# Role of Multiple Reminders on Prospective Memory Performance Across Varied Interference Scenarios

A

Thesis Submitted

In Partial Fulfillment of the Requirement for

the Degree of

**DOCTOR OF PHILOSOPHY**

By

**Pallavi Ojha (196141009)**
Department of Humanities and Social Sciences Indian Institute of Technology Guwahati

Department of Humanities and Social Sciences

Indian Institute of Technology Guwahati, Guwahati

India

JUNE 2024

**Indian Institute of Technology Guwahati**

Department of Humanities and Social Sciences
Guwahati 781039
Assam, India

## DECLARATION

I hereby declare that the thesis entitled "**Role of Multiple Reminders on Prospective Memory Performance Across Varied Interference Scenarios"** is the result of investigation carried out by me at the Sleep and Cognition Laboratory, Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, under the supervision of **Prof. (Dr.) Naveen Kashyap**. The work has not been submitted either in whole or in part to any other university/ institution for a research degree.

IIT Guwahati
June 2024

**Pallavi Ojha**
(Roll No. 196141009)

**Indian Institute of Technology Guwahati**

Department of Humanities and Social Sciences
Guwahati 781039
Assam, India

## CERTIFICATE

This is to certify that Ms. Pallavi Ojha has prepared the thesis entitled "**Role of Multiple Reminders on Prospective Memory Performance Across Varied Interference Scenarios**" for the degree of Doctor of Philosophy at the Indian Institute of Technology Guwahati. The work is carried under my supervision and in strict conformity with the rules laid down for the purpose. It is the result of her investigation and not been submitted either in whole or in part to any other university/institution for a research degree.

IIT Guwahati
June 2024

**Prof. (Dr.) Naveen Kashyap**
Thesis Supervisor

# ACKNOWLEDGMENTS

I express profound gratitude to my thesis advisor, Dr. Naveen Kashyap, an esteemed Professor in Psychology in the Department of Humanities and Social Sciences, IIT Guwahati. His steadfast direction, encouragement, and invaluable insights were instrumental at every stage of the research process. His proficiency, support, and valuable critique were important in moulding and enhancing this piece.

I extend my heartfelt thanks to the members of my thesis committee, Prof. Nachiketa Tripathi, Dr. Sambit Mallik, and Dr. Dilwar Hussain for their time, expertise, and thoughtful contributions to the development of this research. Their valuable feedback and suggestions greatly enriched the quality of my work.

I express my gratitude to Dr. Kedarmal Verma, my senior, and my family and friends for their steadfast support, comprehension, and motivation during my academic endeavour. Their unwavering faith in my capabilities and consistent encouragement played a crucial role in surmounting obstacles and achieving the pinnacle of this research endeavour.

Lastly, I would want to convey my appreciation to all participants and persons who, through diverse means, contributed to the process of gathering data. Their active engagement and readiness to provide their valuable thoughts played a pivotal role in the successful culmination of this thesis.

Concluding this thesis has been a demanding yet fulfilling undertaking, and I am sincerely grateful to all those who have contributed to this academic achievement.

IIT Guwahati
June 2024

**Pallavi Ojha**
**(196141009)**

# ABSTRACT

A famous saying suggests "*more the merrier*". The present thesis is built around the central premise of the quote. We tested volunteers' performance on future tasks involving prospective memory cued through specific events and future time. Results suggest that, in general, two cues improve future task performance. We tested future memory performance across varying levels of attention and cognitive load, variables that can modulate the memorability of cues on future learning tasks. While attention moderately influences performance, cognitive load majorly influences future task performance. We conducted experiments to test whether the benefit of multiple cues on future task performance holds over intervals filled with restful naps. We found that naps do not beneficially modulate the relationship. Overall, the results of the thesis suggest that "*more the merrier*" does hold in terms of prospective memory. Still, many constraints guide the relationship as it happens in real-world relationships.

**Keywords:** Prospective Memory, Event cues, Mixed cues, Attention, Cognitive load, Nap

# LIST OF PUBLICATIONS

## JOURNAL PUBLICATIONS

- **Pallavi Ojha,** Kedarmal Verma, & Naveen Kashyap (2021). Does Learning Styles Influence False Memory Generation? Psychological Thought. 14 (2), 363-377. [ISSN: 2193-7281]

## CONFERENCE PUBLICATIONS/PROCEEDINGS

1. **Pallavi Ojha,** & Naveen Kashyap **(2024)**. Cue Modality in Prospective Memory Performance at 33rd International Congress of Psychology (ICP 2024) on "Psychology for the Future : Together in Hope" in Prague, Czech Republic.
2. **Pallavi Ojha,** & Naveen Kashyap **(2023)**. Effect of load on availability of cues in prospective memory performance: Comparing event and mixed cues in *Virtual Congress, European Sleep Research Society*.
3. Kedarmal Verma, Naveen Kashyap, **Pallavi Ojha (2023)**. Relationship between the Sleep Spindle and False Recall. IBRO Neuroscience Report, 15 (Suppl. S1): 1487 in Conference of 11th International Brain Research Organization (IBRO), Granada, Spain.
4. Naveen Kashyap, Kedarmal Verma, **Pallavi Ojha (2022)**. Role of sleep in recognition memory of faces and objects. Journal of Sleep Research, 31 (Suppl. S1): e13740, 54 in 26th Conference of the European Sleep Research Society, Athens, Greece.
5. **Pallavi Ojha,** Kedarmal Verma, & Naveen Kashyap (**2019**). **How Different Learning Styles Can Affect False Memory**, at *29th Annual Convention of NAoP* (India) and

*International Conference on "Making Psychology Deliverable to the Society"* at Pondicherry University, India.

6. Kedarmal Verma, **Pallavi Ojha,** & Naveen Kashyap (**2019**). **Sleep Modulates Retrieval of False Memory: Comparing Semantic and Category Associates**, at *29th Annual Convention of NAoP* (India) and *International Conference on "Making Psychology Deliverable to the Society"* at Pondicherry University, India.

# CONTENTS

**Page Numbers**

# ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| DH | Dreem Headband |
| EBPM | Event based prospective memory |
| EEG | Electroencephalogram |
| ESS | Epworth Sleepiness Scale |
| JATOS | Just Another Tool for Online Studies |
| MMSE | Mini Mental State Examination |
| MPM | Mixed prospective memory |
| NREM | Non-Rapid Eye Movement |
| OT | Ongoing Task |
| PFC | Pre Frontal Cortex |
| PM | Prospective Memory |
| PRMQ | Prospective and Retrospective Memory Questionnaire |
| PSQI | Pittsburgh Sleep Quality Index |
| REM | Rapid Eye Movement |
| RT | Reaction Time |
| SWS | Slow Wave Sleep |
| URL | Uniform Resource Locator |
| WASF | Wake After Sleep Offset |
| WASO | Wake After Sleep Onset |
| WM | Working Memory |

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF GRAPHS

# CHAPTER 01: INTRODUCTION AND LITERATURE REVIEW

***"The future is not something we enter. The future is something we create." - Leonard I. Sweet***

## INTRODUCTION

It is a common occurrence for all of us to occasionally forget to do important tasks, such as picking up groceries on our way home, sending a friend a message later in the day, or taking out the trash. These common occurrences demonstrate the importance of prospective memory in our daily lives. Prospective memory, the act of recalling to perform an action in the future, can pose challenges and intricacies in our daily routines. Nevertheless, what if there existed a brilliant technique to streamline this procedure? Envision a realm where we could effortlessly enhance our memory for such objectives by employing simple techniques. The primary aim of our thesis was to investigate the effectiveness of integrating two distinct types of cues, specifically event cues and time cues, in order to enhance prospective memory. The combination of both cues was referred to as mixed cues. To enhance our comprehension, let us commence by scrutinizing an illustrative instance: Imagine the task of remembering to contact a friend after completing work responsibilities. Instead of relying solely on the time (e.g., setting an alarm for 6 PM), we can also synchronize it with an event, such as planning to make a phone call immediately after the conclusion of our preferred television program, which ends at 6 PM. Currently, our memory has two instances to remind us - when the clock strikes 6 PM and when our show ends. It offers an extra level of safeguarding for your memory, similar to having two safety nets. By incorporating both types of cues, we can improve prospective memory retention.

Prospective remembering also relies on a multidimensional set of cognitive processes (Marsh, & Hicks, 1998). The thesis study acknowledged that prospective memory involves various cognitive processes and proposed research questions to examine the complex aspects of intention formation. The complexities of real-life situations entail the process of encoding intentions, which often occur concurrently with the execution of multiple tasks that may potentially interfere with successful encoding. Our objective was to examine the influence of the factors that play a role in encoding intention in daily activities on the performance of prospective memory. Among them are **attention and cognitive load**.

The thesis study also investigates the impact of daytime napping, on the process of memory consolidation and reduction of interference. Sleep has been found to mitigate retroactive interference by preventing new information from disrupting previously acquired knowledge. Although it is widely accepted that sleep has a positive influence on memory consolidation, there is ongoing debate regarding the specific factors that are essential for this effect, such as the minimum duration of sleep required. This study examines the potential impact of daytime napping on the prospective memory performance of young adults. Additionally, it explores how these effects may apply to different types of prospective memory. The objective is to shed light on the connection between taking a nap during the day, retaining information, and reducing interference across event and mixed prospective memory.

## LITERATURE REVIEW

Humans plan for the future which tend to guarantee a safe and successful life. Planning inherently includes forming intentions to complete actions at the appropriate opportunity, however, not all intentions are realized leading to unfinished / incomplete tasks. A number of these unfinished tasks can be attributed a failure to retrieve the intention to perform the task at the appropriate future time (Terry, 1988) leading to failures in prospective / future memory. Prospective memory represents our ability to remember to do things in the future (Einstein & McDaniel, 1990). It is one's ability to remember do to something in the future. That something could be meeting a friend by the end of the day, or taking medicines at particular time of the day. Failing to complete the intended actions can lead to problem which can have mild to extreme negative impact. The situation becomes graver when future task requires multiple unique responses leading to forgetting of prospective memory (Ellis, 1996; Dismukes, 2012) especially for complex future tasks. Completion of these future tasks depends on the initiation of prospective intentions by either event, time, activity or mixed (both event and time) reminders. In the event-based scenario, clear environmental cues (events) prompt the recollection of the deferred intention. In time-based situation, intentions are completed at a specific future time with no clear environmental cues. The distinction between the two-retrieval context blurs in real-world scenarios (Loukopoulos, Dismukes, & Barshi,2009; Grondin, 2001), and delayed intentions do not always fit neatly into event-based or time-based categories. There can be situations, where both time and environmental cues work in combination to signal delayed intention.

Planning the day is an exercise in remembering to carry out a variety of future tasks, both simple and complex, and this process of intention formation typically occurs in the midst of a number of other activities, some of which may compete with one another. When faced with conflicting information or numerous stimuli, people might not be able to comprehend and encode the intention into memory. It is likely that this will have an immediate impact on prospective memory retrieval. In such cases, using multiple reminders is justified because doing so would raise the likelihood that prospective intentions will be completed successfully.

The current thesis investigates the proposal that use of multiple reminders across varied encoding scenarios increase the probability of success of prospective memory task. The results of the thesis suggest that multiple reminders do indeed increase the likelihood of prospective memory task performance but this benefit depends of the encoding scenario in question.

Memory is a multi-step process that involves encoding, storage, and retrieval. It is a fundamental cognitive capacity that enables us in recalling prior knowledge and retaining information for future use. Memory is a complex process that plays a critical role in our daily lives and has been the subject of study and research for centuries. The ability to memorize information was considered essential to learning in ancient Greece and Rome. It was believed that having a good memory was a sign of wisdom, intelligence, and virtue. They developed various memory techniques to assist individuals in remembering information more efficiently. Popular techniques included the "method of loci," which involves mentally placing things to be remembered along a familiar route or in familiar rooms of a building. The use of mnemonics, such as rhyming phrases, was another method of remembering information. Greek philosophers such as Plato and Aristotle examined memory and its function, initiating a long line of study on the subject.

Ancient Greek philosopher Plato (428–347 B.C) believed that rational thought was the best way to understand the world. According to his perspective, memory acts as the connecting link between the world of perception and the world of rational, idealized abstractions (Viney & King, 1998). Other rationalist philosophers, such as Rene Descartes (1596–1650) and Immanuel Kant (1724–1804), built upon Plato's ideas and developed them further.

Aristotle (384–322 B.C.) was Plato's most famous and influential student. Aristotle was an empiricist who believed that reality itself should serve as the foundation for inquiry. One of the most important ideas that Aristotle contributed was the concept that memories are primarily made up of associations between a variety of stimuli or experiences. Aristotle, in his work "On Memory and Recollection," viewed memory as a faculty of the soul, which is capable of storing and retrieving past experiences. He outlined his theories on the nature of memory, its connection to the soul, and the role it plays in our lives. He explored the idea that memories are not permanent but can fade over time. He suggests that this is due to the process of "decay," in which memories gradually lose their clarity and become harder to recall.

Later on, the ideas of Aristotle were developed into their modern form by the British empiricists, such as George Berkeley (1685–1753), John Locke (1632–1704), David Hume (1711–1776), and John Stuart Mill (1806–1873). The study of memory made significant strides forward in the nineteenth century. Many prominent psychologists, philosophers, and neuroscientists of the time period advanced our current understanding of the brain's memory processes.

Hermann Ebbinghaus (1850-1909), a German psychologist, played a pivotal role in the evolution of our understanding of memory at this time. He is known for his work on the forgetting curve, which describes the exponential loss of information that one has learned. Memory decay is rapid in the first few hours after learning and then levels off over time. According to his findings, after just 20 minutes of learning, we are only able to recall approximately 60 percent of what we have been taught. Just 45% of what we have learned is still present in our memories after just one hour, and that number drops to 34% after just one day. The percentage of information retained in memory drops to 23% just six days after learning, and only 15% of that information is ever truly retained. He also introduced the use of nonsense syllables to study memory, which is still a widely used method today.

William James (1842-1910), an American psychologist and philosopher, was another significant figure in the history of memory in the 19th century. James is also known for his contributions to the functionalist school of thought, which was one of the first schools of thought in the field of psychology. His book, "The Principles of Psychology," is considered one of the most important and seminal contributions to the history of psychology. He also provided descriptions of memory that are astonishingly similar to theories that are currently in use today. His distinction between primary and secondary memory, for instance, closely parallels the distinction between short-term and long-term memory. In the same way, he was one of the first academics to talk about problems with retrieving memories, such as the tip-of-the-tongue phenomenon, in which a person can't remember something, like someone's name, but has a strong feeling that they will remember it soon.

In the late 19th century, the study of memory was also influenced by developments in the fields of biology and neuroscience. For example, the discovery of the structure of the nervous system and the development of new techniques for studying the brain were beginning to shed new light on the processes underlying memory. In the field of neuroscience, Paul Broca and Carl Wernicke made important contributions to our understanding of the brain regions involved in language. They discovered that certain regions of the brain, such as the hippocampus and amygdala, play a critical role in the formation and retrieval of memories. In the year 1861, a French neurosurgeon named Paul Broca began the process of locating the regions of the brain that are responsible for language. After making the now-famous observation that "we speak with the left hemisphere," he discovered, for the very first time, the existence of a "language center" in the posterior portion of the frontal lobe of the left hemisphere of the brain. This region of the brain, which is now known as Broca's area, was in fact the very first part of the brain to be linked to a particular function; in this case, it was language.

Carl Wernicke, a German neurologist, made the discovery ten years later. He found that the posterior portion of the left temporal lobe of the brain is responsible for the comprehension of language. People who had a lesion in this region were able to communicate verbally, but their words were frequently jumbled and made no sense.

The study of memory made great strides in the nineteenth century, paving the way for studies in the twentieth and twenty-first centuries. Memory was a topic of great interest and study among psychologists, philosophers, and scientists in the nineteenth century. During this period, memory research underwent significant change as new theories and concepts were developed. Several influential researchers made significant contributions to memory research in the 20th century. These researchers and others helped establish the field of memory research and laid the foundation for continued investigation into the nature of memory and its underlying processes.

**1. Ivan Pavlov -** Pavlov's work on classical conditioning laid the foundation for the study of how associations are formed between stimuli and responses, and how these associations can impact memory.

**2. Wolfgang Köhler -** Köhler's research on animal intelligence and problem-solving helped establish the field of cognitive psychology, and his ideas about the role of insight and perception in problem-solving have had a lasting impact on the study of memory.

**3. George Miller -** Miller's work on the capacity of short-term memory and the chunking of information into meaningful units had a profound impact on our understanding of working memory and its limitations.

**4. Endel Tulving -** Tulving's research on the distinction between semantic and episodic memory and the role of conscious awareness in memory has been highly influential, and he has been a leading figure in the study of memory for many decades.

The categorization of memory has been the subject of discussion among scientists and experts for quite some time. According to many experts, there are four main types of memory. Most other types of memory can be classified into one of these four main groups. There are several types of memory, including:

I. **Sensory Memory**: This type of memory is a very brief record of sensory information, such as what we see or hear, that is stored in the brain for a very short time (a few seconds).

II. **Short-term Memory**: Also known as working memory, this type of memory temporarily holds information that is being actively used, such as the phone number you are dialing or a grocery list.

III. **Long-term Memory**: This type of memory is the permanent storage of information, and it can last for days, months, or even years. There are two subtypes of long-term memory: declarative memory (knowledge that can be consciously remembered, such as facts and events) and non-declarative memory (skills and habits that are performed automatically, such as riding a bike).

IV. **Episodic Memory**: This type of declarative memory refers to the memory of specific events and experiences, such as the memory of your first day of school or a family vacation.

V. **Semantic Memory**: This type of declarative memory refers to general knowledge and facts, such as the meaning of words, the capitals of countries, and basic arithmetic.

Some researchers use the concept of the "temporal direction of the memories" as a significant alternative method for classifying different types of long-term memory. On temporal dimensions– memory can be divided into **retrospective and prospective memory.**

**Retrospective memory** refers to the ability to recall information, events, or experiences that have already occurred in the past. This type of memory involves retrieving information from long-term memory, such as recalling a past event or a past conversation. **Prospective memory,** on the other hand, refers to the ability to remember to perform an action in the future, such as remembering to attend a meeting or take medication at a specific time. Prospective memory requires planning, attention, and monitoring of the environment for cues that trigger the intended action. In a nutshell, the act of remembering things that happened in the past is known as retrospective memory, whereas remembering things that will happen in the future is known as prospective memory.

**Differences in Prospective and Retrospective Memory**

According to Marsh et al. (2006), there are a number of fundamental differences that distinguish prospective and retrospective memories. **First,** the nature of prospective memories is twofold, in that intentions contain both a retrospective and a prospective component (Einstein & McDaniel, 1990), and it is the prospective component of an intention that distinguishes it from other retrospective memories. In event based prospective memory, there is an association of an intended action to some type of cues in the environment which again makes it different from retrospective memory. **Second,** intentions regarding future activities are stored in memory at a higher activation level than baseline (i.e., the intention superiority effect). Differential processing of intention-related information in the context of an otherwise seemingly unrelated ongoing task is a hallmark of the superiority effect (Goschke & Kuhl, 1996; Marsh, Cook, Meeks, Clark-Foos, & Hicks, 2007). **Third,** retrieving prospective memories requires some degree of self-initiated processing, whereas retrieving retrospective memories does not always require this type of processing (Lockhart and Craik, 1990).

**Fourth** and finally, prospective memories consist of two contextual representations whereas retrospective memories typically consist of only one. That is, when people encode a prospective memory they not only have a mnemonic representation of that original encoding episode, but they also simulate a representation of the future in which event-based cues might be noticed and the target action might ultimately be carried out. This future simulation ability is related to the constructive nature of episodic memory and is quite important for the realization of delayed intentions (Atance & O'Neill, 2001).

**Differences between prospective and retrospective memory laboratory paradigms**

If we consider memory paradigms, we can divide them into three distinct stages: encoding, retrieval, and retention. Both the prospective and retrospective memory laboratory paradigms differ in some key aspects depending on these phases. Both the paradigms, with regard to the encoding process, have some similarities as well as differences between them. During the retrospective memory (RM) tasks, the participants are given the instruction to pay attention and encode the information that is provided, and during the PM tasks, the intention is encoded. The difference between RM encoding and PM encoding is that the latter is usually intentional (i.e., one explicitly encodes a future task with the intention of completing it later), while the former can be either intentional or incidental.

Furthermore, in contrast to some RM tasks, retrieval does not occur immediately after the intention formation in PM tasks. Individuals make the decision to retrieve the PM task at some point in the future in order to successfully complete the task. The retention or delay period in the PM task can be minutes, days weeks or months depending on the type of study. In RM tasks, retrieval is often prompted by external instruction, such as a researcher asking you to recall the words you studied earlier or, in everyday life, someone asking you about an event you attended. Whereas PM intention retrieval is self-initiated. It could be reminded by an external cue (such as seeing a clock and remembering to go to an appointment or seeing an animal word and remembering that the researcher asked you to respond to animal words by pressing the "z" key on the keyboard). Thus, one must "remember to remember" the PM intention, and an element of planning is involved in PM tasks (e.g., Meier & Graf, 2000).

Lastly, when it comes to RM tasks, your attention is typically solely focused on retrieving information after being given a prompt to retrieve it. However, in PM tasks, the task is embedded within other tasks that are already in progress, and therefore switching tasks is required in order to successfully retrieve the task.

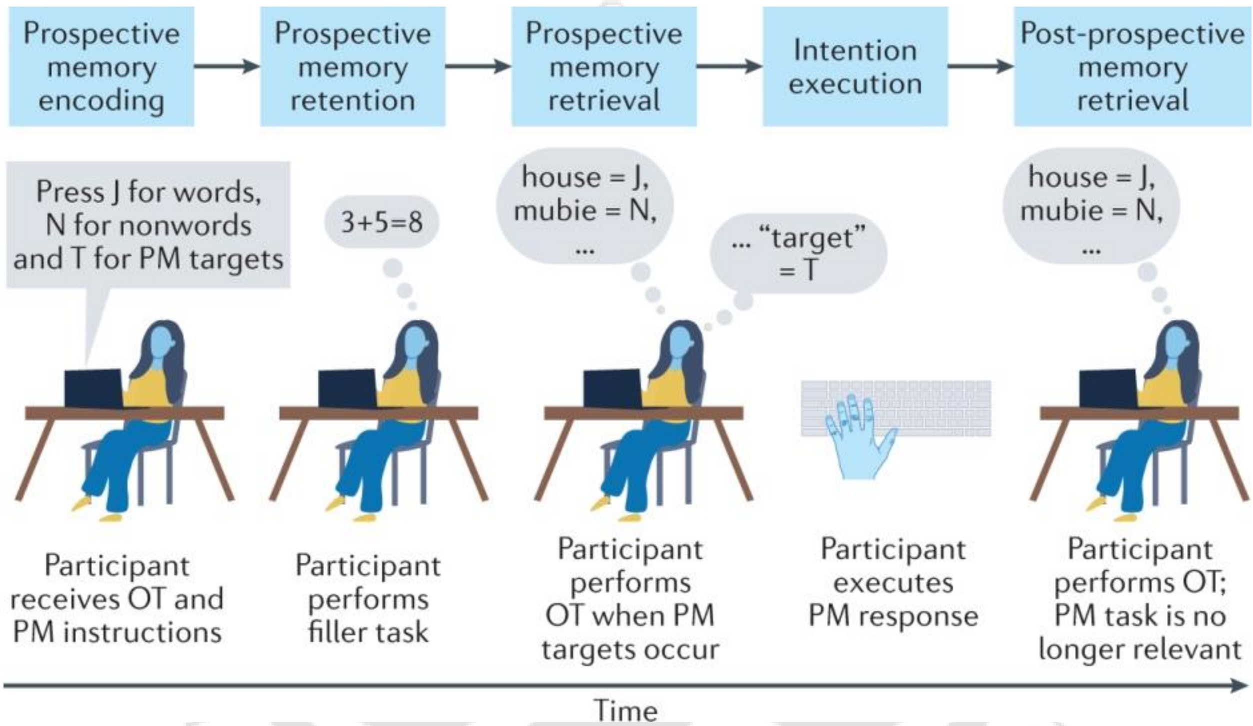



**Figure I: Phases of commonly used prospective memory laboratory paradigm.**
*(Adapted from Rummel and Kvavilashvili, 2023)*

**Prospective Memory and its historical roots**

One of the earliest references to prospective memory can be found in the works of the philosopher John Locke, who discussed the idea of "future remembrance" in his 1690 Essay Concerning Human Understanding.

Later, Freud (1901) explicitly considered instances of forgetting one's intentions in everyday life. According to Freud, forgetting future plans is a form of defense mechanism called "repression." Repression occurs when we unconsciously block out a thought or memory that is associated with anxiety or discomfort. Forgetting future plans may occur when we have an unconscious fear or anxiety associated with that plan. For example, if someone has a fear of public speaking, they may unconsciously repress the memory of an upcoming presentation or speech, causing them to forget about it until the last minute.

In 1926, Kurt Lewin published an influential paper titled "Vorsatz, Wille und Bedürfnis" ("Intention, Will, and Need"), which discussed the role of intentions in guiding future actions (Mahler, 1996). Lewin argued that people's intentions are a crucial factor in determining their future behavior. He believed that people form intentions based on their needs and desires, and that these intentions guide their actions towards achieving those goals. Lewin also suggested that people's intentions can be influenced by their environment and the social context in which they find themselves. For example, if someone is surrounded by people who are engaging in a particular behavior, they may be more likely to form an intention to engage in that behavior as well. He commented that 'a good memory, ability to reproduce knowledge and actions, need not be accompanied by the virtue of not being forgetful in carrying out intention' (p. 106). Birenbaum (1930), a student of Lewin, carried out experimental work that was groundbreaking at the time. However, it was not until the 1970s and 1980s that psychologists and neuroscientists began to study prospective memory as a distinct cognitive function and to develop theories to explain its underlying mechanisms. Midway through the 1970s, there were only a handful of experimental and questionnaire studies (Meacham & Leiman, 1975; Meacham & Singer, 1977; Wilkins & Baddeley, 1978; Meacham & Colombo, 1980; Harris & Wilkins, 1982; Harris, 1978; Herrman & Neisser, 1978; Bennett-Levy & Powell, 1980; Meacham & Kushner, 1980).

First experimental research on prospective memory was conducted by Loftus (1971) within the discipline of cognitive psychology. In this study, participants were instructed at the beginning of the experiment to report their birth state at the conclusion of the experiment in order to study the role of intention in memory. It was discovered that providing a retrieval cue at the time a subject formed an intention enhanced the subject's ability to recall the intention (Loftus, 1971). Another early study was conducted by John Duncan and Peter Gollwitzer in the 1980s. Their research focused on the processes and strategies that help people successfully remember and execute their future intentions. They investigated the role of implementation intentions in prospective memory. Implementation intentions are specific plans that link a future event (cue) with a particular response (action). They found that the key to successful prospective memory is to form an implementation intention, which is a specific plan for when, where, and how to perform the intended action. This approach has been found to be effective in enhancing prospective memory performance in a variety of real-world situations.

In order to shed light on the nature of the processes involved and the developmental and contextual determinants, Ceci and Bronfenbrenner (1985) looked into the strategies children use when performing tasks that require prospective memory (i.e. remembering to do something in the future). Children were instructed to perform future activities after waiting. These preliminary studies paved the way for future investigations into prospective memory and increased our understanding of the processes that underlie this crucial memory function. The findings of the earliest researchers have important implications for many different fields, including psychology, education, and health, and have contributed significantly to our understanding of how people can remember and successfully carry out future intentions. In recent years, advances in technology have provided new opportunities for the study of prospective memory, and researchers have been exploring the effects of technology, such as smartphones and wearable devices, on our ability to remember to perform future tasks (Peper and Ball.,2022). Overall, the study of prospective memory has grown into a vibrant and interdisciplinary field of research that continues to expand and evolve, offering new insights into the workings of the human mind and the nature of memory.

## Conceptual structure of prospective memory

Various theories attempt to explain the mental mechanisms underlying humans' prospective memory capacities. Some of them are discussed below.

### MONITORING VIEW

Theories based on this view are labeled as monitoring theories. This perspective asserts that retrieving PM necessitates a resource-intensive process of monitoring the environment for target events. Akin to Shallice and Burgess's (1991) supervisory attentional system, an executive attentional system monitors the environment for target events after an intention has been formed. The executive attentional system interrupts the ongoing activity upon encountering a target event, and if favorable conditions are encountered, action for the intended action is initiated. One of the most influential monitoring view theories is the preparatory attentional and memory processes (PAM) theory, developed by Smith (2003). According to the preparatory attentional and memory processes (PAM) theory (Smith, 2003), successful completion of event-based PM requires preparatory processes that are capacity-consuming.

It has been shown, as presented by Smith (2003), that working on an event-based PM task concurrently with an ongoing task reduces the response latency rate at which the latter can be completed. She used a lexical decision task as an ongoing task. In this task, a string of letters was presented, and participants were asked to indicate whether or not the string represented a word. In her study, PM task was to press a key whenever one of six target items appeared. Performance was compared between participants who only did an ongoing task and those who performed both an ongoing and PM task concurrently. It was found that response latencies were slower when participants performed both ongoing task and PM task concurrently. Smith concluded that people were spending cognitive resources on monitoring of the letter strings for the PM targets because this slowing down also occurred in trials without PM targets. The monitoring theory is supported by research that demonstrates a decrease in performance on the PM task when attention is divided during retrieval (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh & Hicks, 1998; McDaniel, Robinson-Riegler, & Einstein, 1998; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). These findings can be interpreted in a number of ways, one of which suggests that dividing one's attention disrupts the executive monitoring process, which is essential for determining which environmental occurrences are needed to encounter PM targets. The reduction in performance of an ongoing task that occurs while an intention is being maintained has variously been referred to as an "attentional cost," "task interference," and "intention cost," among other names.' In various studies, it has been found that the intention cost of an ongoing activity positively correlates with PM performance (Smith & Bayen, 2004). Many studies have used different ongoing tasks and PM tasks and found similar results, providing support for the PAM theory and showing that preparatory attention is required for monitoring (e.g., Cook, Marsh, Clark-Foos, & Meeks, 2007; Einstein, McDaniel, Thomas, Mayfield, Shank, Morrisette et al., 2005; Gilbert, Gollwitzer, Cohen, Burgess, & Oettingen, 2009; Guynn, 2003; Loft & Yeo, 2007; Marsh, Hicks, & Cook, 2005; Marsh, Hicks, & Cook, 2006; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, Bayen, & Martin, 2010; Smith, Hunt, McVay, & McConnell, 2007, Smith, 2003).

**SPONTANEOUS VIEW**

Introspectively, the experience of spontaneous retrieval is like an intention suddenly "popping" into one's mind (e.g., Meier, Zimmerman, & Perrig, 2006). Spontaneous retrieval processes can also support prospective memory (McDaniel & Einstein, 2007). The reflexive-associative theory exemplifies spontaneous retrieval theory (Einstein & McDaniel, 1996; Guynn et al., 2001; McDaniel & Einstein, 2000; McDaniel et al., 1998, 2004). According to this theory, an association is formed between the PM target cue and intended action. Later, when the target event occurs, an automatic associative system (such as the hippocampal system proposed by Moscovitch, 1994) conveys the desired action to consciousness. According to Moscovitch, the retrieval of this information is a relatively automatic process that happens quickly, is necessary, and requires very few cognitive resources. Whether the retrieval occurs, however, depends on the extent to which the cue is fully processed at retrieval and the degree to which participants form a good association between the prospective cue or target and the intended action (the action to be carried out) in the encoding phase. Even when the prospective memory task is temporarily suspended, the target occurrence can trigger the automatic recall of the intention representation, followed by the execution of the intended action. In numerous studies, it has been discovered that spontaneous retrieval is associated with the hippocampus, as opposed to monitoring retrieval, which requires preparatory activation of the prefrontal cortex (McDaniel, LaMontagne, Beck, Scullin, & Braver, in press), (Gordon, Shelton, Bugg, McDaniel, & Head, 2011; Moscovitch, 1994).

## MULTIPROCESS THEORY

The multiprocess view was proposed by McDaniel and Einstein (2000). This view considers evidence for both monitoring and spontaneous retrieval processes. According to the postulates of this theory, there are two distinct cognitive paths that can lead to successful prospective memory retrieval: monitoring and spontaneous retrieval. This theory proposes that the characteristics of the target event and their relation to the target actions, the nature of the ongoing task, and individual differences all play a role in determining whether or not an individual relies on a monitoring or spontaneous retrieval process and what prospective strategy is used to remember intentions. McDaniel and Einstein (2000) contended that it is adaptive to have a system that can accomplish PM retrieval through a variety of mechanisms because of the pervasiveness of prospective demands in everyday life.

In everyday life, an individual can have multiple intentions and concurrent demands, along with a long retention period between the formation of the intention and performing the intended action. These considerations suggest that putting all of one's cognitive capacity into the monitoring task may not be the best strategy. Therefore, the multiprocess theory suggests that people tend to rely on spontaneous retrieval.

**DYNAMIC MULTI PROCESS THEORY**

According to the dynamic multiprocess theory, prospective memory can be supported by monitoring or spontaneous retrieval (Scullin et al., 2013). This framework proposes that monitoring and spontaneous retrieval are dynamically interconnected processes. Individuals dynamically use their attention demanding processes (monitoring) and spontaneous retrieval processes. Individuals are able to monitor the PM task with a degree of flexibility and selectivity when the time or context of the PM task can be predicted. Prior to the appearance of the PM cue, the only investment of cognitive resources that is required is in the performance of the ongoing task, and there is no need to set attention allocation policies. Near the emergence of the PM cue, individuals will invest a significant amount of cognitive resources in order to search for and monitor the PM cue. As a consequence of this, the individuals' attention consumption will demonstrate dynamic changes (Scullin et al., 2013; Moyes et al., 2019). In one such study demonstrating dynamic changes in the attention allocation policies, it was found that participants who successfully remembered to perform the prospective memory intention monitored following, but not prior to, encountering the initial prospective memory cue. These findings contradict monitoring-only theories holding that prolonged retrieval modes (Guynn, 2003) or prolonged preparatory monitoring (Smith, 2003) are necessary to retrieve intentions (Shelton and Scullin, 2017; Scullin et al., 2013). In their research, Kuhlmann and Rummel (2014) showed that, after initial intention encoding, people are able to flexibly update their attention-allocation policy and optimize their prospective memory performance.

**Prospective Memory Paradigms**

*Naturalistic and laboratory studies*

Paradigms for examining prospective memory can be broadly classified as naturalistic or laboratory-based. During its formative years, experimental PM tasks were used in only a smattering of studies, with the majority of early PM research focusing on naturalistic settings. Research done outside of a controlled laboratory setting typically consisted of asking subjects to repeat a simple task in their day-to-day life (Marsh et al.,1998). In the naturalistic studies, participants were asked to do things like send postcards to the experimenter (Meacham & Singer, 1977), press a button on a clock multiple times per day (Wilkins & Baddeley, 1978), or make phone calls at predetermined times throughout the day or week (Maylor, 1990; Moscovitch, 1982). For example, Meacham and colleagues introduced a simple task of posting a blank postcard (stamped and addressed to the researcher) on pre-specified dates, a method that allowed them to investigate the role of external reminders (Meacham & Leiman, 1982) and incentives (Meacham & Singer, 1977) for remembering time-based PM tasks over long delays. In a study conducted by Wilkins and Baddeley in 1978, participants were given a small clock device to carry around for a week and were instructed to press a button at set times multiple times per day.

In a similar kind of study, participants were instructed to call the researcher at a set time every day for a set number of days and leave a message on an answering machine (Moscovitch, 1982; Maylor, 1990). Even though the tasks were done in real-life settings (such as at home, the post office, or the grocery store), the goals were not always natural. For example, pressing a button on the clock is not something we do every day, and the participants knew that their PM was being evaluated (Kvavilashvili, 1992). There have been few studies examining naturalistic PM without participants knowing that their performance was being assessed.

In one such study, Dobbs and Rule (1987) gave participants a questionnaire to fill out at home and mail back. The researchers stressed the importance of knowing the exact time the questionnaire was completed, so participants were asked to write the time they finished on the first page. In Ellis's (1998) research, participants were asked to write down their plans for the following day and, later that night, to indicate which of those plans they had actually carried out. This was done over the course of several days. In addition, participants kept a diary throughout the day in which they recorded any instances of fleeting thoughts or recollections of their intent. The lack of experimental control in naturalistic research was one of its main flaws. Researchers could quickly obtain PM performance scores from naturalistic studies because they were based on multiple observations, but they were restricted in their ability to influence how often participants used external memory aids (such as calendars and reminders) in their everyday lives. Therefore, there was need to study PM in the laboratory setting with controlled variables. The primary benefit of studying PM in a controlled environment like a laboratory is that it accurately represents key features of real-world situations involving PM.

