



Faculty of Cognitive Sciences and Human Development

**THE RELATIONSHIP BETWEEN SMARTPHONE USAGE AND
WORKING MEMORY PERFORMANCE AMONG UNDERGRADUATE
STUDENTS**

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THE RELATIONSHIP BETWEEN SMARTPHONE USAGE AND WORKING MEMORY PERFORMANCE AMONG UNDERGRADUATE STUDENTS

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ABSTRACT

This research paper analyses the connection between smartphone usage and working memory performance among undergraduate students. As many lectures are incorporating technology-based learning, it is imperative to determine whether the overuse of smartphones poses a risk to the degradation of working memory performance among undergraduate students. To investigate this, the research included 34 participants from the Universiti of Malaysia Sarawak (UNIMAS) who were required to complete a pair of working memory performance tests, which were correlated with their average weekly smartphone screen time. The results show an inverse link between smartphone usage and working memory performance, indicating that participants with longer smartphone screen time were likely to have poorer working memory performances. Therefore, the findings imply that smartphone users, particularly undergraduate students, should take into consideration how long they use their smartphones to preserve their working memory performance for academic purposes. In addition, universities may implement programs to raise awareness of the dangers of smartphone overuse, as well as policy changes in restricting smartphone practices during lectures.

Keywords: smartphone usage, working memory performance, undergraduate students, technology-based learning, screen time.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

The contents of this chapter discuss the background of the topic of study as well as its problem statement. Following that, this chapter outlines the research objectives in establishing a base for formulating a hypothesis and structuring a conceptual framework. At the end of this chapter, the terms will have their definitions cleared, closed by the summary of the chapter.

1.1 Background of Study

In this era, smartphones have become an integral part of life, not only allowing for widespread communication such as access to the Internet, social media, and email applications but also changing societal structures (Ng et al., 2017). Due to their wide range of uses, smartphones have been increasingly integrated into education causing extensive smartphone use among students. Parasuraman et al. (2017) observed that an average of 26.3% of students are addicted to smartphones, with future estimates projected to be increasing. This is worrying as smartphones are known to be damaging to cognition as smartphones can change the way a person thinks through their flexibility, causing dependencies. Besides that, smartphones may cause other problems such as social deficiencies, reduced productivity, and unwanted psychological conditions (Parasuraman et al., 2017). Thus, it is advisable to prevent smartphone addiction by maintaining proper hours on the smartphone.

Due to its many consequences on cognition, smartphone usage has been studied to see its connection with working memory. According to Liu et al. (2023), working

memory is thought to be the human mind's capability to process and utilize information to be operated on. Baddeley's model proposed working memory as a centralised executive function that operates on visual-spatial and phonological information (Baddeley, 1986). Satisfactory working memory requires acceptable levels of attentional performance to enable adequate information to be operated on. In hindsight, as smartphones are known to cause attention deficits, it is reasonable to assume that smartphones may decrease a person's working memory by impairing attention span. However, Liu et al. (2023) disprove this and found no significant correlation between working memory and attention in their visual working memory tests, suggesting that the link between smartphones and working memory needs to be tested directly.

There has been no definite explanation for how smartphones affect working memory but current studies have only linked poor working memory performance to other attributing factors of smartphone use such as anxiousness caused by the absence of smartphones, or 'nomophobia', poor academic abilities that are usually associated with smartphone addiction, and other habitual consequences of smartphone use like poor sleeping schedules (Tanil & Yong, 2020).

1.2 Problem Statement

The consensus is that multimedia devices, especially smartphones, have been regularly condemned for the current decline in human cognition (Al-khlaiwi et al., 2020). However, current research on the effects of prolonged phone usage on work memory performance remains sparse. This is in part due to technology only being massively used in recent years as more and more countries are becoming developed

states. One of these modernizing changes is that smartphones are becoming a daily necessity in one's livelihood, which calls for more research to discover potential consequences that smartphones may have on the human brain (Wilmer et al., 2017).

Current knowledge of the connection between smartphone usage and working memory is inconclusive and warrants more experimentations to pinpoint its possible negativity on working memory, albeit there is evidence of adverse effects of smartphone usage on other aspects of human cognition. The basis for attributing smartphone usage to many cognitive deficiencies, including working memory, stems from the idea that regular smartphone users have little to no control over using their smartphones when their smartphones produce a stimulus (i.e. vibrations, sounding ringtones), termed the user's inhibitory control. Poor inhibitory control over smartphones results in impaired attentional processes that reduce a person's potential for proper cognitive performance (Liebherr, 2020).

However, there are findings that conflict with the theory that the chronic usage of smartphones affects working memory negatively. A study involving participants of different ages also reported similar results in that chronic smartphone usage does not affect a person's working memory. However, it was observed that the participants performed better at memory tasks when their smartphones were taken away (Hartmann et al., 2020). The experimentations also involved the memory tasks of others and the performance for these separate memory tasks was significantly different from smartphone-addicted participants and their non-addicted counterparts. This indicates that other aspects of cognitive abilities that were compromised by smartphone use are not indicative of working memory abilities. Thus, this finding discredits the proposition as mentioned earlier of how inhibitory control and

attentional problems caused by smartphone usage impact working memory as this study categorises a person's working memory as an independent cognitive ability, unaffected by any mediating cognitive competencies. Therefore, this study aims to continue to investigate the relationship between smartphone usage and working memory.

1.3 General Objectives

To identify the relationship between smartphone usage and working memory performance among undergraduate students.

1.3.1 Specific Objectives

- a) To identify the relationship between smartphone usage and verbal working memory performance based on the total correct recall.
- b) To identify the relationship between smartphone usage and verbal working memory performance based on the total time taken.
- c) To identify the relationship between smartphone usage and visual working memory performance based on the total correct recall.
- d) To identify the relationship between smartphone usage and visual working memory performance based on the total time taken.

1.4 Research Questions

- i) Is there any significant relationship between smartphone usage and verbal working memory performance based on the total correct recall?
- ii) Is there any significant relationship between smartphone usage and verbal working memory performance based on the total time taken?

- iii) Is there any significant relationship between smartphone usage and visual working memory performance based on the total correct recall?
- iv) Is there any significant relationship between smartphone usage and visual working memory performance based on the total time taken?

1.5 Research Hypotheses

H₁: There is no significant relationship between smartphone usage and verbal working memory performance based on the total correct recall.

H₂: There is no significant relationship between smartphone usage and verbal working memory performance based on the total time taken.

H₃: There is no significant relationship between smartphone usage and visual working memory performance based on the total correct recall.

H₄: There is no significant relationship between smartphone usage and visual working memory performance based on the total time taken.

1.6 Conceptual Framework

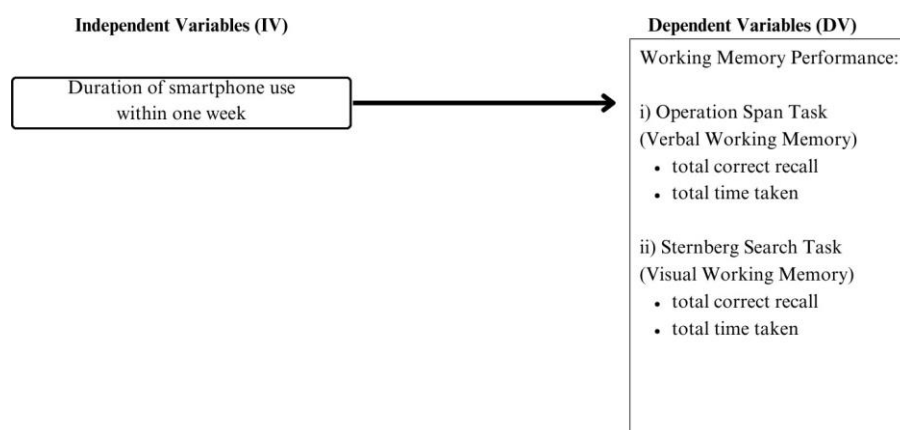


Figure 1. *The Conceptual Framework for The Relationship Between Smartphone Usage and Working Memory Performance among Undergraduate Students*

The figure above represents the conceptual framework for studying the relationship between smartphone usage and working memory performance among undergraduate students. It will be assessed how the average duration of smartphone use within one week of a UNIMAS student can affect participants' verbal and visual working memory performance through the Operation Span Task and Corsi Block-Tapping Test respectively.

1.7 Significance of Study

The purpose of this study is to investigate the effect of smartphone usage on working memory performance among students attending Universiti Malaysia Sarawak (UNIMAS). As young adults have among the highest average usage of smartphones among all age groups, using students from Universiti Malaysia Sarawak enables the replication of working memory studies to be applied to undergraduates for further exploration into the potential negative effects of smartphone usage on a UNIMAS student's working memory, particularly on their verbal and visual working memory performance (Csibi et al., 2021). It is expected that this study can either reinforce the idea that smartphones are detrimental to one's working memory or further support the contradictory findings that claim that there is no connection between smartphone usage and regressed working memory performance. Overall, this research is to provide additional context to current working memory performance studies to discuss any possible observable differences and to pinpoint the significance of the differences. It is hoped that the resulting findings allow young adults, especially university students, to take into consideration the total hours that they spend on their smartphones to have a cognitive advantage when it comes to their academics. In

addition, educators can make more informed choices in structuralizing their lesson curriculums whether to include technology-based learning for learners.

1.8 Definition of Terms

1.8.1 Smartphone

Conceptual Definition: Smartphones can be defined as multipurpose communication devices that through the installation of various applications, allow their users to engage in many functions such as communication, entertainment, searching information, and navigation (Deng et al., 2018).

Operational Definition: The operational definition of ‘smartphone’ in this study would not include its literal definition but rather the duration of usage that an average university student, specifically a UNIMAS student, would have on his or her smartphone within one week, recorded through their phones’ in-built screen time tracking. The duration of smartphone use would therefore indicate the level of dependency a UNIMAS student has on his or her smartphone. Hence, it will be seen how the frequency of smartphone usage by a UNIMAS student has impacted his or her working memory performance.

1.8.2 Working Memory

Conceptual Definition: Baddeley (1986) defines working memory as an interdependent system of the visual-spatial sketchpad and phonological loop, governed by the central executive that allows for the operation and manipulation of information.

Operational Definition: In this study, working memory refers to the verbal and visual working memory performance of a UNIMAS student. The verbal working memory performance will be tested through the Operation Span Task while the visual working memory performance will be evaluated through the Corsi Block-Tapping Test. The performance for both tests will be based on the total correct recall and total time taken by a participant.

