQI Questionnaire (cont.)

9. During the past month, how would you rate your sleep quality overall? *

- ☐ Very good
- ☐ Fairly good
- ☐ Fairly bad
- ☐ Very bad

Section D: Reading Span Task (RSPAN)

This sections aims to assess the verbal working memory performance by using RSPAN. Please input your scores and the total time taken below. (Refer to the experimenter)

<https://www.millisecond.com/download/library/v6/rspan/rspan/automatedrspan.web>

Total Correct Recall

Your answer

Total Time Taken (***e.g 1min 1sec***)

Your answer

Figure B8. *Reading Span Task Score and Total Time Taken Input*

Section e: Sternberg's Search Task

This sections aims to assess the visual working memory performance by using Sternberg's Search Task. Please input your scores and the total time taken below. (Refer to the experimenter)

Total Correct Recall

Your answer _____

Total Time Taken (**e.g 1min 1sec**)

Your answer _____

Figure B9. *Sternberg's Search Task Score and Total Time Taken Input*

APPENDIX B

RAW SPSS OUTPUTS

Demographic Data Analysis

		Count	Column N %
Gender	Female	16	53.3%
	Male	14	46.7%
Age	18-21	8	26.7%
	22-25	20	66.7%
	26-29	2	6.7%
Race	Bumiputera	9	30.0%
	Chinese	12	40.0%
	Indian	2	6.7%
	Malay	5	16.7%
	Siam	1	3.3%
	Timor	1	3.3%
Year of Study	Year 1	6	20.0%
	Year 2	7	23.3%
	Year 3	10	33.3%
	Year 4	7	23.3%
Faculties	Faculty of Applied and Creative Arts (FACA)	5	16.7%
	Faculty of Built Environment (FBE)	1	3.3%
	Faculty of Cognitive Sciences and Human Development (FCSHD)	7	23.3%
	Faculty of Computer Science and Information Technology (FCSIT)	4	13.3%
	Faculty of Economics and Business (FEB)	6	20.0%
	Faculty of Engineering (FENG)	4	13.3%
	Faculty of Language and Communication (FELC)	2	6.7%
	Faculty of Medicine and Health Sciences (FMHS)	1	3.3%

Table A1. Raw SPSS Output for Demographic

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
PSQI Score	30	1	14	6.27	3.183
Total Correct Recall (RSPAN)	30	2	13	8.80	3.010
Total Time Taken (RSPAN)	30	08:07	18:21	12:02	02:32
Total Correct Recall (Sternberg Search Task)	30	25	30	27.97	1.245
Total Time Taken (Sternberg Search Task)	30	03:39	05:53	04:30	00:31
Valid N (listwise)	30				

Table A2. Raw SPSS Output for Descriptive Statistics

Inferential Data Analysis

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total Correct Recall (RSPAN)	.129	30	.200*	.947	30	.144
Total Time Taken (RSPAN)	.157	30	.058	.933	30	.059
Total Correct Recall (Sternberg Search Task)	.211	30	.002	.931	30	.052
Total Time Taken (Sternberg Search Task)	.147	30	.098	.939	30	.083

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table A3. Raw SPSS Output for Test of Normality

Correlations			
		PSQI Score	Total Correct Recall (RSPAN)
PSQI Score	Pearson Correlation	1	-.718**
	Sig. (2-tailed)		<.001
	N	30	30
Total Correct Recall (RSPAN)	Pearson Correlation	-.718**	1
	Sig. (2-tailed)	<.001	
	N	30	30

** . Correlation is significant at the 0.01 level (2-tailed).

Table A4. *Raw SPSS Output for Pearson Correlation Coefficient on the Relationship between Sleep Quality and Verbal Working Memory Performance based on the Total Correct Recall.*

Correlations			
		PSQI Score	Total Time Taken (RSPAN)
PSQI Score	Pearson Correlation	1	.458*
	Sig. (2-tailed)		.011
	N	30	30
Total Time Taken (RSPAN)	Pearson Correlation	.458*	1
	Sig. (2-tailed)	.011	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Table A5. *Raw SPSS Output for Pearson Correlation Coefficient on the Relationship between Sleep Quality and Verbal Working Memory Performance based on the Total Time Taken.*

Correlations			
		PSQI Score	Total Correct Recall (Sternberg Search Task)
PSQI Score	Pearson Correlation	1	-.711**
	Sig. (2-tailed)		<.001
	N	30	30
Total Correct Recall (Sternberg Search Task)	Pearson Correlation	-.711**	1
	Sig. (2-tailed)	<.001	
	N	30	30

** . Correlation is significant at the 0.01 level (2-tailed).

Table A6. Raw SPSS Output for Pearson Correlation Coefficient on the Relationship between Sleep Quality and Visual Working Memory Performance based on the Total Correct Recall.

Correlations			
		PSQI Score	Total Time Taken (Sternberg Search Task)
PSQI Score	Pearson Correlation	1	.107
	Sig. (2-tailed)		.572
	N	30	30
Total Time Taken (Sternberg Search Task)	Pearson Correlation	.107	1
	Sig. (2-tailed)	.572	
	N	30	30

Table A7. Raw SPSS Output for Pearson Correlation Coefficient on the Relationship between Sleep Quality and Visual Working Memory Performance based on the Total Time Taken.