In the year 1990, McDaniel and Einstein presented a standardized laboratory paradigm that went on to have a significant influence on the expansion of research into prospective memory and is widely regarded as a watershed moment in the field. Participants in this paradigm are tasked with remembering a PM intention while simultaneously carrying out an ongoing activity. This ongoing action is reminiscent of real-life situations in which a person is occupied with one task while simultaneously, at some point, being required to carry out another intended action. Researchers have pioneered two computer-based tasks, one event-based and the other time-based, depicting real-life settings. (Einstein et al., 1995). In the time-based task, people monitor a clock and respond at fixed intervals (e.g., every 10 min) while performing a second, attention-demanding task (for example, an ongoing task can be a lexical decision task). The dependent measures in this paradigm include the number of successful responses and the frequency of clock checking. In the event-based task, participants are given one or two words to remember (e.g., rake) and are told to press a key whenever they encounter the word(s) in the ongoing recall task. Both of these laboratory-based tasks represent new attempts to collect empirical data on prospective memory. To date, many studies have used this paradigm or its variant extensively for studying PM processes (Smith, 2003; Kliegal et al.,2001).

## TYPES OF INTENTIONS

The context of the retrieval is a useful identifier of prospective memory intentions. Major research conducted on intentions distinguishes between event-based intentions and time-based intentions.

***Event based intentions*** are to be-performed action when a certain external event occurs. In the event-based scenario, clear environmental cues (events) prompt the recollection of the deferred intention. For example, an intention to post a letter on seeing the post office.

***Time based intentions*** are actions which are to be performed at a specific time or after a set amount of time has elapsed. For example, an intention to take cookies out of the oven in 20 min to take medicine at a particular time. In time-based situations, intentions are completed at a specific future time with no clear environmental cues.

An essential distinction between event-based and time-based prospective memory was proposed by Einstein and McDaniel (1990). They theorized that unlike time-based prospective memory, event-based memory is triggered by some kind of event or cue (e.g., the letterbox reminds one to post a letter) and requires less self-initiated processing or mental effort. Time Based prospective memory is more effortful because it requires a participant-initiated response at a specific time in the absence of cues.

Further distinctions within both event-based and time-based prospective memory have sometimes been made. For example, Kvavilashvili and Ellis (1996) distinguished intentions to be executed when an individual is at a particular location from those to be executed when performing a particular activity. Certain activities also signal intention's execution in addition to time and events. Such intentions need to be fulfilled after or before the start of some other activity (such as going to the market after or before having lunch) (Kvavilashvili & Ellis, 1996).

Ellis (1996) divided time-based prospective intentions into two types: pulse, to be executed at a specific time (e.g., "at 10:00 tomorrow"), and step, to be executed during a broader time window. Meacham and Leiman (1982) distinguished habitual remembering of routinely performed intentions, such as brushing one's teeth at a particular time, from episodic remembering of infrequent tasks, such as getting milk on the way home from work, for which one must form a separate intention for each episode. Episodic tasks can be either event based or time based. In addition to episodic and habitual intentions, Loukopoulos, Dismukes, and Barshi (2009) identified two other situations in which individuals (specifically, pilots) must remember to perform intended actions: remembering to resume an interrupted task and remembering to switch attention between concurrent tasks.

## MIXED PROSPECTIVE MEMORY

Most laboratory studies have explored the cognitive processes underlying only event based and time-based prospective memories. In real life scenarios, there are various situations where delayed intentions do not fall into event based or time-based categories and distinction between the two-retrieval contexts becomes vague (Loukopoulos, Dismukes, & Barshi, 2009; Grondin, 2001). The time dimension is an inseparable part of any human activity. There can also be situations, where time and event cues work together or in combination to elicit intentions. For example, I have to take my medicine at six p.m. every day and around the same time, the floodlights of the tennis court outside my window get turned on. In this case, both lights and six o'clock on the clock remind me to take my medicine. Such kind of prospective remembering is termed as mixed type prospective memory (Block & Zakay, 2006). Ellis (1996) explained a similar kind of distinction and named such contexts as “pure and combined retrieval context”. The vast majority of experimental research so far has been directed at event based, time based prospective memory tasks or on comparisons of event and time-based prospective memory tasks. Not much literature is available for this hybrid version of event and time based prospective, and is still in its budding phase.

**PHASES OF PROSPECTIVE MEMORY**

The realization of a delayed intention can be described in terms of the following phases (Ellis,1996).

**(1) Encoding phase**: In this phase intent/decision to act is formed and encoded. It also includes the action associated with that intent, and the cues that specify when this action and intent should be retrieved.

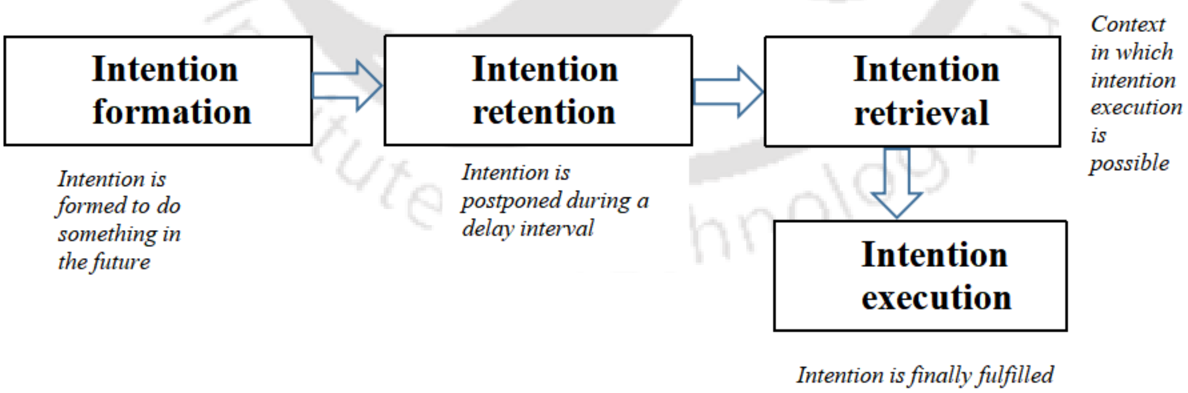
**(2) Delay or retention interval**: It is the time between encoding and start of the performance interval. The reason to why individuals forms an intention is that they cannot carry out that particular action immediately. Thus, there is usually a delay during which they engage in other activities before the intended actions are executed. This delay may be a matter of a few minutes or may be days, weeks, or even months.

**(3) Performance intervals** during which the appropriate retrieval criteria occur and the action can be carried out. The person has to monitor the environment for the appropriate cue or point in time before they can initiate and execute the intended action.

**(4) Initiation and execution of intended action**: This phase is concerned with the performance of the action. need to interrupt ongoing activities to executive intention. Because people do not just wait and do nothing after forming an intention to carry out an action in the future, typically they have to stop what they are doing when they realize that the time has come to carry out the intended action.

**(5) Evaluation phase**: In this phase some record and evaluation of the outcome of a delayed intention occurs. The processes that operate during these phases are frequently described by the term 'prospective remembering' or 'prospective memory' (Meacham & Leiman, 1975).

Depending on the goals of the experiment or study, prospective memory can be manipulated during the encoding, retention, or retrieval phases to determine the impact of different variables on performance.




Phases of prospective memory adapted from Ellis (1996) and Kliegel et al. (2002)

**Figure II: Phases of Prospective Memory**

## ENCODING INTENTION

The first step in the prospective memory process is called "encoding the intention," and it is during this phase that the intention is either formulated or planned out for future execution. The encoding phase plays a significant role in the execution of delayed intentions. During this phase, participants are instructed to perform an additional action while concurrently performing an ongoing task later in the experiment. Even though there is widespread consensus that both encoding and retrieval are necessary for effective remembering, the majority of research on prospective memory has concentrated on factors associated with retrieval. Numerous variables that can influence the retrieval or completion of delayed actions have been evaluated in research studies that have manipulated this phase. But to gain a comprehensive understanding of prospective memory processes, it is also essential to investigate the effects of encoding on prospective memory performance

What one does while encoding, or planning, can impact one's ability to retrieve PM, as shown by Burgess and coworkers (e.g., Burgess, Veitch, Costello, & Shallice, 2000; Burgess et al., 2008). Encoding prospective memories can be an active process that relies upon episodic memory, planning, and coordination in order to form an intention to perform some behavior in the future (Brewer & Marsh, 2010; Yaacovi and Burgess, 2012). According to research (McDaniel & Einstein, 2000; McDaniel, Einstein, & Rendell, 2008), effective intention encoding can lessen the load on cognitive control systems at retrieval. While effective prospective memory performance relies heavily on the encoding of intentions and cues, this process can be influenced by a number of different factors. Some of which are discussed below.

- **Task Relevance**

Encoding of intentions and cues can be affected by the prospective memory task's significance. Whether or not instructed task importance affects PM performance was investigated by varying the importance given to the intention while encoding (Kliegel et al., 2001; Walter and Meier, 2014). Tasks that are perceived as more important or personally relevant are more likely to be encoded and remembered (Andrzejewski et al., 1991; Ellis, 1988; Goschke & Kuhl, 1996; Kvavilashvili, 1987, Exp 2; Meacham & Singer, 1977; Somerville, Wellman, & Cultice, 1983). Andrzejewski et al. (1991) found that people were most likely to remember important appointments. Ellis (1988) also found that the degree to which an intention was remembered correlated positively with its perceived significance. Over the course of 8 weeks, Meacham and Singer (1977) had participants send prepaid postcards to the psychology department on specific days. The instructions stated that out of all of the postcards that were turned in on time, four winners would each receive a maximum of five dollars if they were drawn from the pool. This was the high-incentive group of participants. According to the findings, the high-incentive condition led to significantly better performance. Kvavilashvili (1987) instructed participants to replace a telephone receiver on the rest at the end of a 5-minute period that was either empty or filled with activity. To manipulate importance, participants were either asked to replace the receiver at the end of the session or to do so because the experimenter expected an important call. The results demonstrated a significant positive effect of task importance on prospective memory performance. Kliegel et al. (2001) conducted an experiment that demonstrated the importance effect in time-based prospective memory, which has been linked to better prospective memory accuracy. Half of the participants were told that the prospective memory task was more important than the ongoing task (word-rating task), the other half was told that the ongoing task was the more important task. Participants who were told that the prospective memory task was more important than the ongoing task produced more correct target responses in the prospective task compared to the participants who received the opposite instruction. They also found a significant increase in time monitoring when emphasizing the importance of the PM task (Exp. 1). According to McDaniel and Einstein (2007), the amount of planning used to encode the intention may depend on the significance of the PM task. Penningroth and Scott (2013) found that people who rated a task as more important used PM strategies to a greater extent than those who rated the task as less important.

- **Enhancing the strength of intention representations**

Encoding can also be affected by strengthening intention representations or by changing the content of the intended action. During such encoding, multiple associations are formed, which include associations to the encoding context, associations between the cue and the target action, and associations between the cue and the future context in which the intention is to be fulfilled (Smith, & Skinner 2019; Rummel & Kvavilashvili, 2023).

***Implementation intentions***

Enhancing encoding through intervention can greatly enhance prospective memory performance. Multiple studies have shown that implementation intentions may improve retrieval and initiation of delayed intentions (e.g., Chasteen, Park, & Schwarz, 2001; McFarland & Glisky, 2011; Meeks & Marsh, 2010). Implementation intentions are specific if-then plans that “specify the when, where, and how of responses leading to goal attainment," such as “when situation x arises, I will perform response y” (Gollwitzer, 1999, p. 494). Participants form implementation intentions by verbalizing their intention at encoding (e.g., participants state “when I see an animal word, I will make a special response”; McDaniel, Howard, & Butler, 2008). The cue-action link can be strengthened through the use of implementation intentions (e.g., Gollwitzer, 1999; McDaniel &

Einstein, 2007; Wieber, Thürmer, & Gollwitzer, 2015) and this is thought to lead to a more robust and deeper encoding of the delayed intention (McDaniel & Einstein, 2007; Chen et al., 2015). Linking a specific, situational cue (the if-component) to goal-directed behavior (the then-component) is also thought to support automatic, rather than consciously-controlled, goal-directed behavior (McDaniel, Howard, & Butler, 2008; Webb & Sheeran, 2003; Wieber, Von Suchodoletz, Heikamp, Trommsdorff, & Gollwitzer, 2011). Implementation intentions are believed to increase the ease with which PM cues can be accessed and the strength of the association between PM cues and their intended actions by forcing a more elaborate and specific encoding. It has also been established that the encoding phase can be manipulated to improve prospective memory in clinical populations by incorporating strategies such as implementation intentions (Goedeken et al, 2018). The clinical population and the elderly population have both benefited from this approach. Foster et al. (2017) conducted a study in a controlled setting and found that participants with Parkinson's disease benefited from the use of implementation intentions as an encoding strategy. When compared to the standard PM instructions, Zimmermann and Meier (2010) found that prompting participants to form implementation intentions resulted in improved PM performance in older adults. However, this improvement was not found in adolescents or young adults.

***Imagery encoding***

Past research has shown that strategies that aid in the complete encoding of PM cues and actions can boost PM performance. Researchers have developed several other encoding strategies to facilitate participants' ability to respond to prospective memory cues. Another encoding strategy that has been used in many studies is imagery encoding. Asking participants to visualize themselves performing the prospective memory task during intention formation is a common manipulation in such encoding. In imagery, participants imagine themselves witnessing and responding to prospective memory target (e.g. an animal word) while performing the ongoing task (e.g., lexical decision task).

Meeks and Marsh (2010) discovered that, compared to standard encoding conditions for nonspecific cues (e.g., respond to prospective memory target), imagery encoding does produce benefits in prospective memory performance.

Imagery encoding facilitates several important aspects of intention fulfillment by strengthening contextual associations. Engaging in imagery at encoding serves to better specify the contextual information that is relevant to the intention which facilitates the ease with which one can verify if the characteristics of the current context match those that are associated with the cue. This facilitation of the verification process in turn protects one from distraction by intention-related material that is encountered outside of the appropriate context. Context is an important determinant in the successful formation and fulfillment of prospective memories (Marsh et al., 2008; Brewer et al., 2011). Having one's attention constantly drawn to things related to a future goal could be very bad for activities that one is already doing before the goal can be accomplished. Therefore, it is thought to be beneficial to encode an intention through the use of imagery in order to strengthen the association between event-based cues and the proper responding context.

***Enactment***

In enactment encoding, participants are asked to physically perform the action on the imagined designated object (e.g., participants would have to pretend to comb their hair, or play the piano). PM performance was consistently higher in population with Alzheimer's disease (AD) when physical enactment was used during encoding, and when target-action pairs were strongly associated with one another, according to a study that was conducted by Pereira et al. (2015). The role of enactment in improving prospective memory performance has also been observed in healthy young and older adults (Pereira et al., 2012a, 2012b), in addition to being recognizable in patients with mild cognitive impairment. The positive effects of enactment were cumulative and visible over the course of a lifetime, in both healthy and cognitively impaired individuals (e.g., Charlesworth, Allen, Morson, Burn, & Souchay, 2014)

Multiple encoding methods can also be used together. It is common practice to combine different encoding strategies or techniques in order to facilitate better intention encoding; however, the effects of these combinations can be distinguished from one another. For example, in recent studies of implementation intentions, researchers added an imaging component to the verbal if-then statement by asking participants to imagine how they would do the PM task later in the experiment and found improved prospective memory performance. (Kardiasmenos, Clawson, Wilken &Wallin, 2008; McDaniel et al., 2008; McDaniel & Scullin, 2010; Schnitzspahn & Kliegel, 2009). In a similar study, Chasteen et al. (2001) found that older adults who were instructed to create an implementation intention and visualize themselves carrying it out outperformed those who only rehearsed instructions.

It is believed that the combination is especially efficient because it leads to further elaboration of the target and a strengthened association between the target and the action to be performed. Research (Chasteen, Park, & Schwarz, 2001; Zimmermann & Meier, 2010) has begun to examine the effectiveness of encoding strategies during the intention-formation phase to improve subsequent PM performance.

- **Intention-encoding-strength effects – Role of Context and contextual cues**

One form of manipulation at encoding is done by providing specific information about the context in which the PM cues will appear (Marsh, Hicks et al., 2006). Experiments have examined whether prospective memory performance is influenced by contextual cues. Experiments by Nowinski and

Dismukes (2005) indicate that context cues available at both encoding and retrieval support the retrieval of intentions. They demonstrated that targets were more effective at eliciting a prospective response when they were presented in the context of an associated task, one that had been encoded along with the prospective memory instruction, than when they were presented in a different task context. In other words, the context of the ongoing task impacts the retrieval. It was also found that Performance was also improved by a strong association between the prospective memory target. Highly associated or typical targets supported retrieval better than less associated, less typical targets. The presentation of context information at both encoding and retrieval has been shown to be crucial, according to extensive studies of retrospective memory (e.g., Godden & Baddeley, 1975; Smith et al., 1978)

In a similar task by Cook et al 2005, in a time-based prospective memory task, when participants associated the response window with a future context, time-based responding was better if that context expectation was correct as compared with having no context expectation at all. By contrast, if the response window occurred in a context that preceded the expected context, time-based performance was worse than having no context expectation at all. The level of prospective memory performance is increased when an intention is linked to a context (Experiment 1A; Marsh et al., 2006). This is because the context determines whether or not attentional processes must be engaged to monitor for the occurrence of prospective cues.

The level of association or integration between a retrieval cue and its intended action is also a key factor in determining the likelihood of successfully completing a PM task (Ellis, 1996; McDaniel, Guynn, Einstein, & Breneiser, 2004), especially for non-focal cues (Scullin, McDaniel & Einstein, 2010). Moreover, faster response times have been identified for cues semantically related with the respective PM action than for those that were semantically unrelated in healthy young and older adults (Maylor, Smith, Della Sala, & Logie, 2002; Pereira, Ellis, & Freeman, 2012a). This pattern of results reveals that a strong semantic relation between the items might support retrieval by enhancing not only accuracy but also speed.

Retrieval cues can be manipulated at the encoding phase by manipulating the specificity of instructions given. The instructions can be specific or general. For example, participants can be asked to give their response whenever they see an animal (category) or a particular exemplar of an animal (e.g., tiger) in the test phase. In the former task, the instructions would be general and the participants will need more self-initiated processing in recognizing the retrieval cue. In the latter task instructions will be more specific. The retrieval cue in the test phase will be the same as that was presented in the encoding phase thus confirming the specificity principle. Einstein and colleagues (1995; Exp 2) observed this specificity effect. In their study, younger and older adults were given an event- based prospective memory task embedded in a continuous memory span task. They manipulated the instructions associated with the cues i.e. the specificity of the participants' instructions concerning the target events. Some participants were asked to perform an action whenever the items leopard, lion, and tiger occurred (specific instructions), and others were asked to perform an action whenever any animal occurred (general instructions). Better prospective memory performance was observed when the instructions were specific as compared to the general instructions for both the age groups. The reason given was that specific instructions provided a full description of the cue. Thus, it is simpler for participants to recognize the cue in the test phase and recall the delayed intention. When given specific instructions, the cues presented at the encoding will be the same as presented in the test phase thus making retrieval easy for participants. Katie et al. (2010) in their study asked participants to press F9 key in response to the target cue. One group of participants were instructed to respond to the specific target (airplane) and other were told to respond to an exemplar of a specific taxonomic category (type of vehicle). Prospective performance was found to be greater in the specific than with the general cue condition.

- **Emotional state**

Manipulating emotional states during the encoding process has also been shown to affect the formation of future intentions and, by extension, the success of their retrieval (Knight.et al., 2015). When a future intention is being made, a person's mood may affect how easy it will be to access in the future, possibly by affecting associative binding. Processing that is evoked by being in a positive mood is more helpful to the encoding of intentions, whereas processing that is evoked by being in a negative mood is more harmful to the encoding of such intentions. The process by which future-oriented thinking is carried out (i.e., the processing promoted) and the content bound to the intention representation (i.e., the content) are both affected by one's mood, making prospective memory encoding mood-dependent. Knight.et al. (2015) found that one's mood state when forming a future intention plays a determining role in whether or not that intention will be ultimately acted upon.

- **Encoding Modality**

In the retrospective memory literature, the effect of encoding modality on the free recall and recognition is widely studied. (Cohen,1983; Craik and Lockhart, 1972). Memory performance is influenced by the modality in which the stimuli are presented and the type of encoding activity that is employed. There is evidence that auditory presentation results in a better performance than visual presentation of the same verbal material (e.g., Gardiner & Gregg, 1979; Murdock & Walker, 1969). Many laboratory studies have been conducted to know the influence of modality on memory performance.

But not much literature is present on the effect of cue encoding modalities on the prospective memory performance. Robinson (1992) in their study manipulated the presentation of cue in the encoding phase. Some participants were shown target cues in the word form whereas some in the form of line drawings. The prospective memory performance was better in picture cue (line drawing) condition as compared to the word form condition. Thus, indicating that manipulations done at the encoding stage can affect the prospective memory performance. Passolunghi et al. (1995) studied the effect of cue encoding modalities (verbal, visual and motoric enactment of the to be performed action) on the prospective memory performance of children aged between 7-11 years. Motoric enactment at the encoding phase was found to increase the performance. Guangzheng Li and Lijuan Wange (2015) also tested the effect of encoding modality and object presence at encoding on prospective memory performance of children (age 7-9). They compared the memory performance under verbal encoding and enactment encoding conditions. In the enactment condition, the participants were asked to perform the action at the encoding time itself. They found that the prospective memory performance of eight- and nine-year-old children was significantly better than that of seven-year-old children. Second, the combined group of eight- and nine-year-old children showed prospective memory improvement in enactment condition compared with verbal condition.

Vedhara et al. (2004) did a laboratory study to find out the relationship between medication adherence and habitual prospective memory (HPM) of type 2 diabetic elderly patients. In addition to that, they also find out the way to improve the medication adherence by using cues to help them remember. Forty-eight elderly diabetic patients were randomly allocated to one of four HPM task conditions: no cue, visual cue, auditory cue or dual cue (auditory and visual cue) to aid performance. The results showed that HPM task performance was optimal in the dual cue condition.

- **Attention**

Attention is essential for encoding intentions and cues in prospective memory. Divided attention tasks or distractions during the encoding phase can lead to reduced encoding and subsequent forgetting. Intentions may be harder to encode, plan, and/or retrieve in situations where executive control is being heavily taxed. As a multi-phase process, PM necessitates the synchronization of various attentional control mechanisms.

***ROLE OF ATTENTION IN MEMORY ENCODING***

It has been known for a while that dividing your attention (DA) during the encoding phase of a memory task makes it harder for you to remember things later on. Early research by Murdock (1965) and subsequent research by Baddeley, Scott, Drynan, and Smith (1969) and Anderson and Craik (1974) all confirmed this effect. When the memory task was prioritized over the secondary task, Murdock (1965) found that free-recall performance was enhanced under dual-task conditions. Therefore, the participant's attention is required for the memory-encoding process, and this attention can be allocated differently between the encoding task and the subsidiary task. Numerous studies show that free recall, cued recall, and recognition memory performance all suffer under conditions where participants' attention is divided during encoding by a concurrent task, as opposed to conditions where participants' attention is focused solely on encoding the items of one task (e.g., Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Eftekhari, & Binns, 2018; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Fernandes & Moscovitch, 2000; Murdock, 1965; Naveh-Benjamin, Craik, Gavrilescu, & Anderson, 2000; NavehBenjamin, Craik, Guez, & Dori, 1998). Similarly, divided attention (DA) at encoding has been shown to have similar effects on a variety of memory features, including memory for temporal order information (Naveh-Benjamin, 1990) and memory for spatial location (Naveh-Benjamin, 1987). Moreover, encoding information is associated with a consistent drop in performance on a secondary task (e.g., Griffith, 1976; Johnston, Greenberg, Fisher, & Martin, 1970; Johnston, Griffith, & Wagstaff, 1972). The findings have been interpreted to suggest that paying attention during the encoding of memories is essential.

The reduced resources/reduced processing time hypothesis proposes that the decrease in memory performance under DA at encoding occurs because participants spend some of their time or attentional resources performing the concurrent secondary task. As a result, participants have fewer attentional resources or time available to process the pertinent information, which leads to the observed decrease in memory performance. This hypothesis has been put to the test in a number of studies that have been carried out by Craik and Byrd (1982) and by Naveh-Benjamin et al. (2000). The results of the latter study demonstrated that the decreased memory performance as a result of DA at encoding was only partially related to the decreased amount of functional time that was available for encoding. Similarly, Craik et al. (1996) demonstrated, through the utilization of a shared time model analysis, that the reduction in processing time experienced during encoding could only account for a portion of the deficit.

Another, more nuanced suggestion is that the mechanism disrupted under DA at encoding that reduces memory performance is linked to a reduction in semantically elaborative, effortful processing (e.g., Hasher & Zacks, 1979). This proposal is based on the supposition that participants, while occupied with the secondary task, do not have the mental capacity to engage in the more taxing, in-depth elaborative processes that would allow them to better encode the pertinent information. This recommendation stems from the idea of limited attentional resources, which states that when people have fewer resources available to devote to encoding, they are less able to put in the effort required to process information in a way that is semantically rich and nuanced (or to engage in other forms of deep-level cognitive processing), and as a result, their memory suffers. Several studies that have varied the difficulty of the secondary task during encoding have provided empirical support for the reduced deep-semantic elaboration hypothesis. According to this theory, the impact of DA will be minimal on encoding features that do not involve effortful, deep level semantic processes. Naveh Benjamin et al. (2000), for instance, demonstrated that the difficulty of the secondary task at encoding affects memory performance by manipulating the number of choices in a continuous choice reaction-time (CRT) task. The reasoning behind these tests was that less cognitive capacity would be available for elaborate semantic processing of encoded words if participants were exposed to a greater number of options. The amount of processing power required to complete a secondary reaction-time task (as demonstrated by Anderson and Craik, 1974) is inversely related to subsequent memory performance. Results reported by Craik and Byrd (1982) and Rabinowitz, Craik, and Ackerman (1982) showed that under DA at encoding, participants use shallower and less semantic processes to encode the information. In addition, Naveh-Benjamin et al. (2000) reported results indicating that as emphasis shifted from the memory task to the concurrent task, the observed recall levels departed progressively from the values predicted by the deep levels of processing calibration function. This provides support for the claim that DA at encoding changes the nature of encoding such that it becomes less semantic in nature. Neuroimaging research has also shown that DA during encoding decreases encoding-related brain activity in the left inferior prefrontal cortex, an area that is linked to semantic processing (e.g., Anderson et al., 2000; Kapur et al., 1994; Shallice et al., 1994).

***DIVIDED ATTENTION AT ENCODING AND PROSPECTIVE MEMORY***

Previous research has demonstrated that divided-attention tasks impair prospective memory (e.g., Einstein et al., 1997; McDaniel & Scullin, 2010)

According to the findings of a study that was carried out by Einstein and colleagues in 1997, increasing the attentional demands placed on participants at the time of encoding led to a decline in the prospective memory performance of both older and younger participants. They observed a lower probability of responding to targets when participants were engaged in an attention-demanding digit-monitoring task during the encoding of the prospective memory instructions compared to participants who did not have the additional digit-monitoring load.

The effect also depends on the complexity of the attentional demand and the type of cue available at the time of retrieval. Marsh and Hicks (1998) demonstrated that divided attention tasks that demand attentional resources (e.g., a random number generation task) disrupt prospective memory performance. The divided attention task at retrieval interferes with an effortful search for the prospective memory cues (McDaniel & Scullin, 2010). Harrison et al, 2013 examined the effects of divided attention on the spontaneous retrieval of a prospective memory intention. Participants performed an ongoing lexical decision task with an embedded prospective memory demand, and also performed a divided-attention task during some segments of lexical decision trials. Their results indicate that the effects of divided attention on spontaneous retrieval processes depend on the nature of the divided-attention task and the salience of the prospective memory target cue.

- **Target-list-length effect.**

The number of stimuli encoded as prospective memory targets also affects prospective memory processing and intention execution. Prospective memory performance suffers in proportion to the number of targets that are encoded.

In studies, increasing the number of targets to remember is referred to as Prospective load (PL). It refers to the number of prospective memory targets or target categories that are pertinent to one or more pending prospective memory tasks (Einstein et al., 1992, 2005; Meier and Zimmermann, 2015). Rarely has the number of cues used in a PM experiment been manipulated, but when it has, it has typically been used in conjunction with other variables. (Anderson and McDaniel 2019).

Previous findings regarding the effect of prospective load (the number of cues associated with a prospective memory intention) on prospective memory performance are inconsistent. Wesslein et al. (2014) manipulated the prospective memory target list by giving four cues in low-load condition and ten cues in the high-load condition. They found that prospective memory accuracy declined with an increased target list. In a study conducted by Cohen (2013), participants were made to remember one to six target cues in six different experiments. In the upcoming ongoing task (lexical decision task), they were asked to respond to these targets. Study concluded that the performance of prospective memory decreased with the increase in the number of prospective targets.

The limited number of studies that have attempted to influence prospective load by varying the number of prospective memory targets have produced conflicting results. Cohen et al. (2008) increased the number of prospective memory targets in their study and found no difference in prospective memory accuracy. However, the increase in prospective load has been found to increase the interference effect in the ongoing task. Reaction time of the nontarget trials in the ongoing task was found to be affected by manipulating the number of prospective memory targets. A high prospective load necessitates more monitoring processes during retrieval, which increases the task cost of working memory. Number of prospective memory targets have the potential to affect the allocation of attention away from an ongoing task. This effect is investigated by reporting increased reaction time latencies of an ongoing task. Arguments are given that more load exert attentional demands on the limited available working memory capacity. Doing parallel complex task takes use of the limited attentional process that leaves the person with little or no resources to remember the delayed intention. All these can lead to forgetting of the intentions (Li et al., 2022). Even though a few studies have discovered that prospective memory performance decreases with increasing task load (Stone et al., 2001; Cohen, 2013; Wesslein et al., 2014; Einstein et al., 2005), additional research is necessary to confirm these findings.

**SLEEP IN MEMORY**

The importance of sleep to memory functions has been the subject of experimental research for quite some time. This section will summarize the findings and contributions that have shaped our understanding of the complex relationship between sleep and memory. "Sleep is defined as a natural and reversible state of reduced responsiveness to external stimuli and relative inactivity, accompanied by a loss of consciousness" (Rasch and Born.,2013, p1). Numerous cognitive functions, including memory, attention, and decision-making, are known to be influenced by sleep. The relationship between sleep and memory has fascinated scientists for centuries, spawning a wealth of investigation and new understanding. Many studies in the 1990s and 2000s, as well as neuroimaging data showing continued learning-related brain activity during sleep, pointed to the importance of sleep in the consolidation of newly learned material in humans. Sleep is known to act by passively protecting memories from retroactive interference. Ebbinghaus (1885/1964) observed a reduction in the rate of forgetting from 9 hour to 24 hours after learning (2.1%), relative to the rates of forgetting from 1 to 9 hour (8.4%) and from 24 to 48 hours (6.1%) after learning. In other words, there was significantly less forgetting during the time period that included the first night's sleep after learning compared to the other two time periods. Learning before going to sleep at night leads to less forgetting 24 hours later, as shown by a more systematic study conducted by Rosa Heine (1914). Her study offered preliminary evidence for the significance of sleep to memory. In the first half of the twentieth century, studies of memory focused primarily on what led to forgetting. Forgetting was initially explained in two different ways: the "decay" account, which postulated that memory traces deteriorated with time (Thorndike.,1913), and the "interference" account, which postulated that forgetting was caused by learning new information that (retroactively) interfered and overwrote the old memory traces (McGeoch, J. A., 1932). It would appear that sleep plays a crucial role in reducing interference, as it is during this time that new encoding of external and possibly also internal information is greatly reduced. The memory traces are passively preserved during sleep because it acts as a "temporary shelter" that merely delays the effect of interference (Ellenbogen et al., 2006).

Studies by Patrick and Gilbert (1896) and the later, famous study by Jenkins and Dallenbach (1924) demonstrated that regardless of how long the retention period (the time between learning and recall), it was more effective when spent in sleep. Using experimental manipulation of sleep and wake retention intervals, Jenkins and Dallenbach (1924) found that syllable recall was improved after a sleep delay compared to a wake delay. It has also been shown that sleep deprivation negatively affects the activity of brain networks essential for proper cognitive function and learning (Chee & Chuah (2008); Peigneux (2015); Peigneux, Laureys, Delbeuck, & Maquet (2001); Rasch & Born (2013)).

Sleep can be divided into two phases: non-rapid eye movement (NREM) and rapid eye movement (REM). NREM consists of four stages: stages 1, 2, 3 and 4. Stages 3 and 4 are referred to collectively as slow wave sleep (SWS) as both exhibit a slow wave EEG pattern (Schulz.,2008). On average, one night of sleep involves four or five sleep cycles. Sleep cycles are the progression through various stages of NREM sleep and REM sleep, each lasting close to 90 minutes (Billiard.,2008). Slow-wave sleep (SWS) and rapid-eye-movement sleep (REM) occur in alternating cycles (FIGURE 2A). Early in the sleep cycle, slow-wave sleep (SWS) predominates and while rapid-eye movement (REM) sleep increases toward the end of the sleep cycle. Slow wave sleep (SWS) is characterized by slow EEG oscillations of high amplitude (slow wave activity, SWA), while rapid eye movement (REM) sleep (also called paradoxical sleep) is characterized by fast and low amplitude oscillatory brain activity, similar to wakefulness. Almost 50% of sleep in adult humans is marked by a lighter form of non-REM sleep (stage “N2”) that is characterized by the occurrence of distinct (waxing and waning) sleep spindles (FIGURE 2B) and K-complexes in the EEG, but minor SWA.