1.9 Summary

This research aims to study the relationship between smartphone use and the working memory performance of undergraduate students attending Universiti Malaysia Sarawak (UNIMAS) to provide more conceptualization to the conflicting data on whether smartphone use does indeed impact a person's working memory performance. Hence, this study opts to utilise working memory tasks that evaluate a UNIMAS student's working memory performance in both verbal and visual aspects while taking note of the student's smartphone duration. Through this, the resulting data may provide more insight into this speculative problem.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

In this chapter, a collection of the foundational theories, models, concepts and past findings relating to the effects of smartphone usage on working memory performance is presented in order to evaluate and analyze existing research on its possible impacts. This entails covering its addictiveness, the potential cognitive risks, and discovering its possible links within the context of working memory performance. Thus, this review provides a thorough understanding of the topic and also highlights data inconsistencies that warrant further research.

2.1 Discussion of Related Theories and Models

2.1.1 Baddeley & Hitch's Working Memory Model

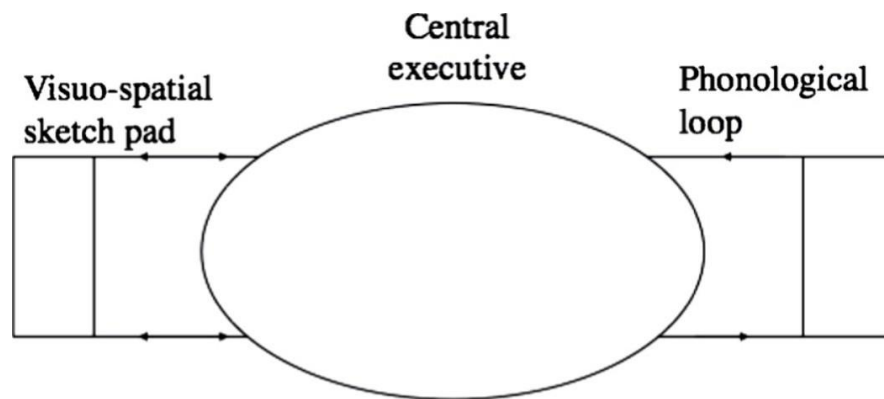


Figure 2.1 *The Baddeley & Hitch's Working Memory Model*

According to Baddeley (2012), Baddeley & Hitch's Working Memory Model (1986) is a hypothetical framework of a system that involves manipulating and controlling information required for carrying out a selection of cognitive tasks. Referring to the figure above, the model is governed by a centralised component that is known as the

central executive. Baddeley (2012) has high regard for the complexity of the central executive to the point of describing it with an analogy akin to a homunculus, like a miniature human in the brain tinkering with inputted information. He postulates that the central executive is responsible for cognitive actions such as decision-making, storage and attention. The central executive splits between two temporary storage subsystems. The first subsystem termed the visuospatial sketchpad, linked to the visual working memory, can be thought of as a temporary space for visual or spatial information, which depends on the nature of the perceived information. The second subsystem named the phonological loop, associated with verbal working memory, is another concept of temporary space for information for auditory and articulatory information. These two subsystems have a two-way cooperation with the central executive.

2.1.2 Miyake et al.'s Theory of the Central Executive

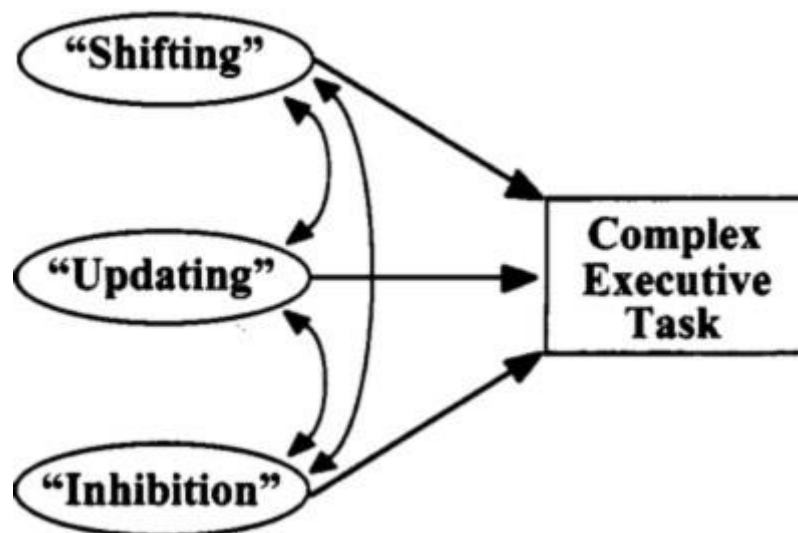


Figure 2.2 *Theoretical Extension of the Working Memory (Miyake et al., 2000)*

Miyake et al. (2000) expanded the roles of the central executive in the working memory. The study involved the gathering of university students to carry out tasks related to working memory. While the students were doing so, the students' prefrontal and frontal lobes were monitored as these regions of the brain are largely linked to where the central executive performs. They found that the central executive is responsible for three additional functions, which are shifting, updating, and inhibition. Shifting refers to the action of switching the attention between mental models depending on the information being received. Next, updating represents the monitoring and revising of incoming information and improving it to keep it up to date. Lastly, inhibition is related to the prevention of primed responses in avoiding cognitive rigidity. While these three functions are said to be independent of each other, they do seem to work cooperatively with one another depending on the executive tasks presented.

2.2 Discussion of Issues Related to the Topic

2.2.1 Overview of Smartphone Usage

The first ever mobile phone to be made commercially available was in 1984 (Parasuraman et al., 2017). During these times, owning a mobile phone was unconventional as not only was the device itself pricey but using its services such as phone calls were exorbitant too (Hossain et al., 2022). With time, mobile phones and the utilities for owning one became progressively affordable, especially when widespread internet connection was readily available. As mobile phones evolved into smartphones, their functionality also expanded, to the point that it has become a necessity in society's daily life. For example, smartphones have enabled us to easily connect regardless of the distances between us, making it easy to make new friends

and far-away employment. Now, many smartphone companies are rushing to create new models that contain new features to satisfy customers. This in itself has created a trend of smartphones being a symbol of status as the latest smartphones have the most advanced features along with their price tag (Hossain et al., 2022).

2.2.2 Smartphone Addiction

According to Ratan et al. (2022), an estimated six billion people, or over 83% of the global population are owners of a smartphone(s). Based on their studies, they found that 61.4% of their surveyed young adults admit to having an addiction to their smartphones. The cause of smartphone addiction could be primarily associated with the flexibility of the Internet, as it allows smartphone users to connect with multiple platforms that satisfy the person's social needs, retracting the need for physical interactions (Ratan et al., 2021). In Griffiths' (2005) component model of addiction, smartphone addiction can be contextualised into a few descriptive symptoms. Firstly, the term "salience" is used to specify a user who would be preoccupied with the usage of his or her smartphone. The second would be "mood modification", and this can be observed when the users exhibit mood swings throughout the usage of the smartphone. The third indication is "tolerance", which denotes an increased duration of smartphone usage without conscious awareness. The next one would be the showings of negative emotions when smartphone usage is forcibly unavailable, and these are termed "withdrawal symptoms". Another description would be "conflict", which signifies when a person encounters interpersonal and intrapersonal problems that are caused by his or her use of smartphones. Lastly, a person may face "relapses", where a person regains the addiction towards smartphones despite showing temporary improvement.

2.2.3 Effect of Smartphone Usage on Cognitive Performance

If used in moderation, smartphone usage is proven to be effective in increasing cognitive functions among its users, as demonstrated in a study by Bless et al. (2014), who had a few participants undergo their mobile training application. It was found that the application was able to decrease neural activation of their participants in brain regions that were associated with executive functioning and selective auditory processing, indicating an increase in the participants' neural efficiencies.

The problem occurs when smartphones are chronically overused among users which can cause a few cognitive impairments. Ward et al. (2017) attributed the decrease in attention from the dependency on smartphones when it comes to observed cognitive insufficiencies in smartphone addicts. Their study involved participants who were instructed to complete tasks with the difference in experimental groups being the distance of the participants' smartphones from their possession. It was found that the group who were the closest to their smartphones showed a significant decrease in cognitive performance as they were more likely to be tempted to check their phones, limiting attentional resources to be used for their given tasks. Similarly, Kancharla et al. (2022) attributed smartphone addiction to distractibility, forgetfulness, and false triggerings. Participants who were addicted to their smartphones were more prone to being distracted by their phones and checking their phones despite not being signalled to do so, which led to forgetfulness as they had forgotten what they were supposed to do while being occupied with their smartphones. From a neurological standpoint, excessive smartphone use was linked to weaker activation in the right prefrontal cortex, causing attentional and processing impairments (Hadar et al., 2017).

The key takeaway here is that while smartphone usage can improve a person's cognitive functions when used in moderation, it has negative effects when a person's smartphone usage becomes uncontrollable and develops a dependency.

2.3 Previous Findings

The basis for attributing smartphone usage to working memory stems from the idea that regular smartphone users have little to no control over using their smartphones, termed the user's inhibitory control (Liebherr, 2020). When smartphones produce a stimulus (i.e. vibrations, sounding ringtones), people who have low inhibitory control over their smartphones find it hard to abstain from responding to them due to the inability to control the automatic thoughts and behaviours of checking their smartphones. Poor inhibitory control over smartphones results in impaired attentional processes, which limits the amount of informational input derived from inadequate attention resources to be worked on. Besides that, poor inhibitory control causes processes of working memory to be disrupted as a result of distractive phone-checking (Liebherr, 2020).

Past studies on Smartphone Usage and Working Memory Performance have yielded conflicting findings, with some claiming that smartphone usage impacts working memory performance and some discrediting this claim. Aharony & Zion (2019) conducted research involving the messaging application WhatsApp to explore how smartphone use can affect working memory performance. The basis of the experiment is centred around placing their smartphones next to them and using WhatsApp texts as a distraction for their participants of teenage ages during their completion in the

working memory section of the *Wechsler Intelligence Scale for Children-IV*. Hence, they found that those who had their WhatsApp open performed significantly worse than the control group, indicating that smartphone use does negatively impact working memory.

In another research, the visual working memory capacity of college student participants was tested against the mere presence of their phones. It was found that those who had more impulsivity to check their phones performed worse in the working memory task, signifying that there may be an emotional mediator in how smartphone usage can affect working memory (Canale et al., 2019). Similarly, Hartmann et al. (2020) also found that participants performed better in working memory tasks if the participants' smartphones were absent when progressing through the working memory tasks.

Therefore, the studies that link smartphones to poor working memory performance are mostly attributing the smartphone's ability to distract. Liu et al. (2023) disapprove of this and suggest that direct tests of smartphone usage and working memory are needed to be done. Other possible cognitive deficiencies caused by smartphone usage that are interlinked with processes of working memory may also inevitably interfere with the isolation of the measurement of working memory performance (Hartmann et al., 2020).