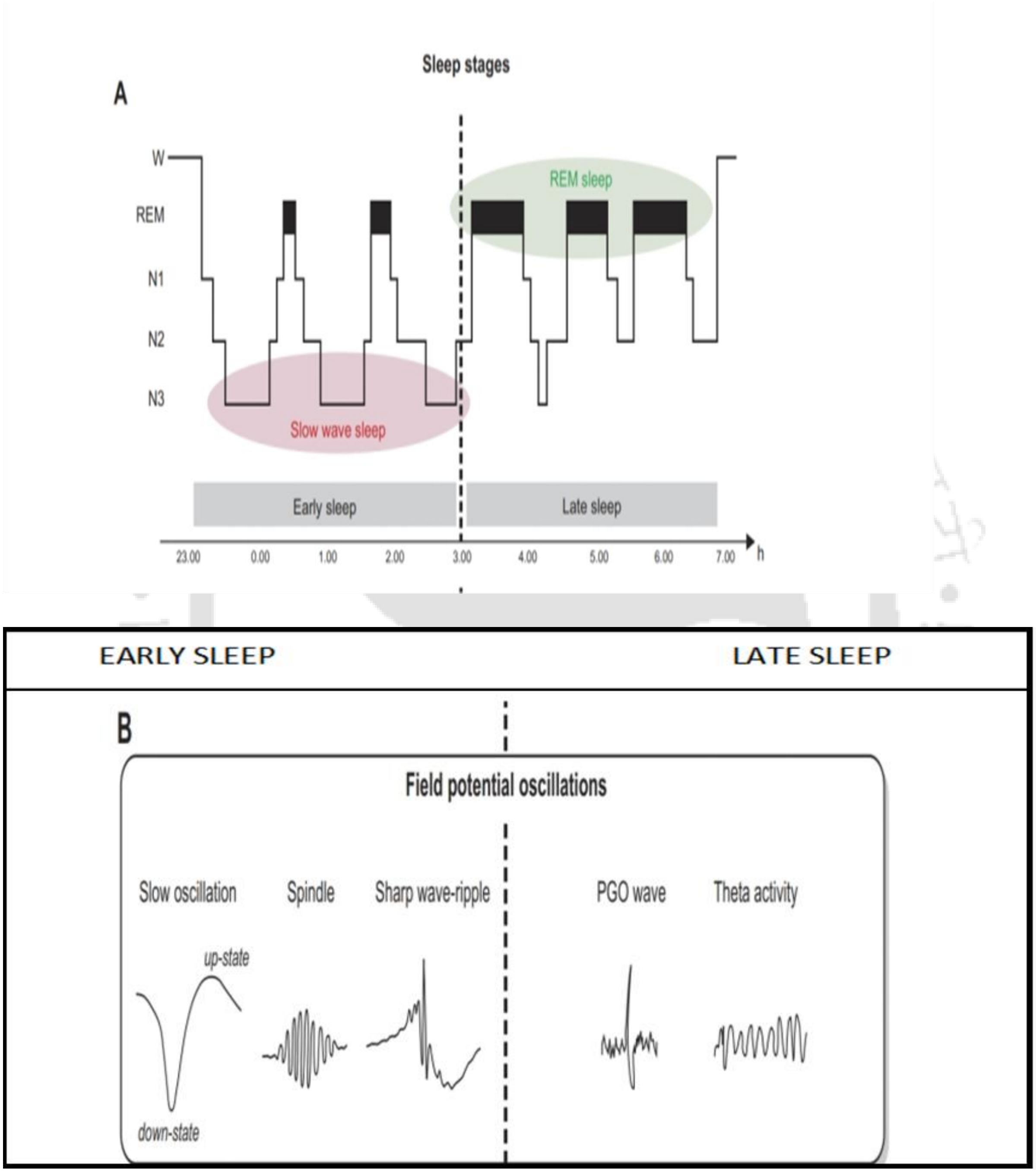



**Figure III:** ***(A)*** **Cyclic occurrence of rapid-eye-movement (REM) sleep and non-REM sleep.** ***(B)*** **Electrical field potential oscillations during early and late sleep stage.**

*(Adapted from Rasch and Born, 2013)*

Memory functions comprise three major subprocesses, i.e., encoding, consolidation, and retrieval. A new memory trace is formed when we encode a stimulus; this trace is extremely vulnerable to interference and decay (forgetting) in its early stages. The weak memory traces are being stabilized by the involvement of multiple waves of short and long-term consolidation processes in the consolidation stage and sleeping brain provides optimal conditions for consolidation of memory traces (McGaugh.,2000). The consolidation account of memory processing was first proposed by Müller and Pilzecker (1900). Beneficial effect of sleep consolidation has been studied on various types of memory systems (Sarode et al.,2013; Muehlroth et al.,2020). Studies have found that reactivation of hippocampal-based episodic memory during sleep leads to cortical-level memory component activation, reinforcing cortico-cortical connections while transforming short-term representations into permanent memories and thus enhancing memory (BuzsÁk., 1998). There have also been studies demonstrating a correlation between rapid eye movement sleep (REM) and episodic memory performance. Late sleep, which is associated with primarily REM sleep, has been linked to better episodic memory performance than early sleep or no sleep, according to research by Rauchse et al., (2004). Semantic memory consolidation during sleep and wakefulness was compared using total sleep deprivation by Fischer et al., (2006). Twenty subjects with regular sleep schedules were taught the material and randomly assigned to the "sleep" or "wake" groups. After either nine hour of sleep or wakefulness, subjects were tested on the previously learned material using a reaction time test. Subjects assigned in the 'sleep' condition performed significantly better on the reaction test, suggesting a possible relationship between sleep and the consolidation of semantic memory. In another kind of study, subjects were shown pairs of semantically associated words and their brain -wave activity was measured using an EEG during wakefulness and sleep. The purpose was to determine the pattern of brain waves displayed when two semantically associated words were processed. The instances of matched brain waves corresponded to active semantic memory processing and occurred most often in REM and stage 2 of sleep, suggesting that these stages may play an important role in the processing of semantic memory (Brualla et al.,1998). More recent research has confirmed that getting enough sleep can help retain information from past. (e.g., Payne, Stickgold, Swanberg, & Kensinger, 2008; Rasch, Buchel, Gais, & Born, 2007). It follows from these results that sleep might improve all types of memory, including prospective memory.

## SLEEP IN PROSPECTIVE MEMORY

Prospective memory is a relatively new field that investigates whether or not our memories of intentions are strengthened by sleep. Meta-analytical results indicate that the benefit of sleep on prospective memory is statistically significant but in the small to medium range (Leong et al., 2019). Sleep supports the maintenance of prospective memory over time by strengthening intentional memory representations, thus favoring the spontaneous retrieval of the intended action at the appropriate time. It benefits both components of prospective memory, i.e. to remember that something has to be done (prospective component) and to remember what has to be done (retrospective component (Diekelmann.,2013). Rehel et al. (2019) in their study used a virtual task to investigate the role of consolidation on time-based and event-based intentions of young and old age participants. The link between cue and intentions was also manipulated. Participants were required to learn and carry out intentions following waking or sleeping periods. In young participants, sleep aided in the consolidation of all types of intentions. All intentions in the elderly benefited from sleep, except for those that were event-based and had a weak connection between the cue and the action to be taken. Prospective memory was found to be unaffected by age across all intention types and types of retention intervals (sleep/wake), suggesting that prospective memory does not decline with age when evaluated in complex realistic situations. In another kind of study by Diekelmann et al. (2013), subjects were instructed on a plan that had to be executed after a delay of 2 days. After plan instruction, subjects were either allowed to sleep or stayed awake for one night (Exp. 1) or had a 3-h sleep period either during the early night (SWS-rich sleep) or late night (REM-rich sleep; Exp. 2). In both experiments, retesting took place 2 days later after one recovery night. Sleep, especially slow wave sleep, played an important role for the successful implementation of delayed intentions (Diekelmann et al.,2013). In contrast to previous research suggesting that SWS aids in prospective memory consolidation, Cunningham et al., 2021 found a negative association between SWS and prospective memory. In their study participants were healthy young adults who completed three ongoing tasks either in the morning or evening. They were instructed to remember to press "Q" when seeing the words "horse" or "table" when resuming the ongoing task after a 12-h delay, during which they could have been asleep (as measured by polysomnography) or awake (as measured by observation during the day). In order to examine the SWS spectral power correlates of prospective memory, spectral power analysis was performed on recorded sleep EEG. The findings implied that if SWS is enriched with delta-theta activity, the benefit of sleep for prospective memory maintenance may be diminished. In conclusion, these findings shed light on the complexities of the relationships between sleep and memory and the challenges of comparing studies that employed various cognitive paradigms.

## ROLE OF NAP

The positive role of sleep for memory consolidation of material learned before sleep (either procedural or declarative) has been largely explored and is widely accepted. But there is still an intense scientific debate on which sleep or memory related factors are crucial for the sleep effect. The role of a minimum sleep duration is amongst those factors which has never been fully clarified.

Studies of napping are natural model for investigating the time component of sleep for memory, but surprisingly few studies have even considered the possibility of a "nap effect''. Naps during the day serve as a robust experimental model for understanding how sleep helps with memory (Ficca and Salzarulo.,2004; Ficca et al.,2010).

Napping is a normal part of human life. There is a wide range of estimates for how often people nap. The percentage of people who nap at least once a week ranged from 36% to 80% across multiple countries in a compilation of surveys (Dinges, 1989). Daytime napping is a frequent habit of many individuals, whether healthy or not, and may occur in a wide variety of contexts. Multiple studies in controlled environments have found that short naps during the day (anywhere from 3-30 minutes) can boost alertness and performance for up to 2-3 hours. (Hayashi et al.,2005; Brooks and Lack.,2006) Daytime naps, with their unique sleep architecture, are ideally suited to provide clues as to the importance of sleep organization (i.e., the presence of uninterrupted NREM-REM cycles) in the consolidation of memories (Backhaus and Junghanns.,2006; Ficca et al.,2010).

Several studies (Bonnet., 1991; Song et al., 2002; Milner and Cote, 2008) have confirmed the usefulness of naps for enhancing awake performance. Napping appears to aid in the formation of both long-term and short-term memories (Ficca et al.,2010; Dutheil et al.,2021). Napping during the day, as reported by Backhaus and Junghanns (2006), enhances procedural motor learning, as measured by effectiveness on a mirror-tracing task. Using a serial reaction time task (SRT) and a circadian protocol, Cajochen et al. (2004) demonstrated the beneficial effects of naps on procedural memory consolidation. In a recent study, Bennion and colleagues (2016) investigated the impact of sleep on performance when multiple salience cues were present. Participants were asked to encode multiple salient future relevant cues (emotion, reward, and instructed learning). A recognition test was conducted following a nap or the same amount of wakefulness. It was discovered that sleep favors top-down, goal-directed cues (instructed learning, and to a lesser extent, reward) over bottom-up, stimulus-driven characteristics (emotion) when multiple dimensions of future relevance co-occur. Additionally, it was found that the effect of a nap on intentionally encoded information was especially strong for neutral (relative to emotional) information, suggesting that once one cue for future relevance is present, there are diminishing returns with additional cues. Sleep may binarize information based on whether it is future-relevant or not, preferentially consolidating memory for the former category. Naps in the afternoon have also been shown to aid in the selective preservation of emotionally salient and relevant aspects of experience for future use. Memory consolidation occurs during both naps and nighttime sleep, but the underlying mechanisms are not always the same (Payne et al., 2015).

## RESEARCH QUESTIONS

In order to better understand the processes involved in successful prospective memory remembering and execution, we have formulated the following research question based on a review of the existing literature on prospective memory, specifically the encoding phase.

1. **Effect of attention at prospective memory encoding on performance.**

***Rationale:*** The present study attempts to examine the role of attention (divided and sustained) at prospective memory encoding on performance. Studies evaluating the role of attention of prospective memory performance generally use retrieval-based paradigm (Brewer et al., 2011; Guynn & McDaniel, 2007). However, a few even tested encoding base manipulation of attention and its effect on prospective memory performance (Einstein et al., 1997; McGann, Ellis, & Milne, 2002). In real-world situations, intention formation frequently occurs in the midst of a number of other, potentially competing tasks. People may not be able to process and encode the intention into memory if they are confronted with multiple stimuli or competing information. As a direct result of this, it is possible that interference could be created and the prospective memory task will not be correctly established in the memory.

The strength of the link between the event cue (the trigger for the intended action) and the action itself may be diminished if encoding is disrupted by interference. This could prevent the potential memory cue from triggering the desired action at the appropriate time. Diverting attention away from intention formation to attend to multiple stimuli may result in an incomplete encoding of the prospective memory intention. Competition for resources could reduce the efficiency with which the intention is encoded and stored.

Interference can also introduce errors in the encoding process, leading to the recall of inaccurate or unrelated information during the prospective memory retrieval attempt. In some cases, interference during encoding may lead to the formation of false memories as disrupted encoding can cause error in source monitoring thus leading to false memories (Mammarella and Fairfield, 2008). Therefore, knowing the processes involved in the encoding of intention while performing other tasks becomes more critical. In the typical setting of a laboratory, the level of attention is preserved. But in order to depict a setting that is closer to real life, we attempted to use interference in the encoding process. We hypothesized that an intervention that uses common cognitive resource requirements at encoding would have an effect on intention formation and that the performance in the interference task would be lower when compared to the performance in the non-interfering task.

2. **The role of cognitive load (in terms of the number of targets) on prospective memory performance.**

***Rationale:*** Our daily routine is full of activities that require remembering to take actions in the future. This ability to form an intention that needs to be carried out in the future is important for survival, considering that failure to perform such actions may have disastrous consequences. We have to juggle a number of delayed intentions at the same time, the majority of which we forget about by the time it is necessary to retrieve them. One of the many factors that affect the successful completion of prospective memory intention is cognitive load. Previous studies have shown that cognitive load affects the performance of PM (Meier & Zimmermann, 2015). Specifically, it has been shown to effect the retrieval of prospective memory cues (Li et al.,2022; Cantarella et al.,2023; McDaniel & Scullin, 2010).

Cognitive load can be manipulated by varying the complexity of the task in which the prospective memory task is embedded, i.e., the ongoing task (Einstein et al., 1997; Kidder et al., 1997; Otani et al., 1997); by manipulating the number of intentions related to the prospective memory action (Meier & Zimmermann, 2015) or by manipulating the number of prospective memory targets linked with the prospective action. In this study, we aimed to test how different levels of cognitive load (low and high) as an encoding variable affect ability to remember prospective intentions.

**3. Role of mixed and event cued remembering in successful completion of prospective memory intention.**

***Rationale:*** Completion of delayed intentions require that one should remember what to do and exactly when (time, event, location, activity etc.) to do. It can be broadly classified as either event-based or time-based (Einstein, & McDaniel, 1990) depending on the nature of the cues. In the event-based scenario, clear environmental cues (events) prompt the recollection of the deferred intention. In time-based situation, intentions are completed at a specific future time with no clear environmental cues. The distinction between the two-retrieval context blurs in real-world scenarios (Loukopoulos, Dismukes, & Barshi,2009; Grondin, 2001), and delayed intentions do not always fit neatly into event-based or time-based categories. There can also be situations, where time and events cues work in combination to elicit intentions. Such kind of prospective remembering is termed as mixed type prospective memory (Block & Zakay, 2006). Contradictory findings have been found in the limited research literature on the effect of mixed cues. Consequently, more studies are needed to comprehend the mechanism entailed in processing both event and time cues in some combination in prospective memory task.

**4. Role of nap on prospective memory performance.**

***Rationale:*** Given the importance of prospective memory in daily life and the dire consequences that can result from its failure, much attention has been paid to determining what factors influence prospective memory, and sleep is one of those factors. Research on whether or not young adults' intentions are consolidated while they sleep has produced contradictory results (Hoedlmoser et al., 2022). According to a meta-analysis (Leong, Cheng, Chee, & Lo, 2019), the positive effect of sleep on prospective memory is statistically significant but small to moderate in size. Most of the studies compared the effects of 7-8 hours of nighttime sleep versus staying awake for the same amount of time (Cunningham, 2021; Diekelmann et al., 2013). It has been shown that naps improve various forms of memory (Sugawara et al., 2018). Research by Dijk et al. (2014) found that napping is especially helpful for processing information that is easy to forget later on.

A nap during the day can be beneficial when it comes to remembering intentions on a day filled with competing plans and goals, so we used prospective memory to determine whether napping aids in memory consolidation. The current study also explores the novel question of how nap prioritizes information when there are multiple cues present in prospective memory.

# CHAPTER 02: GENERAL METHODOLOGY

In this chapter, we will provide a brief overview of the resources that have been utilized throughout the course of this thesis. In addition to this, we present a comprehensive analysis of the procedure that was followed in order to make use of the tool or apparatus for this thesis. The purpose of this section is to reduce the redundancy in terms of repeated mentioning of common stimuli design, procedures in subsequent experiments

## 1. BEHAVIORAL EXPERIMENT

### A. Participants

All of the participants were undergraduate students at the Indian Institute of Technology Guwahati. They volunteered for the experiments in the exchange of partial credit towards a course requirement or equivalent monetary benefit. On an average, the participant's age for all the experiments was 19.27 ± 1.7 years. The range of age varied between 19-22 years. Both males and females were included in the experiments. The inclusion criteria involved average academic performance, normal scores on behavioral questionnaires, young adults, eyesight corrected to normal vision and no known history of any psychological, psychiatric and physical abnormalities in the last six months prior to experimentation. The exclusion criteria were mild to moderate neurological/psychiatric conditions, mild to moderate addictions in any form, low scores on Mini Mental State Examination (MMSE), high scores on Working Memory Questionnaire and The Prospective and Retrospective Memory Questionnaire (PRMQ). All the participants belonged to middle income households.

## B. TASK

### I. Questionnaires and Tools

Questionnaires included a personal data form including questions about age, gender, etc. along with informed consent form, Mini-Mental State Examination (Folstein et al.,1975), Working Memory Questionnaire (Vallat-Azouvi et al.,2012), The Prospective and Retrospective Memory Questionnaire (Smith et al.,2000). All questionnaires were mandatory filled by volunteers in each experiment unless otherwise mentioned. (Please Refer Appendix A, pg. no. 177 )

- ***Mini-Mental State Examination (MMSE):*** The mini-mental state examination (MMSE) is the most commonly used instrument for screening cognitive function. It was developed by Folstein et al. (1975). MMSE consists of eleven items questionnaire that tests five area of cognitive functions (orientation, registration, attention and calculation, recall and language). The maximum achievable score on this test is 30. A score less than 23 indicates cognitive impairment. The administration of the MMSE takes between 5 and 10 minutes and is widely used in clinical and research settings. The Mini-Mental State Examination (MMSE) was administered to a total of 206 patients diagnosed with various conditions including dementia syndromes, affective disorder, affective disorder with cognitive impairment (also known as "pseudodementia"), mania, schizophrenia, and personality disorders. Additionally, the MMSE was also given to 63 normal individuals who did not have any known mental health conditions.

  Validity - The MMSE effectively distinguished between the three diagnostic groups, as well as differentiating them from the normal group. Of a total possible score of 30, the mean score for patients with dementia was 9.7, depression with cognitive impairment 19.0, and uncomplicated affective disorder, depressed 25.1. The mean score for normals was 27.6. Concurrent validity was established by calculating the correlation between MMSE scores and the scores from the Wechsler Adult Intelligence Scale, specifically the Verbal and Performance scores. For Mini-Mental Status vs Verbal IQ, Pearson r was 0.776 ($p < 0.000l$). For Mini-Mental Status vs Performance IQ, Pearson r was 0.660 ($p < 0.00l$). Reliability

Reliability - The Mini-Mental State Examination (MMSE) demonstrates reliability when administered for retesting purposes over a period of 24 hours or 28 days, regardless of whether it is conducted by a single examiner or multiple examiners. When the Mini-Mental Status was given twice, 24 hr. apart by the same tester on both occasions, the correlation by a Pearson coefficient was 0.887. Scores were not significantly different using a Wilcoxon T. Examiner effect on 24 hr. test retest reliability- the MMS was given twice, 24 hr. apart by two examiners. The Pearson r remained high at 0.827. The scores did not change; Wilcoxon T was not significant. Thus, the scores seem stable even when multiple examiners are used, the practice effect is small.

**Use in the current thesis**, the MMSE is used to screen for mild to severe cognitive impairments in subjects. Thus, it is an essential recruitment criterion for participants. We found that the participants had a mean MMSE score of 26 ± 1.3, which was higher than the normal threshold of 23, indicating that they have healthy cognitive functioning. Unless otherwise mentioned, all the volunteers in the experiments scored above average score.

- **The Prospective and Retrospective Memory Questionnaire (PRMQ):** This questionnaire is used to evaluate subjective prospective and retrospective memory skills (PM and RM, respectively) in daily life (Smith, Del Sala, Logie, & Maylor, 2000) . It is a self-report measure and consists of sixteen items in which eight items asks about prospective memory failure and eight about retrospective memory failure in everyday life. Each question was rated on a five-point scale, ranging from 1 (“never”) to 5 (“very often”) resulting to possible minimum score of 16 and maximum score of 80. Higher scores correspond to more memory failures. The PRMQ was administered to a sample of the general adult population (N = 551) ranging in age between 17 and 94. The reliability (internal consistency ) of the PMRQ was estimated using Cronbach’s Alpha. Cronbach’s Alpha was 0.84 (95% CI = .82 to .86) for the Prospective scale.

**Use in the current thesis:** This test served as inclusion criteria for participants with no apparent subjective complaints of prospective and retrospective memory. The total score obtained (35.5±6.7) was in normal range for instances of memory failure.

- ***Working Memory Questionnaire:*** It is a self-administered questionnaire addressing working memory-related difficulties/complaints in everyday life. The questionnaire includes 30 questions, in three different domains of 10 questions each. The three subdomains include short-term storage, attentional and central executive aspects of working memory, such as dual-tasking, mental effort and distractibility. Each question was rated on a five-point Likert-type scale, ranging from 0 (“no problem at all”) to 4 (“very severe problem in everyday life”). Three sub scores are computed, for each of the three domains (maximal score 40 for each), as well as a total score (out of 120). Higher scores correspond to more difficulties/complaints (Vallat-Azouvi et al.,2012). The normative sample consisted of 313 healthy participants recruited among hospital staff, university students, and through local advertisements. The patient group included 69 brain injured patients, who were compared to a subsample of 69 matched healthy controls. The questionnaire was found to have a good internal consistency, both in healthy participants and in patients with brain injury (Cronbach's alpha = .89 and .94, respectively). The WMQ was found to have the sensitivity to discriminate patients from matched controls, in the three domains ($p < .0001$). A good concurrent validity was found with the Cognitive Failure Questionnaire and the Rating Scale of Attentional Behaviour (Spearman's Rho = .90 and .81, respectively, both ps < .0001).

**Use in the current thesis:** The total complaint score obtained (M=20.5± 4.5) was within the normal range of scores depicting normal working memory-related difficulties in everyday life.

- ***E-Prime version 2.0.10.353:*** E-Prime is a presentation software used in behavioral sciences to present the psychological task. In this study, it was used to design and present the prospective memory paradigm in both behavioral and nap experiments. For more specifications, refer to **APPENDIX B (page no. 191 ).**

## II. EXPERIMENTS

In the present thesis, the experiments were designed with a modified version of McDaniel and Einstein's standardized laboratory paradigm. Each participant was tested individually in experimental sessions that lasted approximately for 60 minutes. Paradigms for examining prospective memory can be broadly classified as naturalistic or laboratory-based. McDaniel and Einstein presented a standardized laboratory paradigm in 1990, which went on to have a substantial impact on the expansion of research into prospective memory and is widely regarded as a watershed moment in the field. In order to find the answers to the questions that we posed for this research, we made use of a modified version of the McDaniel and Einstein paradigm was used. Participants in this paradigm are tasked with remembering a prospective memory intention while simultaneously carrying out an ongoing activity. This ongoing action is reminiscent of real-life situations in which a person is occupied with one task while simultaneously, at some point, being required to carry out another intended action.

The well-defined structure of the laboratory paradigm proposed by McDaniel and Einstein consists of the following parts:

**ENCODING**

In the encoding phase, participants are given a prospective memory cue or target and are asked to remember to carry out an action in response to it. Prospective memory cue or target is the stimulus that is supposed to trigger the retrieval of the action in the working memory task presented at retrieval.

**RETRIEVAL**

*Working memory task with embedded prospective memory task*

In the retrieval, participants are given a working memory task (also termed as ongoing task). This working memory task is intended to be mentally taxing on the participants and thus requires their full attention and concentration.

Within working memory task, prospective memory target is embedded. It is presented at a specific point during the working memory task, providing the signal for participants to execute the intended action. The intended action can be as simple as pressing a key or saying a specific word.

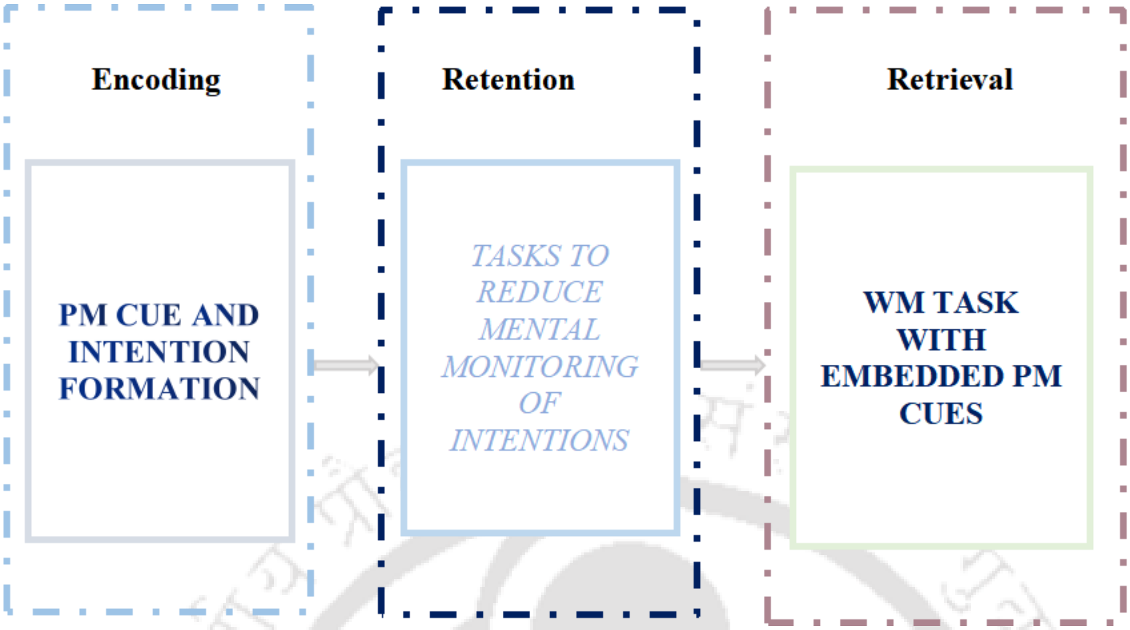



**FIGURE 1**: Laboratory paradigm commonly used to measure prospective memory performance.

**a) STIMULI**

***Experimental stimuli***

As experimental stimulus, English alphabets with the exception of m and z were used. The letters 'm' and 'z'' were designated keys for obtaining responses in the working memory task.

**b) VARIABLES**

**The independent variables were altered in accordance with the requirements of each experiment.**

**Dependent Variables are same throughout all the studies. Prospective memory and ongoing task performance have been measured by statistically analyzing the accuracy and reaction time.**

**Prospective memory performance**

***Accuracy:*** Participants' responses were marked as correct if participants pressed the correct response key (SPACE key) on the prospective memory target in the working memory task.

***Reaction Time:*** Response latencies were measured by averaging the reaction time of the correct responses (i.e., the time required to press the "SPACE" key) on the prospective memory target trials in the working memory task.

**Ongoing task performance**

To analyze the effect of interference caused due to monitoring of prospective memory target at the same time acting on the working memory target, accuracy and reaction time was measured.

***Accuracy:*** Correct response to the ongoing working memory task was measured. Subjects' responses were marked as correct if participants pressed the correct response key (m and z) on the non-target trials in the working memory task.

***Reaction Time:*** Response latency of non-target trials (i.e., the time required to press the 'm' and 'z' keys) in the working memory task was measured. Data was trimmed and the response time of the prospective memory target trials was removed. In order to exclude potential after effects of responding to prospective memory targets and to lessen the likelihood that switch costs would artificially inflate our measurement of ongoing task latencies, six trials following a prospective memory response (Cohen et al., 2008; Meier and Rey-Mermet, 2012; Meier & Zimmermann, 2015) were also excluded. Response latencies of trials in which a working memory (1 back task) decision error was made were also not included in the analysis.

## c) GENERAL PROCEDURE

### i. Pre-Experimentation Procedures

- ***Briefing of subjects***

Participants were called in the laboratory on the day of experiment for briefing on the nature of the experiment. They were asked to fill the consent form and were provided with a condensed overview of the experimental procedure.

- ***Filling of Informed consent form and Questionnaires***

Participants filled out the informed consent, questionnaires such as MMSE, Working memory questionnaire, prospective and retrospective memory questionnaire before the beginning of the experiment. *All the questionnaires have been discussed in the questionnaires section of the General Methodology. PLEASE REFER TO PAGE NUMBER 52.*

- **Introduction to the experiment**:

The participants were initially shown the screen that contained the instructions at the beginning of the experiment. In order to provide a verbal explanation of the procedures that were being carried out, the experimenter was present in the laboratory. After the participants demonstrated a thorough understanding of the instructions, they were given the instructions to begin the assessments.

- ***Practice on Working Memory Task***

First, participants read instructions for the working memory task (*1-back*) task. They were told that they would see alphabets appear one at a time on the middle of the computer screen and that they should compare the present alphabet on the screen with the previous alphabet and press 'z' if they were the same and 'm' if they were different. This phase served as a practice session for the participants, during which they became acquainted with the ongoing working memory task. They competed in a total of forty practice trials. The feedback of both correct and incorrect responses was provided during the practice trials. Before moving on to the next phase of the experiment, the participants had to demonstrate that they had a full understanding of the ongoing working memory task.

### ii. Main Experiment

**In this section, we will cover the standard operating procedure that was used for each and every session of the experiments.** Modifications made specific for particular experiments are mentioned with the specific section of the thesis.

- ***Encoding:***

This session started with seating the volunteer in front of the computer screen with a viewing angle of $2^{0.}$ Stimuli as alphabets appeared in the center of the screen in size 14 Times New Roman font. Participants were required to memorize the presented alphabets on the screen. Alphabets movement to the next screen was controlled by the participants. Once all the alphabets were presented, the subjects were asked to repeat them on paper. They were then given the instructions to press the prospective memory key on encountering the alphabets. After this, the participants repeated the prospective memory instructions on paper.

Prospective memory intention is modified based on the purpose of the experiment; consequently, it is discussed in the particular section of the thesis.

- ***Retention Interval****: DISTRACTION TASK*

Soon after encoding, participants were given a brief series of tasks, including some arithmetic problems, to keep them occupied before the main retrieval task began. Tasks were meant to divert attention away from the conscious effort required to keep track of the future memory intent. After completing the distraction task for the allotted thirty minutes, participants were again given the instructions for the working memory task.

- ***Retrieval****:*

*Ongoing task with embedded prospective memory cues:*

Following the completion of the distraction task, the ongoing/working memory task started. The working memory/ongoing experiment was broken up into five blocks, and each block had twenty trials carried out within it. Each trial refers to one alphabet stimuli. This resulted in a total of one hundred trials being carried out in a full experimental session. The prospective memory cues were presented in four of the five blocks, while the fifth block was a control block with no prospective cue in it. Prospective memory cue appeared once in each block of working memory task positioned at the same number in all the blocks. The task trial started with a fixation cross in the center of the screen for one second followed by an alphabet appearing in the center of the screen for eight seconds. A one-second inter-trial interval separated two successive trials. Subjects had to make a response to either the 1 back working memory task or the prospective memory task. Overall the experiment took 45 minutes to complete. The study ended with participants' feedback on the study.

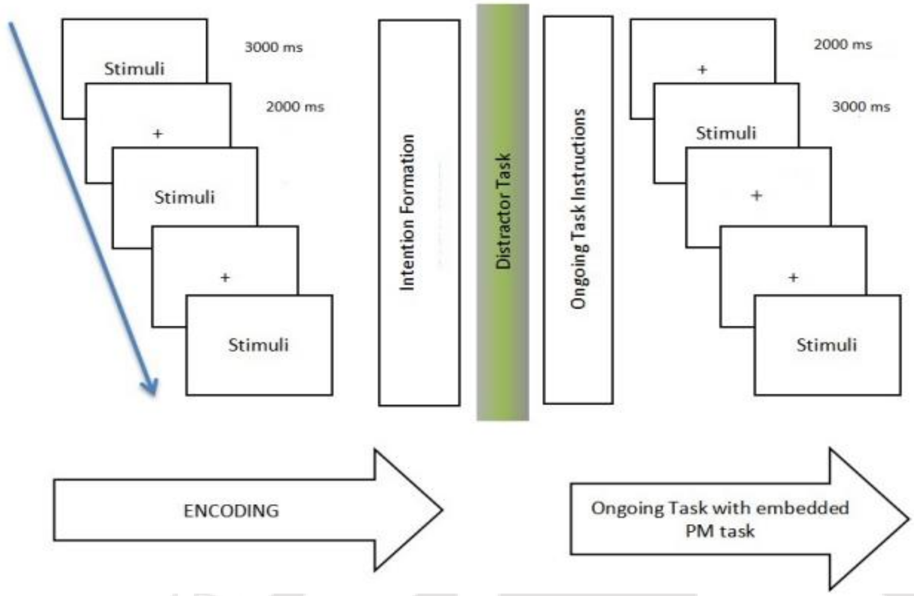



**FIGURE 2 : General Experimental flow followed for all the experiments.**

## 2. Nap Experiments:

During the nap experiment, the sleep architecture of volunteers was monitored by recording their daytime sleep. All of the standards and procedures are nearly identical to those used in the behavioral experiment. Modifications have been thoroughly discussed in the specific section of the thesis.

### A. TASK

**Tools and Questionnaires**

- **Drug Questionnaire**: DAST-20 is used to assess the information about participants' potential involvement with drugs excluding alcohol and tobacco during the past 12 months. The DAST-20 is scored by summing the number of responses that indicate the drug usage problems. Measurement properties of the DAST were initially evaluated using a clinical sample of 256 drug/alcohol abuse clients with 20 items (Skinner, Addictive Behaviors, 1982). The internal consistency reliability estimate was substantial at .92. and a factor analysis of item intercorrelations suggested a unidimensional scale. Concurrent validity was examined by correlating the DAST with background variables, frequency of drug use, and psychopathology. The internal consistency reliability of the 20-item DAST was high (.95 for the total sample

**Use in the present thesis**: the DAST-20 is used to screen participant's involvement with drugs and is an important part of the exclusion criteria. The average self-reported score obtained across participants was less than 5 indicating absence of drug use during the entire experimental procedure among all the participants.

- **Epworth Sleep Scale**: ESS was developed in 1990 by Dr. Murray Johns to assess the daytime sleepiness. This is a self-administered sleep questionnaire. This questionnaire has 8 questions, and respondents are asked to fill each question with 4-point rating scale (0-3), with chances of dozing while they are engaged in 8 different daytime activities. This questionnaire approximately takes 2- 3 minutes to fill. The score ranges can sum up to 24 and are categorized as normal (ESS $< 10$) or positive for daytime sleepiness (ESS $\geq 10$) (Johns,2000). Higher values indicate the excessive daytime sleepiness and lower values indicates normal sleepiness. When 87 healthy medical students were tested and retested 5 months later, their paired ESS scores did not change significantly and were highly correlated ($r = 0.82$). The questionnaire had a high level of internal consistency as measured by Cronbach's alpha (0.88).

**Use in the present thesis**: ESS was used as inclusion criteria component. Average ESS scores obtained by subjects across nap experimental days was 9 ± 2 which indicates normal propensity towards daytime sleepiness.

- **ACTi watch**: This is the device to use to track the daily physiological activity and sleep/wake patterns of participants. This is very small, comfortable, and waterproof wrist watch. This device is scientifically proven to access the daily activity and sleep/wake patterns. Actigraphy data provide estimates of sleep timings. In our study, data were recorded in 30-sec epochs and analyzed using Actiware-software, version 5.0 (Phillips Respironics).

**Use in the present thesis**: ACTi watch was used to measure four sleep parameters of : total sleep time (TST), defined as the number of minutes scored as sleep between lights off and lights on; sleep onset latency (SOL), the number of minutes between lights out and the first epoch scored as sleep; wake after sleep onset (WASO), the number of minutes scored as wake after sleep onset; and sleep efficiency (SE), the ratio between TST and total time spent in bed (TIB; from lights off to lights on).

- **Dreem Headband (DH)**: The DH device is a wireless headband worn during sleep which records, stores, and analyzes physiological data in real time. Following the recording, the DH connects to a mobile device (e.g. smart phone and tablet) via Bluetooth to transfer aggregated metrics to a dedicated mobile application and via Wi-Fi to transfer raw data to the sponsor's servers. Five types of physiological signals are recorded via three types of sensors embedded in the device: (1) brain cortical activity via five EEG dry electrodes yielding seven derivations (FpZ-O1, FpZ-O2, FpZ-F7, F8-F7, F7-O1, F8-O2, FpZ-F8. Data was recorded with 250 Hz sampling with bandpass filter of 0.4–35 Hz. Additionally, sensors of the DH device also measured (2) movements, (3) position (4) breathing frequency via a 3D accelerometer located over the head; and (5) heart rate was measured via a red-infrared pulse oximeter located in the frontal band.

All the **other** questionnaires and tools which were used in nap experiment have been discussed in the **Tools and Questionnaires sub-section of Behavioral experiment section (Please refer to page no. 52).**

**EXPERIMENT**

**Have been thoroughly discussed in** the specific section of the thesis. ***Please refer to page no.114.***

*** Throughout the thesis, we have used the terms multiple and mixed interchangeably for cues.**

*** Throughout the thesis we have used prospective memory intention type and cue type interchangeably.**

# CHAPTER 03: BEHAVIORAL AND NAP EXPERIMENTS

## EXPERIMENT 3.1: ROLE OF CUES ON PROSPECTIVE MEMORY PERFORMANCE INTERNET VERSION

Owing to nationwide lockdown, the administration of the experiment 1 was done using an internet-based version of the prospective memory task. Our aim primarily was to establish the baseline in performance of event and mixed prospective memory tasks.

We tried to find out the role of event cues and mixed cues on the prospective memory performance.

***Calibration and setup of online prospective memory task setup***

### Materials and Procedure

In order to ensure that the online experiment ran smoothly, multiple practice runs with alternate versions of the prospective memory task were carried out. The errors that were found were fixed, and an experimental protocol that was completely free of errors was developed for use in the experiments.

*Outline of workflow for running behavioral experiments online.*

For calibration of our prospective memory task using an online prospective memory task, a variety of steps were followed. Our online experiment relied primarily on two components: a browser-based experiment and a server to host the experiment.

The efficiency of our workflow was dependent on the following two tools:

1. **OpenSesame/OSWeb** is open source software that offers a graphical user interface that is friendly to users and is conducive to the creation of experiments.

2. **JATOS** is server software that is open source and is used for hosting experiments.