In short, the research that claims smartphone usage impacts working memory is based on the reactions towards smartphones, not the smartphone use itself. Thus, there should be more studies conducted to directly examine the effects of smartphone usage

on working memory performance in other ways, instead of indirect reasoning such as the attribution of the distractibility of smartphones.

2.4 Summary

In summary, working memory is a multifaceted theory of interlinked cognitive components that work together in processing information while maintaining other information. As smartphones have become a staple in society, many cognitive impacts on the minds of smartphone users have been identified. However, the effect of smartphone usage on working memory needs to be further explored as there are no solid conclusions for it. On one hand, researchers have attributed the distractibility of smartphone usage to negatively affecting working memory performance. On the other, researchers have shown that there are no direct implications for smartphone usage on working memory performance as observed effects are based on indirect variables. Therefore, more research is needed to be conducted to pinpoint the negative consequences of smartphone usage on working memory performance.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

The present chapter delineates a thorough methodological strategy for investigating the effect of smartphone usage on working memory performance among a selected population, which are UNIMAS university students. It explains the reasoning behind the study's selected research design and sampling techniques. This chapter also defines the research tools used and discusses the feasibility of conducting a pilot study. Next, the procedures used to evaluate the research instrument's validity and reliability will be described along with a thorough analysis of the ethical issues. Lastly, the methods for gathering and analysing data are covered.

3.1 Research Design

The research design chosen for this study is the correlational research design. The correlational research design is quantitative research that measures the relationship between two or more variables (Lillykutty & Samson, 2018). The concept of the design of the study is shown as such:

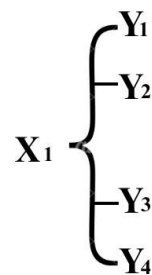


Figure 3. *The Research Design of this Study (Correlational Research Design)*

The figure above illustrates the design of the research. For the independent variable, X_1 refers to the number of hours of smartphone usage within one week. For the

dependent variables, Y_1 is the participants' total correct recall in verbal memory performance, Y_2 is the participants' total time taken in verbal memory performance, Y_3 denotes the participants' total correct recall in visual memory performance, and Y_4 refers to the participants' total time taken in visual memory performance. Thus, The participants will have the duration of their smartphone usage measured against the total correct recall and time taken of the verbal and visual working memory performance. This is done by engaging in the selected task, which is the Operation Span Task and Corsi Block-Tapping Test respectively.

3.2 Population and Sample

The population that this study hopes to be applicable to are young adults undergoing higher tertiary education in Malaysia, namely Malaysian undergraduate students. Acquiring the general population of existing undergraduate students in Malaysia would be unfeasible for the experiment. Hence, a sample size consisting of students attending Universiti Malaysia Sarawak (UNIMAS) hopes to be representative of the typical Malaysian university student. The sampling method that will be conducted in this study is convenience sampling, in which subjects are accessed from sources that are convenient for the researcher (Andrade, 2021). With that being said, a sample size of 34 UNIMAS undergraduate students is targeted.

3.3 Instruments

Firstly, the instruments that shall be used to track the number of hours that participants use on their smartphones come from their smartphones' built-in screen time trackers that are usually found in the settings application within their respective smartphones' operating systems. Thus, the number of hours that are shown by the

tracker will be recorded for each participant, which is input by the participants in another instrument in the study, which is a Google Form survey. Along with the tracking information, the participants' demographics are also collected in the survey and a consent form is provided to be filled.

Besides that, the instrument for evaluating verbal working memory performance that shall be administered in this study will be sourced from the application named Wadsworth CogLab on a CD, shortly known as CogLab, created by Francis & Neal (2004). CogLab is an application that contains multiple experiments that are aimed at assessing the cognitive abilities of users adopted from past research. Within the application, the Operation Span Task is available to be tested, with instructions for the user to heed. Next, the instrument for evaluating visual working memory performance that shall be administered in this study will be sourced online from an organization known as PsyToolkit which is operated by a team of academicians. PsyToolkit is a web-based instrument that offers a selection of experiments and questionnaires that are suitable to be used for research projects in the field of psychology due to academic sourcing from credible documentation (Stoet, n.d.). PsyToolkit has adopted the Corsi Block-Tapping Test on its website which will be used in assessing visual working memory performance.

The Operation Span Task, short for "Ospan task", is a working memory task by Turner & Engle (1989) that can be used to assess verbal working memory performance. In this task, participants are presented with a collection of mathematical questions that participants have to read out loud and solve. Then, they will be shown a set of randomized sets of two to five words that need to be memorized and recalled in

the same order. To ensure that participants complete the task properly, participants are required to obtain an acceptable score in the number of mathematic questions answered (Turner & Engle, 1989).

Corsi Block-Tapping Test is a memory-scanning task that can be used to measure visual working memory performance. The test starts by presenting the participants with a series of nine blocks that are randomly arranged on the screen. At the beginning of the test, two of the nine blocks will produce a highlighting sequence (in PsyToolkit the block will be changing colours) and the participants shall replicate these sequences. The tests progress with more blocks being included in the sequence until the participants are no longer able to recall the sequences correctly (Brunetti et al., 2014).

3.4 Procedures

Participants are required to track the number of hours that they use their smartphones by screenshotting the number of hours and uploading it to a Google survey as well as filling out their demographic information and the consent form. Straight after that, the participants are guided to a controlled environment in which they will be doing the working memory tests. The participants will access the CogLab application and PsyToolkit website with the devices provided, which is the researcher's laptop, and complete the Operation Span Task and Corsi Block-Tapping Test respectively. After completing the tests, the participants are to report the number of total correct recalls and time taken for the respective tasks. Participants may leave the controlled room after doing so.

3.5 Pilot Study

A pilot study is carried out to evaluate the safety of treatments or interventions, investigate randomisation and blinding procedures, and enhance familiarity with study methodologies to enhance the effectiveness and calibre of the primary research plan (Suresh, 2011). The pilot study consists of six random UNIMAS undergraduate student participants who will go through the same procedures as the primary research plan. Through this, the pilot study yielded a majority opinion that the procedures, research instruments, and methodologies were all suitable and relevant to the study. Regardless, there was one participant who criticized the noisy environment of the testing space, and this could be in part due to the audio produced by the Corsi Block-Tapping Test that would continuously say “Go!” to prompt the user to engage in the test. To resolve this, the test shall be conducted with the device’s volume muted during data collection.

3.6 Ethics of Study

To maintain academic integrity for research purposes and to protect participants in terms of their rights, dignity, and welfare (Sivasubramaniam, 2021), there are a few methods of maintaining integrity and ethics in this study. Immediately before conducting the test, participants are asked to fill in a consent form to assure participants that their identity will be kept confidential and their data will only be used for academic purposes. A debriefing will be given after the participants have completed the study to inform the participants of their purpose for conducting the study, and should there be any wishes for withdrawal shall be respected.

3.7 Data Analysis Procedures

With regard to the design and type of data used, this study utilised the quantitative methodology. Quantitative research entails evaluating quantifiable variables to obtain results. The results are analysed through the use of statistical reporting to describe the outcome of the hypothesis or phenomenon (Apuke, 2017). In the experiment, scores from the participants' performance and their total time taken on the Operation Span Task and Corsi Block-Tapping Test will be obtained and related to the no. of hours of smartphone usage that have been tracked through their smartphones. The results will be processed through the statistical software IBM Statistical Software Package for the Social Sciences, abbreviated as SPSS, to enable interpretation of the data. Specifically, IMB SPSS Statistical 27 will be applied in this study.

3.7.1 Descriptive Data Analysis

Descriptive data refers to data in the form of central tendency measures such as mean, mode, and median that are presented through graphical representations such as histograms or bar charts (Kaliyadan & Kulkarni, 2019). In this study, the demographical features and results of the participants will be summarized in the form of charts, tables, and graphs for easier comprehension.

3.7.2 Inferential Data Analysis

The selected statistical analysis technique for the research is deemed to be the Pearson Correlation Coefficient. The Pearson Correlation Coefficient is an inferential statistical test that measures the strength of the relationship between two variables (Chen & Anderson, 2023). The Person Correlation Coefficient has a range value of -1 to +1 where a positive sign indicates a linear relationship and a negative sign shows

an inverse relationship, whilst the closer the value is to 0 indicates a weakening relationship while the opposite is true for a value closer to 1 (Schober et al., 2018).

The scores of the total number of correct recalls and time taken by the participants will be tallied and analysed against their smartphone use to find whether there is a statistical significance in the relationship between how smartphone usage can influence the performance of verbal and visual working memory.

Hypotheses	Statistical Test
H ₁ : There is no significant relationship between smartphone usage and verbal working memory performance based on the total correct recall.	Pearson Correlation Coefficient
H ₂ : There is no significant relationship between smartphone usage and verbal working memory performance based on the total time taken.	Pearson Correlation Coefficient
H ₃ : There is no significant relationship between smartphone usage and visual working memory performance based on the total correct recall.	Pearson Correlation Coefficient
H ₄ : There is no significant relationship between smartphone usage and visual	Pearson Correlation Coefficient

working memory performance based on the total time taken.	
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Table 3. *Data Analysis for the Study's Hypotheses*

3.8 Summary

To summarise, the study will be conducted in the form of a correlation research design where participants' average smartphone usage per week will be recorded and related to their working memory performance. More specifically, the groups are measured on the verbal and visual working memory performance, which are the Operation Span Task and Corsi Block-Tapping Test respectively. The measurement of the participants' working memory performance is done through the collection of the no. of correct recalls and time taken among the participants. Through SPSS, the results are analysed with the Pearson Correlation Coefficient to establish the relationship between smartphone usage and verbal and visual working memory performance, which is used to prove or disprove the research's hypothesis.

CHAPTER FOUR

FINDINGS AND DISCUSSION

4.0 Introduction

The results of the experimental study, in which collected data are acquired using a Google Forms quiz, are discussed in this chapter. Along with the demographic data of the respondents, the inferential statistics of the relationship between the independent factor (average weekly smartphone usage) and the dependent variables (verbal and visuo-spatial working memory) will be correlated through the Pearson Correlation Coefficient in establishing hypotheses and research objectives.

4.1 Demographic Data

		<i>n</i>	%
Gender	Male	17	50.0
	Female	17	50.0
Age	19-22 years old	21	61.8
	23-26 years old	13	38.2
CGPA	2.49 and below	1	2.9
	2.99 - 2.50	1	2.9
	3.49 - 3.00	16	47.1
	4.00 - 3.50	16	47.1

Table 4.1. *Demographics*

A Google Forms questionnaire was distributed to undergraduate students at Universiti Malaysia Sarawak (UNIMAS) upon completion of the two testing instruments.