**Programming experiment using OpenSesame/ OSWeb**

The Open Sesame (1.4.0.0a5) desktop application was utilized in the programming of our experiment. It is a free, open-source program that works on Windows, Mac OS X, and Linux that lets you create graphical experiments for the social sciences (Mathôt et al., 2012). Experiments in the fields of psychology, neuroscience, and even economics can be designed with the help of this software. The interface is simple and straightforward. OpenSesame's extensive GUI makes it easy to conduct a wide variety of experiments. Users have the option of scripting their experiment for even more customization. The OpenSesame experiments can be run in a browser using an application called OSWeb, which is written in JavaScript. When it comes to conducting lab-based experiments, OSWeb supports a significant portion of the functionality provided by OpenSesame, but not all of it. In our experimental programming, we discovered that while the OSweb supported the vast majority of the desktop application's features, a few were not available during the online run of the experiment. In order to conduct our experiment in an online browser, we incorporated additional OSWeb-compatible JavaScript code (inline_javascript items).

**Hosting the experiment using JATOS**

For the management of our online experiments, we utilized JATOS (Lange et al., 2015), which is a web-server application that is open-source and free. It is utilized in the production of study URLs that can be given to participants, the storage of experimental data, and other similar activities. Users of OpenSesame have the ability to export their experiments to a format that is compatible with JATOS, allowing for immediate importation. In our study, we used a freely available JATOS server named as MindProbe, provided and sponsored by European Society for Cognitive Psychology (ESCoP). Experiment was uploaded to the JATOS server, and participants were given URLs to access the experiment via email. The participants logged into their web browsers in order to access the experiment. They were requested to join Google meet before the commencement of the experiment. The Google meet platform served as a forum for the dissemination of instructions pertaining to the experiment, as well as for the online monitoring of participants. Every participant was given an individual online test that lasted approximately half an hour. Participants were not given any background information on prospective memory before the experiment began, and instead were told that this is just a computer-based memory task. After a sufficient number of participants had completed the experiment, the data were downloaded from JATOS so that they could be analyzed further. For the purpose of our experiment, we sought feedback from participants and attempted to gain an understanding of the issues that participants were encountering while carrying out the experiment online. This allowed us to try to fill in the blanks and ensure that the experiment was carried out without any hiccups or other technical issues.

**Work Flow for Online Experiment**

**Experiment 1**

**Objective**

To study the role of event and mixed cues on prospective memory performance.

**Hypothesis:**

There will be significant difference in prospective memory performance across event cued and mixed cued prospective memory.

## Variables

Independent variable: Prospective memory cues - event and mixed

Dependent variable: Accuracy of correct detection of prospective memory targets

## Design

In the study, a between-subjects design was used. The participants were assigned to either one of the two conditions through a random process.

## METHOD

### Participants

Thirty healthy participants (20 males and 10 females) (age = 18-25; mean ± SD 19.3± 1.3 years) volunteered for the experiment. The volunteers were students from IIT Guwahati who received a portion of their study credit in exchange for their time. Participants gave their consent by signing a form outlining the requirements of the experiment and confirming that their participation was voluntary.

Using a variety of questionnaires, information regarding the participants' demographics was gathered, and a preliminary screening was carried out to identify serious medical conditions or drug dependence. All aspects of the research were conducted in an online environment.

### Materials and Design

The study was programmed using Open Sesame (1.4.0.0a5) software and was run remotely through a web browser. The experiment files were hosted on JATOS (Lange et al., 2015) server.

**Experimental stimuli**

Twenty-three English alphabets (excluding *'j', 'm' and 'n'*) were used as experimental stimuli. The letters *'m'* and *'n'* were excluded because they were the response keys for the working memory task and *'j'* was set as the prospective memory response key. Rest all twenty-three alphabets were randomly used as task stimuli for the ongoing working memory task trials.

*Experimental paradigm*

Modified version of McDaniel and Einstein (1990) paradigm was used to design the prospective memory task that was embedded in the ongoing working memory task.

*Working Memory task*

The working memory task was 1-back task designed after the popular N-back task. The participants were asked to compare the current alphabet on the screen with the previous alphabet and press 'm' if they were the same and 'n' if they were different.

*Prospective Memory task*

The prospective memory task was either a pure event cued task or a mixed cue task. In the former, a specific event cued prospective memory response generation and in the latter task both time and specific event cue evoke prospective memory response generation ('j' key press).

**Procedure**

The entire study was put up online on a JATOS server and participants ran it remotely through their web browsers. Each time a new experimental session began, the participants received an invitation to for a virtual Google Meeting via email. It was utilized to both provide instructions for the execution of the experiment and additionally monitor the online performance of the participants while they were engaged in a task. The participants were informed that the experiment was a computer-based memory task designed to monitor their memory. However, prior to the beginning of the actual experiment, no specific information regarding prospective memory involvement was revealed. Through the use of a virtual meet session, the participants were given an overview of the experimental procedure as well as the flow of the task. In order to determine whether or not the participants had a complete understanding of the experimental task flow, they were asked to verbally reproduce the instruction that had been given to them regarding the performance of the task. They then received an email with a link of the remote experiment. Using the provided link, participants were able to access and run the experiment on their own personal laptop. Around 30 minutes were spent testing each individual. They were given the option to quit the experiment at any point during the task by pressing the escape key on their keyboard.

***Event based prospective memory task***

The experiment for the event-based prospective memory began with a welcome screen that informed participants that the experiment had just begun. Following that, instructions for prospective memory were displayed, and the participants were prompted to read them and commit them to memory. Participants then had to memorize three alphabet cues (target stimuli) that appeared on the screen. Each alphabet was presented for 1.5 second with inter stimuli delay of 1 second between cues. Participants were then given prospective memory instructions to press key *"j"* every time they encountered the target stimuli within the upcoming working memory task. Next, participants were provided with the instructions required to perform the working memory task. They were then made familiar with the working memory task with some practice trials. There was no prospective memory target in the practice trial. Following the practice trial, distraction task was given to minimize mental monitoring of the prospective memory intentions. After the completion of ten-minute distraction task, working memory task instructions were repeated. The instructions were followed by the main experimental trial of the working memory task. Target stimuli appeared once in random order across three blocks of main experimental working memory task.

Task trial started with a fixation cross in the center of the screen for 1000 milliseconds followed by an alphabet appearing in screen center for 1500 milliseconds and disappearing upon response initiation by participants. A 1 second inter-trial interval separated two successive trials. The main experiment consisted of four blocks with 15 trials in each block. Three out of the four block consisted of randomly appearing prospective memory cues and one control block did not have any prospective memory cues. The study ended with participants' feedback on the study. Experimental data was downloaded from the hosting server for further analysis.

***Mixed prospective memory task***

The procedure for the mixed prospective memory task was similar to that of the event cued prospective memory task except the following additional procedure. Participants completed cue learning similar to the earlier task, followed by a distraction task. After the completion of the distraction task, additional information regarding time of the appearance of the PM cues was also given to the participants. They were instructed that the cue, which was encoded earlier, would appear after 1 minute (time) from the start of the working memory task (time-based intention). Time checking behavior was discouraged (by making sure no digital/manual clock was used in between the experiment). After a 5-minute break, participants were given working memory task. Upon completion of the four blocks of working memory task, the subjects were thanked for their participation and were allowed to disconnect. Data was downloaded from the hosting server for analysis.

**Procedure flow:**

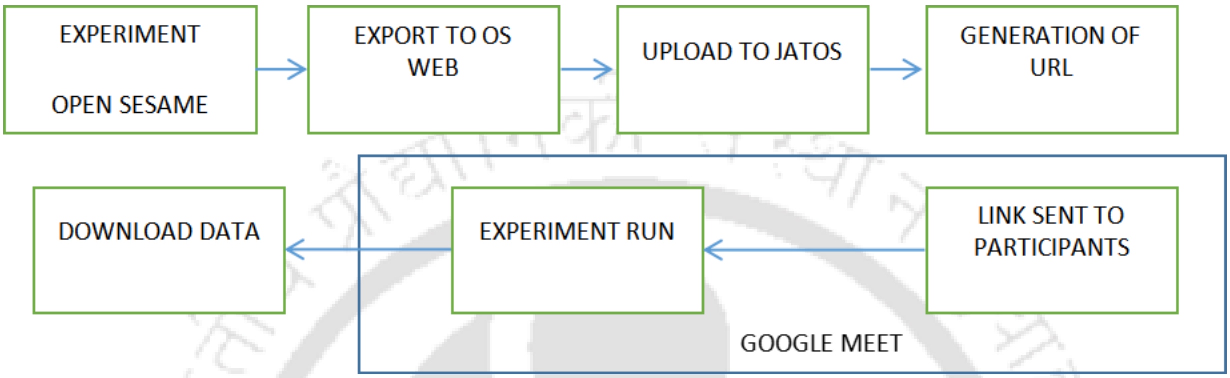



**FIGURE 3.1.1: Procedural flow for the online experiment**

**Results**

**Prospective Memory Performance**

***Accuracy***

Subject's data in terms of total number of correct key presses for the prospective targets for both the event cued and mixed cued tasks were obtained and subjected to statistical analysis. Subject's responses were marked as correct if participants pressed the correct response key on PM target. The results of the analysis, report mean accuracy of target detection for mixed cue sessions (M = .74, SD = 1.2) were higher than for event cued sessions (M = .58, SD = 1.4). This suggests that subjects were more accurate in detecting prospective memory cues on mixed cued PM tasks as compared to event-cued tasks. Independent sample t-test was conducted to test prospective memory performance on event based and mixed prospective memory cue detection scenarios and the test statistic reported was $t_{(28)} = 2.1$, $p < 0.05$. This would suggest that there was significant difference in accuracy of PM cue detection between both the tasks and the mixed cued tasks reported higher accuracy in target detection (M=.74).

***Reaction time***

Additionally, reaction times for target detection on the mixed and event cued tasks were analyzed. The results of the analysis reported very little difference in the performance of subjects in event (M = 0.95, SD = 0.08) and mixed (M= 0.86, SD= 0.10) cued tasks. Independent sample test of mean also reported non-significant difference in the target detection speeds on the mixed and event cued PM task; $t_{(29)} = 0.9$, $p > 0.05$.

We also calculated the reaction time and accuracy data of the ongoing task but results were insignificant.

**Conclusion**

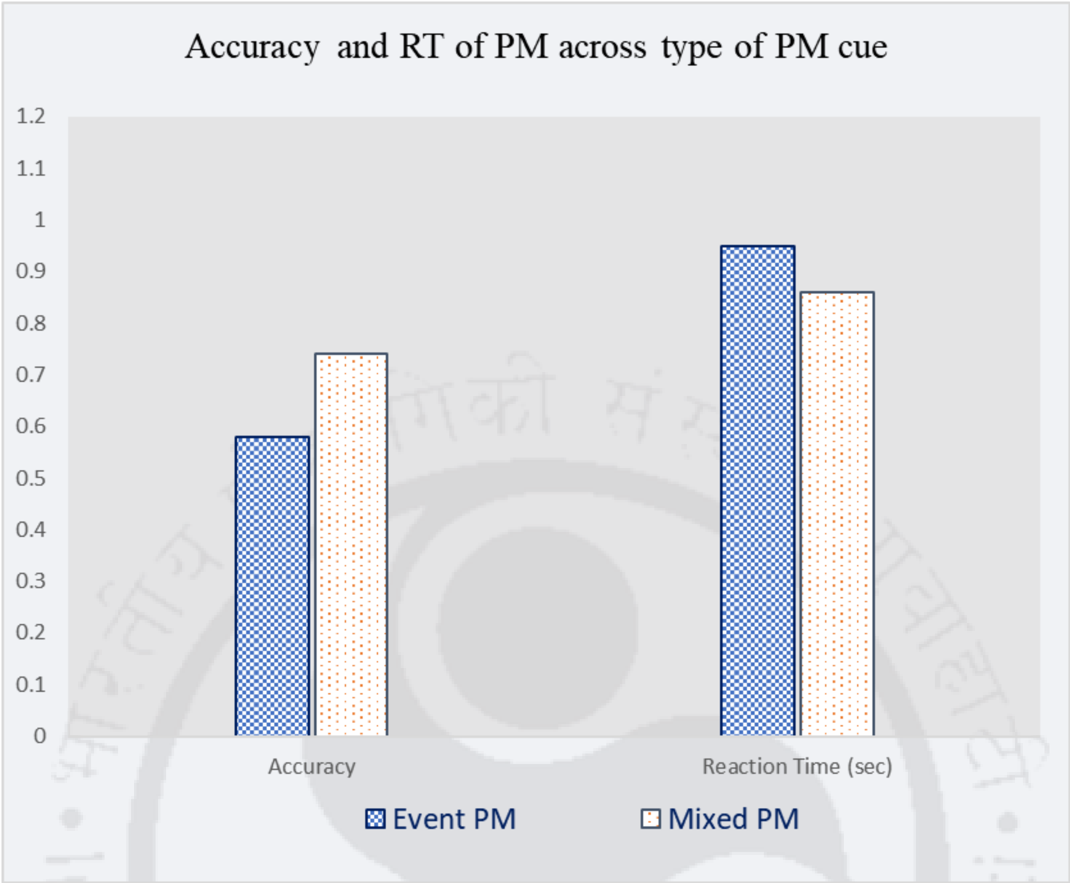
The goal of the present research was to examine the role of mixed and event cued remembering in successful completion of prospective memory intention. In our study, performance on mixed prospective memory task was found to be better and enhanced as compared to event based prospective memory. Accuracy of detecting the correct prospective memory target in the ongoing task was greater in mixed cue memory condition.

**Table 3.1.1:** Accuracy and Reaction Time of Prospective Memory across Cue type (Mean ± SD)

| Dependent Measures / PM Cue | Event cue | Mixed cue |
|---|---|---|
| **Accuracy** | .58 ± 1.4 | .74 ± 1.2 |
| **Reaction Time (sec)** | 0.95 ± 0.08 | 0.86 ± 0.11 |

**Table 3.1.2:** Accuracy and Reaction Time of Ongoing task across Cue type (Mean ± SD)

| Dependent Measures / PM Cue | Event cue | Mixed cue |
|---|---|---|
| **Accuracy** | .98 ± 2.3 | .97 ± 0.2 |
| **Reaction Time (sec)** | 0.89 ± 0.07 | 0.88 ± 0.09 |




**GRAPH 3.1.1**: **Mean Accuracy and Reaction Time of Prospective Memory across PM Cue Type**

## EXPERIMENT 3.2: ATTENTION AND PROSPECTIVE MEMORY

### EFFECT OF ATTENTION ON PROSPECTIVE MEMORY

### The rationale of the research

The present study attempts to examine the role of attention (divided and sustained) at prospective memory encoding on performance. Studies evaluating the role of attention of prospective memory performance generally use retrieval-based paradigm (Brewer et al., 2011; Guynn & McDaniel, 2007). However, a few even tested encoding base manipulation of attention and its effect on prospective memory performance (Einstein et al., 1997; McGann, Ellis, & Milne, 2002).

In real-world situations, intention formation frequently occurs in the midst of a number of other, potentially competing tasks. People may not be able to process and encode the intention into memory if they are confronted with multiple stimuli or competing information. As a direct result of this, it is possible that the prospective memory task will not be correctly established in the memory.

The strength of the link between the event cue (the trigger for the intended action) and the action itself may be diminished if encoding is disrupted by interference caused by divided attention. This could prevent the potential memory cue from triggering the desired action at the appropriate time.

Diverting attention away from intention formation to attend to multiple stimuli may result in an incomplete encoding of the prospective memory intention. Competition for resources could reduce the efficiency with which the intention is encoded and stored.

Interference caused by attention disruption can also introduce errors in the encoding process, leading to the recall of inaccurate or unrelated information during the prospective memory retrieval attempt. In some cases, interference during encoding may lead to the formation of false memories as disrupted encoding can cause error in source monitoring thus leading to false memories (Mammarella & Fairfield, 2008). Therefore, knowing the processes involved in the encoding of intention while performing other tasks becomes more critical. In the typical setting of a laboratory, the level of attention is preserved. But in order to depict a setting that is closer to real life, we attempted to use interference in the encoding process. We hypothesized that an intervention that uses common cognitive resource requirements at encoding would have an effect on intention formation and that the performance in the interference task would be lower when compared to the performance in the non-interfering task.

**Objective**

To assess the role of attention at cue encoding on prospective memory performance.

**Hypothesis**

H1: Varying attention at encoding will lead to performance variation on Prospective Memory task

**Rationale:** Executive processes are involved in the encoding and initial planning or intention formation. Additional attentional capacity consumption at the encoding will interfere with the elaborative encoding and eventually affect prospective memory performance. Performance on the divided attention (DA) task will be decreased as compared to the sustained attention task. Encoding is a strategic process requiring working memory capacity and attention lapse at the time of encoding can negatively affect prospective memory performance.

**Independent variable (IV):** Levels of attention (sustained, divided)

**Dependent Variable (DV):** Discussed in the Variables subsection of **General Methodology** section**. Please refer to page number 56.**

A within subject design with sustained and divided attention as IV levels and prospective memory performance as DV was employed.

**METHODOLOGY**

**Participants**

Fifty healthy participants volunteered for the experiment. All other details have been thoroughly mentioned in the General Methodology section. **Please refer to page number 51.**

**Procedure**

**Please refer to Sub Section (i) of General Procedure section (page no. 57 ).**

**ENCODING**

*Cue learning under varied attention task*

As part of the experiment's condition involving the **divided attention task**, they were presented with four distinct alphabets enclosed in geometric shapes. They were also given the directive to concentrate on the alphabet and the figures, as well as to memorize this information in preparation for later application. In contrast, the condition that required **sustained attention** consisted solely of the presentation of alphabets without any geometric figures. Each cue was shown for a duration of 1.5 seconds, and there was an inter-stimulus delay of 1 second between each cue.

***Prospective memory instructions***

Upon the target presentation, participants were instructed about the intention. Prospective memory intention was to press a specific 'SPACE' key whenever they encountered earlier presented alphabets in any form during the subsequent working memory task. They were to press the ‘SPACE’ key instead of making their ongoing task response.

We were also interested in knowing about mental processes and strategies that participants used during the process of forming an intention. After the instructions had been presented to the participants, self-report open end question was given to them in order to investigate the thoughts that crossed their minds while forming the intention. The participants were given the task of writing freely about what was going through their minds while encoding intention. Following that, they were given the task of rewriting the instructions given for the intention. In each of the conditions, the experiment continued only when the participants showed an absolutely perfect recall of the intention.

***Distraction Task:*** Please refer to **GENERAL PROCEDURE** section **(PAGE NUMBER 59).**

***Ongoing task with embedded PM cues:*** Please refer to **GENERAL PROCEDURE** section **(PAGE NUMBER 60).**

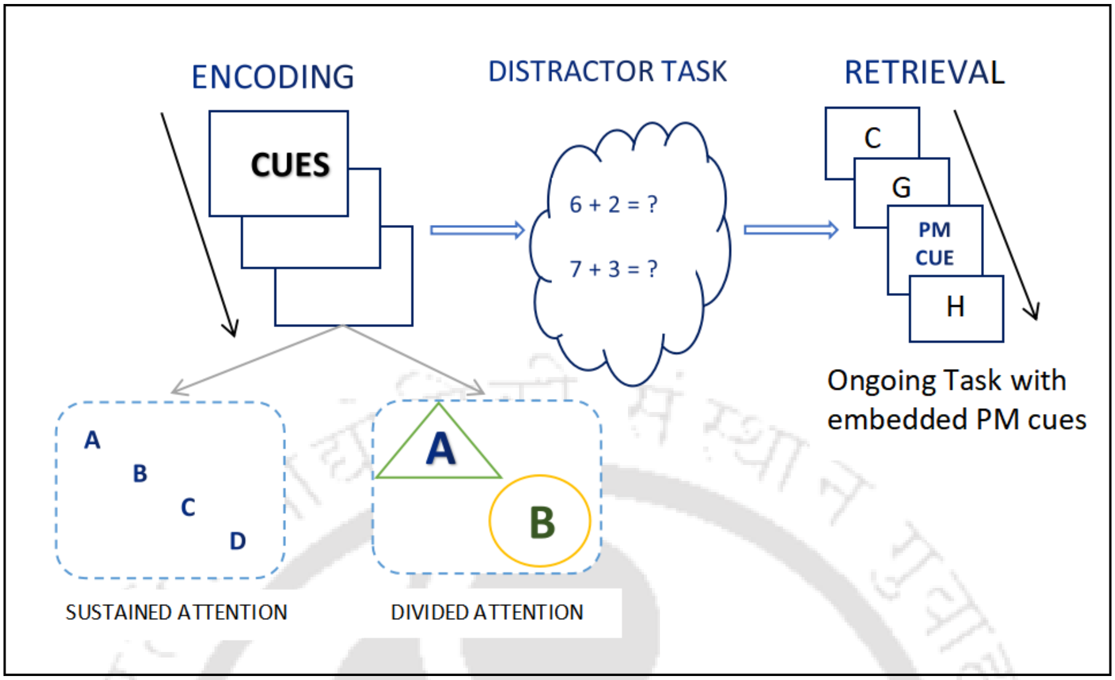



**Figure 3.2.1: Experimental Flow for the Attention Task**

## Data Analysis and Results

### Prospective memory performance

*Accuracy*

To measure the effect of attention (sustained and divided) on prospective memory, the accuracy of response on prospective memory target trials were obtained and statistically analyzed. Subject's responses were marked as correct if participants pressed the correct response key (SPACE) for the prospective memory target. A paired sample t-test was used as a statistical tool to analyze the data. The results from the sustained (M =0.86) and divided (M =0.82) attention tasks indicate that prospective memory was not significantly affected by our manipulation of attention, $t_{(49)} = 1.1$, $p > 0.05$.

*Reaction Time*

Response latencies were measured by averaging the reaction time of the correct responses on the prospective memory target trials. Results revealed a significant overall effect of the attention condition, $t_{(49)} = 8.2$, $p < 0.05$. Prospective memory targets elicited a faster response (seconds) in sustained attention (M = 0.86) condition as compared to the divided attention (M = 1.5) condition. Presumably, this difference reflects that longer reaction time resulted from more extensive item checking in the divided condition.

**Ongoing Task**

***Accuracy***

To assess the impact of interference resulting from monitoring prospective memory cues and performing a working memory task, we sought to determine the accuracy, specifically the ability to correctly respond to working memory task trials. A paired sample t-test was applied and we did not find any significant differences. The results from the sustained (M = 0.83) and divided (M =0.85) attention tasks indicate that prospective memory was not significantly affected by our manipulation of attention, $t_{(49)} = .26$, $p > 0.05$. Accuracy on the non-target trials did not differ as a function of attention condition.

***Reaction Time***

To calculate the response latency of non-target trials in the working memory task, we trimmed the data and removed the response time of the prospective memory target trials. Response latencies of trials in which a working memory (1 back task) decision error was made were also not included in the analysis. The results from the sustained (M =1.1) and divided (M =1.3) attention tasks indicate that prospective memory was not significantly affected by our manipulation of attention,

$t_{(49)}$ =.33, $p > 0.05$. Latencies on working memory task performance did not differ as a function of attention condition.

The data is summarized in **Tables 3.2.1 and 3.2.2.**

**Conclusion and Discussion**

Through our study we tried to find out whether having an interfering task at encoding would affect the prospective memory performance. Among many reasons of error in memory, one reason for the difficulty in correctly identifying an intended cue is poor encoding (Hannon and Daneman, 2007). According to the findings of Holbrook and Dismukes (2009), people frequently fail to adequately encode conditions for carrying out deferred intentions, which is one factor that contributes to the failure of PM.

Prospective memory encoding in real life predominantly involves intentions formed while engaged in other concurrent activities. Prospective memory encoding may be chaotic and may happen to be along with another interfering task. This kind of encoding situation may require multitasking. Encoding processes are consciously controlled and attention-demanding, and therefore division of attention due to interfering task may be associated with a reduction in memory performance. In most of the laboratory experiments, intention is formed in the absence of any additional task. Through our study, we tried mimicking real-life situation where more than one task could be present while encoding intentions.

Previous studies which tried to investigate the role of attention in encoding found that memory performance dropped substantially if encoding was accompanied by any other concurrent task

(Craik et al., 1996). Free recall, paired-associate learning, and recognition studies all led to the same conclusions.

To investigative the impact of increased encoding demands on prospective memory performance, only few experiments have been conducted. The results obtained from those studies observed decreased performance with increased demand in encoding in both younger and older population. A demanding background activity disrupts encoding of the intended activity and its associated signaling event, as well as any planning involved in preparing strategies for performing the intended activity in the future context (Einstein & Smith,1997).

Nonetheless, we did not find any significant role of attention in prospective memory remembering, which runs counter to the results obtained from them. There could be many possible reasons for such results. **First** reason could be that attentional selection is sensitive to the nature of task demands. Interfering conditions may have placed some small demands on executive resources, but those demands were not high enough to adversely affect encoding. More likely (Baddeley and Hitch, 1974), the interference task condition may have placed some modest demands on executive resources, but these demands were insufficient to impair the encoding of intention. The demanding background condition at encoding in the Einstein and Smith (1997) experiment was a digit monitoring task. Participants were required to monitor a continuously presented series of digits during a time interval that included presentation of the prospective memory target word in yellow (the encoding presentation). Both the task could have shared limited attentional resources leading to decreased attention in encoding prospective memory target. When looking at the various types of divided attention that have been reported in previous studies, we can deduce that the tasks' varying demands on working memory are responsible for the contradictory findings.

**Second,** our interfering task was to pay attention to the geometrical shapes and the alphabets in the encoding phase. Most of the evidence supports the idea that visuospatial attention and central attention are distinct forms of attention. Consolidation of a visuospatial array can occur undeterred while central attention is engaged (Blake & Fox, 1969; Pashler, 1991; Posner & Boies, 1971; Comstock, 1973). Visuospatial and central attention operate at separate temporal stages, a conclusion that dovetails with the supposition that the two types of attention can be allocated to distinct events. In a study by Marsh and Hicks, 1998, concurrent visuospatial task did not interfere with reading and retaining the words that were presented. The performance on the short-term recall was also not effected. These results show that low visuospatial load on the central executive do not interfere very much with prospective memory.

**Third,** prospective memory performance outside the laboratory depends on metaknowledge (Dobbs & Reeves, 1996). That is, people know how good or poor their memories are, what their level of motivation is, and what the completion of an intention requires. As a consequence, people take steps to adopt strategies that will compensate for their own shortcomings. By analyzing the thought probes, we found that in the majority of on-task thinking, participants made mnemonics in the interfering task condition. Literally speaking, all mnemonic devices can be interpreted as "aids to memory. They could be conceptualized internally. They can be used to bring to mind either an intention or a fact, such as the need to call someone or the person's phone number (Morris, 1978, p. 160).

The **fourth** possibility is that of cognitive control. Cognitive control allows memories to be encoded and retrieved strategically, in line with current goals. An adaptive memory system benefits from the capability to process and store only the information that is actually useful. Humans may employ a variety of strategies, such as flexible allocation of cognitive resources and cognitive control mechanisms, in order to adapt to PM demands in complex environments (Boag et al., 2019). The processes of cognitive control not only help a person retrieve goal-relevant information in the present, but they also actively weaken memories that are undesirable, irrelevant, or interfere with the retrieval of goal-relevant information. In our study, it is possible that because the questions relating to geometric shapes were not asked in the retrieval phase, participants were able to suppress the irrelevant memory of shapes and were able to perform the prospective memory task. In many studies, it has been shown that the prospective memory task can be completed without interfering with performance on the ongoing task if the participant exercises sufficient cognitive control over both the ongoing task and PM processes. According to resource theory, tasks that share the same resources are unlikely to conflict with one another unless that demand exceeds the cognitive system's capacity limit (Navon & Gopher, 1979; Norman & Bobrow, 1976). This makes sense given that the mean reaction time to respond to non-target trials in the ongoing task did not differ significantly between the divided attention condition and the sustained attention condition indicating that the participants were able to perform the prospective memory task without specifically interfering with the working memory task.

We did not find any cost to ongoing task in the divided attention task. Our findings are in line with Einstein et al.’s (2005) multiprocess framework and reflect that in certain circumstances, an intention can be realized automatically with no negative impact on ongoing task performance. The lack of costs in the divided attention condition suggests that participants were able to juggle ongoing and prospective memory task requirements. One plausible explanation is that participants used an encoding strategy when they received the instructions.

We also found that the response latencies of the prospective memory target are higher in divided attention condition as compared to sustained attention condition. Successfully performing an event-based intention requires cognitive processes involved in noticing the cue, retrieving the intention, and coordinating its execution with the ongoing activity (Marsh et al.,2002).

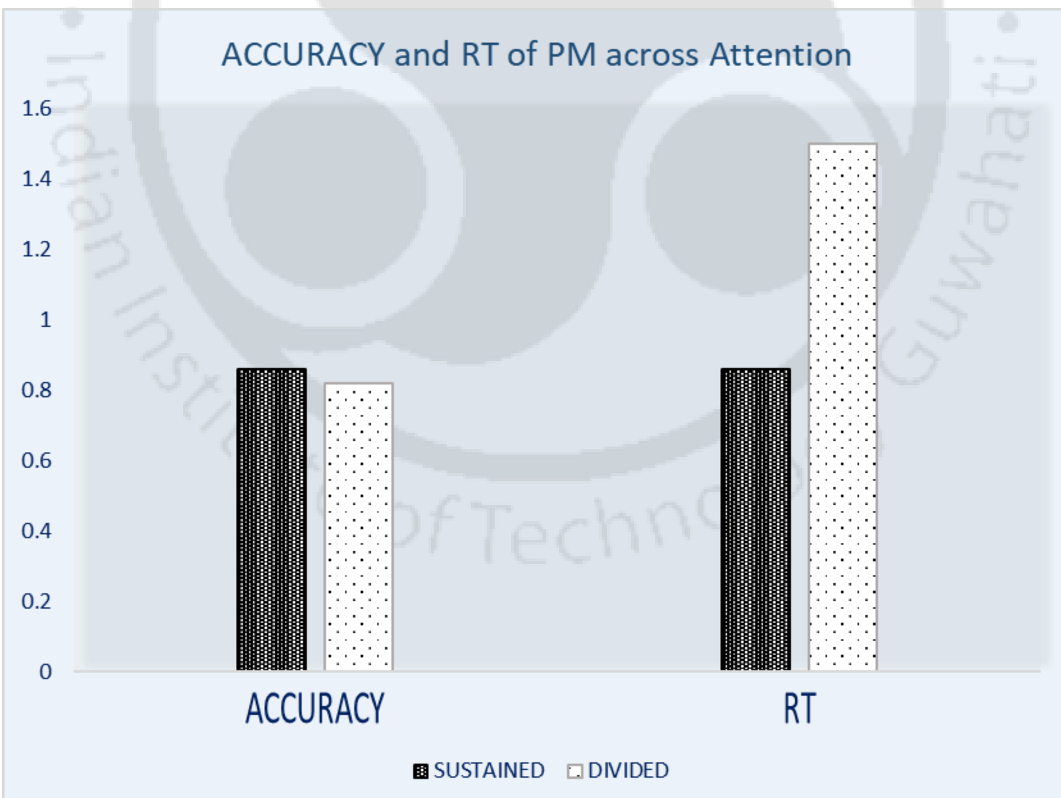
We draw the conclusion that the slowing effect in the divided attention task may have been caused because participants spent more time in the microprocess of detecting, retrieving, deciding, and coordinating prospective memory responses with the task demands of the ongoing task. This assumption is based on the fact that we presume that these activities required some amount of time when the alphabets were encoded with geometrical shapes.

**Table 3.2.1:** Accuracy and Reaction Time of Prospective Memory across Attention (Mean ± SD)

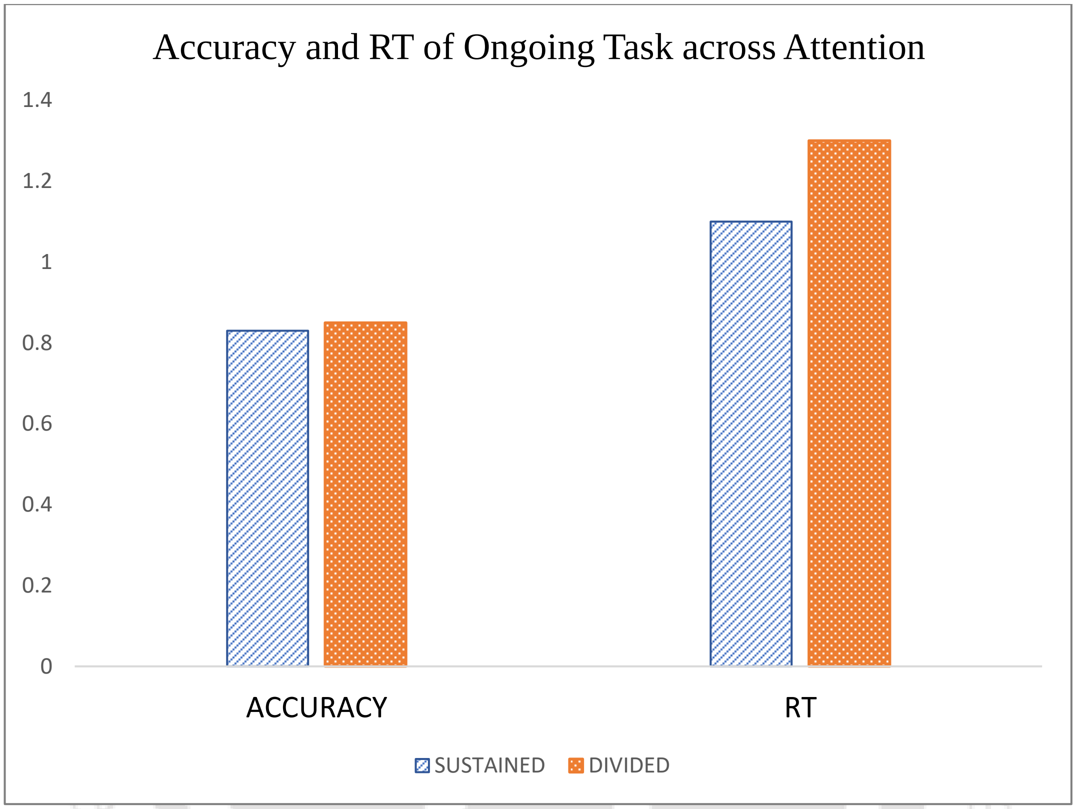
| | **Attention Levels** | |
|---|---|---|
| **Dependent Measures** | **Sustained** | **Divided** |
| **Accuracy** | .86 ± 1.5 | .82 ± 1.2 |
| **Reaction Time (sec)** | 0.86±1.3 | 1.5±1.6 |

**Table 3.2.2:** Accuracy and Reaction Time of Ongoing task across Attention (Mean ± SD)

| | Attention | |
|---|---|---|
| **Dependent Measures** | **Sustained** | **Divided** |
| **Accuracy** | 0.83±1.2 | 0.85±1.4 |
| **Reaction Time (sec)** | 1.1± 0.6 | 1.3 ± 0.9 |




**Graph 3.2.1: Accuracy and Reaction Time of Prospective Memory across Attention**




**Graph 3.2.2: Accuracy and Reaction Time of Ongoing Task across Attention**

## EXPERIMENT 3.3: EFFECT OF COGNTIVE LOAD ON PROSPECTIVE MEMORY

Our daily routine is full of activities that require remembering to take actions in the future. This ability to form an intention that needs to be carried out in the future is important for survival, considering that failure to perform such actions may have disastrous consequences. We have to juggle a number of delayed intentions at the same time, the majority of which we forget about by the time it is necessary to retrieve them. One of the many factors that affect the successful completion of prospective memory intention is cognitive load. Previous studies have shown that cognitive load affects the performance of PM (Meier & Zimmermann, 2015). Specifically, it has been shown to effect the retrieval of prospective memory cues (Li et al.,2022; Cantarella et al.,2023; McDaniel & Scullin, 2010).

Cognitive load can be manipulated by varying the complexity of the task in which the prospective memory task is embedded, i.e., the ongoing task (Einstein et al., 1997; Kidder et al., 1997; Otani et al., 1997); by manipulating the number of intentions related to the prospective memory action (Meier & Zimmermann, 2015) or by manipulating the number of prospective memory targets linked with the prospective action. In this study, we aimed to test how different levels of cognitive load (low and high) as an encoding variable affect ability to remember prospective intentions.

**Objective**

To assess the role of cognitive load (in terms of the number of targets) on prospective memory performance.

## Hypothesis

H1: Prospective memory accuracy will be greater in the low cognitive load as compared to high cognitive load.

Rationale: By manipulating the cognitive load, we are trying to manipulate the number of target cues to respond. Only a handful of studies have manipulated the cognitive load by changing the number of prospective memory targets, thus giving contradictory results. We hypothesize that manipulating number of to be remembered items of prospective memory target list will effect prospective memory performance. In line with list-length effects in retrospective memory (Strong, 1912), we expect more (high) prospective memory target to affect the probability of cue detection in ongoing task detrimentally.

## VARIABLES

**Independent variable (IV):** Cognitive load (high and low)

**Dependent variable (DV):** Discussed in the Variables subsection of General Methodology section. **PLEASE REFER TO PAGE NUMBER 56.**

A within subject design with cognitive load (low and high) as IV and prospective memory performance as DV was employed.