Demographic data were collected from Section B: Demographics from a total of 34 participants. The table above provides a summary of the demographic details of the participants.

4.1.1 Gender of Participants

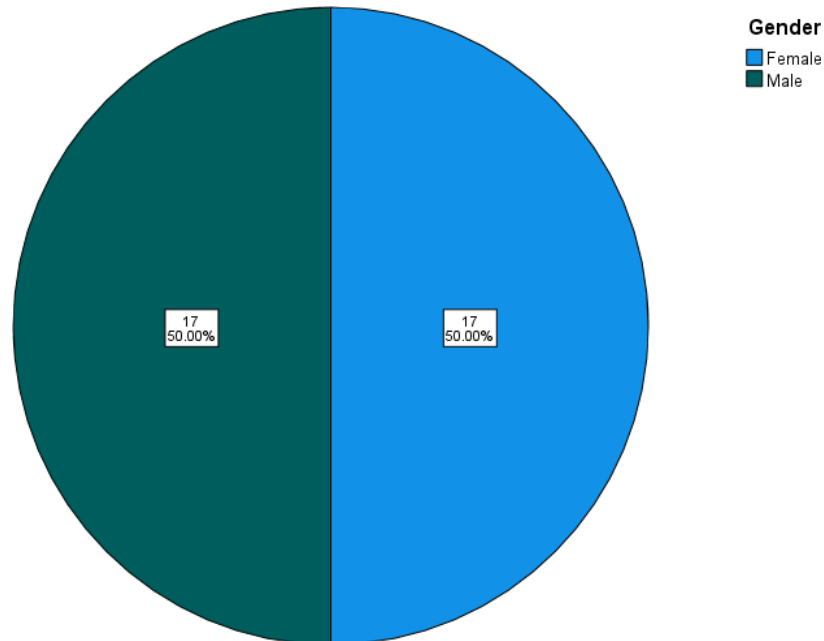


Figure 4.1 *Pie Chart of Participants' Gender*

In this study, an effort has been made to ensure that there are an equal amount of participants among the genders. Thus, referring to the pie chart above, 17 or 50% of participants belong to each male and female gender among the 34 participants.

4.1.2 Age of Participants

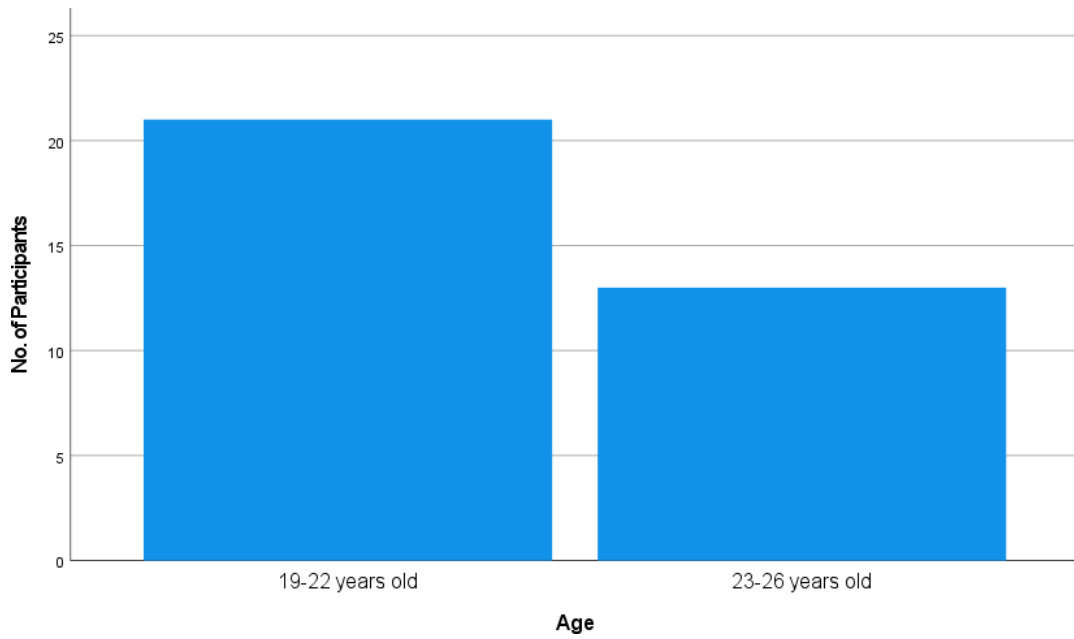


Figure 4.2. *Bar chart of the Participants' Ages*

Figure 4.2 shows the distribution of ages among the selected participants in the study. As participants all fall under the same cohort of undergraduate students, it is reasonable to assume that the ages of participants will not differ much. Hence, most participants are young adults, with 21 participants categorised under 19-22 years old and 13 of them being 23-26 years old.

4.1.3 CGPA of Participants

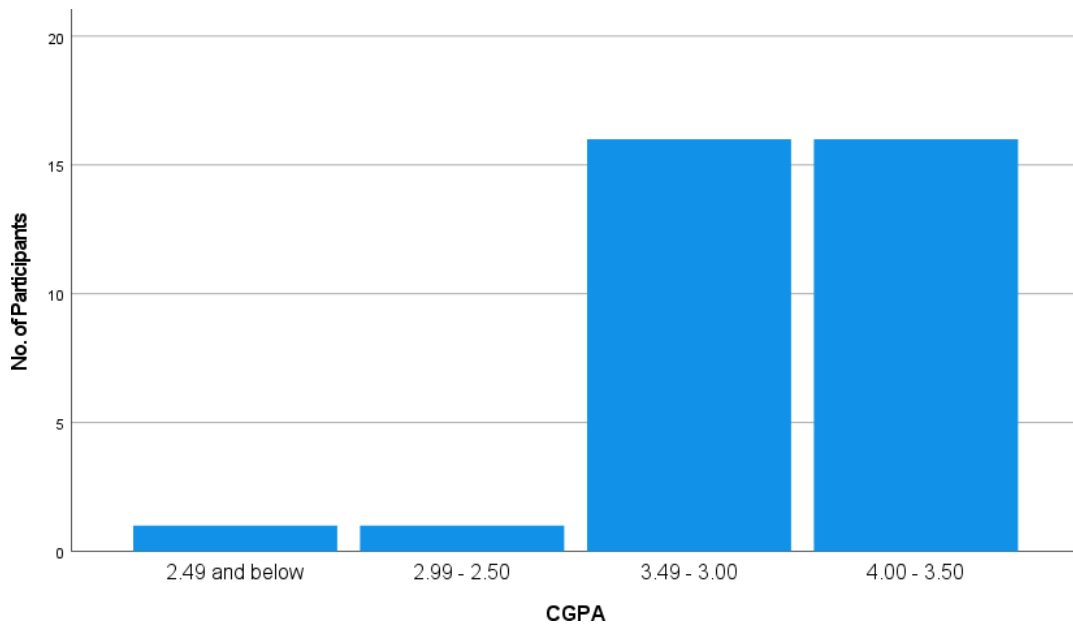


Figure 4.3 Bar Chart representing the CGPA of Participants

The bar chart in Figure 4.3 shows the distribution of CGPAs among the 34 participants. It can be seen that most participants possess a CGPA ranging from 3.49-3.00 and 4.00-3.50 at 16 participants each. The CGPA range of 2.99-2.50 and 2.49 and below only have one participant each.

4.1.4 Descriptive Statistics

N	Minimum	Maximum	Mean	Std. Deviation
---	---------	---------	------	----------------

Average Weekly	34	2:44	14:39	8:00	3:00
Smartphone Usage					
Operation Span Task	34	4	54	29.35	14.818
Score					
Operation Span Task Total	34	7:57	13:42	10:14	1:28
Time Taken					
Corsi Block-Tapping Test	34	4	9	6.21	1.200
Score					
Corsi Block-Tapping Test	34	0:45	2:09	1:21	0:19
Total Time Taken					

Table 4.2. *Descriptive Statistics*

Table 4.2 represents the descriptive statistics for the four factors of working memory performance with respect to the average weekly smartphone usage of the 34 participants. The average weekly smartphone usage of participants ranged from 2:44 hours to 14:39 hours (M=8:00, SD=3:00). The Operation Span Task, measuring verbal working memory performance, based on total correct recall has a minimum score of 4 and a maximum score of 54 (M=29.35, SD=14.818). For total time taken, the participants range from 7:57 minutes to 13:42 minutes (M=10:14, SD=1:28). In terms of the Corsi Block-Tapping Test, which measures visual working memory performance, the score of the participants shows a range of 4 to 9 (M=6.21, SD=1.2) while the total time taken of participants range between 0:45 minutes to 2:09 minutes (M=1:21, SD=0.19).

4.2 Inferential Data (Main Findings)

			Tests of Normality					
			Kolmogorov-Smirnov ^a			Shapiro-Wilk		
			Statistics	df	Sig.	Statistics	df	Sig.
Operation	Span	Task	.085	34	.200*	.957	34	.197
Score								
Operation	Span	Task	.149	34	.055	.954	34	.161
Total Time Taken								
Corsi	Block-Tapping		.167	34	.017	.937	34	.051
Test Score								
Corsi	Block-Tapping		.095	34	.200*	.981	34	.798
Test Total Time Taken								

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

a. Lilliefors Significance Correction

Table 4.3 *Test of Normality*

Referring to Table 4.3, the Shapiro-Wilk test of normality was computed to determine whether the data gathered in this study is normally distributed. The results indicate that the null hypothesis is failed to be rejected for the Operation Span Task Score ($p = 0.197$) and conclude that data is normally distributed. Next, the results show that the null hypothesis for the Operation Span Task Total Time Taken is failed to be rejected ($p = 0.161$) and conclude that data is normally distributed. Following that, the null hypothesis for the Corsi Block-Tapping Test Score is failed to be rejected ($p = .051$) which shows that the data is normally distributed. Lastly, the results show that the null hypothesis for the Corsi Block-Tapping Test Total Time Taken is failed to be rejected as $p = .798$, which means that the data is normally distributed.

Hence, the correlative study employed the Pearson Correlation Coefficient in establishing the relationships of the independent variable of smartphone usage with the dependent variables of verbal and visual working memory performance based on total correct recall and time taken in assessing the study's hypotheses. Besides that, scatterplot diagrams are provided to give an illustration of the participants' working memory performances against their smartphone usage.

4.2.1 The Relationship between Smartphone Usage and Verbal Working Memory Performance Based on Total Correct Recall

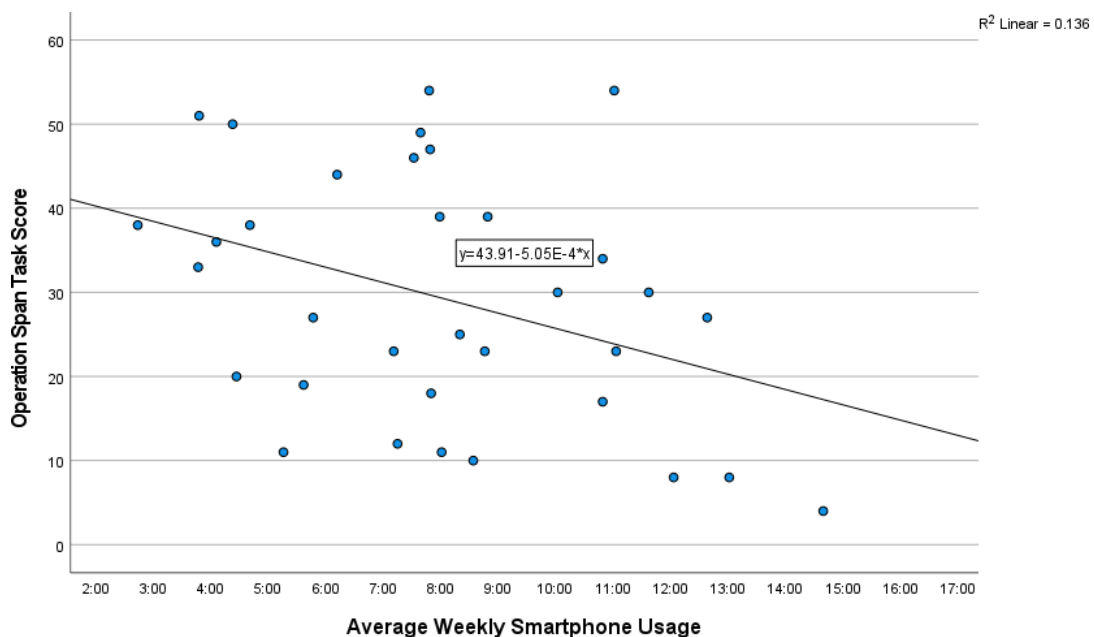


Figure 4.4. Scatter Plot on the Relationship between the Average Weekly Smartphone Usage and Operation Span Task Score

H₀: There is no significant relationship between smartphone usage and verbal working memory performance based on the total correct recall.

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

		Average Weekly Smartphone Usage	Operation Span Task Score
Average Weekly	Pearson Correlation	1	-.369*
Smartphone	Sig. (2-tailed)		.032
Usage	N	34	34
Operation Span	Pearson Correlation	-.369*	1
Task Score	Sig. (2-tailed)	.032	
	N	34	34

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

Table 4.4 *Pearson Correlation Coefficient on the Relationship between the Average Weekly Smartphone Usage and Operation Span Task Score*

Pearson Correlation Coefficient produced a moderate negative correlation of the relationship between the Average Weekly Smartphone Usage and Operation Span Task Score, reporting a correlation coefficient of $r(32) = -.369$, $p = .032$. As $p = .032$, the null hypothesis is rejected. Hence, there is a significant relationship between smartphone usage and verbal working memory performance based on the total correct recall.

4.2.2 The Relationship between Smartphone Usage and Verbal Working Memory Performance Based on Total Time Taken

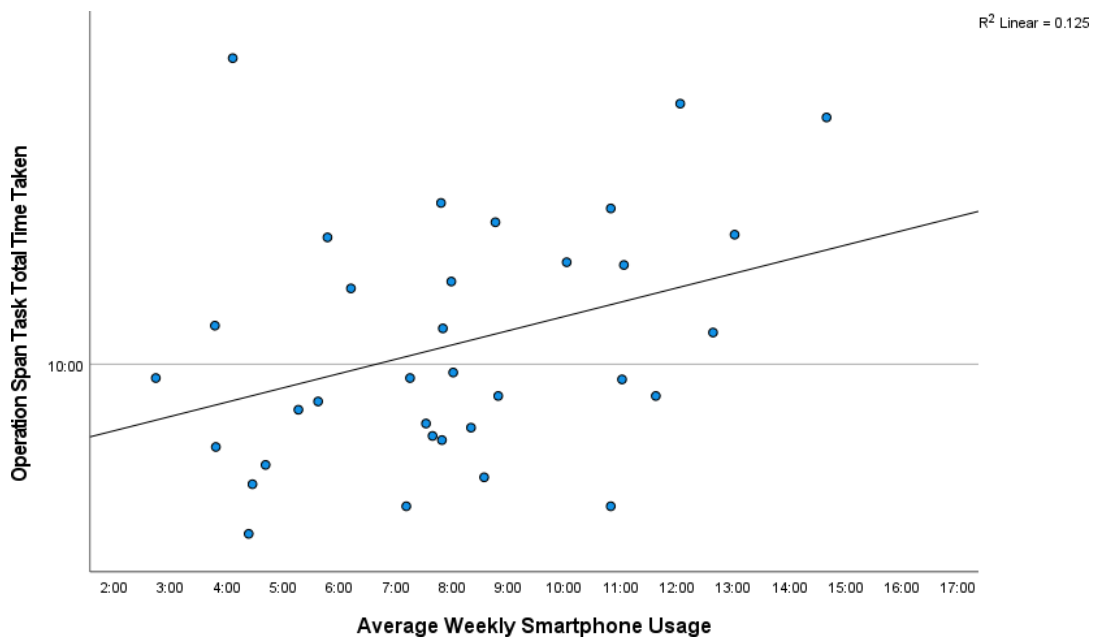


Figure 4.5 *Scatter Plot on the Relationship between the Average Weekly Smartphone Usage and Time Taken to complete the Operation Span Task*

H_0 : There is no significant relationship between smartphone usage and verbal working memory performance based on the total time taken.

H_1 : There is a significant relationship between smartphone usage and verbal working memory performance based on the total time taken.

		Average Weekly Smartphone Usage	Operation Span Task Total Time Taken
Average Weekly	Pearson Correlation	1	.353*
Smartphone	Sig. (2-tailed)		.040
Usage	N	34	34

Operation Span	Pearson Correlation	.353*	1
Task Total Time Taken	Sig. (2-tailed)	.040	
	N	34	34

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

Table 4.5 *Pearson Correlation Coefficient on the Relationship between the Average Weekly Smartphone Usage and Time Taken to Complete the Operation Span Task*

Among the 34 undergraduate UNIMAS students, the average no. of hours that the participants spent on their phone weekly and the time taken to complete the Operation Span Task had a moderate positive correlation, with $r(32) = .353$, $p = .040$. Due to $p = .040 < .05$, the null hypothesis is rejected. Thus, there is a significant relationship between smartphone usage and verbal working memory performance based on total time taken.

4.2.3 The Relationship between Smartphone Usage and Visual Working Memory Performance Based on Total Correct Recall

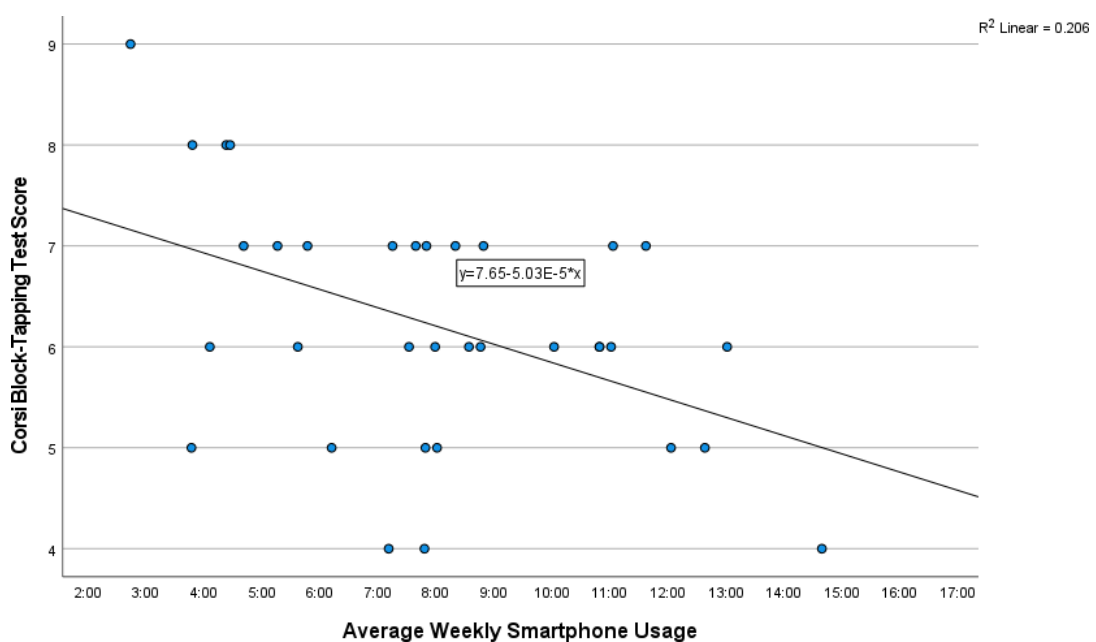


Figure 4.6 *Scatter Plot on the Relationship between the Average Weekly Smartphone Usage and Corsi Block-Tapping Test Score*

H₀: There is no significant relationship between smartphone usage and visual working memory performance based on the total correct recall.

H₁: There is a significant relationship between smartphone usage and visual working memory performance based on the total correct recall.

		Average Weekly Smartphone Usage	Corsi Block-Tapping Test Score
Average Weekly Smartphone Usage	Pearson Correlation	1	-.453*
	Sig. (2-tailed)		.007
	N	34	34
Operation Span	Pearson Correlation	-.453**	1
Task Total Time Taken	Sig. (2-tailed)	.007	
	N	34	34

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

Table 4.6 *Pearson Correlation Coefficient on the Relationship between the Average Weekly Smartphone Usage and Corsi Block-Tapping Test Score*

The relationship between the Average Weekly Smartphone Usage and Corsi Block-Tapping Test Score among the participants shows a moderate negative correlation, $r(32) = -.453$, $p = .007$. With $p = .007 < .05$, the null hypothesis is rejected, indicating that there is a significant relationship between smartphone usage and visual working memory performance based on the total correct recall.