## METHODOLOGY

### Participants

Fifty healthy participants volunteered for the memory experiment. All other details have been thoroughly mentioned in the General Methodology section. **Please refer to page number 51.**

## Procedure

**Please refer to Sub Section (i) of General Procedure section (page no. 59 ).**

### *Encoding of cues*

Four different alphabets (**e.g.** *a,c,h,j* ) were presented on the screen as the target stimuli and instructions for prospective memory intention was given. Each cue was shown for a duration of 1.5 seconds, and there was an inter-stimulus delay of 1 second between each cue.

*Prospective memory intention: Intentions for low load and high load were different.*

**Low Load**

*While performing the working memory task, we have an additional interest in your ability to remember to perform an action in the future. In the upcoming working memory task, whenever you encounter [one particular alphabet;* ***e.g. c****], remember to press the 'SPACE' key instead of making any other response.*

**High Load**

*While performing the working memory task, we have an additional interest in your ability to remember to perform an action in the future. In the upcoming working memory task, whenever you encounter any of the four targets presented earlier, you will have to remember to press the 'SPACE' key instead of making any other response.*

Following the intention formation, participants were tasked with rewriting the intention's corresponding instructions. In each scenario, the experiment continued only if the participant demonstrated perfect recall of the intention.

***Distraction Task:*** Please refer to **GENERAL PROCEDURE** section **(PAGE NUMBER 59).**

***Ongoing task with embedded PM cues:*** **Please refer to GENERAL PROCEDURE section (PAGE NUMBER 60).**

## Results

### Prospective memory performance

To measure the effect of load (low and high) on successful prospective memory completion, the accuracy and response latencies on target trials were obtained and statistically analyzed.

#### *Accuracy*

Subjects' responses were marked as success if participants pressed the correct response key (SPACE key) on the prospective memory target within the working memory task. An analysis was performed using a paired sample t-test to examine the data. A statistically significant difference in the accuracy scores was observed; $t_{(49)} = 2.1$, $p < 0.05$. This indicates that there was significant difference in accuracy of PM cue detection between both the load condition. The mean accuracy of target detection was greater under low load (M =.87) than under high load (M =.71). The results suggest that subjects were more accurate in detecting prospective memory cues in low load condition as compared to high load condition.

***Reaction Time***

We were interested in analyzing prospective memory reaction time (i.e., the time required to press the "SPACE" key). Response latencies were measured by averaging the reaction time of the correct responses on the prospective memory target trials. Results revealed a significant overall effect of the load condition, $t_{(49)} = 15.4$, $p < 0.05$. Prospective memory targets elicited a faster response (seconds) in low load (M = 0.96) condition as compared to the high load (M = 1.8) condition. Presumably, this difference reflects that longer reaction time resulted from more extensive item checking in the high load condition.

**Ongoing task performance**

***Accuracy***

To analyze the effect of interference caused due to carrying prospective memory target at the same time acting on the working memory target, we tried to find out the accuracy i.e. correct response to the ongoing working memory task. A paired sample t-test was applied and we did not find any significant differences. The results from the low load (M =0.89) and high load (M =0.87) tasks indicate that accuracy of ongoing task was not significantly affected by our manipulation of load, $t_{(49)} =.26$, $p > 0.05$. Accuracy on the non-target trials did not differ as a function of cognitive load condition.

***Reaction Time***

To calculate the response latency of non-target trials in the working memory task, we trimmed the data and removed the response time of the prospective memory target trials. In order to exclude potential after effects of responding to prospective memory targets and to lessen the likelihood that switch costs would artificially inflate our measurement of ongoing task latencies, we also excluded six trials following a prospective memory response (Cohen et al., 2008; Meier and Rey-Mermet, 2012; Meier & Zimmermann, 2015). Response latencies of trials in which a working memory (1 back task) decision error was made were also not included in the analysis. A paired sample t-test revealed significant difference between both low and high load conditions, $t_{(49)} = 18.9$; $p < 0.05$. Analysis indicated that that the mean reaction time (in seconds) were significantly slower in the high load condition (M = 1.7) than in the low load condition (M = 1.01) showing that participants took more time to react in high load condition as compared to low load condition in the working memory task. It indicates that holding more number of prospective memory targets contributes to higher cost to ongoing task.

The data is summarized in **Tables 3.3.1 and 3.3.2.**

**Conclusion and Discussion**

We tried to study the effect of cognitive load on prospective memory performance by manipulating the number of cue intention, subject needed to encode. Two levels of manipulations were high and low load. Participants had to react to only one specific target (alphabet in our case) in the low cognitive load encoding condition. In the high cognitive load encoding conditions, they had to respond to all the four targets embedded in the working memory task. We found the main effect of cognitive load indicating that prospective memory performance was influenced by the load manipulation. When compared to the high cognitive load encoding, the low cognitive load condition yielded more accurate responses on prospective memory targets. Prospective memory performance varied as a function of the number of targets and is in line with previous research (Einstein et al., 2005; Cohen, 2013; Wiesslein et al., 2014). For instance, Cohen et al., 2013 increased the target cue from one to six words in the lexical decision task. They observed decreased prospective memory performance as the number of prospective targets increased. Cognitive load reduces individuals' likelihood of attending or successfully recognizing a target during the task. It was only in this study that significant differences were found. Otherwise, only marginal and non-significant results were obtained in all the other studies (Meier & Zimmermann, 2015; Liu & Hou, 2020) conducted to find the effect of the target list on prospective memory performance.

Large-scale studies have also calculated reaction time (RT) performance on an ongoing task trial to demonstrate how the presence of an embedded prospective memory intention affects ongoing task performance. It has been discovered that slower reaction latencies on the ongoing task trials with embedded intention depict the limits of cognitive capacities that are shared by two processes. In some situations, prospective memory is supported by capacity-demanding monitoring of the environment for targets that trigger an associated intention. This results in decreased performance on ongoing tasks and a slower reaction time.

To examine the interference effect of the prospective memory targets on the ongoing working memory task and know how number of prospective memory targets contributes to ongoing task costs, we calculated the response latencies on non-target trials in ongoing task. Increased reaction time in ongoing task was found in high load condition (1.7 seconds) and linked to decreased performance as compared to low-load condition (1.01 seconds). Past research has shown that increasing the number (list length) of words to which participants are required to make a prospective memory response increases costs to ongoing tasks. The cost or effect of holding intention however does not affect prospective memory error (Cohen, Jaudas, & Gollwitzer, 2008; Einstein et al., 2005; Marsh, Hicks, Cook, Hanson, & Pallos, 2003). A high cognitive load requires more monitoring processes during retrieval, increasing the working memory task cost. The larger the number of prospective memory cues, the more they start interfering in ongoing task performance. We did also find monitoring cost differences in the ongoing task as a function of load. Slower RTs for the high load condition indicated that participants had to engage cognitive resources to maintain prospective intentions, while at the same time executing the ongoing task (Matos et al., 2020). It is plausible that increasing the number of prospective intentions could have determined a shift from an automatic process to a more consuming monitoring process. participants' strategies appear to have differed according to the cognitive requirements of the prospective memory task (Einstein et al., 2005; Barban et al., 2014; Cantarella et al., 2023). A handful of studies came to the same conclusion regarding the cost. Under high-load conditions, more resources need to be allocated to strategically monitor the occurrence of the PM targets (Einstein et al., 1992; 2005). This is in line with research suggesting that monitoring PM targets and carrying out the ongoing task share some of the same cognitive resources (Cantarella et al., 2023).

In low load condition which also resembles as only one target condition in our study, participants might have employed strategies such as an if–then statement (e.g., "If I see 'X,' then I will press Y"), which freed up processing resources and resulted in lower costs to ongoing task performance (Gollwitzer & Sheeran, 2006). As the number of prospective memory targets increased, such an if–then plan no longer worked, and some other strategy had to be employed which have caused in increasing reaction time to react. There was no difference in the accuracy of the ongoing task which clearly shows that more cues placed a larger burden on cognitive resources (Cohen et al., 2008).

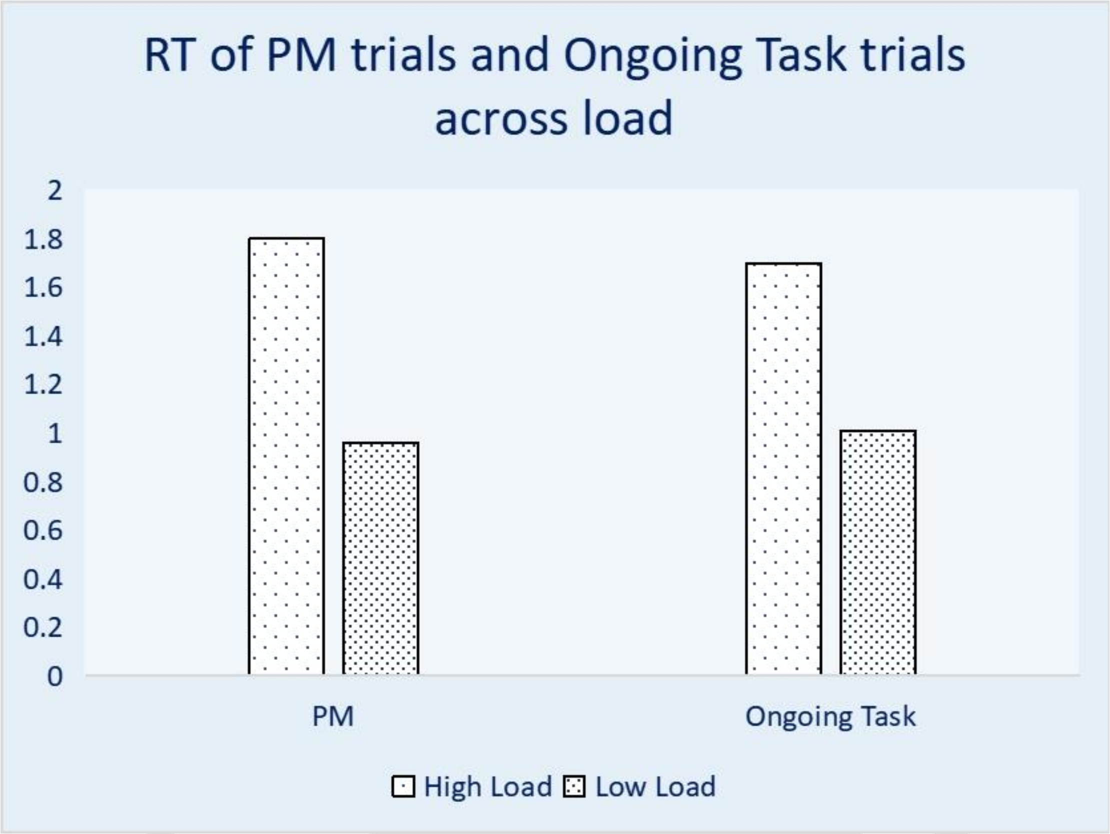
The slowed latencies in the ongoing task did not necessarily preserve prospective memory performance and did not necessarily affect both prospective memory tasks in the same way. This outcome highlights that task interference does not always functionally contribute to fulfilling an intention (Marsh et al.,2003; Cohen et al.,2008).

**Table 3.3.1:** Accuracy and Reaction Time of Prospective Memory across Load (Mean ± SD)

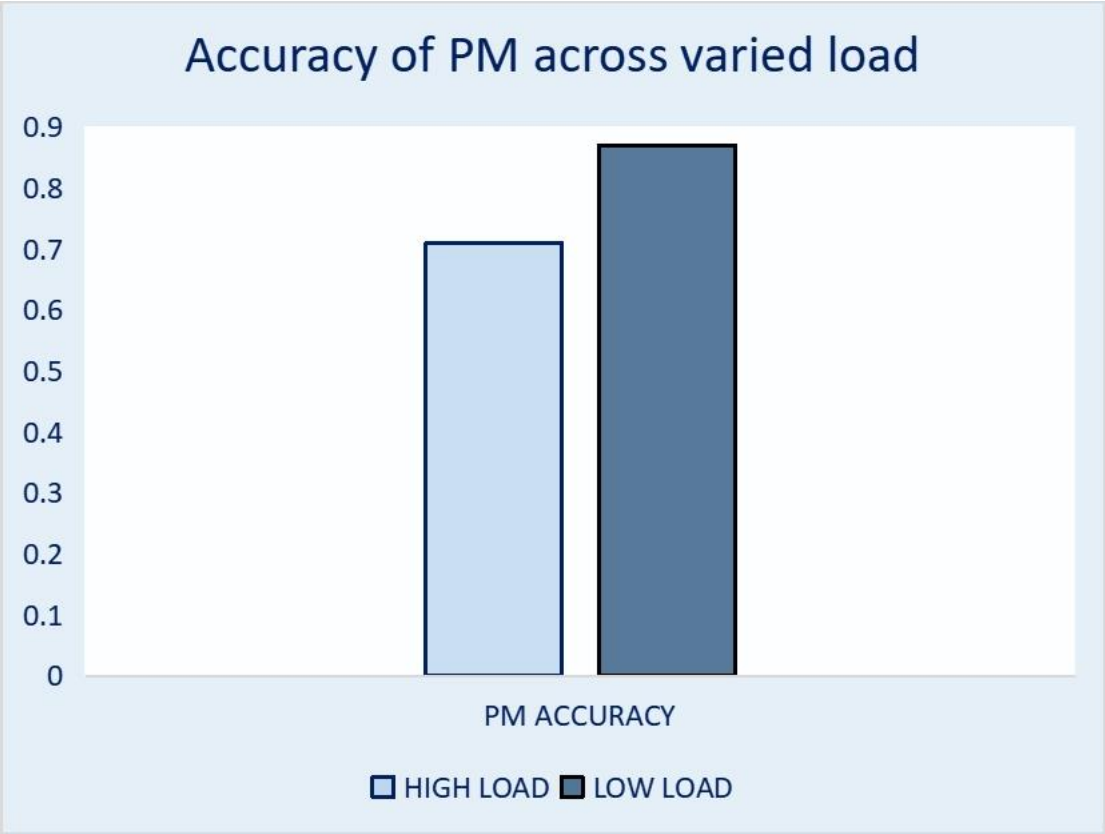
| | Load Types | |
|---|---|---|
| **Dependent Measures** | **High** | **Low** |
| **Accuracy** | .71 ± .30 | .87 ± .25 |
| **Reaction Time (sec)** | 1.8 ± 1.5 | 0.96 ± 1.2 |

**Table 3.3.2:** Accuracy and Reaction Time of Ongoing task across Load (Mean ± SD)

| | Load Types | |
|---|---|---|
| **Dependent Measures** | **High** | **Low** |
| **Accuracy** | 0.87 ± 1.2 | 0.89 ± 1.9 |
| **Reaction Time (sec)** | 1.7 ± 0.65 | 1.01 ± 0.71 |




**Graph 3.3.1: Reaction time of prospective memory trials and ongoing task trials across load**




**Graph 3.3.2: Accuracy of prospective memory across load**

## EXPERIMENT 3.4: Role of prospective memory cues in prospective memory performance

**Objective**: To examine the role of mixed and event cued remembering in successful completion of prospective memory intention

Rationale: Completion of delayed intentions require that one should remember what to do and exactly when (time, event, location, activity etc.) to do. It can be broadly classified as either event-based or time-based (Einstein & McDaniel, 1990) depending on the nature of the cues. In the event-based scenario, clear environmental cues (events) prompt the recollection of the deferred intention. In time-based situation, intentions are completed at a specific future time with no clear environmental cues. The distinction between the two-retrieval context blurs in real-world scenarios (Loukopoulos, Dismukes, & Barshi,2009; Grondin, 2001), and delayed intentions do not always fit neatly into event-based or time-based categories. There can also be situations, where time and events cues work in combination to elicit intentions. Such kind of prospective remembering is termed as mixed type prospective memory (Block & Zakay, 2006). Contradictory findings have been found in the limited research literature on the effect of mixed cues. Consequently, more studies are needed to comprehend the mechanism entailed in processing both event and time cues in some combination in prospective memory task.

**Hypothesis:**

There will be significant difference in prospective memory performance across event cued and mixed cued prospective memory.

**Variables**

Independent variable: Types of prospective memory (Event and Mixed)

Dependent variable: Discussed in the **Variables** subsection of **General Methodology** section **(Please refer to page no. 56 ).**

In this study, a between-subjects design was used. Participants were randomly assigned to two groups [(mixed and event] (N = 20 in each group)].

**METHODOLOGY**

Participants

40 healthy participants volunteered for the memory experiment. All other details have been thoroughly mentioned in the **General Methodology** section. **Please refer to page number 51.**

**Procedure**

A brief overview of the procedures that would be carried out during the experiment were provided to the participants in the form of pre-experiment instructions before the experiment got underway **and have been mentioned in the General Procedure section (Please refer to page number 57).**

*Encoding of intention*

The participants were instructed to memorize the alphabets and were given prospective memory instructions. The instructions were similar for event cue and mixed cue prospective memory.

**Prospective memory Intention**

*While performing the working memory task, we have an additional interest in your ability to remember to perform an action in the future. In the upcoming working memory task whenever you encounter the earlier presented alphabets, you will have to remember to press the 'SPACE' key instead of making any other response.*

In both (event and mixed) encoding conditions, each cue was presented for 2 second with inter stimuli delay of 1 second between cues. The experimenter verbally instructed all the intention instructions to participants to ensure they fully understood the intention.

*Distraction Task:* **Please refer to GENERAL PROCEDURE section (page number 59).**

Ongoing task:

The working memory/ongoing experiment was different for mixed-cued prospective memory and event-cued prospective memory. Aside from the time cue instruction presentation, the remaining parts of the procedure were the same as the event-based prospective memory task.

*Instructions for event cues*

*"While performing the working memory task, we have an additional interest in your ability to remember to perform an action in the future. In the upcoming working memory task whenever you encounter the earlier presented alphabets, you will have to remember to press the 'SPACE' key instead of making any other response. "*

### Mixed prospective memory

In mixed prospective memory retrieval task, participants were given an extra information of when will the event cue appear in the working memory task. This extra time cue linked with the event cue is called as mixed cue. Within time-based tasks, the distinction has been drawn between intentions that must be carried out at a specific time (called pulse intentions) versus those that can be completed within a window of time called step intentions (Ellis, 1988). In our study we have used pulse intention giving the participants the specific time of the event cue appearance. After a five-minute break, they were given working memory task instructions again.

*Time cue instruction*

*"For your convenience, we are giving you an additional time cue. The cue to respond will appear exactly one minute from the start of each block in the experiment."*

The working memory/ongoing experiment was divided into five blocks, and each block had twenty trials carried out within it. This resulted in a total of one hundred trials being carried out in a full experiment. Prospective memory cue appeared once in each block of working memory task positioned at the same number in all the blocks. Event cues in an event-based task were presented in trial position number (7), corresponding to the position of mixed cues in a mixed-based prospective task, to ensure the similarity between both tasks. This trial number fell after sixty seconds from the start of the working memory task. The task trial started with a fixation cross in the center of the screen for one second followed by an alphabet appearing in the center of the screen for eight seconds. A one-second inter-trial interval separated two successive trials. Subjects had to make a response to either the 1 back working memory task or the prospective memory task.

Overall the experiment took 45 minutes to complete. The study ended with participants' feedback on the study.

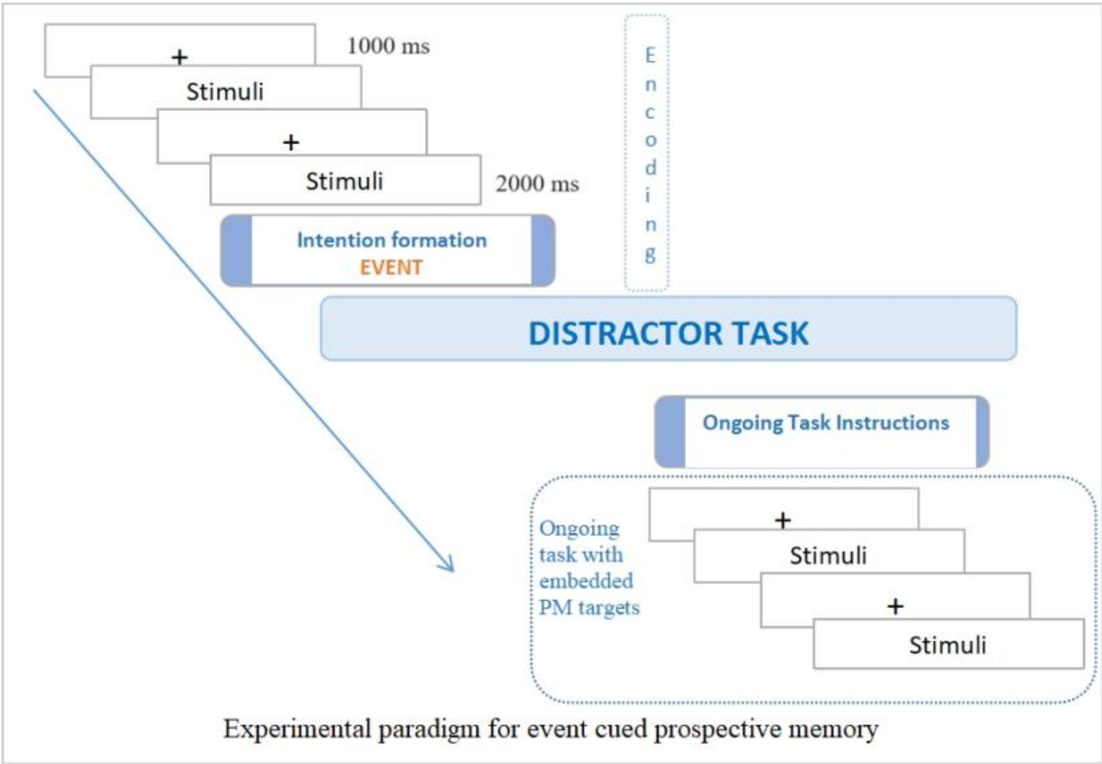



**Figure 3.4.1: Experimental paradigm for event cued prospective memory**

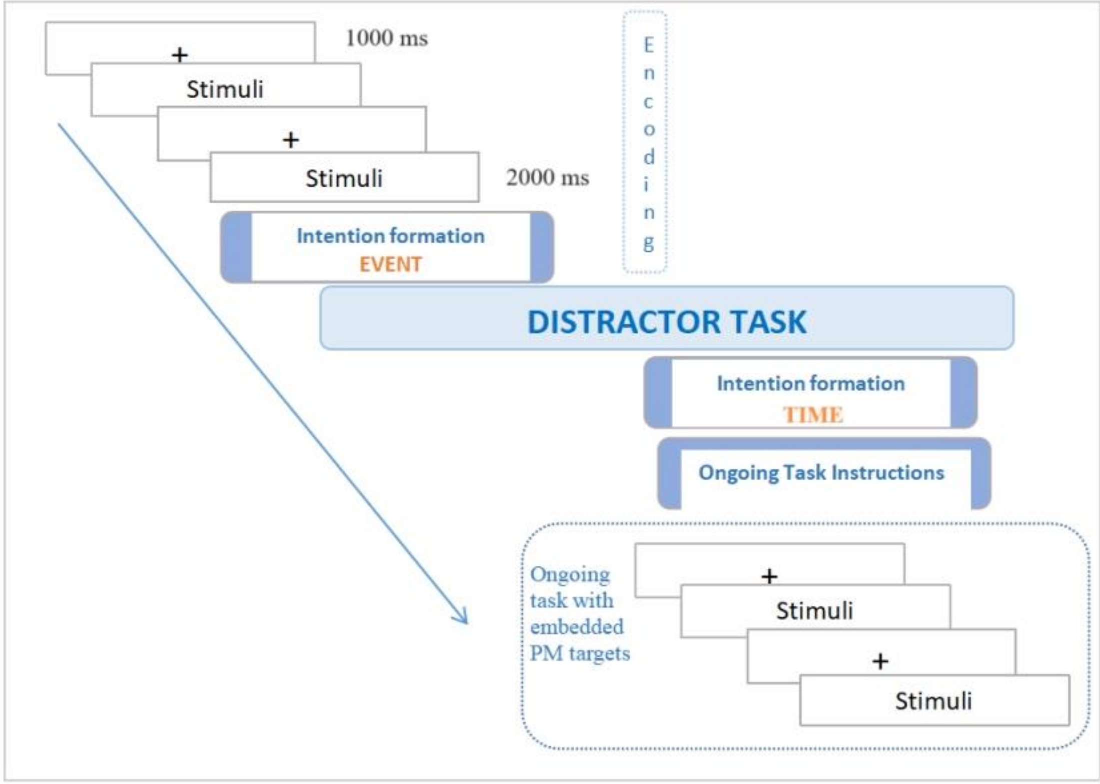



**Figure 3.4.2: Experimental paradigm for mixed cued prospective memory**

**Results**

**Prospective memory performance**

To measure the effect of cues on prospective memory performance, the accuracy and response latencies on target trials were obtained and statistically analyzed.

*Accuracy*

Independent sample t-test was conducted to analyze the data. Subjects' responses were marked as correct if participants pressed the correct response key (SPACE key) on the prospective memory target in the working memory task. We found a significant difference in event cued and mixed cued prospective memory, $t_{(38)} = 3.8$, $p < 0.05$. Participants were able to respond accurately to more cues in the mixed prospective memory task (M = 0.90) compared to the event prospective memory task (M = 0.77).

*Reaction Time*

We were interested in analyzing prospective memory reaction time (i.e., the time required to press the “SPACE” key) in both (event and mixed) condition. Response latencies were measured by averaging the reaction time of the correct responses on the prospective memory target trials. Results revealed no significant effect of prospective memory cue type, $t_{(38)}$ =1.5, $p > 0.05$.

**Ongoing task performance**

To analyze the effect of interference caused due to carrying prospective memory target at the same time acting on the working memory target, we tried to find out the accuracy i.e. correct response and response latencies on the non-target trials in the ongoing working memory task.

*Accuracy*

An independent sample t-test was applied and we did not find any significant differences. The results from the event cue (M =0.82) and mixed cue (M =0.83) prospective memory tasks indicate that prospective memory was not significantly affected by our manipulation of cues, $t_{(38)}$ = .24, $p > 0.05$. Accuracy on the non-target trials did not differ as a function of type of prospective memory.

*Reaction Time*

To calculate the response latency of non-target trials in the working memory task, we trimmed the data and removed the response time of the prospective memory target trials. In order to exclude potential after effects of responding to prospective memory targets and to lessen the likelihood that switch costs would artificially inflate our measurement of ongoing task latencies, we also excluded six trials following a prospective memory response (Cohen et al., 2008; Meier and Rey-Mermet, 2012; Meier & Zimmermann, 2015). Response latencies of trials in which a working memory (1 back task) decision error was made were also not included in the analysis. The significant effect of prospective memory type, [$t_{(38)} = 8$, $p < 0.01$] was found indicating slower reaction time (in seconds) on working memory targets in mixed cued intention condition (M = 1.7 seconds) as compared to event cued intention condition (M = 0.98 seconds).

The data is summarized in **Tables 3.4.1 and 3.4.2.**

**Conclusion and Discussion**

We found significant differences in the prospective memory performance in both mixed and event-based prospective memory task. The higher accuracy for mixed prospective memory targets showed that participants performed better when provided with both cues. Accuracy in hitting the prospective memory target was more significant when participants knew the time of the appearance of event cues in an ongoing task. Our results align with the findings of the study by Gan et al., 2021. They found increased performance in the prospective memory task condition where the event-based intention was given along with the exact timing of its occurrence in an ongoing task. The clarity of available cues can affect the performance in event-based and mixed-type intentions. Careful consideration of when an intention can be carried out has the potential to improve significantly everyday prospective memory (Cook et al., 2005). In our study, time cue provided a clear prediction of the event cue-target, enhancing the accuracy of detecting target cues in mixed prospective memory. Participants were more likely to carry out their intentions when they associated them with a specific time, suggesting that doing so helped them prioritize and allocate mental resources more efficiently.

The results of the present study can also be understood using the principle of cognitive offloading. Mixed cues may have acted as a natural cognitive offloader in the task. Individuals in their everyday life use alarms and notes as a reminder for their future actions. There is an increase in the use of smart phones and smart watches as external aids to outsource intentions (Svoboda, Rowe, & Murphy, 2012). Aided memory has been found to be more beneficial in fulfilling intentions than unaided prospective memory (Gilbert, 2015). However, if mixed cues could act as offloader, an individual's unaided prospective memory could be enhanced. Using time cues and event cues could help offload the cognitive load, thus enhancing memory without the hustle of using any external aid. Offloading can also help decrease prospective memory failures in our daily life.

Results also indicated that maintaining mixed intentions were more cognitive resource taxing to the ongoing tasks. The response speed of the participants in the ongoing task of event based prospective memory was faster than that of the mixed prospective memory, showing that additional time information added and provided increased the accuracy at the cost of slower response time in nontarget trials of working memory task. We divided the working memory task into two stages to better understand the cause of the increased interference in mixed prospective memory. According to the Dynamic multiprocess theory (Scullin, 2013), participants selectively engage in monitoring when they enter a context in which the prospective memory cue is expected. The monitoring difference between both types of prospective memory was throughout the working memory task or dynamic according to the characteristics of the task. Pairwise comparison of four trials before the first target appearance and four trials after the response was conducted. We found that the difference arose only when the participants had to detect first target. For the trials after the target appearance, the interference increased in event-based prospective memory compared to mixed prospective memory. Therefore, it can be said that the presence of a time cue increased the monitoring for the target cue in a mixed prospective memory. In our study, mixed cues served as a gentle prompt to focus on the impending occasion of action. The likelihood of consciously looking for relevant environmental cues increased when participants became aware of the exact time at which the intended action should be performed. Potential anticipatory preparation occurred when participants were given mixed cues. Due to increased environmental monitoring, which is reflected in longer response latencies, knowing when an event is likely to occur allows them to mentally rehearse the intended action in advance, increasing the chances of successful retrieval when the time arrives.

It is also possible that the time cue served as a reminder and did not dissipate from the individuals' consciousness. In order to verify this, we compared the mean reaction time of the control block in both conditions. In our experimental design, we incorporated five blocks for both the mixed and event prospective memory tasks. There were 20 trials in each block. One of the five blocks served as a control block and did not contain any prospective memory cues. Response latencies were measured by averaging the reaction time of the correct responses on the trials of that control block. An independent sample t-test was applied and we did not find any significant differences. The mean reaction time of the control block of event based (M=0.85 seconds) and mixed (M=0.9 seconds) prospective memory task indicated no significant differences, $t(49) = 1.1, p > 0.05$. This suggests that the increased monitoring visible in the ongoing working memory trials of mixed prospective memory task is due to the anticipation of time cue and not just because it was presented before the retrieval.

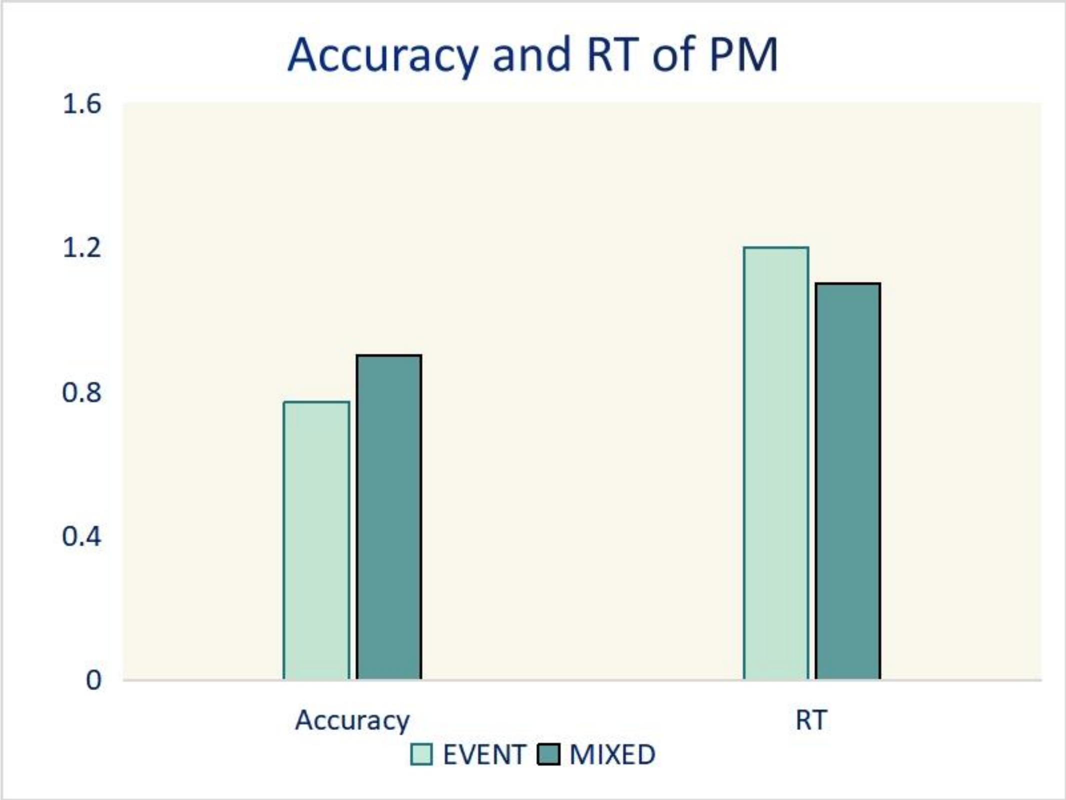
In sum, when time cues are combined with event cues, it improves retrieval of prospective memories by providing more retrieval cues, focusing attention, reducing interference, planning ahead, and anticipating what might come. These advantages help ensure that intended actions are carried out effectively and efficiently.

**Table 3.4.1:** Accuracy and Reaction Time of Prospective Memory (Mean ± SD)

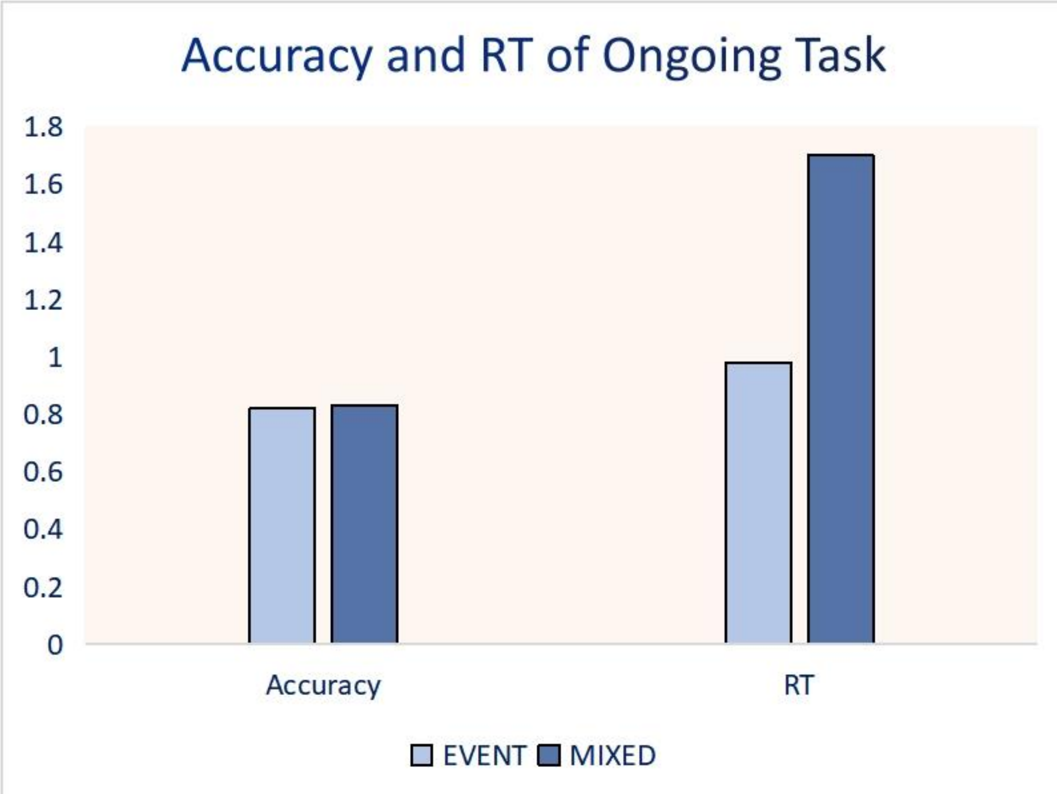
| | PM type | |
|---|---|---|
| **Dependent Measures** | **Event** | **Mixed** |
| **Accuracy** | 0.77 ± .20 | 0.90 ± .65 |
| **Reaction Time (sec)** | 1.2 ± 2.3 | 1.1 ± 2.7 |

**Table 3.4.2:** Accuracy and Reaction Time of Ongoing task (Mean ± SD)

| | PM type | |
|---|---|---|
| **Dependent Measures** | **Event** | **Mixed** |
| **Accuracy** | 0.82 ± 1.3 | 0.83 ± 1.9 |
| **Reaction Time (sec)** | 0.98 ± 1.9 | 1.7 ± 2.3 |




**Graph 3.4.1: Accuracy and Reaction Time of Prospective Memory Task across Type of Cue**




**Graph 3.4.2: Accuracy and Reaction Time of Ongoing Task across Type of Cue**

## EXPERIMENT 04: NAP AND PROSPECTIVE MEMORY

**Objective**: Do mixed reminders improve performance on prospective memory task across nap

**Hypothesis:**

There will be difference in event and mixed cued prospective memory performance across nap.