4.2.4 The Relationship between Smartphone Usage and Visual Working Memory

Performance Based on Total Time Taken

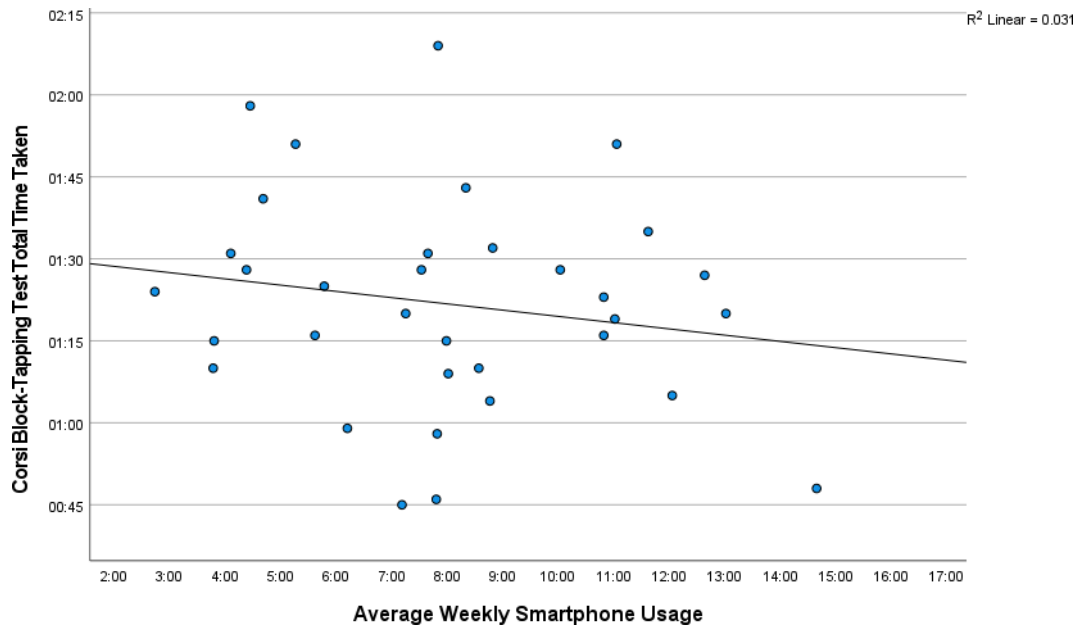


Figure 4.7 Scatter Plot on the Relationship between the Average Weekly Smartphone Usage and Total Time Taken to Complete the Corsi Block-Tapping Test

H₀: There is no significant relationship between smartphone usage and visual working memory performance based on the total time taken.

H₁: There is a significant relationship between smartphone usage and visual working memory performance based on the total time taken.

		Average Weekly Smartphone Usage	Corsi Block-Tapping Test Total Time Taken
Average Weekly	Pearson Correlation	1	-.175
Smartphone	Sig. (2-tailed)		.322
Usage	N	34	34
Operation Span	Pearson Correlation	-.175	1
Task Total Time	Sig. (2-tailed)	.322	
Taken	N	34	34
Correlation is not significant at the 0.05 level (2-tailed).			

Table 4.7 *Pearson Correlation Coefficient on the Relationship between the Average Weekly Smartphone Usage and Total Time Taken to Complete the Corsi Block-Tapping Test*

Pearson correlation coefficient report of $r(32) = -.175$, $p = .322$ indicates that there no correlation of the relationship between the average weekly smartphone usage and the total time taken to complete the Corsi Block-Tapping Test by the participants. As $p = .322 > .05$, the null hypothesis is failed to be rejected. Therefore, there is no significant relationship between smartphone usage and visual working memory performance based on the total time taken.

4.3 Discussion

The data showed significance in the hypotheses of the relationship between smartphone usage and verbal working memory performance based on total correct recall and time taken as well as the relationship between smartphone usage and visual working memory performance based on total correct recall. Only the hypothesis of the

relationship between smartphone usage and visual working memory performance in terms of total time taken showed no significance.

Going into the first hypothesis of the relationship between smartphone usage and verbal working memory performance based on total correct recall, despite showing a weak correlation, the negative correlation coefficient coincides with the stipulated idea that prolonged use of smartphone can lead to poorer verbal working memory performance, as seen in the results that the longer the participants use their smartphone, the lower their scores on the Operation Span Task will be. To support this, Tamil & Yong (2020) conducted a comparable test that also used the Operation Span Task, in which the mean scores of their participants were higher in those with low dependencies on their smartphones than those with high dependencies.

Similarly, the second hypothesis of the relationship between smartphone usage and verbal working memory performance based on the total time taken also shows a weak correlation. However, the positive correlation coefficient concludes that poorer verbal working memory performance is seen among participants with longer smartphone usage in that it takes them a longer time to complete the Operation Span Task compared to their shorter smartphone usage counterparts. In fact, it was observed that some of the participants who had more average weekly hours on their smartphones were visibly restless or irritated as they took longer to complete the Operation Span Task, matching the theory of Liebherr (2020) in that smartphone usage caused attentional problems which in turn causes working memory performance to drop.

Next, the third hypothesis of the relationship between smartphone usage and visual working memory performance based on the total correct recall shows a negative weak correlation, which indicates that the fewer participants use their smartphones, the higher the score the participants can get in the Corsi Block-Tapping Test. This provides evidence that frequent smartphone usage may impair not only verbal working memory performance but also visual working memory performance in participants. This coincides with findings from Uncapher et al. (2015) that those who regularly engage in media content, including through the use of smartphones, have poorer visual working memory performance than those who have lighter media usage. Ito & Kawamura (2016) explained that this may be in part due to the attachment or appeal of a smartphone that causes distractions in a visual search task that is attentionally demanding, such as that of the Corsi Block-Tapping Task that is used in this study.

Lastly, the fourth hypothesis of the relationship between smartphone usage and visual working memory performance based on the total time taken provided a weak negative correlation which means that the lower the smartphone use, the longer they need to complete their Corsi Block-Tapping Test. It can be seen that the correlation of this hypothesis does not match the one for time taken in verbal working performance. The explanation for this is that the Corsi Block-Tapping Test ends whenever the participants fail to provide the correct input two times in a row while the Operation Span Task requires participants to go through the full 18 trials. Hence, it is understandable that participants who have shorter average smartphone usage would take a longer time to complete the Corsi Block-Tapping Test as their better visual working memory performance allows them to go further into the test. This could also

be the explanation to address its insignificance as participants are not measured according to the same amount of items in the Corsi Block-Tapping Test. For future references, the test should have measured the average reaction times of participants, such as that of Ito & Kawamura's (2016) study, which found that the reaction times of their participants who had high smartphone usage were slower compared to their lower counterparts when engaging in a spatial visual search task.

4.4 Summary

Overall, the results agree with the findings that smartphone usage shows an impact on participants' working memory performance (Aharony & Zion, 2019; Canale et al., 2019) while providing argumentative evidence to studies that assert that there is no evidence of the correlation between smartphone usage and working memory performance (Hartmann et al., 2020; Liu et al., 2023). It is noted that most studies stressed attentional deficits caused by increased dependencies on smartphone overuse which is parallel to that of the theory formed by Liebherr et al. (2020). Hence, it should be noted that the study's results only provide correlative evidence and not causative, and the limitations of this study shall be discussed in the following chapter.

CHAPTER FIVE

LIMITATION, IMPLICATION, RECOMMENDATION AND CONCLUSION

5.0 Introduction

This chapter outlines the research implications and limitations of the study on the relationship between undergraduate students' smartphone usage and working memory performance. Recommendations for future research are also discussed, ending with an executive summary of the entire research.

5.1 Implications of Study

In this study, the overall results suggest that excessive use of smartphones negatively correlates with the working memory performance of the participants. Specifically, participants who spend more time on their smartphones tend to have inferior performance on the given working memory tasks compared to those who use their smartphones less frequently. Theoretically speaking, it concurs with supporting past findings that agree that prolonged smartphone use negatively affects working memory performance. A consistent explanation among these studies is that the distractibility of a smartphone is the reason for poorer working memory performance among those who are addicted to it (Aharony & Zion, 2019; Canale et al., 2019), providing verification of the theory set by Liebherr et al. (2020) that the distraction caused by smartphones depending on an individual's level of inhibitory control over it can lead to attentional deficits that limit working memory performance. This study's findings add to this theory by providing empirical evidence that increased time spent on smartphones deprives attention needed by participants to perform well in working memory task.

With the participants being demographers of undergraduate students, this information allows them to have a higher level of consideration over their smartphone usage, which could lead to improved attentional resources and working memory, fostering improvements in all aspects of academic performance. Regardless, other potential side effects associated with smartphone overuse should also be noted by students, such as depression, anxiety, stress, and poor sleep quality (Shoukat, 2019).

Besides that, the findings seem to imply that higher tertiary educational institutions should implement programs to educate students about the potential negative impacts of excessive smartphone use not only on their working memory capability but also on their cognitive function in regard to their academics. Additionally, usual smartphone practices that are accepted among lecturers and students should be restricted. For example, the use of smartphones should be prohibited during lectures to ensure that students pay attention to lecture contents rather than passing the time by scrolling through their smartphones. In addition, as most lecturers pass lecture information through messaging platforms such as WhatsApp or Telegram, lecturers can use other mediums such as emails or word of mouth which reduces phone checking by students.

Overall, this section highlights the contribution of the current research findings to understanding how smartphone use can cause changes in working memory performance. It gives a concise assessment of the research findings' possible influence in pertinent domains and offers insightful recommendations for further actions, especially in the context of undergraduate students.

5.2 Limitations of Study

The study had only encompassed students undergoing degrees from UNIMAS. This limits the generalizability of the study to the average undergraduate student. Studies that aim to research similar populations should opt to expand the study to multiple universities to include undergraduate students of multiple ethnicities, cultures, nationalities, and other population variations. Even so, the study still encompasses many students of different ethnicities, and the average UNIMAS undergraduate student could still be representative of Sarawakian undergraduate students. In conjunction with that, despite meeting the minimum number of participants for a correlation study at 29 participants, this study's number of participants is still lacking as it only has 34 participants (Bujang & Baharum, 2016). Hence, the diversification of participants allows for the increase of participants. These modifications enhance the applicability and validity of the results to be more generalizable to the population of undergraduate students.

Although the study considered various external factors that could affect the final data collected. For example, the study confirmed that the participants possess the minimum required comprehension abilities needed to complete the measuring instruments as well as providing a conducive environment with the participants consistently using the same tool (the researcher's laptop) to complete the working memory tasks. It may not have accounted for all potential confounding variables that could influence working memory performance. To start, a person who has smartphone addiction possesses different habitual use than those who do not. These habitual differences can indirectly affect the working memory performances of participants. For example, participants who average long hours on their smartphones are more

likely to sleep in and have their sleep quality disturbed, and this in turn can lead to a decrease in working memory performance (Tu et al., 2023). Other confounding variables may include factors such as individual working memory capacities, the level of motivation, and the physical or mental conditions of participants.

Next, complications arise with the inaccuracy in the actual number of hours tracked within each participant's smartphone tracking application. While the smartphones were able to record the total amount of time spent on participants' smartphones on a weekly basis, it does not account for applications that may not require active engagement from the user. For example, background-oriented software like music applications is still being tracked for screen time despite the user not engaging in the application. To add to that, it is possible that the participants' smartphones may be tracking screen time that is spent idling, depending on the screen timeout that has been set or whether the user consistently turns off their smartphones after use. Lastly, smartphone applications may contribute to differing levels of effect on working memory performance. It is plausible that a person whose most used application is a working application such as Gmail can have a different effect on his or her working memory performance compared to those who regularly use social media applications. Nonetheless, while possibly inducing inaccuracy due to the broad tracking of screen time, it considers the total screen time to reflect a holistic view of smartphone interaction, such as accounting for variables like cumulative cognitive load. It also provides a baseline for further research that may categorise data by application type to explore specific impacts.

In terms of the measuring instruments, the Operation Span Task poses an issue with its assessment method, as one part of the test involves the solving of mathematics, emphasising the mathematical abilities and speed of the participants. As a consequence, the total time taken by participants to complete the Operation Span Task may not be a reflection of their verbal working memory performance but rather the speed and proficiencies of their mathematics skills. Nevertheless, the mathematic questions only involved addition, subtraction, multiplication, and division problems, which should not be an issue for undergraduate students to solve easily. Furthermore, it is noted that the Operation Span Task is prone to inducing cognitive fatigue among the participants. This is reasoned by the fact that the test consists of 18 trials that contain two to six pairs of mathematic questions and words to be memorised. Some of the participants were visibly irritated or tired when progressing through the Operation Span Task, with some inquiring about the remaining duration of the test in the midst of it. However, it is reasonable to assume that fatigue may be a part of the measurement of an individual's working memory capacities. Regardless, it is reasonable to assume that the participants may perform poorer as the test progresses due to decreased energy, motivation levels, and cognitive/mental resources (Ackerman & Kanfer, 2009). As for the Corsi Block-Tapping Test, it has been mentioned that the number of trials given to participants is not the same across the participants, as the tests end when the participants provide an incorrect input two times in a row.

5.3 Recommendations

The fundamentals of the current research design need to be modified based on the limitations discussed in the previous section. In essence, future studies should include

a higher number of participants, each with different ethnicities, nationalities cultural backgrounds. This may done so by collaborating with other Malaysian universities across multiple states and regions, and this will provide additional statistical power and validity of results, ensuring that findings are applicable to a broader population of undergraduate students.

To account for the confounding variables that may be present in similar studies, strategies should be implemented to control factors that may affect working memory performance. To give an example, potential participants should undergo screening processes through the administration of interviews, surveys, or tests to assess individual variances of factors such as sleep quality, physical & mental health, baseline working memory performance, and smartphone habits. In this way, gathering comprehensive participant background data can aid in identifying and adjusting for these variables during data analysis.

Furthermore, the study relied on the screen time tracking applications of the participants' smartphones to record the average smartphone usage of the participants on a weekly basis. However, these applications fail to distinguish between applications that require active engagement and those that are passively used. Hence, future studies should explore methods for refining the tracking of smartphone usage by differentiating applications in terms of engagement levels. This can be achieved by developing a more sophisticated tracking application that can distinguish between different types of application usage. Another simpler alternative would be to exclude background applications or to focus the study on more engaging applications like social media or video-sharing platforms. On that note, it is also recommended to

standardise the screen timeout settings across participants' smartphones and to instruct them to consistently turn off their screens when not in use for more precision in screen time tracking.

Lastly, the measuring instruments utilised could be revised for a more suitable measurement of working memory performance. For the Operation Span Task, the level of difficulty of the mathematics should be made easier by excluding multiplication and division problems and only including addition and subtraction items. This not only minimises the reliance on mathematical skills but can help minimise cognitive fatigue to provide a clearer measure of verbal working memory performance. In relation, the reduction of the number of trials of the Operation Span Task may reduce cognitive fatigue to maintain participants' motivation and energy levels throughout the test. As for the Corsi Block-Tapping Test, it is suggested that measuring the reaction time or average speed at which participants complete a stage will be a more accurate judgment of visual working memory performance rather than the total time taken. Alternatively, the test could also be standardised in that participants experience all nine trials regardless of their performance. In this case, the total time taken could be a useful measurement of visual working memory performance.

5.4 Conclusion

The findings of this research demonstrate the working memory performance of undergraduate students is adversely affected by excessive smartphone use. These results highlight the necessity for students to exercise caution when using smartphones in order to maintain the cognitive abilities necessary for success in the classroom. To improve students' performance and attentiveness, educational

institutions should limit smartphone use during lectures and encourage awareness programmes. To guarantee more precise and broadly applicable findings, future research should build on this one by incorporating a more varied participant pool and improving measurement techniques.

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APPENDIX A

RAW SPSS OUTPUT

		N	Percentage %
Gender	Female	17	50.0%
	Male	17	50.0%
Age	19-22 years old	21	61.8%
	23-26 years old	13	38.2%
CGPA	2.49 and below	1	2.9%
	2.99 - 2.50	1	2.9%
	3.49 - 3.00	16	47.1%
	4.00 - 3.50	16	47.1%

Table A1. Raw SPSS Output for Demographic Table

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Average Weekly Smartphone Usage	34	2:44	14:39	8:00	3:00
Operation Span Task Score	34	4	54	29.35	14.818
Operation Span Task Total Time Taken	34	07:57	13:42	10:14	01:28
Corsi Block-Tapping Test Score	34	4	9	6.21	1.200
Corsi Block-Tapping Test Total Time Taken	34	00:45	02:09	01:21	00:19
Valid N (listwise)	34				

Table A2. Raw SPSS Output for Descriptive Statistics

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Average Weekly Smartphone Usage	.099	34	.200 [*]	.971	34	.486
Operation Span Task Score	.085	34	.200 [*]	.957	34	.197
Operation Span Task Total Time Taken	.149	34	.055	.954	34	.161
Corsi Block-Tapping Test Score	.167	34	.017	.937	34	.051
Corsi Block-Tapping Test Total Time Taken	.095	34	.200 [*]	.981	34	.798

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

a. Lilliefors Significance Correction

Table A3. Raw SPSS Output for Tests of Normality

Correlations			
		Average Weekly Smartphone Usage	Operation Span Task Score
Average Weekly Smartphone Usage	Pearson Correlation	1	-.369 [*]
	Sig. (2-tailed)		.032
	N	34	34
Operation Span Task Score	Pearson Correlation	-.369 [*]	1
	Sig. (2-tailed)	.032	
	N	34	34

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

Table A4. Raw SPSS Output for Pearson Correlation Coefficient on the Relationship between the Average Weekly Smartphone Usage and Operation Span Task Score

Correlations			
		Average Weekly Smartphone Usage	Operation Span Task Total Time Taken
Average Weekly Smartphone Usage	Pearson Correlation	1	.353 [*]
	Sig. (2-tailed)		.040
	N	34	34
Operation Span Task Total Time Taken	Pearson Correlation	.353 [*]	1
	Sig. (2-tailed)	.040	
	N	34	34

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

Table A5. *Raw SPSS Output Pearson Correlation Coefficient on the Relationship between the Average Weekly Smartphone Usage and Operation Span Task Total Time Taken*

Correlations			
		Average Weekly Smartphone Usage	Corsi Block-Tapping Test Score
Average Weekly Smartphone Usage	Pearson Correlation	1	-.453 ^{**}
	Sig. (2-tailed)		.007
	N	34	34
Corsi Block-Tapping Test Score	Pearson Correlation	-.453 ^{**}	1
	Sig. (2-tailed)	.007	
	N	34	34

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

Table A6. *Raw SPSS Output for Pearson Correlation Coefficient on the Relationship between the Average Weekly Smartphone Usage and Corsi Block-Tapping Test Score*

Correlations		Average Weekly Smartphone Usage	Corsi Block- Tapping Test Total Time Taken
Average Weekly Smartphone Usage	Pearson Correlation	1	-.175
	Sig. (2-tailed)		.322
	N	34	34
Corsi Block-Tapping Test Total Time Taken	Pearson Correlation	-.175	1
	Sig. (2-tailed)	.322	
	N	34	34

Table A7. *Raw SPSS Output Pearson Correlation Coefficient on the Relationship between the Average Weekly Smartphone Usage and Corsi Block-Tapping Test Total Time Taken*

APPENDIX B

MATERIALS/INSTRUMENT

Google Forms:

The Relationship between Smartphone Usage and Working Memory Performance among Undergraduate Students

Greetings to all,

I am Brian Bong Wei (77890), a third-year psychology student from the Faculty of Cognitive Science and Human Development (FCSHD) of Universiti Malaysia Sarawak (UNIMAS). I am currently conducting a Final Year Project (FYP) on understanding The Relationship Between Smartphone Usage and Working Memory Performance among Undergraduate Students. Thus, I would like ask that you commit a little bit of time in participating in this research. After completing the given tests, you may answer this questionnaire.

Supervised by: En. Mohamad Azhari bin Abu Bakar

Instruction: This questionnaire consists of four (4) sections:

SECTION A: Informed Consent

SECTION B: Demographics

SECTION C: Operation Span Task

SECTION D: Corsi Block-Tapping Test

Please answer all the questions. All information will be kept confidential and used for academic purposes only.

For inquires/clarification, please contact:

Email: 77890@siswa.unimas.my

Phone no: 010-9777288

Your cooperation and participation in this research is much appreciated. Thank you and have a nice day.

brianlodge98@gmail.com [Switch accounts](#)



The name, email address and photo associated with your Google Account will be recorded when you upload files and submit this form

* Indicates required question

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

SECTION A: Informed Consent

Before proceeding, please read carefully

Title of Study: The Relationship between Smartphone Usage and Working Memory Performance among Undergraduate Students

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. I 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.

I hereby declare that I agree to participate in the study. *

☒ Yes, I consent.

Next

Clear form

Figure B2. *Consent Form*

SECTION B: Demographics

Name *

Your answer _____

Gender *

☐ Male

☐ Female

Age *

☐ 19-22 years old

☐ 23-26 years old

☐ 27-30 years old

☐ 31 years old and above

Figure B3. *Demographics*

CGPA *

☐ 4.00 - 3.50

☐ 3.49 - 3.00

☐ 2.99 - 2.50

☐ 2.49 and below

Duration of Average Smartphone Screen Time (per weekly basis) *

Your answer _____

Please upload the screenshot of your **weekly** screen time.