Rationale:

Given the importance of prospective memory in daily life and the dire consequences that can result from its failure, much attention has been paid to determining what factors influence prospective memory, and sleep is one of those factors. Research on whether or not young adults' future memories are consolidated while they sleep has produced contradictory results (Hoedlmoser et al., 2022). According to a meta-analysis (Leong, Cheng, Chee, & Lo, 2019), the positive effect of sleep on prospective memory is statistically significant but small to moderate in size. Most of the studies compared the effects of 7-8 hours of nighttime sleep versus staying awake for the same amount of time (Cunningham, 2021; Diekelmann et al., 2013). It has been shown that naps improve various forms of memory (Sugawara et al., 2018). Research by Dijk et al. (2014) found that napping is especially helpful for processing information that is easy to forget later on.

A nap can be beneficial when it comes to remembering intentions on a day filled with competing plans and goals, so we used prospective memory to determine whether napping aids in memory consolidation. The current study also explores the novel question of how nap prioritizes information when there are multiple cues present in prospective memory.

## Variables

Independent variable: Types of prospective memory and Resting period

Dependent variable: Accuracy of prospective cue detection (Total number of correct responses to the prospective memory target); Reaction time of the non-target trials in the ongoing task to measure the interference.

## Design

This experiment used a [2 Type of prospective memory (Event, Mixed) x 2 Resting Period (nap, wake)] mixed factorial design with repetition on second factor.

## METHODOLOGY

### *Participants*

24 healthy undergraduate students volunteered for the memory experiment.

- ***Average Age:* :** On an average, the participant's age for all the experiments was 19.27 ± 1.7 years. The range of age varied between 19-22 years.

***Inclusion criteria*:** Average academic performance, normal scores on behavioral questionnaires, young adults, eyesight corrected to normal vision, no known history of any psychological, psychiatric and physical abnormalities in the last six months prior to experimentation, average scores on Epworth Sleep Scale and adaptation of sleep laboratory conditions.

***Exclusion criteria*:** Any kind of sleep disorders, smokers, alcohol consumption, consumption of stimulants (coffee/tea) prior to the experiment; abnormal sleep/wake cycles.

## Procedure

*For pre-experimental procedure, please refer to* ***GENERAL PROCEDURE*** *subsection of* ***GENERAL METHODOLOGY*** *section* ***(page no. 59).***

## MAIN EXPERIMENT

### Cue Encoding:

Four different alphabets (e.g. *f,r,q,s*) as target stimuli were displayed on a computer using the e-prime presentation program in the middle of the screen in size 14 Times New Roman font. The participants were instructed to memorize the alphabet and were given prospective memory instructions. The instructions were different for event cue and mixed cue prospective memory.

### Prospective Memory Intention

***Event based prospective memory***

*While performing the working memory task, we have an additional interest in your ability to remember to perform an action in the future. In the upcoming working memory task whenever you encounter the earlier presented alphabets, you will have to remember to press the 'SPACE' key instead of making any other response.*

***Mixed prospective memory***

In mixed prospective memory task, participants were given an extra information of when will the event cue appear in the working memory task.

*We have an additional interest in your ability to remember to perform an action in the future. In the upcoming working memory task whenever you encounter the earlier presented alphabets, remember to press the 'SPACE' key instead of pressing any other response key. For your convenience, we are giving an additional time cue to you. The target to respond will appear exactly at one minute from starting of each block in the experiment.*

**RESTING PERIOD: NAP/WAKE SESSION**

Following the encoding, participants were given Actiwatch (PHILIPS Respironics, Inc) and Dreem Headband to wear. Physiological activity in terms of EEG and body movement for the nap condition was recorded by both the devices. An Actiwatch was programmed [person's name, age, gender and epoch length (30 seconds)] before positioning it on the non-dominant wrist of each participant. The model also includes an event marker and participants were asked to push it both when they started trying to fall asleep before actual sleep and when they awoke fully for the day.

The DH device is a wireless headband worn during sleep which records, stores, and automatically analyzes EEG and physiological data in real time. Five types of physiological signals were recorded via three types of sensors embedded in the device.

Detailed information about the headband have been discussed **Tools and Questionnaires sub-section of Nap experiment section of General Methodology. Please refer to page number 62.**

Participants either napped (nap condition) for 90 minute or were kept quietly awake (wake condition) for the same time in the laboratory. In the wake condition, participants were kept in a state of restful wake by reading books and doing quiet activities (e.g., puzzles), as necessary. Participants were awakened in the nap condition after completion of 90 minutes. In the nap condition, participants were given 150 minutes before the subsequent retrieval test to eliminate sleep inertia. Sleep inertia reflects a transition from a sleep state to a waking state and is characterized by a reduction in the ability to think and perform upon awakening due to sleep This period is a state of grogginess, confusion and lowered arousal (Hilditch et al., 2017; Dutheil et al., 2021).

To balance the time gap between encoding and retrieval in both groups, both wake and nap groups completed the retrieval test at the same time.

**Retrieval:** *Please Refer to the General Procedure section (page number 59)*

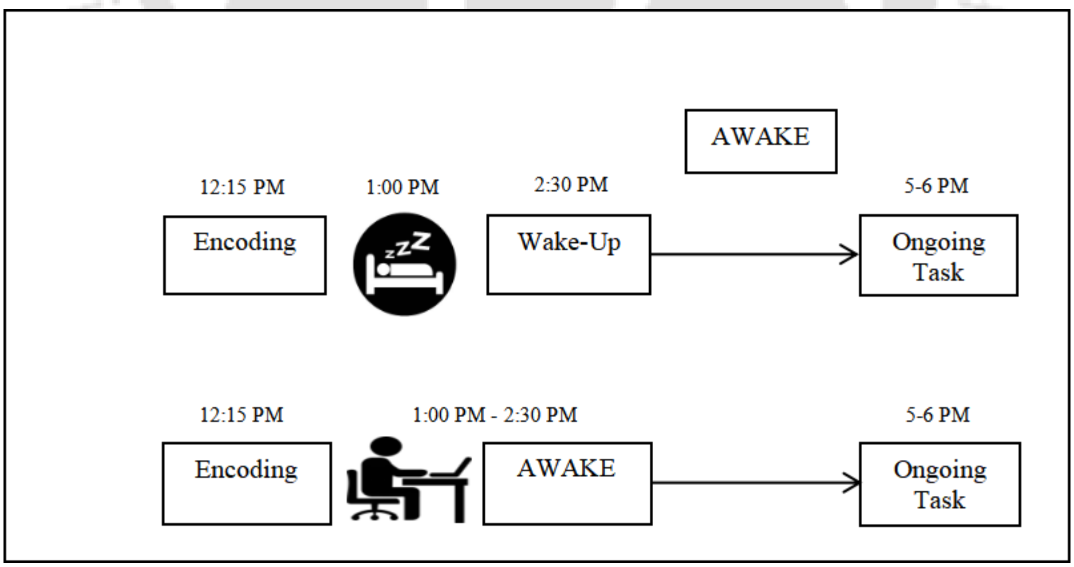



**FIGURE 4.1:** ***Experimental Paradigm for Nap experiment***

## Results

### PM Performance

*Accuracy*

Subjects' responses were marked as correct if participants pressed the correct response key (SPACE key) for the prospective memory target in the working memory task.

Mixed factorial ANOVA [2 Type of prospective memory (Event, Mixed) x 2 Daytime nap (nap, no-nap) ] was conducted for statistical analysis. There was no significant main effect of nap on prospective memory [$F (1, 22) = 0.089$, $p > 0.05$, partial eta-squared = .002]. There was a significant interaction effect between type of prospective memory and nap, [$F (1, 22) = 6.278$, $p < 0.05$, partial eta-squared = .22] with mixed prospective memory more benefited by nap. Participants were able respond more accurately to targets after nap (M=.94) than after being awake in the mixed prospective memory (.60). For event based prospective memory task, no significant accuracy results were obtained between nap and awake condition. Significant main effect of pm type was also found [$F (1, 22) = 6.02$, $p < 0.05$, partial eta-squared = .02]. Participants pressed correct key on pm targets in mixed pm (M=.86) as compared to event based pm (M=.56)

### Ongoing Task Performance

*Reaction Time*

To calculate the response latency of non-target trials in the working memory task, response time of prospective memory target trials were removed. Response latencies of trials in which a working memory (1 back task) decision error was made were also not included in the analysis. Significant main effect of nap [$F (1, 22) = 8.9$, $p > 0.05$, partial eta-squared = .01] with participants responding quicker and faster after nap (M=0.82 seconds) as compared to being awake (M=1.2 seconds). Significant main effect of types of prospective memory [F (1, 22) = 10.08, p > 0.05, partial eta-squared = .005] was also found indicating that participants were slower to respond in event based prospective memory task (M=1.4 seconds) as compared to mixed prospective memory (M=0.9 seconds). All other results were insignificant.

**Discussion**

It is well-documented that sleep have strengthening effects on memory retention (Born et al., 2006; Rasch & Born, 2013; Klinzing et al., 2019). Both animals and humans benefit from its ability to enhance memory and underlying neural plasticity (Kopasz et al., 2010). When subjects are allowed to sleep after learning, they retain more of what they have learned compared to when they stay awake for the same amount of time. Taking a short nap during the day has also been shown to be more effective at preserving memory than staying awake in a variety of memory tests (Scullin et al., 2017). Though sleep has been shown to improve memory, this benefit is primarily for recalling past events; the potential role of sleep for recalling future plans and intentions has been largely ignored. The question is whether a nap during such a day of postponed activities would help with memory retention. Our purpose in conducting this research was to verify whether or not taking a nap in the afternoon improves future memory performance in healthy, young adults. In addition, we aimed to determine whether or not the naps' positive effects on memory retention seen in other memory types also apply to various forms of prospective memory. Participants in our study were randomly assigned to nap for 90 minutes or stay awake for the same amount of time. We discovered that future intentions did not differ significantly between taking a nap in the afternoon and staying awake quietly for the same amount of time. Accuracy in recalling future intentions was similar between participants who napped after encoding intentions and those who remained awake.

One possible explanation for our results is that the non-rapid eye movement (NREM) stage of sleep predominates during daytime naps. According to research (Ficca, Axelsson, Mollicone, Muto, & Vitiello, 2010), nap-induced performance gains would vary with the sleep stages and total nap time. It is common to get only NREM sleep during short day time without rapid eye movement (REM) sleep. Few studies have used this information to examine the impact of daytime naps on memory. In one such research, the role of slow wave sleep (SWS, also known as deep sleep) on prospective memory was investigated and was discovered that the SWS negatively correlates with the prospective memory component (Cunningham et al., 2017). It has been found that REM sleep enhances the binding of information needed for future memories (Boyce at al., 2016). Scullin et al., 2019 in their study found that REM sleep duration was significantly associated with prospective memory consolidation in young adults. Cue-based prospective memory is known to be an associative memory that links future and past information (the prospective memory cue with the intention to do something) (Diekelmann et al., 2013b; Leong et al., 2019a). According to the findings, REM sleep helps preserve the association between what needs to be remembered and when it needs to be remembered. Therefore, the failure to benefit from consolidation of prospective memory may be attributed to the lack of REM sleep used in the current study.

Another reason could be the need for conscious monitoring of cues. Some studies of prospective memory predict that being awake is more beneficial to achieving one's objectives than sleeping. Cues (such as a letter) related to a goal (such as remembering to give a letter to a friend) are encountered frequently, and these cues naturally remind people of their goal (Kvavilashvilil &

Fisher, 2007) and conscious retrieval strengthens the goal representation (Roediger & Karpicke, 2006).

Our findings are consistent with the small body of research that has not found a link between sleep and PM. Leong et al. (2019) in their study found no evidence that sleep significantly altered prospective memory, or the ability to carry out an intention. While a few studies have found that sleeping after encoding seems to influence and strengthen the memory to perform an intended action at the planned time but all those studies did compare the effects of sleeping for 7-8 hours of nocturnal sleep versus staying awake for the same amount of time (Cunningham, 2021; Diekelmann et al., 2013).

Despite failing to find a main effect, we did find an interaction effect of nap and prospective memory type to be statistically significant. After a nap, people were able to respond accurately to prospective memory targets in mixed prospective memory compared to when they were awake but not sleeping. The ability to remember that something will happen at a specific time and cued by certain event in the future is called mixed prospective memory and is similar to episodic memory in this regard. "A prospective memory is an episodic representation stored in a memory," Marsh et al. (2006) wrote. Episodic memory is the memory for events, experiences or information and their respective context (e.g., location, time; Tulving, 2002). In general terms, prospective memory is the capacity to store and recall future plans through the activation of episodic memory processes. (Brewer & Marsh, 2010). Research shows that the benefits of NREM sleep for consolidating episodic memory are greatest after a night of SWS as opposed to a night of REMS (Plihal & Born, 1997). NREM sleep in our nap study might have helped in the consolidation of mixed prospective memory intentions.

Context binding also plays an important role in memory consolidation during sleep (Schechtman et al., 2023). Context guides memory processing during sleep. Combining time cue along with the event cue gives a clear context to the participants in the mixed prospective memory. The ability to "remember to remember" also depends on the associative strength between what must be remembered (intention) and when it must be remembered (cue). It is clear from the earlier findings that mixed cues increases the strength of the cue and intended action, thus enhancing the successful retrieval of prospective memory intention. The association of the mixed cues with the intention might have been much stronger than that of event cues, and only NREM sleep might have helped the consolidation of the intention. Together, these results speak for a selective beneficial impact of naps on prospective memory cued by mixed cues.

To know the effect of monitoring, we analyzed reaction time of the non-target trials for both the groups (nap and wake). We included only those blocks of trials in which prospective memory target was detected. Participants were faster to respond to the trials after taking a nap as compared to being awake after encoding of the intentions. It has been shown that sleep supports the maintenance of prospective memory over time by strengthening intentional memory representations, thus favoring the spontaneous retrieval of the intended action at the appropriate time (Diekelmann et al., 2013).

**Table 4.1: Actigraphy report of nap**

| Nap Parameter (Actiwatch) | M± SD |
|---|---|
| TST (minutes) | 75±15 |
| Sleep efficiency (%) | 70.13 (15.7) |
| SOL (minutes) | 16.6 (11.4) |
| WASO (minutes) | 11.3(8) |

**Table 4.2: Stages and Quality of Nap measured by Dreem Headband**

| **Stage (Dreem Headband)** | **Percentage (%)** | **Duration (Minutes)** |
|---|---|---|
| Wake | 22.5 | 18.3 |
| Deep sleep | 45 | 38.1 |
| Light sleep | 22 | 15.4 |
| REM sleep | 10.5 | 9.2 |
| Efficiency | 80 | -- |
| Sleep Onset | -- | 16.8 |
| Awakening Duration | -- | 5 |

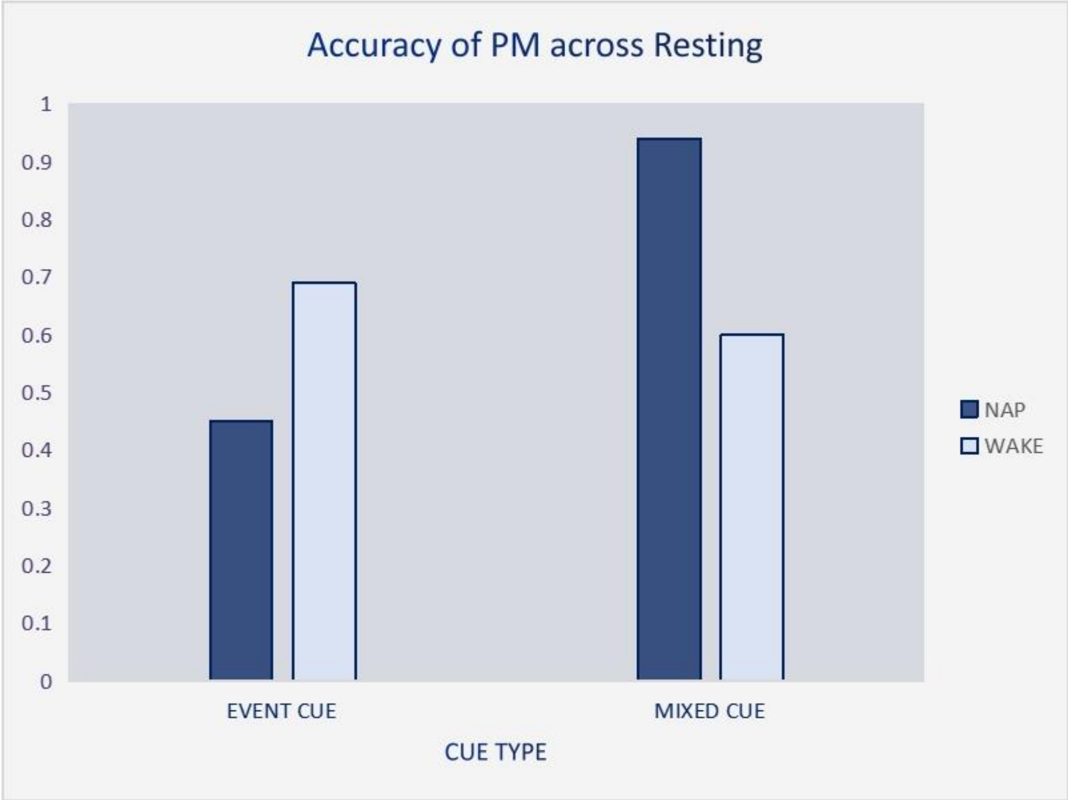
Four sleep parameters of actigraphy were examined in this study: total sleep time (TST), defined as the number of minutes scored as sleep between lights off and lights on; sleep onset latency (SOL), the number of minutes between lights out and the first epoch scored as sleep; wake after sleep onset (WASO), the number of minutes scored as wake after sleep onset; and sleep efficiency (SE), the ratio between TST and total time spent in bed (TIB; from lights off to lights on).

**Table 4.3:** Accuracy of Prospective Memory across Resting Period (Mean ± SD)

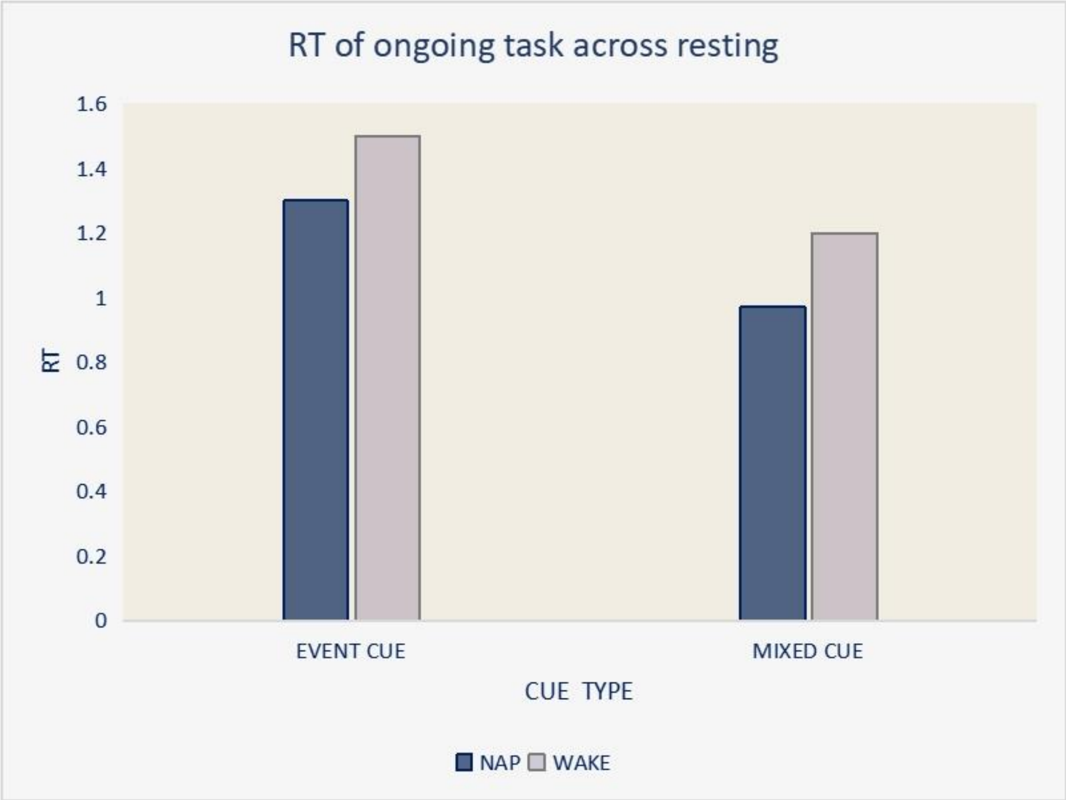
| Cue type / Resting | NAP | WAKE |
|---|---|---|
| EVENT CUE | .45 ± .34 | .69 ± .13 |
| MIXED CUE | .94 ± .59 | .60 ± .7 |

**Table 4.4:** Reaction Time of Ongoing task across Resting Period (Mean ± SD)

| Cue type / Resting | NAP | WAKE |
|---|---|---|
| EVENT CUE | 1.3 ± .78 | 1.5 ± .59 |
| MIXED CUE | 0.97 ± .60 | 1.1 ± .22 |




**GRAPH 4.1: Accuracy of Prospective Memory Type Across Resting**




**GRAPH 4.2: Reaction of Ongoing Task across Resting**

# CHAPTER 04: GENERAL DISCUSSION

## ANSWERS TO THE RESEARCH QUESTIONS OF THIS THESIS

The present thesis is primarily based on two notions. First, finding, if learning with multiple cues (event and time) improves prospective memory performance and second to know the role of nap in preserving prospective memory cued using dual cues. In our everyday life, we face many instances where there are goals that cannot be completed at the moment and they are set for future. Memory for such intentions is known as prospective memory. The recollection of these deferred intentions is prompted by the cues and are completed while obstructing other tasks in hand (termed as ongoing tasks). The cues that help initiating the intentions can be broadly differentiated into event and time cues. But situations in the environment that can act as cue, cannot be clearly defined in event-based scenarios and time-based scenarios. The difference between the use of time cues and event cues gets blurred in the real world. Research used to study the strategies used by people to complete their deferred intention has found that individuals use both time and event cues together by linking them (Graf & Grondin., 2006; Siu & Graf., 2005). These combinations of cues have been termed as mixed cues.

Previous research on retrospective memory has demonstrated that employing multiple cues enhances the effectiveness of memory retrieval (Hajime et al., 1999). In one of such study conducted by Pearson and Wilbiks, 2021, a recall task was administered where participants were presented with their self-generated memory cues and asked to determine the target word. The results indicated that multiple self-generated memory cues were more effective in recall as compared than one memory cue. In another study, Won and Jiang (2010) found that presenting four identical faces simultaneously yielded better results on a discrimination task than presenting one lone face. Tulving & Osler (1968) also investigated the effect of single and double retrieval cues in aiding recall of a list of words. They found that if two cues were presented with the stimulus word in learning, and then either one or both were presented to aid recall, the subject did better with two than with one cue. The likelihood of a successful retrieval is increased, and the risk of a failed retrieval is decreased, when more cues are used to gain access to the information that has been stored. When a cue is presented, every associated pathway is activated at the same time and competes with one another in some way to retrieve a response (Nobel & Shiffrin, 2001; Ratcliff, 1978; Ross & Anderson, 1981). Using multiple cues during retrieval can improve recall, especially if the cues are related to one another or provide additional context. For instance, episodic memory which comprises of an event of multiple elements, was found to be enhanced when cued by the multiple cues at the retrieval (Horner and Burgess,2013). It has also been found that multiple cues by themselves insufficient to produce a response, may be beneficial to retrieval when presented together (McLeod et al.,1971). Studies have also demonstrated that the manner in which stimuli are presented (i.e., modality, sequence and quantity) each affects the encoding and in turn retrieval of information. Underwood (1969) conceptualized that the memory of an event can be encoded with various attributes, and these multiple attributes can then subsequently function as retrieval cues.

The target's contextual features, such as the time, place, and method of interaction with it at encoding, aid in the retrieval process. It has been demonstrated that the strength of the temporal associations made between items and their serial positions during encoding strongly predicts episodic memory performance (Howard et al., 2002; Sederberg et al., 2010). Also, spatial and temporal information can both play a role in cued recall. Several studies have shown that spatial cues, such as familiar locations, can lead to faster recall and a higher likelihood of selecting a location as the first thing that comes to mind (Gibson et al., 2021). Additionally, the use of temporal cues, such as the timing of events, can also influence recall. For example, predictable temporal structures can help prioritize items in working memory, leading to higher accuracy and shorter reaction times (Mellisa et al., 2014). In the field of image retrieval also, the fusion of structural, content, and spatial information from multiple cues has been found to improve the performance of partial-duplicate image retrieval systems (Yan et al.,2014).

Results obtained from our study showed similar results indicating increased intention retrieval when provided with both event and time cues. In our study we investigated this effect of mixed cues (event and time) and found that when provided with event cues along with temporal information of the occurrence of the cue, participants performed better in prospective memory remembering as compared to when only event cue was present to signal the prospective intention. Participants accurately pressed the designated key (prospective memory action) when encountered with the prospective memory target in the retrieval task. The results indicate that mixed cues have potential to be more efficient in signaling prospective action. Careful consideration of when an intention can be carried out has the potential to improve significantly everyday prospective memory (Cook et al., 2004). The clearer and precise occurrence time of the event cue has the potential to improve prospective memory. Our results fall into line with few limited researches of prospective memory, which tried to dive into knowing the effect of mixed cues over only event cues. In one such study by Gan et al., 2021, increased performance was found in the prospective memory task condition where the event-based intention was given along with the exact timing of its occurrence in an ongoing task. When compared to the event based prospective memory, mixed prospective memory has different processing mechanism as it contains both the cues (Chen et al., 2010; 2014; Gan et al., 2021).

The results of the present study can also be understood using the principle of cognitive offloading. Cognitive offloading has been defined as "the use of physical action to alter the information processing requirements of a task so as to reduce cognitive demand" (Risko & Gilbert, 2016; Gilbert et al.,2023, p. 2). The type of cognitive offloading for to be remembered intentions is termed as 'intention offloading'. In this form of cognitive offloading, a cue is created in the external environment to help in triggering a delayed intention. A typical example of intention offloading is placing reminders in the environment (e.g., putting sticky notes on the fridge) or using smartwatches for alarming. Offloading can help decrease prospective memory failures in our daily life. Although intention offloading is done by using external cues, it is possible that using mixed could help offload the cognitive load, thus enhancing memory without the hustle of using any external aid. Mixed cues could act as an offloader to enhance the individual's unaided prospective memory. Intention offloading strategies can help in mitigating the individual differences related to the unaided ability (Gilbert et al.,2023).

We also investigated the interference that can be caused by holding an intention into the memory. It has been debated that holding an intention increases monitoring processes and produces some costs which is being visible in the reaction time on the non-target trials in the working memory task (Smith et al., 2003). Whereas some studies indicate that depending on the nature of the cue and under some circumstances, there could be spontaneous retrieval with minimum or no cost of monitoring (Einstein et al., 2005). For that reason, if mixed cues were more salient or were able to offload the intention, than they should have produced less monitoring effect and have less cost as compared to single event cues. But to our surprise, monitoring costs were higher in mixed prospective memory task as compared to event based prospective memory. Reaction time on the non-target trials in working memory task were slower when mixed cues were provided in the prospective memory task.

In mixed prospective memory task, inclusion of time cue in addition to an event cue improved accuracy but resulted in slower response time in non-target trials of the working memory task. Therefore, to better understand the cause of the increased interference in mixed prospective memory, we divided the working memory task into two stages. Pairwise comparison of four trials before the first target appearance and four trials after the response was conducted. We found that the difference arose only when the participants had to detect first target. For the trials after the target appearance, the interference increased in event-based prospective memory compared to mixed prospective memory. According to the Dynamic multiprocess theory (Scullin, 2013), participants selectively engage in monitoring when they enter a context in which the prospective memory cue is expected. Therefore, it can be said that the presence of a time cue increased the monitoring for the target cue in a mixed prospective memory. In our study, mixed cues served as a gentle prompt to focus on the impending occasion of action. The likelihood of consciously looking for relevant environmental cues increased when participants became aware of the exact time at which the intended action should be performed. Potential anticipatory preparation occurred when participants were given mixed cues. Due to increased environmental monitoring, which is reflected in longer response latencies, knowing when an event is likely to occur allows them to mentally rehearse the intended action in advance, increasing the chances of successful retrieval when the time arrives. In sum, when time cues are combined with event cues, it improves retrieval of prospective memories by providing more retrieval cues, focusing attention, reducing interference, planning ahead, and anticipating what might come. These advantages help ensure that intended actions are carried out effectively and efficiently.

Multiple cognitive processes including attention, planning, monitoring, and many more influences prospective memory. By this view, prospective remembering clearly relies on a multidimensional set of cognitive processes. (Marsh, & Hicks, 1998). For this reason, we formulated few other research questions to explore. In addition to find the role of multiple cues, we were also interested in determining the influence of cognitive components utilized in everyday life on prospective memory performance. Among them is the attention and cognitive load of the items to be remembered.

In our **second** research question, we varied interference during encoding by manipulating attentional levels. In real-world situations, intention formation frequently occurs in the midst of a number of other, potentially competing tasks. Prospective memory encoding may be chaotic and may happen to be along with another interfering task. Diverted attention at encoding of intention formation may result in an incomplete encoding of the prospective memory intention thus effecting successful completion of prospective memory. Competition for limited resources could also reduce the efficiency with which the intention is encoded and stored. In our study, attention was divided by presenting participants four distinct alphabets enclosed in geometric shapes. They were also given the directive to concentrate on the alphabet and the figures, as well as to memorize this information in preparation for later application. In contrast, the condition that required **sustained attention** consisted solely of the presentation of alphabets without any geometric figures.

We did not find any significant role of interference in prospective memory remembering, which runs counter to the results obtained from the studies which have found the interference to impact the encoding (Einstein and Smith,1997). But there exist many reasons for our results. Among them **first** was the *nature of the task demands*. Interfering conditions may have placed some small demands on executive resources, but those demands were not high enough to adversely affect encoding. More likely (Baddeley & Hitch, 1974), the interference task condition may have placed some modest demands on executive resources, but these demands were insufficient to impair the encoding of intention. **Second**, our interfering task was paying attention to the geometrical shapes. Most of the evidence supports the idea that visuospatial attention and central attention are distinct forms of attention. Consolidation of a visuospatial array can occur undeterred while central attention is engaged (Blake & Fox, 1969; Pashler, 1991; Posner & Boies, 1971; Comstock, 1973). Visuospatial and central attention operate at separate temporal stages, a conclusion that dovetails with the supposition that the two types of attention can be allocated to distinct events. **Third**, prospective memory performance outside the laboratory depends on *metaknowledge* (Dobbs & Reeves, 1996). That is, people know how good or poor their memories are, what their level of motivation is, and what the completion of an intention requires. As a consequence, people take steps to adopt strategies that will compensate for their own shortcomings. The **fourth** possibility is that of *cognitive control*. An adaptive memory system benefits from the capability to process and store only the information that is actually useful. The processes of cognitive control not only help a person retrieve goal-relevant information in the present, but they also actively weaken memories that are undesirable, irrelevant, or interfere with the retrieval of goal-relevant information. In our study, it is possible that because the questions relating to geometric shapes were not asked in the retrieval phase, participants were able to suppress the irrelevant memory of shapes and were able to perform the prospective memory task. Regarding the interference caused by holding a prospective memory intention, we found that the response latencies of the prospective memory target was higher in divided attention condition as compared to sustained attention condition. Successfully performing an event-based intention requires cognitive processes involved in noticing the cue, retrieving the intention, and coordinating its execution with the ongoing activity (Marsh et al., 2002). Slowing effect in the divided attention task may have been caused because participants spent more time in the microprocess of detecting, retrieving, deciding, and coordinating prospective memory responses with the task demands of the ongoing task. This assumption is based on the fact that we presume that these activities required some amount of time when the alphabets were encoded with geometrical shapes.

For our **third** research exploration, **cognitive load** was varied. People have to juggle a number of delayed intentions at the same time, the majority of which we forget about by the time it is necessary to retrieve them. People may not be able to process and encode the intention into memory if they are confronted with multiple stimuli or competing information. As a direct result of this, it is possible that the prospective memory task will not be correctly established in the memory. We tried to study the effect of cognitive load on prospective memory performance by manipulating the number of cue intention, subject needed to encode. Participants had to react to only one specific target (alphabet in our case) in the low cognitive load encoding condition. In the high cognitive load encoding conditions, they had to respond to all the four targets in the working memory task. The results of our third investigation indicated that prospective memory performance was influenced by the load manipulation. When compared to the high cognitive load encoding, the low cognitive load condition yielded more accurate responses on prospective memory targets. Prospective memory performance varied as a function of the number of targets and is in line with previous research (Einstein et al., 2005; Cohen, 2013; Wiesslein et al., 2014). Cognitive load reduces individuals' likelihood of attending or successfully recognizing a target during the task. We did also find monitoring cost differences in the ongoing task as a function of load. Slower RTs for the high load condition indicated that participants had to engage cognitive resources to maintain prospective intentions, while at the same time executing the ongoing task (Matos et al., 2020). It is plausible that increasing the number of prospective intentions could have determined a shift from an automatic process to a more consuming monitoring process. Participants' strategies appear to have differed according to the cognitive requirements of the prospective memory task (Einstein et al., 2005 (Barban et al., 2014; Cantarella et al., 2023). Under high-load conditions, more resources need to be allocated to strategically monitor the occurrence of the PM targets (Einstein et al., 1992; 2005).

For our **fourth** research question we incorporated nap after learning to find its role in preserving memory by reducing interference and helping in reconsolidation of memory traces. Sleep have strengthening effects on memory retention (Born et al., 2006; Rasch & Born, 2013; Klinzing et al., 2019). Our purpose in conducting this research was to verify whether or not taking a nap in the afternoon improves future memory performance in healthy, young adults. In addition, we aimed to determine whether or not the naps' positive effects on memory retention seen in other memory types also apply to various forms of prospective memory. We discovered that future intentions did not differ significantly between taking a nap in the afternoon and staying awake quietly for the same amount of time. Accuracy in recalling future intentions was similar between participants who napped after encoding intentions and those who remained awake. One possible explanation for our results is that the non-rapid eye movement (NREM) stage of sleep predominates during daytime naps. According to research (Ficca, Axelsson, Mollicone, Muto, & Vitiello, 2010), nap-induced performance gains would vary with the sleep stages and total nap time. It is common to get only NREM sleep during short naps during the day, and not enter rapid eye movement (REM) sleep at all. It has been found that REM sleep enhances the binding of information needed for future memories (Boyce at al., 2016). Cue-based prospective memory is known to be an associative memory that links future and past information (the prospective memory cue with the intention to do something) (Diekelmann et al., 2013b; Leong et al., 2019a). Therefore, the failure to benefit from consolidation of prospective memory may be attributed to the lack of REM sleep used in the current study.

Another reason could be the need for conscious monitoring of cues. Some studies of prospective memory predict that being awake is more beneficial to achieving one's objectives than sleeping. Cues (such as a letter) related to a goal (such as remembering to give a letter to a friend) are encountered frequently, and these cues naturally remind people of their goal (Kvavilashvilil & Fisher, 2007) and conscious retrieval strengthens the goal representation (Roediger & Karpicke, 2006). To know the effect of monitoring, we analyzed reaction time of the non-target trials for both the groups (nap and wake). We included only those blocks of trials in which prospective memory target was detected. Participants were faster to respond to the trials after taking a nap as compared to being awake after encoding of the intentions. It has been shown that sleep supports the maintenance of prospective memory over time by strengthening intentional memory representations, thus favoring the spontaneous retrieval of the intended action at the appropriate time (Diekelmann et al., 2013).

In sum, through our work, we explored the impact of multiple cues on remembering future intentions, and discovered that providing two cues improves the likelihood of retrieval. Along with the event cue, a time cue indicates when the target will actually occur, which serves to further remember the intention. Additionally, we attempted to mimic real-world situations that typically occur during the encoding of intention. In our thesis, we examined the influence of interfering variables such as attention and cognitive load on our ability to encode future intentions. The cognitive phenomenon of divided attention, characterized by the simultaneous engagement in multitasking or the concentration on multiple tasks, seems to potentially hinder our capacity to remember our intentions. However, our research has revealed a surprising discovery, suggesting that in certain situations, multitasking may not have as harmful an effect on our capacity to recall future events as previously thought. This apparent contradiction has provided an opportunity to comprehend the intricacies in action. When individuals are presented with situations where their attention is divided, they may employ compensatory strategies or wisely distribute their cognitive resources. Observe it from this perspective: The remarkable flexibility of our brain enables us to remember our shopping list even while performing multiple tasks simultaneously. It is akin to having a cognitive contingency strategy - we may be mitigating the effects of divided attention by employing metacognition, which essentially involves being conscious of and managing our own cognitive processes. Furthermore, cognitive control, an additional cognitive ability, may be intervening to resolve the situation. It is akin to having an internal overseer that guarantees the seamless execution of all tasks. Therefore, even when managing numerous tasks, cognitive control actively safeguards our prospective memory.

The thesis also investigated the impact of cognitive load on prospective memory performance by manipulating the number of cue intentions required to encode. Participants were divided into two levels of manipulation: high and low cognitive load. In the low cognitive load encoding condition, participants had to respond to one specific target, while in the high load encoding condition, they had to respond to all four targets in the working memory task. The main effect of cognitive load was found to be that prospective memory performance was influenced by the load manipulation. The low cognitive load condition yielded more accurate responses on prospective memory targets compared to the high load encoding condition. This finding aligns with previous research, which found that cognitive load reduces individuals' likelihood of attending or successfully recognizing a target during the task. It was found that the more goals one has at complete (load), the less likely it is that all of them will be accomplished.

The last objective of this thesis was to examine the impact of daytime naps on prospective memory (PM). Contrary to expectations, taking a nap did not show a significant advantage in consolidation of prospective memory intentions over staying awake. The discussion suggested that factors such as sleep stages (NREM and REM), conscious cue monitoring, and the associative strength between intentions and cues may play an important role in prospective memory, potentially outweighing the overall benefits of napping observed in retrospective memory studies.

The findings also showed that prospective memory selectively benefits from naps, particularly when prompted by mixed cues (event and time). After a nap, people could respond accurately to prospective memory targets in mixed prospective memory compared to when they were awake but not sleeping. During naps, the non-rapid eye movement (NREM) stage of sleep may play a role in the consolidation of mixed prospective memory intentions. Additionally, reaction time analysis suggested that participants who napped showed faster responses in prospective memory trials, supporting the idea that sleep aids in the maintenance of prospective memories.

# CHAPTER 05: IMPLICATIONS AND LIMITATIONS OF THESIS

## Theoretical Implication

The present thesis adds evidence to the limited research available that has studied the efficiency of mixed cues in improving prospective memory. Our investigation revealed that the presence of mixed cues (time and event) resulted in improved accuracy in completing the intended action compared to the use of only event cues. Mixed cues improve the likelihood of successful memory retrieval by providing a clearer occurrence of the event when prospective action must be taken. This decreases the probability of forgetting the intended action and enhances prospective memory performance.

This study uses a controlled experimental design to change the level of task difficulty on purpose and in a planned way during the phase of intention formation (encoding). This is done by changing the cognitive load and attention to make the real-life situations that people face during intention formation stand out more. This phase has predominantly been overlooked in previous research endeavours. Most studies have primarily manipulated the task complexity during the retrieval phase of prospective memory task. Our study is one of the few that has exclusively examined encoding variables by manipulating attentional levels.

Daytime napping is a reliable experimental model used to investigate the role of sleep in memory consolidation. Currently, there is no existing study that has examined the impact of napping on mixed prospective memory. Our study examined the impact of napping on event-based and mixed prospective memory, revealing insights into the specific advantages of napping.

## Methodological Development

All previous studies on mixed prospective memory utilized paradigms where event cues and time cues were presented concurrently. However, in our experimental paradigm, to mitigate the competition for cognitive resources during encoding, we presented the cues separately and at different times rather than simultaneously. This approach aims to prevent additive interference. Participants may encounter difficulty in simultaneously prioritizing and processing both cues, resulting in interference and potentially affecting their performance in prospective memory.

Throughout the entirety of the experiments that were conducted for our thesis, we consistently utilized alphabets as cues. The reason we went with this approach is that alphabets are universal symbols that are easier to comprehend and offer clarity. Conversely, the complexity of shapes, pictures, or words may differ, posing difficulties in managing the cognitive load linked to various stimuli.

## Practical Implication

1. The utilization of multiple reminders (cues) for memory retrieval in prospective memory research can yield various practical ramifications, both within controlled experimental environments and in practical real-life scenarios.

- Practical Applications in Technology: The incorporation of multiple cues is pertinent to the development of technological aids and applications designed to assist with prospective memory in everyday activities. It can offer valuable insights for the development of assistive technologies for individuals with cognitive impairments or conditions that affect prospective memory.

- Methods of intervention: Utilizing multiple reminders as a component of intervention strategies can enhance prospective memory in individuals facing difficulties related to memory. Individuals with mild cognitive impairment or specific neurological conditions can derive advantages from customized reminder systems.

2. An analysis of factors that disrupt the encoding of prospective memory has practical implications that can provide valuable understanding of cognitive processes and inform the creation of strategies to enhance prospective memory in real-world situations.

- Training and Intervention Programs: The knowledge acquired from analyzing interference variables can be applied to enhance the efficacy of training programs aimed at enhancing prospective memory. Interventions could focus on enhancing encoding strategies to mitigate the impact of interference, which can be advantageous for individuals with memory impairments or those operating in high-stress settings.

- Educational Strategies: Teachers and educators can gain advantages from studying interference variables by applying strategies that promote efficient encoding in educational environments. Adapting teaching techniques to reduce interference and improve the process of storing information can enhance students' capacity to recall and accomplish future goals.

- Workplace Productivity and Safety: In work environments, particularly those with high cognitive demands, understanding interference during encoding can lead to the implementation of strategies that enhance prospective memory. This can improve efficiency, task completion, and safety in occupations where the capacity to remember and execute tasks is essential.

- Age-related factors: Examining the phenomenon of interference during the encoding process can provide valuable insights into the age-related alterations in prospective memory. Adapting strategies to reduce interference may be particularly relevant for older adults, who may show increased vulnerability to interference.

**Limitations and Future Directions**:

- Comparative Studies: In our study, only visual cues were utilized. Assessing the efficacy of various types or combinations of cues can be highly valuable. Future studies can investigate the cue formats, such as auditory and tactile, or their combinations with visual cues, that result in the best prospective memory performance.

- Individual Differences: Examining the manner in which individuals react to multiple cues can provide insights into variations in prospective memory among individuals. Certain individuals may derive greater advantages from particular categories or regularities of prompts, and this understanding can guide customized interventions. Our study primarily focuses on young undergraduate students. The findings may not be applicable to the broader population. Subsequent research can employ the elderly demographic, who exhibit a higher susceptibility to forgetting intentions, in order to conduct an experiment. Additionally, conducting a comparative study between the young and elderly populations can produce more robust and universally accepted findings.

# REFERENCES


Alba, J. W., Chromiak, W., Hasher, L., & Attig, M. S. (1980). Automatic encoding of category size information. Journal of Experimental Psychology: Human Learning and Memory, 6(4), 370.

Anderson, C. M. B., & Craik, F. I. M. (1974). The effect of a concurrent task on recall from primary memory. Journal of Verbal Learning and Verbal Behavior, 13(1), 107-113.

Anderson, F. T., & Einstein, G. O. (2017). The fate of completed intentions. Memory, 25(4), 467-480.

Anderson, F. T., & McDaniel, M. A. (2019). Hey buddy, why don't we take it outside: An experience sampling study of prospective memory. Memory & Cognition, 47(1), 47-62.

Anderson, F. T., McDaniel, M. A., & Einstein, G. O. (2017). Remembering to remember: An examination of the cognitive processes underlying prospective memory. Learning and memory: A comprehensive reference E, 2, 451-463.

Anderson, F. T., Rummel, J., & McDaniel, M. A. (2018). Proceeding with care for successful prospective memory: Do we delay ongoing responding or actively monitor for cues? Journal of Experimental Psychology: Learning, Memory, and Cognition, 44(7), 1036.

Anderson, J. R. (1996). ACT: A simple theory of complex cognition. American psychologist, 51(4), 355.

Anderson, N. D., Iidaka, T., Cabeza, R., Kapur, S., McIntosh, A. R., & Craik, F. I. (2000). The effects of divided attention on encoding-and retrieval-related brain activity: A PET study of younger and older adults. Journal of cognitive neuroscience, 12(5), 775-792.

Andrzejewski, S. J., Moore, C. M., Corvette, M., & Herrmann, D. (1991). Prospective memory skill. Bulletin of the Psychonomic Society, 29, 304-306.

Atance, Cristina M., and Daniela K. O'Neill. "Episodic future thinking." Trends in cognitive sciences 5, no. 12 (2001): 533-539.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In Psychology of learning and motivation (Vol. 2, pp. 89-195). Academic Press.

Atkinson, R. C., & Wescourt, K. T. (1975). Some remarks on a theory of memory. Attention and performance V, 485-498.

Backhaus, J., & Junghanns, K. (2006). Daytime naps improve procedural motor memory. Sleep medicine, 7(6), 508-512.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? Trends in cognitive sciences, 4(11), 417-423.

Baddeley, A. D. (1997). Human memory: Theory and practice. psychology press.

Baddeley, A. D., & Hitch, G. (1974). Working memory. In Psychology of learning and motivation (Vol. 8, pp. 47-89). Academic press.

Baddeley, A. D., Scott, D., Drynan, R., & Smith, J. C. (1969). Short-term memory and the limited capacity hypothesis. British Journal of Psychology, 60(1), 51-55.

Baddeley, A., Lewis, V., Eldridge, M., & Thomson, N. (1984). Attention and retrieval from long-term memory. Journal of Experimental Psychology: General, 113(4), 518.

Baird, B., Smallwood, J., & Schooler, J. W. (2011). Back to the future: autobiographical planning and the functionality of mind-wandering. Consciousness and cognition, 20(4), 1604-1611.

Barban, F., Carlesimo, G. A., Macaluso, E., Caltagirone, C., & Costa, A. (2014). Functional interplay between stimulus-oriented and stimulus-independent attending during a prospective memory task. Neuropsychologia, 53, 203-212.

Baumeister, R. F., Vohs, K. D., & Oettingen, G. (2016). Pragmatic prospection: How and why people think about the future. Review of General Psychology, 20(1), 3-16.

Beate, E., Muehlroth., Björn, Rasch., Markus, Werkle-Bergner. (2020). Episodic memory consolidation during sleep in healthy aging. Sleep Medicine Reviews, 52:101304-. doi: 10.1016/J.SMRV.2020.101304

Bennett-Levy, J., & Powell, G. E. (1980). The Subjective Memory Questionnaire (SMQ). An investigation into the self-reporting of 'real-life'memory skills. British Journal of Social and Clinical Psychology, 19(2), 177-188.

Bennion, K. A., Payne, J. D., & Kensinger, E. A. (2016). The impact of napping on memory for future-relevant stimuli: Prioritization among multiple salience cues. Behavioral neuroscience, 130(3), 281.

Billiard, M. (2008). Normal sleep. Sleep medicine, 9-24.

Birenbaum, G. (1930). Untersuchungen zur Handlungs-und Affektpsychologie. Psychologische Forschung, 13(1), 218-284. https://doi.org/10.1007/BF00406768

Birnbaum, M. H. (2004). Human research and data collection via the Internet. Annu. Rev. Psychol., 55, 803-832.

Blake, R. R., & Fox, R. (1969). Visual form recognition threshold and the psychological refractory period. Perception & Psychophysics, 5, 46-48.

Block, R. A., & Zakay, D. (2006). Prospective remembering involves time estimation and memory processes. Timing the future: The case for a time-based prospective memory, 25-49.

Blumenfeld, R. S., & Ranganath, C. (2007). Prefrontal cortex and long-term memory encoding: an integrative review of findings from neuropsychology and neuroimaging. The Neuroscientist, 13(3), 280-291.

Boag, R. J., Strickland, L., Heathcote, A., Neal, A., & Loft, S. (2019). Cognitive control and capacity for prospective memory in complex dynamic environments. Journal of Experimental Psychology: General, 148(12), 2181.

Bonnet, M. H. (1991). The effect of varying prophylactic naps on performance, alertness and mood throughout a 52-hour continuous operation. Sleep, 14(4), 307-315.

Born, J., Rasch, B., & Gais, S. (2006). Sleep to remember. The Neuroscientist, 12(5), 410-424.

Boyce, R., Glasgow, S. D., Williams, S., & Adamantidis, A. (2016). Causal evidence for the role of REM sleep theta rhythm in contextual memory consolidation. Science, 352(6287), 812-816.

Boyce, R., Williams, S., & Adamantidis, A. (2017). REM sleep and memory. Current Opinion in Neurobiology, 44, 167-177.

Brandimonte, M. A., Einstein, G. O., & McDaniel, M. A. (Eds.). (2014). Prospective memory: Theory and applications. Psychology Press.

Brewer, G. A., & Marsh, R. L. (2010). On the role of episodic future simulation in encoding of prospective memories. Cognitive Neuroscience, 1(2), 81-88.

Brewer, G. A., Knight, J., Meeks, J. T., & Marsh, R. L. (2011). On the role of imagery in event-based prospective memory. Consciousness and cognition, 20(3), 901-907.

Brooks, A., & Lack, L. (2006). A brief afternoon nap following nocturnal sleep restriction: which nap duration is most recuperative? Sleep, 29(6), 831-840.

Brualla, J., Romero, M. F., Serrano, M., & Valdizán, J. R. (1998). Auditory event-related potentials to semantic priming during sleep. Electroencephalography and Clinical Neurophysiology/Evoked Potentials Section, 108(3), 283-290. doi: 10.1016/S0168-5597(97)00102-0.

B. Sederberg, P., F. Miller, J., W. Howard, M., & J. Kahana, M. (2010). The temporal contiguity effect predicts episodic memory performance. Memory & cognition, 38, 689-699.

Burgess, P. W., Quayle, A., & Frith, C. D. (2001). Brain regions involved in prospective memory as determined by positron emission tomography. Neuropsychologia, 39(6), 545-555.

Burgess, P. W., Veitch, E., de Lacy Costello, A., & Shallice, T. (2000). The cognitive and neuroanatomical correlates of multitasking. Neuropsychologia, 38(6), 848-863.

Burgess, P.W., Dumontheil, I., Gilbert, S.J., Okuda, J., Scholvinck, M.L., & Simons, J.S. (2008). On the role of rostral prefrontal cortex (area 10) in prospective memory. In M. Kliegel, M.A. McDaniel, & G.O. Einstein (Eds.), Prospective memory: Cognitive, neuroscience, developmental and applied perspectives (pp. 233- 258). Mahwah: Erlbaum.

BuzsÁk, G. (1998). Memory consolidation during sleep: a neurophysiological perspective. Journal of sleep research, 7(S1), 17-23.

Cajochen, C., Knoblauch, V., Wirz-Justice, A., Kräuchi, K., Graw, P., & Wallach, D. (2004). Circadian modulation of sequence learning under high and low sleep pressure conditions. Behavioural brain research, 151(1-2), 167-176.

Cantarella, G., Mastroberardino, S., Bisiacchi, P., & Macaluso, E. (2023). Prospective memory: the combined impact of cognitive load and task focality. Brain Structure and Function, 1-17.

Ceci, S. J., & Bronfenbrenner, U. (1985). " Don't forget to take the cupcakes out of the oven": prospective memory, strategic time-monitoring, and context. Child development, 152-164.

Charlesworth, L. A., Allen, R. J., Morson, S., Burn, W. K., & Souchay, C. (2014). Working memory and the enactment effect in early Alzheimer’s disease. International Scholarly Research Notices, 2014.

Chasteen, A. L., Park, D. C., & Schwarz, N. (2001). Implementation intentions and facilitation of prospective memory. Psychological Science, 12(6), 457-461.

Chee, M. W., & Chuah, L. Y. (2008). Functional neuroimaging insights into how sleep and sleep deprivation affect memory and cognition. Current opinion in neurology, 21(4), 417-423.

Chen, X. J., Wang, Y., Liu, L. L., Cui, J. F., Gan, M. Y., Shum, D. H., & Chan, R. C. (2015). The effect of implementation intention on prospective memory: A systematic and meta-analytic review. Psychiatry research, 226(1), 14-22.

Chen, Y. Z., Huang, X. T., and Yuan, H. (2010). Processing mechanisms underlying a mixed prospective memory. Acta Psychol. Sin. 32, 1034–1037. doi:10.3724/SP.J.1041.2010.01040

Chen, Y., Meng, Y., Hong, Y., and Yang, L. (2014). Neural correlates of the interference effect of a type of mixed prospective memory. J. Psychol. Sci. 37, 1073–1078. doi: 10.16719/j.cnki.1671-6981.2014.05.010

Cohen, A. L. (2013). Attentional decoupling while pursuing intentions: a form of mind wandering? Frontiers in Psychology, 4, 693.

Cohen, A. L., Dixon, R. A., & Lindsay, D. S. (2005). The intention interference effect and aging: Similar magnitude of effects for young and old adults. Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition, 19(9), 1177-1197.

Cohen, A. L., Jaudas, A., & Gollwitzer, P. M. (2008). Number of cues influences the cost of remembering to remember. Memory & cognition, 36(1), 149-156.

Cohen, A. L., Kantner, J., Dixon, R. A., & Lindsay, D. S. (2011). The intention interference effect: The difficulty of ignoring what you intend to do. Experimental Psychology, 58(6), 425.

Cohen, A., Bayer, U. C., Jaudas, A., & Gollwitzer, P. M. (2003). Implementation intentions and executive control: Task switch performance and the Simon effect. Psychological Research.

Cohen, R. L. (1983). The effect of encoding variables on the free recall of words and action events. Memory & Cognition, 11(6), 575-582.

Cole, S., & Kvavilashvili, L. (2019). Spontaneous and deliberate future thinking: a dual process account. Psychological Research, 1-16.

Cole, S., & Kvavilashvili, L. (2019). Spontaneous future cognition: The past, present and future of an emerging topic. Consolidation of strictly episodic memories mainly requires rapid eye movement sleep. Sleep. 2004 May 1; 27(3):395 - 401.

Comstock, E. M. (1973). Processing capacity in a letter-matching task. Journal of Experimental Psychology, 100(1), 63.

Cook, G. I., Marsh, R. L., & Hicks, J. L. (2005). Associating a time-based prospective memory task with an expected context can improve or impair intention completion. Applied Cognitive Psychology, 19(3), 345-360.

Craik, F. I., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In Aging and cognitive processes (pp. 191-211). Boston, MA: Springer US.

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of verbal learning and verbal behavior, 11(6), 671-684.

Craik, F. I., Eftekhari, E., & Binns, M. A. (2018). Effects of divided attention at encoding and retrieval: Further data. Memory & cognition, 46, 1263-1277.

Craik, F. I., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. Journal of Experimental Psychology: General, 125(2), 159.

Crovitz, H. F., & Daniel, W. F. (1984). Measurements of everyday memory: Toward the prevention of forgetting. Bulletin of the Psychonomic Society, 22(5), 413-414.

Cultice, J. C., Somerville, S. C., & Wellman, H. M. (1983). Preschoolers' memory monitoring: Feeling-of-knowing judgments. Child development, 1480-1486.

Cunningham, T. J., Bottary, R., Denis, D., & Payne, J. D. (2021). Sleep spectral power correlates of prospective memory maintenance. Learning & memory, 28(9), 291.

Cunningham, T. J., Pardilla-Delgado, E., & Payne, J. D. (2017). 0227 prospective memory performance negatively correlates with slow-wave sleep. Journal of Sleep and Sleep Disorders Research, 40(suppl_1), A83-A84.

D'Argembeau, A., Renaud, O., & Van der Linden, M. (2011). Frequency, characteristics and functions of future-oriented thoughts in daily life. Applied Cognitive Psychology, 25(1), 96-103.

Diekelmann, S., Wilhelm, I., Wagner, U., & Born, J. (2013). Sleep to implement an intention. Sleep, 36(1), 149-153.

Diekelmann, S., Wilhelm, I., Wagner, U., & Born, J. (2013). Sleep improves prospective remembering by facilitating spontaneous-associative retrieval processes. PloS one, 8(10), e77621.

Dinges, D. F. (1989). Napping patterns and effects in human adults. Sleep and alertness: Chronobiological, behavioral, and medical aspects of napping, 171, 204.

Dismukes, K. (2006, October). Concurrent task management and prospective memory: pilot error as a model for the vulnerability of experts. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 50, No. 9, pp. 909-913). Sage CA: Los Angeles, CA: SAGE Publications.

Dismukes, R. K. (2010). Remembrance of things future: Prospective memory in laboratory, workplace, and everyday settings. Reviews of human factors and ergonomics, 6(1), 79-122.

Dobbs, A. R., & Reeves, M. B. (1996). Prospective memory: More than memory. Prospective memory: Theory and applications, 199-225.

Dobbs, A. R., & Rule, B. G. (1987). Prospective memory and self-reports of memory abilities in older adults. Canadian Journal of Psychology/Revue canadienne de psychologie, 41(2), 209.

Dutheil, F., Danini, B., Bagheri, R., Fantini, M. L., Pereira, B., Moustafa, F., ... & Navel, V. (2021). Effects of a short daytime nap on the cognitive performance: a systematic review and meta-analysis.

International Journal of Environmental Research and Public Health, 18(19), 10212. https://doi.org/10.3390/ijerph181910212

Einstein, G. O., & McDaniel, M. A. (1990). Normal aging and prospective memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16(4), 717.

Einstein, G. O., & McDaniel, M. A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. Prospective memory: Theory and applications, 115-141.

Einstein, G. O., & McDaniel, M. A. (2005). Prospective memory: Multiple retrieval processes. Current Directions in Psychological Science, 14(6), 286-290.

Einstein, G. O., & McDaniel, M. A. (2010). Prospective memory and what costs do not reveal about retrieval processes: A commentary on Smith, Hunt, McVay, and McConnell (2007).

Einstein, G. O., Holland, L. J., McDaniel, M. A., & Guynn, M. J. (1992). Age-related deficits in prospective memory: The influence of task complexity. Psychology and aging, 7(3), 471.

Einstein, G. O., McDaniel, M. A., Manzi, M., Cochran, B., & Baker, M. (2000). Prospective memory and aging: Forgetting intentions over short delays. Psychology and aging, 15(4), 671.

Einstein, G. O., McDaniel, M. A., Richardson, S. L., Guynn, M. J., & Cunfer, A. R. (1995). Aging and prospective memory: Examining the influences of self-initiated retrieval processes. Journal of Experimental Psychology: Learning, Memory, and Cognition, 21(4), 996.

Einstein, G. O., McDaniel, M. A., Thomas, R., Mayfield, S., Shank, H., Morrisette, N., & Breneiser, J. (2005). Multiple processes in prospective memory retrieval: factors determining monitoring versus spontaneous retrieval. Journal of Experimental Psychology: General, 134(3), 327.

Einstein, G. O., Smith, R. E., McDaniel, M. A., & Shaw, P. (1997). Aging and prospective memory: the influence of increased task demands at encoding and retrieval. Psychology and aging, 12(3), 479.

Ekstrand BR, Barret TR, West JN, Maier WG. The effect of sleep on human long-term memory. In: Drucker-Colin RR, McGaugh JL, editors. Neurobiology of sleep and memory. New York: Academic Press; 1977. p. 419–38

Ellenbogen, J. M., Payne, J. D., & Stickgold, R. (2006). The role of sleep in declarative memory consolidation: passive, permissive, active or none? Current opinion in neurobiology, 16(6), 716-722.

Ellis, J. (1996). Prospective memory or the realization of delayed intentions: A conceptual framework for research. Prospective memory: Theory and applications, 1-22.

Ellis, J. A. (1988). Memory for future intentions: Investigating pulses and steps. In M. M. Gruneberg, P. E. Morris, and R. N. Sykes (Eds.), Practical aspects of memory: Current research and issues (Vol. 1, pp. 371–376). Chichester, England: Wiley.

Ellis, J.A. (1998). Prospective memory and medicine-taking. In L.B. Myers & K. Midence (Eds.), Adherence to treatment in medical conditions (pp. 113-131). London: Harwood Academic.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & psychophysics*, *16*(1), 143-149.

Fernandes, M. A., & Moscovitch, M. (2000). Divided attention and memory: evidence of substantial interference effects at retrieval and encoding. Journal of Experimental Psychology: General, 129(2), 155.

Ficca, G., & Salzarulo, P. (2004). What in sleep is for memory. Sleep medicine, 5(3), 225-230.

Ficca, G., Axelsson, J., Mollicone, D. J., Muto, V., & Vitiello, M. V. (2010). Naps, cognition, and performance. Sleep medicine reviews, 14(4), 249-258.

Fischer, S., Drosopoulos, S., Tsen, J., & Born, J. (2006). Implicit learning–explicit knowing: a role for sleep in memory system interaction. Journal of cognitive neuroscience, 18(3), 311-319

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). “Mini-mental state”: a practical method for grading the cognitive state of patients for the clinician. Journal of psychiatric research, 12(3), 189-198.

Foster, E. R., McDaniel, M. A., & Rendell, P. G. (2017). Improving prospective memory in persons with Parkinson disease: A randomized controlled trial. Neurorehabilitation and neural repair, 31(5), 451-461.

Freud, D. (1901). On the psychopathology of everyday life (forgetting, promising, failing) along with comments on the root of superstition. pp. 1–16. Monthly Journal for Psychiatry and Neurology, 10 (1), 1-16.

Gan, J., Guo, Y., & Wang, E. (2021). The Processing Mechanisms of Two Types of Mixed Prospective Memory. Frontiers in psychology, 12, 792852.

Gardiner, J. M., & Gregg, V. H. (1979). When auditory memory is not overwritten. Journal of Verbal Learning and Verbal Behavior, 18(6), 705-719.

Gardner, R. S., & Ascoli, G. A. (2015). The natural frequency of human prospective memory increases with age. Psychology and aging, 30(2), 209.

Gibson, B. S., Healey, M. K., Schor, D., & Gondoli, D. M. (2021). Space and time in the similarity structure of memory. Psychonomic Bulletin & Review, 28, 2003-2011

Gilbert, S. J. (2015). Strategic offloading of delayed intentions into the external environment. Quarterly journal of experimental psychology, 68(5), 971-992.

Gilbert, S. J., Boldt, A., Sachdeva, C., Scarampi, C., & Tsai, P. C. (2023). Outsourcing memory to external tools: A review of ‘intention offloading’. Psychonomic Bulletin & Review, 30(1), 60-76.

Gilbert, S. J., Gollwitzer, P. M., Cohen, A. L., Oettingen, G., & Burgess, P. W. (2009). Separable brain systems supporting cued versus self-initiated realization of delayed intentions. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35(4), 905.

Gillberg M, Kecklund G, Axelsson J, Åkerstedt T. The effects of a short daytime nap after restricted night sleep. Sleep 1996; 19:570–5. 47.

Godden, D. R., & Baddeley, A. D. (1975). Context-dependent memory in two natural environments: On land and underwater. British Journal of psychology, 66(3), 325-331.

Goedeken, S., Potempa, C., Prager, E. M., & Foster, E. R. (2018). Encoding strategy training and self-reported everyday prospective memory in people with Parkinson disease: A randomized-controlled trial. The Clinical Neuropsychologist, 32(7), 1282-1302.

Gollwitzer, P. M. (1999). Implementation intentions: strong effects of simple plans. American psychologist, 54(7), 493.

Gollwitzer, P. M., & Brandstätter, V. (1997). Implementation intentions and effective goal pursuit. Journal of personality and social psychology, 73(1), 186.

Gollwitzer, P. M., & Sheeran, P. (2006). Implementation intentions and goal achievement: A meta-analysis of effects and processes. Advances in experimental social psychology, 38, 69-119.

Gonen-Yaacovi, G., & Burgess, P. (2012). Prospective memory: The future for future intentions. Psychologica Belgica, 52(2-3).

Gordon, B. A., Shelton, J. T., Bugg, J. M., McDaniel, M. A., & Head, D. (2011). Structural correlates of prospective memory. Neuropsychologia, 49(14), 3795-3800.

Goschke, T., & Kuhl, J. (1993). Representation of intentions: Persisting activation in memory. Journal of Experimental Psychology: Learning, memory, and cognition, 19(5), 1211.

Goschke, T., & Kuhl, J. (1996). Remembering what to do: Explicit and implicit memory for intentions. Prospective memory: Theory and applications, 53-91.

Graf, P., & Grondin, S. (2006). Time perception and time-based prospective memory. Timing the future: The case for a time-based prospective memory, 1-24.

Graves EA. The effect of sleep upon retention. J Exp Psychol 1936;19: 316–22.

Griffith, D. (1976). The attentional demands of mnemonic control processes. Memory & Cognition, 4, 103-108.

Grondin, S. (2001). From physical time to the first and second moments of psychological time. Psychological bulletin, 127(1), 22.

Guynn, M. J. (2003). A two-process model of strategic monitoring in event-based prospective memory: Activation/retrieval mode and checking. International Journal of Psychology, 38(4), 245-256.

Guynn, M. J., & McDaniel, M. A. (2007). Target preexposure eliminates the effect of distraction on event-based prospective memory. Psychonomic Bulletin & Review, 14(3), 484-488.

Guynn, M. J., McDaniel, M. A., & Einstein, G. O. (2001). Remembering to Perform Actions. Memory for action: A distinct form of episodic memory?, 25.

Hajime, Otani., Robert, L., Widner., Robert, L., Widner., Howard, L., Whiteman., J., Paul, St., Louis. (1999). Hypermnesia: The role of multiple retrieval cues. Memory & Cognition, doi: 10.3758/BF03198545

Hannon, B., & Daneman, M. (2007). Prospective memory: The relative effects of encoding, retrieval, and the match between encoding and retrieval. Memory, 15(5), 572-604.

Harris, J. E., & Wilkins, A. J. (1982). Remembering to do things: A theoretical framework and an illustrative experiment. Human Learning, 1(2), 123-136.

Harris, R. J. (1978). The effect of jury size and judge's instructions on memory for pragmatic implications from courtroom testimony. Bulletin of the Psychonomic Society, 11(2), 129-132.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. Journal of Experimental Psychology: General, 108, 356-388.

Hayashi, M., Motoyoshi, N., & Hori, T. (2005). Recuperative power of a short daytime nap with or without stage 2 sleep. Sleep, 28(7), 829-836.

Heathcote, A., Loft, S., & Remington, R. W. (2015). Slow down and remember to remember! A delay theory of prospective memory costs. Psychological review, 122(2), 376.

Heine R.über Wiedererkennen und rückwirkende Hemmung. Leipzig, Germany: Barth, 1914.

Herrmann, D. J., & Neisser, U. (1978). An inventory of everyday memory experiences. Practical aspects of memory, 2, 35-51.

Hicks, J. L., Marsh, R. L., & Russell, E. J. (2000). The properties of retention intervals and their affect on retaining prospective memories. Journal of Experimental Psychology: Learning, Memory, and Cognition, 26(5), 1160.

Hilditch, C. J., Dorrian, J., & Banks, S. (2017). A review of short naps and sleep inertia: do naps of 30 min or less really avoid sleep inertia and slow-wave sleep?. Sleep medicine, 32, 176-190.

Hoedlmoser, K., Peigneux, P., & Rauchs, G. (2022). Recent advances in memory consolidation and information processing during sleep. Journal of sleep research, 31(4), e13607.

Holbrook, J., & Dismukes, K. (2009, October). Prospective memory in everyday tasks. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 53, No. 10, pp. 590-594). Sage CA: Los Angeles, CA: SAGE Publications.

Horner, A. J., & Burgess, N. (2013). The associative structure of memory for multi-element events. Journal of Experimental Psychology: General, 142(4), 1370.

Howard, M. W., & Kahana, M. J. (2002). When does semantic similarity help episodic retrieval? Journal of Memory and Language, 46(1), 85-98.

J. M., Payne, J. D., & Stickgold, R. (2006). The role of sleep in declarative memory consolidation: passive, permissive, active or none? Current opinion in neurobiology, 16(6), 716-722.

Jacoby, L. L. (1974). The role of mental contiguity in memory: Registration and retrieval effects. Journal of Verbal Learning and Verbal Behavior, 13(5), 483-496.

Jenkins, J. G., & Dallenbach, K. M. (1924). Obliviscence during sleep and waking. The American Journal of Psychology, 35(4), 605-612.

Johns, M. W. (2000). Sensitivity and specificity of the multiple sleep latency test (MSLT), the maintenance of wakefulness test and the Epworth sleepiness scale: failure of the MSLT as a gold standard. Journal of sleep research, 9(1), 5-11.

Johnston, W. A., Greenberg, S. N., Fisher, R. P., & Martin, D. W. (1970). Divided attention: a vehicle for monitoring memory processes. Journal of Experimental Psychology, 83(1p1), 164.

Johnston, W. A., Griffith, D., & Wagstaff, R. R. (1972). Speed, accuracy, and ease of recall. Journal of Verbal Learning and Verbal Behavior, 11(4), 512-520.

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. Psychological science, 18(7), 614-621.

Kane, M. J., Gross, G. M., Chun, C. A., Smeekens, B. A., Meier, M. E., Silvia, P. J., & Kwapil, T. R. (2017). For whom the mind wanders, and when, varies across laboratory and daily-life settings. Psychological science, 28(9), 1271-1289.

Kanfer, R., & Ackerman, P. L. (1989). Motivation and cognitive abilities: An integrative/aptitude-treatment interaction approach to skill acquisition. Journal of applied psychology, 74(4), 657.

Kapur, S., Craik, F. I., Tulving, E., Wilson, A. A., Houle, S., & Brown, G. M. (1994). Neuroanatomical correlates of encoding in episodic memory: levels of processing effect. Proceedings of the National Academy of Sciences, 91(6), 2008-2011.

Kardiasmenos, K. S., Clawson, D. M., Wilken, J. A., & Wallin, M. T. (2008). Prospective memory and the efficacy of a memory strategy in multiple sclerosis. Neuropsychology, 22(6), 746.

Kidder, D. P., Park, D. C., Hertzog, C., & Morrell, R. W. (1997). Prospective memory and aging: The effects of working memory and prospective memory task load. Aging, Neuropsychology, and Cognition, 4(2), 93-112.

Kliegel, M., Martin, M., McDaniel, M. A., & Einstein, G. O. (2001). Varying the importance of a prospective memory task: Differential effects across time-and event-based prospective memory. Memory, 9(1), 1-11.

Kliegel, M., Martin, M., McDaniel, M. A., Einstein, G. O., & Moor, C. (2007). Realizing complex delayed intentions in young and old adults: The role of planning aids. Memory & Cognition, 35(7), 1735-1746.

Kliegel, M., McDaniel, M. A., & Einstein, G. O. (2000). Plan formation, retention, and execution in prospective memory: A new approach and age-related effects. Memory & cognition, 28(6), 1041-1049.

Klinger, E., Gregoire, K. C., & Barta, S. G. (1973). Physiological correlates of mental activity: Eye movements, alpha, and heart rate during imagining, suppression, concentration, search, and choice. Psychophysiology, 10(5), 471-477.

Klinzing, J. G., Niethard, N., & Born, J. (2019). Mechanisms of systems memory consolidation during sleep. Nature neuroscience, 22(10), 1598-1610.

Knight, J. B., Brewer, G. A., Ball, B. H., DeWitt, M. R., & Marsh, R. L. (2015). The influence of mood on the process and content of encoding future intentions. Quarterly Journal of Experimental Psychology, 68(6), 1082-1100.

Kopasz, M., Loessl, B., Hornyak, M., Riemann, D., Nissen, C., Piosczyk, H., & Voderholzer, U. (2010). Sleep and memory in healthy children and adolescents–a critical review. Sleep medicine reviews, 14(3), 167-177

Kuhl, J. (1984). Volitional aspects of achievement motivation and learned helplessness: Toward a comprehensive theory of action control. In Progress in experimental personality research (Vol. 13, pp. 99-171). Elsevier.

Kuhlmann, B. G., & Rummel, J. (2014). Context-specific prospective-memory processing: Evidence for flexible attention allocation adjustments after intention encoding. Memory & Cognition, 42(6), 943-949.

Kvavilashvili, L. (1987). Remembering intention as a distinct form of memory. British journal of psychology, 78(4), 507-518.

Kvavilashvili, L. (1992). Remembering intentions: A critical review of existing experimental paradigms. Applied Cognitive Psychology, 6(6), 507-524.