[Add File](#)

[Back](#) [Next](#) [Clear form](#)

Figure B4. *Demographic (cont.)*

SECTION C: Operation Span Task

The section aims to assess the verbal working memory performance of the participants using the Operation Span task. In the experiment, participants are presented with a collection of mathematical questions that participants have to read out loud and solve. Then, they will be shown a set of randomized sets of two to five words that need to be memorized and recalled in the same order. To ensure that participants complete the task properly, participants are required to obtain an acceptable score in the number of mathematic questions. Following that, please input your scores and the total time taken below.

Score *

Your answer

Total time taken *

Your answer

Back

Next

Clear form

Figure B5. *Operation Span Task Score and Total Time Taken Input*

SECTION D: Corsi Block-Tapping Test

This section aims to assess the visuospatial working memory performance of the participants using the Corsi Block-Tapping Test. In the experiment, the participants will be presented with a sequence of two blocks and will be required to click on the blocks in the same order as previously shown in the sequence. If the answer is correct, the participant will advance to the next level by completing a sequence with greater number of blocks. However, if the participants provide incorrect answers twice, the test will conclude. Following that, please input your scores and total time taken below.

Score *

Your answer

Total time taken *

Your answer

Back

Next

Clear form

Figure B6. Corsi Block-Tapping Test Score and Total Time Taken Input

Operation Span Task:

Cog Lab

Operation span demonstration

Trials to go

Instructions

s $(7 \times 1) + 6 = 13?$

Yes

No

Next Trial

Figure B7. Mathematic Questions in the Operation Span Task

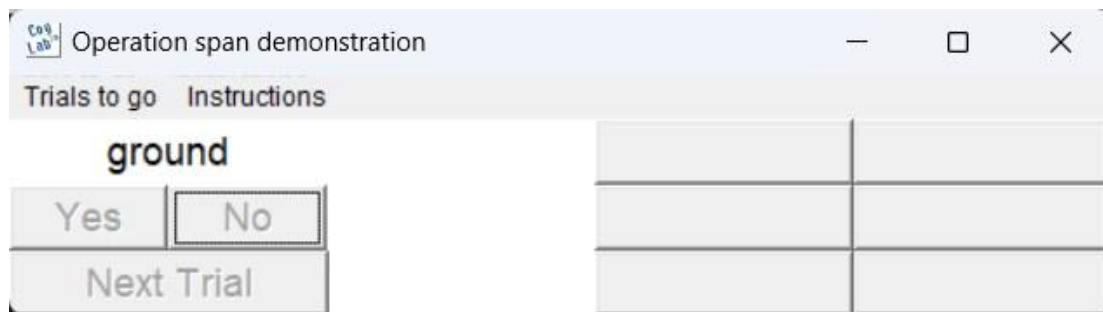


Figure B8. *Appearance of Words to be Memorized*

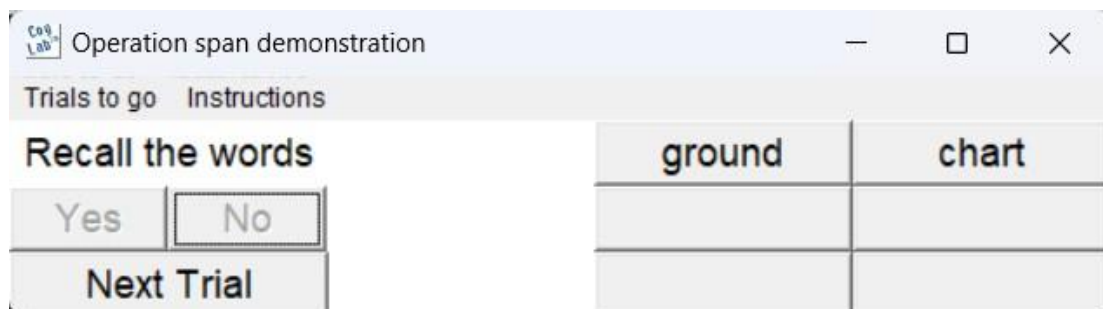


Figure B9. *Recall of Words*

Corsi Block-Tapping Test:

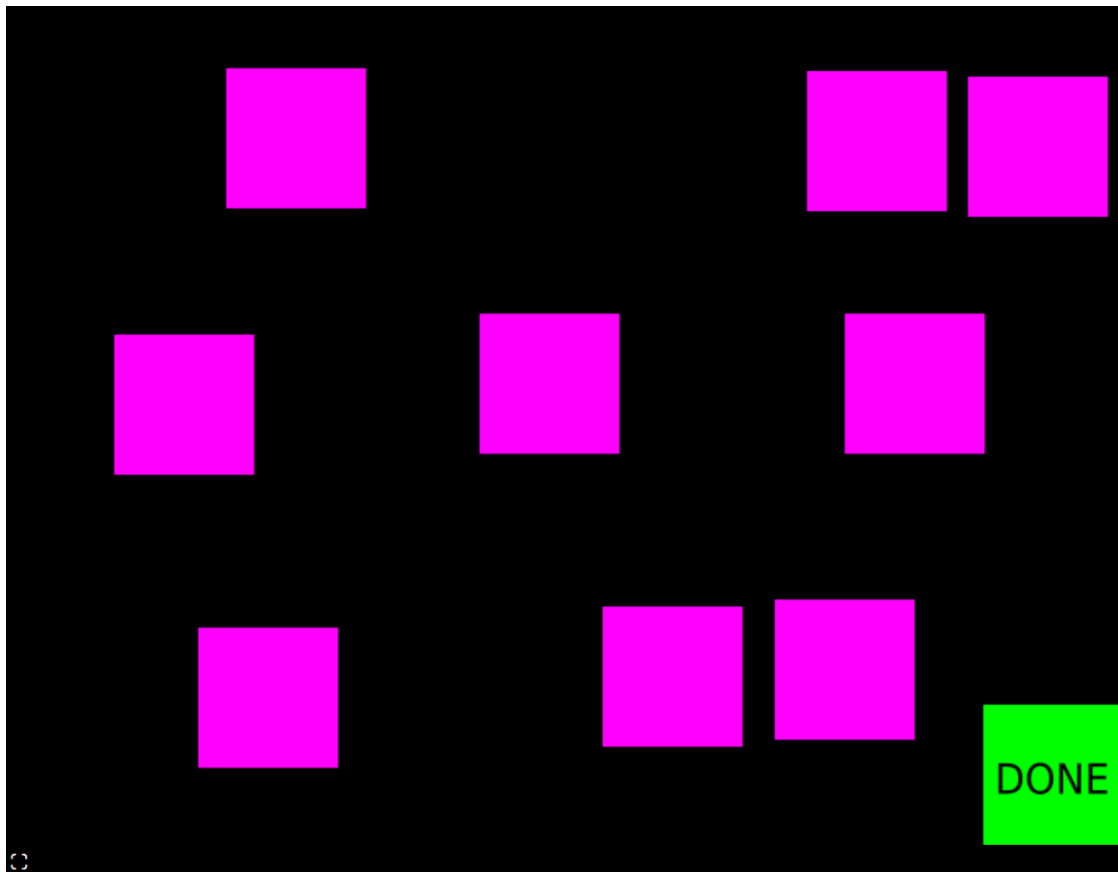


Figure B10. *The Nine Blocks of the Corsi Block-Tapping Test*

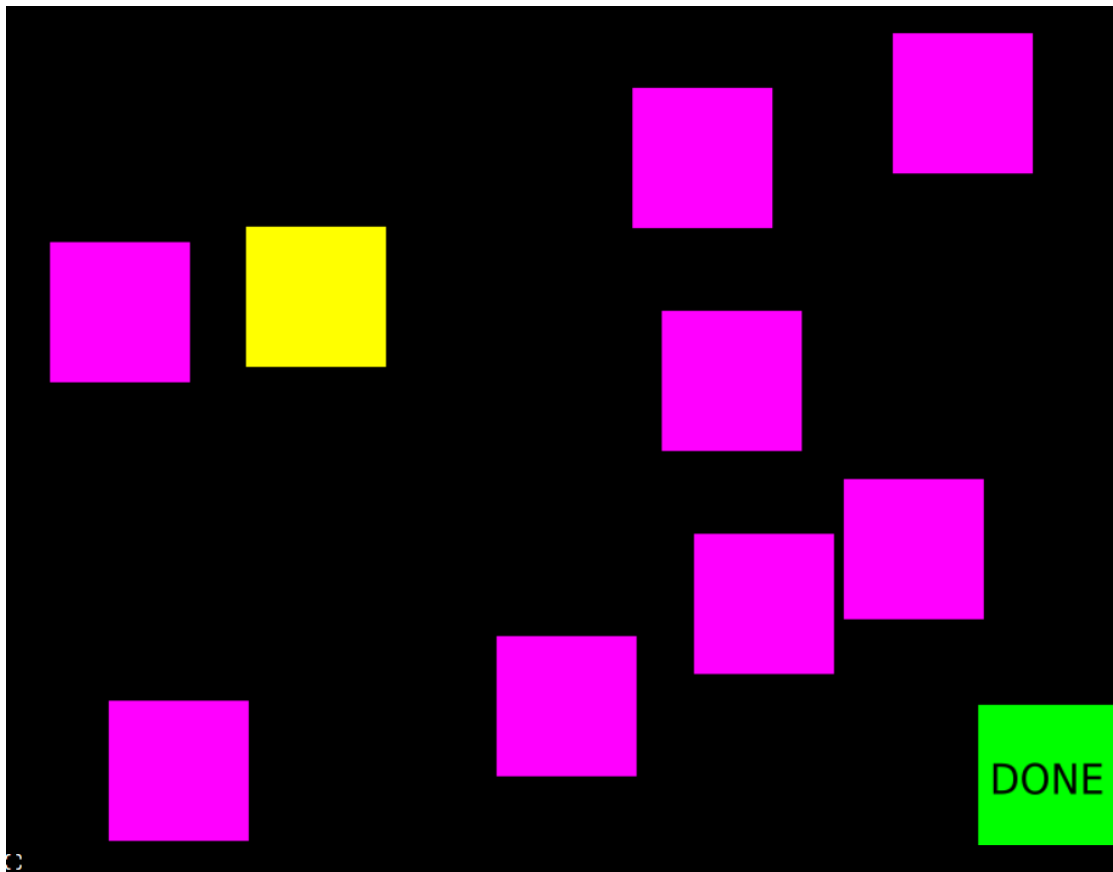


Figure B11. *A Highlighted Block of the Corsi Block-Tapping Test*