Kvavilashvili, L., & Ellis, J. (1996). Varieties of intention: Some distinctions and classifications. Prospective memory: Theory and applications, 6, 183-207.

Kvavilashvili, L., & Fisher, L. (2007). Is time-based prospective remembering mediated by self-initiated rehearsals? Role of incidental cues, ongoing activity, age, and motivation. Journal of Experimental Psychology: General, 136(1), 112.

Lange, K., Kühn, S., & Filevich, E. (2015). " Just another tool for online studies” (JATOS): An easy solution for setup and management of web servers supporting online studies. PloS one, 10(6), e0130834.

Lau, H.; Tucker, M.A.; Fishbein, W. Daytime Napping: Effects on Human Direct Associative and Relational Memory. Neurobiol. Learn Mem. 2010, 93, 554–560

Leong, R. L., Cheng, G. H. L., Chee, M. W., & Lo, J. C. (2019). The effects of sleep on prospective memory: A systematic review and meta-analysis. Sleep Medicine Reviews, 47, 18-27.

Levy, R., & Loftus, G. (1984). Everyday memory, actions, and absent-mindedness.

Lewin, K. (1951). Intention, will and need. In D. Rapaport, Organization and pathology of thought: Selected sources (pp. 95–153). Columbia University Press. https://doi.org/10.1037/10584-005

Li, G., & Wang, L. (2015). The effects of encoding modality and object presence on event-based prospective memory in seven-to nine-year-old children. Journal of Cognitive Psychology, 27(6), 725-738

Li, G., Li, M., Wang, J., Yu, Z., Ma, H., & Li, B. (2022). The effects of cognitive load and encoding modality on prospective memory. Cognitive Processing, 23(3), 441-448.

Liu, X., & Hou, S. (2020, December). Effects of VR on Users' Speaking Performance and Cognitive Load: Design of VR-assisted English-Speaking Application on Mobile Phones. In 2020 International Conference on Intelligent Design (ICID) (pp. 128-131). IEEE.

Lo, J. C., Dijk, D. J., & Groeger, J. A. (2014). Comparing the effects of nocturnal sleep and daytime napping on declarative memory consolidation. PLoS One, 9(9), e108100.

Lockhart, R. S., & Craik, F. I. (1990). Levels of processing: A retrospective commentary on a framework for memory research. Canadian Journal of Psychology/Revue canadienne de psychologie, 44(1), 87.

Loft, S., & Remington, R. W. (2013). Wait a second: Brief delays in responding reduce focality effects in event-based prospective memory. Quarterly Journal of Experimental Psychology, 66(7), 1432-1447.

Loft, S., & Yeo, G. (2007). An investigation into the resource requirements of event-based prospective memory. Memory & Cognition, 35, 263-274.

Loftus, E. F. (1971). Memory for intentions: The effect of presence of a cue and interpolated activity. Psychonomic Science, 23(4), 315-316.

Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. M. M. A. N. U. E. L. (2009). The perils of multitasking. AeroSafety World, 4(8), 18-23.

Lovatt, D. J., & Warr, P. B. (1968). Recall after sleep. The American journal of psychology, 81(2), 253-257.

Maeder, P. P., Meuli, R. A., Adriani, M., Bellmann, A., Fornari, E., Thiran, J. P., ... & Clarke, S. (2001). Distinct pathways involved in sound recognition and localization: a human fMRI study. Neuroimage, 14(4), 802-816.'

Mahler, W. (1996). In memory of my teacher, Kurt Lewin. Psychologie und Geschichte, 7(3).

Mammarella, N., & Fairfield, B. (2008). Source monitoring: The importance of feature binding at encoding. European Journal of Cognitive Psychology, 20(1), 91-122.

Marsh, R. L., & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 24(2), 336.

Marsh, R. L., Cook, G. I., & Hicks, J. L. (2006). An analysis of prospective memory. Psychology of learning and motivation, 46, 115-153.

Marsh, R. L., Cook, G. I., & Hicks, J. L. (2006). The effect of context variability on source memory. Memory & Cognition, 34, 1578-1586.

Marsh, R. L., Cook, G. I., Meeks, J. T., Clark-Foos, A., & Hicks, J. L. (2007). Memory for intention-related material presented in a to-be-ignored channel. Memory & Cognition, 35, 1197-1204.

Marsh, R. L., Hicks, J. L., & Bink, M. L. (1998). Activation of completed, uncompleted, and partially completed intentions. Journal of Experimental Psychology: Learning, Memory, and Cognition, 24(2), 350.

Marsh, R. L., Hicks, J. L., & Bryan, E. S. (1999). The activation of unrelated and canceled intentions. Memory & Cognition, 27(2), 320-327.

Marsh, R. L., Hicks, J. L., & Cook, G. I. (2005). On the relationship between effort toward an ongoing task and cue detection in event-based prospective memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 31(1), 68.

Marsh, R. L., Hicks, J. L., & Cook, G. I. (2006). Task interference from prospective memories covaries with contextual associations of fulfilling them. Memory & cognition, 34, 1037-1045.

Marsh, R. L., Hicks, J. L., & Cook, G. I. (2008). On beginning to understand the role of context in prospective memory.

Marsh, R. L., Hicks, J. L., & Landau, J. D. (1998). An investigation of everyday prospective memory. Memory & cognition, 26(4), 633-643.

Marsh, R. L., Hicks, J. L., Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. Journal of Experimental Psychology: Learning, Memory, and Cognition, 29(5), 861.

Massaro, D. W., Weldon, M. S., & Kitzis, S. N. (1991). Integration of orthographic and semantic information in memory retrieval. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17(2), 277.

Masson, M. E., & McDaniel, M. A. (1981). The role of organizational processes in long-term retention. Journal of Experimental Psychology: Human Learning and Memory, 7(2), 100.

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. Behavior research methods, 44, 314-324.

Matos, P., Santos, F. H., & Albuquerque, P. B. (2020). When we must forget: The effect of cognitive load on prospective memory commission errors. Memory, 28(3), 374-385.

Maylor, E. A. (1990). Age and prospective memory. The Quarterly Journal of Experimental Psychology Section A, 42(3), 471-493.

Maylor, E. A., Smith, G., Sala, S. D., & Logie, R. H. (2002). Prospective and retrospective memory in normal aging and dementia: An experimental study. Memory & Cognition, 30(6), 871-884.

Mazzoni, G. (2019). Involuntary memories and involuntary future thinking differently tax cognitive resources. Psychological research, 83(4), 684-697.

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition, 14(7), S127-S144.

McDaniel, M. A., & Einstein, G. O. (2007). Prospective memory: An overview and synthesis of an emerging field. Sage Publications.

McDaniel, M. A., & Scullin, M. K. (2010). Implementation intention encoding does not automatize prospective memory responding. Memory & cognition, 38, 221-232.

McDaniel, M. A., Einstein, G. O., & Rendell, P. G. (2008). The puzzle of inconsistent age-related declines in prospective memory: A multiprocess explanation. In Meeting of the Psychonomic Society, Toronto, ON, Canada; These experiments were reported in part at the 2005 and 2006 Meetings of the Psychonomic Society, Toronto, Canada and Houston, Texas, respectively. Taylor & Francis Group/Lawrence Erlbaum Associates.

McDaniel, M. A., Guynn, M. J., Einstein, G. O., & Breneiser, J. (2004). Cue-focused and reflexive-associative processes in prospective memory retrieval. Journal of Experimental Psychology: Learning, Memory, and Cognition, 30(3), 605.

McDaniel, M. A., Howard, D. C., & Butler, K. M. (2008). Implementation intentions facilitate prospective memory under high attention demands. Memory & Cognition, 36(4), 716-724.

McDaniel, M. A., LaMontagne, P., Beck, S. M., Scullin, M. K., & Braver, T. S. (2013). Dissociable neural routes to successful prospective memory. Psychological science, 24(9), 1791-1800.

McDaniel, M. A., Robinson-Riegler, B., & Einstein, G. O. (1998). Prospective remembering: Perceptually driven or conceptually driven processes? Memory & cognition, 26(1), 121-134.

McDaniel, M. A., Umanath, S., Einstein, G. O., & Waldum, E. R. (2015). Dual pathways to prospective remembering. Frontiers in human neuroscience, 9, 392.

Mcgann, D., Ellis, J. A., & Milne, A. (2002). Conceptual and perceptual processes in prospective remembering: Differential influence of attentional resources. Memory & cognition, 30(7), 1021-1032.

McGaugh, J. L. (2000). Memory--a century of consolidation. Science, 287(5451), 248-251.

McGeoch, J. A. (1932). Forgetting and the Law of Disuse. Psychological review, 39(4), 352.

McLeod, P. D., Williams, C. E., & Broadbent, D. E. (1971). Free recall with assistance from one and from two retrieval cues. British Journal of Psychology, 62(1), 59-65.

McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: working memory capacity, goal neglect, and mind wandering in an executive-control task. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35(1), 196.

McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008).

McVay, J. C., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. Journal of experimental psychology: general, 141(2), 302.

Meacham, J. A. (1982). A note on remembering to execute planned actions. Journal of Applied Developmental Psychology, 3(2), 121-133.

Meacham, J. A. 3., & Colombo, J. A. (1980). External retrieved cues facilitate prospective remembering in children. The Journal of Educational Research, 73(5), 299-301.

Meacham, J. A., & Kushner, S. (1980). Anxiety, prospective remembering, and performance of planned actions. The Journal of General Psychology, 103(2), 203-209.

Meacham, J. A., & Singer, J. (1977). Incentive effects in prospective remembering. The Journal of Psychology, 97(2), 191-197.

Meacham, J.A., & Leiman, B. (1975). Remembering to perform future actions. In U. Neisser (Ed.), Memory observed: Remembering in natural contexts (pp. 327- 336). San Francisco: Freeman.

Meeks, J. T., & Marsh, R. L. (2010). Implementation intentions about nonfocal event-based prospective memory tasks. Psychological Research PRPF, 74(1), 82-89.

Meier, B., & Graf, P. (2000). Transfer appropriate processing for prospective memory tests. Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition, 14(7), S11-S27.

Meier, B., & Rey-Mermet, A. (2012). Beyond feature binding: Interference from episodic context binding creates the bivalency effect in task-switching. Frontiers in Psychology, 3, 386.

Meier, B., & Rey-Mermet, A. (2012). Beyond monitoring: After-effects of responding to prospective memory targets. Consciousness and cognition, 21(4), 1644-1653.

Meier, B., & Rey-Mermet, A. (2018). After-effects without monitoring costs: The impact of prospective memory instructions on task switching performance. Acta Psychologica, 184, 85-99.

Meier, B., & Zimmermann, T. D. (2015). Loads and loads and loads: the influence of prospective load, retrospective load, and ongoing task load in prospective memory. Frontiers in human neuroscience, 9, 322.

Meier, B., Zimmermann, T. D., & Perrig, W. J. (2006). Retrieval experience in prospective memory: Strategic monitoring and spontaneous retrieval. Memory, 14(7), 872-889.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological review, 63(2), 81.

Miller, G. A., Galanter, E., & Pribram, K. H. (1960). Plans and the Structure of Behavior.

Miller, G. A., Galanter, E., & Pribram, K. H. (1960). The integration of plans.

Milne, S., Orbell, S., & Sheeran, P. (2002). Combining motivational and volitional interventions to promote exercise participation: Protection motivation theory and implementation intentions. British journal of health psychology, 7(2), 163-184.

Milner, C. E., & Cote, K. A. (2008). A dose-response investigation of the benefits of napping in healthy young, middle-aged and older adults. Sleep and Biological Rhythms, 6, 2-15.

Morris, P. E., & Cook, N. (1978). When do first letter mnemonics aid recall? British Journal of Educational Psychology, 48(1), 22-28.

Moscovitch, M. (1982). A neuropsychological approach to perception and memory in normal and pathological aging. In Aging and cognitive processes (pp. 55-78). Boston, MA: Springer US.

Moscovitch, M. (1994). Cognitive resources and dual-task interference effects at retrieval in normal people: the role of the frontal lobes and medial temporal cortex. Neuropsychology, 8(4), 524.

Moyes, J., Sari-Sarraf, N., & Gilbert, S. J. (2019). Characterising monitoring processes in event-based prospective memory: Evidence from pupillometry. Cognition, 184, 83-95.

Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. Psychological science, 24(5), 776-781.

Müller, GE, & Pilzecker, A. (1900). Experimental contributions to the theory of memory (Vol. 1). YES Barth.

Mullet, H. G., Scullin, M. K., Hess, T. J., Scullin, R. B., Arnold, K. M., & Einstein, G. O. (2013). Prospective memory and aging: Evidence for preserved spontaneous retrieval with exact but not related cues. Psychology and Aging, 28(4), 910.

Murdock Jr, B. B. (1965). Effects of a subsidiary task on short-term memory. British Journal of Psychology, 56(4), 413-419.

Murdock Jr, B. B., & Walker, K. D. (1969). Modality effects in free recall. Journal of Verbal Learning and Verbal Behavior, 8(5), 665-676.

Naveh-Benjamin, M. (1987). Coding of spatial location information: An automatic process?. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13(4), 595.

Naveh-Benjamin, M. (1990). Coding of temporal order information: An automatic process? Journal of Experimental Psychology: Learning, Memory and Cognition, 16, 117±126.

Naveh-Benjamin, M., Craik, F. I., Gavrilescu, D., & Anderson, N. D. (2000). Asymmetry between encoding and retrieval processes: Evidence from divided attention and a calibration analysis. Memory & Cognition, 28(6), 965-976.

Naveh-Benjamin, M., Craik, F.I.M., Guez, J., & Dori, H. (1998). The effects of divided attention on encoding and retrieval processes in human memory: Further support for an asymmetry. Journal of Experimental Psychology: Learning, Memory and Cognition, 24, 1091±1104.

Navon, D., & Gopher, D. (1979). On the economy of the human-processing system. Psychological review, 86(3), 214.

Newell, A., Shaw, J. C., & Simon, H. A. (1958). Elements of a theory of human problem solving. Psychological review, 65(3), 151.

Nobel, P. A., & Shiffrin, R. M. (2001). Retrieval processes in recognition and cued recall. Journal of Experimental Psychology: Learning, Memory, and Cognition, 27(2), 384.

Norman, D. A., & Bobrow, D. G. (1976). On the analysis of performance operating characteristics. Psychological Review, 83(6), 508.

Norman, D. A., & Bobrow, D. G. (1979). Descriptions: An intermediate stage in memory retrieval. Cognitive Psychology, 11(1), 107-123.

Nowinski, J. L., & Dismukes, K. (2005). Effects of ongoing task context and target typicality on prospective memory performance: The importance of associative cueing. Memory, 13(6), 649-657.

Otani, H., Landau, J. D., Libkuman, T. M., Louis, J. P. S., Kazen, J. K., & Throne, G. W. (1997). Prospective memory and divided attention. Memory, 5(3), 343-360.

Park, D. C., Hertzog, C., Kidder, D. P., Morrell, R. W., & Mayhorn, C. B. (1997). Effect of age on event-based and time-based prospective memory. Psychology and aging, 12(2), 314.

Pashler, H. (1993). Doing two things at the same time. American Scientist, 81(1), 48-55.

Passolunghi, M. C., Brandimonte, M. A., & Cornoldi, C. (1995). Encoding modality and prospective memory in children. International Journal of Behavioral Development, 18(4), 631-648.

Patrick GT, Gilbert JA. On the effects of loss of sleep. Psychol Rev 1896;3:469–83

Payne, J. D., Kensinger, E. A., Wamsley, E. J., Spreng, R. N., Alger, S. E., Gibler, K., & Stickgold, R. (2015). Napping and the selective consolidation of negative aspects of scenes. Emotion, 15(2), 176.

Payne, J. D., Stickgold, R., Swanberg, K., & Kensinger, E. A. (2008). Sleep preferentially enhances memory for emotional components of scenes. Psychological science, 19(8), 781-788.

Pearson, H. C., & Wilbiks, J. M. (2021). Effects of audiovisual memory cues on working memory recall. Vision, 5(1), 14.

Peigneux, P. (2015). Neuroimaging studies of sleep and memory in humans. Sleep, Neuronal Plasticity and Brain Function, 239-268.

Peigneux, P., Laureys, S., Delbeuck, X., & Maquet, P. (2001). Sleeping brain, learning brain. The role of sleep for memory systems. Neuroreport, 12(18), A111-A124.

Peper, P., & Hunter Ball, B. (2022). Strategic monitoring improves prospective memory: A meta-analysis. Quarterly Journal of Experimental Psychology, 17470218231161015.

Pereira, A., de Mendonca, A., Silva, D., Guerreiro, M., Freeman, J., & Ellis, J. (2015). Enhancing prospective memory in mild cognitive impairment: The role of enactment. Journal of Clinical and Experimental Neuropsychology, 37(8), 863-877.

Pereira, A., Ellis, J., & Freeman, J. (2012). Is prospective memory enhanced by cue-action semantic relatedness and enactment at encoding? Consciousness and Cognition, 21(3), 1257-1266.

Plihal, W., & Born, J. (1997). Effects of early and late nocturnal sleep on declarative and procedural memory. Journal of cognitive neuroscience, 9(4), 534-547.

Plimpton, B., Patel, P., & Kvavilashvili, L. (2015). Role of triggers and dysphoria in mind-wandering about past, present and future: A laboratory study. Consciousness and Cognition, 33, 261-276.

Posner, M. I., & Boies, S. J. (1971). Components of attention. Psychological review, 78(5), 391.

Rabinowitz, J. C., Ackerman, B. P., Craik, F. I., & Hinchley, J. L. (1982). Aging and metamemory: The roles of relatedness and imagery. Journal of Gerontology, 37(6), 688-695.

Randall, J. G., Oswald, F. L., & Beier, M. E. (2014). Mind-wandering, cognition, and performance: a theory-driven meta-analysis of attention regulation. Psychological bulletin, 140(6), 1411.

Rasch, B., & Born, J. (2013). About sleep's role in memory. Physiological reviews.

Rasch, B., Büchel, C., Gais, S., & Born, J. (2007). Odor cues during slow-wave sleep prompt declarative memory consolidation. Science, 315(5817), 1426-1429.

Ratcliff, R. (1978). A theory of memory retrieval. Psychological review, 85(2), 59.

Rauchs, G., Bertran, F., Guillery-Girard, B., Desgranges, B., Kerrouche, N., Denise, P., ... & Eustache, F. (2004). Consolidation of strictly episodic memories mainly requires rapid eye movement sleep. Sleep, 27(3), 395-401.

Rehel, S., Legrand, N., Lecouvey, G., Laniepce, A., Bertran, F., Fleury, P., ... & Rauchs, G. (2019). Effects of sleep and age on prospective memory consolidation: a walk in a virtual museum. Clocks & Sleep, 1(3), 332-351.

Risko, E. F., & Gilbert, S. J. (2016). Cognitive offloading. Trends in cognitive sciences, 20(9), 676-688.

Robinson, M. B. (1992). Contextual effects in prospective memory. Unpublished master's thesis, Purdue University.

Roediger III, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. Psychological science, 17(3), 249-255.

Ross, B. H., & Anderson, J. R. (1981). A test of parallel versus serial processing applied to memory retrieval. Journal of Mathematical Psychology, 24(3), 183-223.

Rummel, J., & Boywitt, C. D. (2014). Controlling the stream of thought: Working memory capacity predicts adjustment of mind-wandering to situational demands. Psychonomic bulletin & review, 21(5), 1309-1315.

Rummel, J., & Kvavilashvili, L. (2019). Take the field!: Investigating prospective memory in naturalistic and real-life settings. Prospective memory, 157-169.

Rummel, J., & Kvavilashvili, L. (2023). Current theories of prospective memory and new directions for theory development. Nature Reviews Psychology, 2(1), 40-54.

Sarode, D. P., Mathie, I. D., Gao, N. P., Gray, L. I., Monaghan, I. J., Preston, A. P., ... & Watters, M. (2013). A Sleep to Remember: The Effects of Sleep on Memory. Res Medica, 21(1), 23-34.

Schacter, D. L. (1987). Implicit memory: History and current status. Journal of experimental psychology: learning, memory, and cognition, 13(3), 501.

Schechtman, E., Heilberg, J., & Paller, K. A. (2023). Context matters: Changes in memory over a period of sleep are driven by encoding context. Learning & memory, 30(2), 36-42.

Schnitzspahn, K. M., & Kliegel, M. (2009). Age effects in prospective memory performance within older adults: The paradoxical impact of implementation intentions. European Journal of Ageing, 6, 147-155.

Schooler, J. W., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. Trends in cognitive sciences, 15(7), 319-326.

Schulz, H. (2008). Rethinking sleep analysis: Comment on the AASM manual for the scoring of sleep and associated events. Journal of Clinical Sleep Medicine, 4(2), 99-103.

Scullin, M. K., Fairley, J., Decker, M. J., & Bliwise, D. L. (2017). The effects of an afternoon nap on episodic memory in young and older adults. Sleep, 40(5), zsx035.

Scullin, M. K., McDaniel, M. A., & Einstein, G. O. (2010). Control of cost in prospective memory: Evidence for spontaneous retrieval processes. Journal of Experimental Psychology: Learning, Memory, and Cognition, 36(1), 190.

Scullin, M. K., McDaniel, M. A., & Shelton, J. T. (2013). The Dynamic Multiprocess Framework: Evidence from prospective memory with contextual variability. Cognitive psychology, 67(1-2), 55-71.

Seli, P., Risko, E. F., Smilek, D., & Schacter, D. L. (2016). Mind-wandering with and without intention. Trends in cognitive sciences, 20(8), 605-617.

Sellen, A. J., Louie, G., Harris, J. E., & Wilkins, A. J. (1997). What brings intentions to mind? An in situ study of prospective memory. Memory, 5(4), 483-507.

Shallice, T., Fletcher, P., Frith, C. D., Grasby, P., Frackowiak, R. S., & Dolan, R. J. (1994). Brain regions associated with acquisition and retrieval of verbal episodic memory. Nature, 368(6472), 633-635.

Sheeran, P., & Orbell, S. (1999). Implementation intentions and repeated behaviour: Augmenting the predictive validity of the theory of planned behaviour. European journal of social psychology, 29(2-3), 349-369.

Shelton, J. T., & Scullin, M. K. (2017). The dynamic interplay between bottom-up and top-down processes supporting prospective remembering. Current Directions in Psychological Science, 26(4), 352-358.

Siu, D., & Graf, P. (2005). Plans for success: Improving prospective memory task performance. In 2nd International Conference on Prospective Memory, Zurich, Switzerland.

Smallwood, J. (2013). Distinguishing how from why the mind wanders: a process–occurrence framework for self-generated mental activity. Psychological bulletin, 139(3), 519.

Smallwood, J., & Schooler, J. W. (2006). The restless mind. Psychological bulletin, 132(6), 946.

Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: empirically navigating the stream of consciousness. Annual review of psychology, 66, 487-518.

Smallwood, J., Brown, K., Baird, B., & Schooler, J. W. (2012). Cooperation between the default mode network and the frontal–parietal network in the production of an internal train of thought. Brain research, 1428, 60-70.

Smeekens, B. A., & Kane, M. J. (2016). Working memory capacity, mind wandering, and creative cognition: An individual-differences investigation into the benefits of controlled versus spontaneous thought. Psychology of Aesthetics, Creativity, and the Arts, 10(4), 389.

Smith, G., Del Sala, S., Logie, R. H., & Maylor, E. A. (2000). Prospective and retrospective memory in normal ageing and dementia: A questionnaire study. Memory, 8(5), 311-321.

Smith, R. E. (2003). The cost of remembering to remember in event-based prospective memory: investigating the capacity demands of delayed intention performance. Journal of Experimental Psychology: Learning, Memory, and Cognition, 29(3), 347.

Smith, R. E., & Bayen, U. J. (2004). A multinomial model of event-based prospective memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 30(4), 756.

Smith, R. E., & Skinner, D. J. (2019). Prospective memory in context: Methods, findings, and future directions. In Prospective Memory (pp. 27-43). Routledge.

Smith, R. E., Bayen, U. J., & Martin, C. (2010). The cognitive processes underlying event-based prospective memory in school-age children and young adults: a formal model-based study. Developmental Psychology, 46(1), 230.

Smith, R. E., Hunt, R. R., McVay, J. C., & McConnell, M. D. (2007). The cost of event-based prospective memory: Salient target events. Journal of Experimental Psychology: Learning, Memory, and Cognition, 33(4), 734.

Smith, S. M., Glenberg, A., & Bjork, R. A. (1978). Environmental context and human memory. Memory & Cognition, 6(4), 342-353.

Song, G., Huangfu, E., & Miao, D. (2002). Effects of naps during sleep deprivation on symbols recognizing task and P300. Chinese Mental Health Journal.

Squire, L. R., Knowlton, B., & Musen, G. (1993). The structure and organization of memory. Annual review of psychology, 44(1), 453-495.

Stawarczyk, D. (2018). Phenomenological Properties of Mind-Wandering and Daydreaming: A Historical Overview and Functional. The Oxford handbook of spontaneous thought: Mind-wandering, creativity, and dreaming, 193.

Stawarczyk, D., Cassol, H., & D'Argembeau, A. (2013). Phenomenology of future-oriented mind-wandering episodes. Frontiers in Psychology, 4, 425.

Stawarczyk, D., Majerus, S., Maj, M., Van der Linden, M., & D'Argembeau, A. (2011). Mind-wandering: Phenomenology and function as assessed with a novel experience sampling method. Acta psychologica, 136(3), 370-381.

Stone, M., Dismukes, K., & Remington, R. (2001). Prospective memory in dynamic environments: Effects of load, delay, and phonological rehearsal. Memory, 9(3), 165-176.

Strong Jr, E. K. (1912). The effect of length of series upon recognition memory. Psychological Review, 19(6), 447.

Sugawara, S. K., Koike, T., Kawamichi, H., Makita, K., Hamano, Y. H., Takahashi, H. K., ... & Sadato, N. (2018). Qualitative differences in offline improvement of procedural memory by daytime napping and overnight sleep: An fMRI study. Neuroscience Research, 132, 37-45.

Sun, R., Merrill, E., & Peterson, T. (2001). From implicit skills to explicit knowledge: A bottom-up model of skill learning. Cognitive science, 25(2), 203-244.

Svoboda, E., Rowe, G., & Murphy, K. (2012). From science to smartphones: Boosting memory function one press at a time. Journal of Current Clinical Care, 2(4), 15-27.

Terry, W. S. (1984). A'forgetting journal'for memory courses. Teaching of Psychology, 11(2), 111-112.

Thorndike, E. L. (1913). Educational Psychology. (Vol. 2). Teachers college, Columbia university.

Tilley AJ, Brown S, Donald M, et al. Human sleep and memory processes. In: Broughton RJ, Ogilvie R, editors. Sleep, arousal and performance. Boston: Birkhauser; 1992. p. 117–26

Tulving, E. (1972). 12. Episodic and Semantic Memory. Organization of memory/Eds E. Tulving, W. Donaldson, NY: Academic Press, 381-403.

Tulving, E. (1985). Memory and consciousness. Canadian Psychology/Psychologie canadienne, 26(1), 1.

Tulving, E. (2002). Episodic memory: From mind to brain. Annual review of psychology, 53(1), 1-25.

Tulving, E., & Osler, S. (1968). Effectiveness of retrieval cues in memory for words. Journal of experimental psychology, 77(4), 593.

Underwood, B. J. (1969). Attributes of memory. Psychological Review, 76(6), 559.

Vallat-Azouvi, C., Pradat-Diehl, P., & Azouvi, P. (2012). The Working Memory Questionnaire: A scale to assess everyday life problems related to deficits of working memory in brain injured patients. Neuropsychological rehabilitation, 22(4), 634-649.

Vedhara, K., Wadsworth, E., Norman, P., Searle, A., Mitchell, J., Macrae, N., ... & Memel, D. (2004). Habitual prospective memory in elderly patients with Type 2 diabetes: implications for medication adherence. Psychology, Health & Medicine, 9(1), 17-27.

Walter, S., & Meier, B. (2014). How important is importance for prospective memory? A review. Frontiers in psychology, 5, 657.

Warden, E. A., Plimpton, B., & Kvavilashvili, L. (2019). Absence of age effects on spontaneous past and future thinking in daily life. Psychological Research, 83(4), 727-746.

Waugh, N. C., & Norman, D. A. (1965). Primary memory. Psychological review, 72(2), 89.

Webb, T. L., & Sheeran, P. (2003). Can implementation intentions help to overcome ego-depletion? Journal of Experimental Social Psychology, 39(3), 279-286.

Weinstein, Y., De Lima, H. J., & Van Der Zee, T. (2018). Are you mind-wandering, or is your mind on task? The effect of probe framing on mind-wandering reports. Psychonomic Bulletin & Review, 25(2), 754-760.

Wesslein, A. K., Rummel, J., & Boywitt, C. D. (2014). Differential effects of cue specificity and list length on the prospective and retrospective prospective-memory components. Journal of Cognitive Psychology, 26(2), 135-146.

West, R., & Craik, F. I. (1999). Age-related decline in prospective memory: The roles of cue accessibility and cue sensitivity. Psychology and aging, 14(2), 264.

Wieber, F., Von Suchodoletz, A., Heikamp, T., Trommsdorff, G., & Gollwitzer, P. M. (2011). If-then planning helps school-aged children to ignore attractive distractions. Social Psychology.

Wilkins, A. J., & Baddeley, A. D. (1978). Remembering to recall in everyday life: An approach to absentmindedness. Practical aspects of memory, 1, 27-34.

Wixted, J. T. (2004). The psychology and neuroscience of forgetting. Annu. Rev. Psychol., 55, 235-269.

Won, B. Y., & Jiang, Y. V. (2013). Redundancy effects in the processing of emotional faces. Vision Research, 78, 6-13.

Yan, C. C., Li, L., Wang, Z., Yin, J., Shi, H., Jiang, S., & Huang, Q. (2014). Fusing multi-cues description for partial-duplicate image retrieval. Journal of Visual Communication and Image Representation, 25(7), 1726-1731

Zimmermann, T. D., & Meier, B. (2010). The effect of implementation intentions on prospective memory performance across the lifespan. Applied Cognitive Psychology, 24(5), 645-658.

# Appendices

## Appendix A

# Questionnaires used in the Study

## INFORMED CONSENT FORM

We invite you to take part in a research study at the Sleep and Cognition Laboratory, IIT Guwahati. The purpose of this research is to analyze the memory performance and is being conducted by Ms. Pallavi Ojha at the Department of HSS, Research Scholar, under the guidance of Dr Naveen Kashyap, Associate Professor, HSS Department IITG.

**Information to the Participants**

The experiment is a behavioral and nap study to investigate the effect of encoding variables on prospective memory performance. Your participation will involve spending a designated period in a controlled laboratory environment where various aspects of your sleep patterns and cognitive function will be monitored and assessed. The study will include the recording of sleep patterns, cognitive tests, and potentially the administration of specific sleep-related interventions.

**Risks and Benefits:**

There may be minimal risks associated with participating in this study, including potential discomfort from wearing monitoring devices during nap. However, the information gathered from this study may contribute to a better understanding of the relationship between nap and memory performance, potentially leading to advancements in the field of nap research and the development of interventions for improving nap quality and cognitive function.

**Voluntary Participation and Withdrawal:**

Participation in this study is entirely voluntary, and you have the right to withdraw at any time without consequence. Withdrawing from the study will not result in any penalties or loss of benefits. If you choose to withdraw, any data collected up to that point will be anonymized and included in the study analysis unless you request otherwise.

**Undertaking by the investigator**

You are requested to participate in the above mentioned study and your consent for the same is sought. The results obtained from the study would be kept confidential. Data collected will be used for research purposes only and will be stored in a secure database.
If you have any doubts about the study, please feel free to clarify the same. You are free to contact the investigator and guide, for any further clarification or assistance if you need.

**Consent**

"I have been informed about the procedure used in the study. I understand that the information I provide will be kept strictly confidential, data will not identify me in any way and if needed. I have been informed that I will not receive any direct benefit for participating in this study and that I have the right to refuse my consent or withdraw it any time during the study without giving any reason. I
am aware that by participating in this study, I will have to give time to investigator for assessment."

I ________________________________________ the undersigned, give my consent to be a participant in this study."

Signature of the participant Signature of the investigator
Name:-
Hostel Address-
Contact No. -

Place:
Date:

# GENERAL QUESTIONNAIRE

Name:
Age:
Gender:
Occupation/Academic:

Handedness: Left / Right
Spectacles: Yes / No
Non Smoker: Yes / No

Do you sleep during the day? (If yes when, how many hours) ………………………...

At what time do you take nap? ……………………………...

How many hours of sleep in the daytime do you have normally? ………………………...

Do you suffer from Chronic Illness? …………………………………………………...

Do you suffer from Chronic Allergies? ………………………………………………..

Do you suffer from any clinical sleep disorder at present or in the past? ……………...

Do you suffer from any endocrinological, neurological or psychiatric illness at present or in the past? ………………………………………………………………………………..

Have you been a subject in a sleep experiment? (If yes when and with whom) ……….

Do you have partial health restriction? (If yes, what) ………………………………….

Do you take any medications/Drugs? …………………………………………………..

Did you consumed cola or coffee before coming to the experiment ? (If yes when and how much) …………..

Have been you undergoing special stress? (If yes, which and what exact) …………….

What time did you awake today Morning? …………………………………………….

# DRUG USE QUESTIONNAIRE (DAST-20)

Name: ___________________________________

Case: ___________________________________

Number: ___________________________________

Charges: ___________________________________

Test Date: ___________________________________

Score: ___________________________________

**Preliminary Comments**

Adapted from language provided by Dr. Harvey Skinner (January 5, 2009)

The following questions concern your potential involvement with drugs other than alcohol. When you answer the questions, remember that the term "drug abuse" does not include alcohol. Instead, it refers to your use of prescribed or over the counter drugs in excess of the recommended dosage. For example, if you were given a prescription for pain killers, but took more than you were supposed to, that would be included. The phrase "drug abuse" also includes *any* non-medical drug use, including illegal drugs. This includes substances like marijuana, valium, cocaine, amphetamines, LSD, and heroin. Remember that the term "drug abuse" does not include alcohol. If you have difficulty with a statement, then choose the response that is mostly right.

Do you understand?

## Questions

| These questions refer to the past 12 months. | Circle Your Responses | |
|---|---|---|
| 1. Have you used drugs other than those required for medical reasons? | YES | NO |
| 2. Have you abused prescription drugs? | YES | NO |
| 3. Do you abuse more than one drug at a time? | YES | NO |
| 4. Can you get through the week without using drugs? | YES | NO |
| 5. Are you always able to stop using drugs when you want to? | YES | NO |
| 6. Have you had “blackouts” or “flashbacks” as a result of drug use? | YES | NO |
| 7. Do you ever feel bad or guilty about your drug use? | YES | NO |
| 8. Does your spouse (or parents) ever complain about your involvement with drugs? | YES | NO |
| 9. Has drug abuse created problems between you and your spouse or your parents? | YES | NO |
| 10. Have you lost friends because of your use of drugs? | YES | NO |
| 11. Have you neglected your family because of your use of drugs? | YES | NO |
| 12. Have you been in trouble at work (or school) because of drug abuse? | YES | NO |
| 13. Have you lost your job because of drug abuse? | YES | NO |
| 14. Have you gotten into fights when under the influence of drugs? | YES | NO |
| 15. Have you engaged in illegal activities in order to obtain drugs? | YES | NO |
| 16. Have you been arrested for possession of illegal drugs? | YES | NO |
| 17. Have you ever experienced withdrawal symptoms (felt sick) when you stopped taking drugs? | YES | NO |
| 18. Have you had medical problems as a result of your drug use? (e.g. memory loss, hepatitis, convulsions, bleeding, etc.) | YES | NO |
| 19. Have you gone to anyone for help for a drug problem? | YES | NO |
| 20. Have you been involved in a treatment programs specifically related to drug use? | YES | NO |

# THE EPWORTH SLEEPINESS SCALE

**How Sleepy Are You?**

How likely are you to doze off or fall asleep in the following situations? You should rate your chances of dozing off, not just feeling tired. Even if you have not done some of these things recently try to determine how they would have affected you. For each situation, decide whether or not you would have

Write down the number corresponding to your choice in the right hand column. Total your score below.

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

Total Score = ________________________

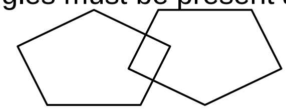
## Mini-Mental State Examination (MMSE)

Patient's Name: ______________________________

Date: ___

***Instructions:*** ***Ask the questions in the order listed. Score one point for each correct response within each question or activity.***

| Maximum Score | Patient's Score | Questions |
|---|---|---|
| 5 | | "What is the year? Season? Date? Day of the week? Month?" |
| 5 | | "Where are we now: State? County? Town/city? Hospital? Floor?" |
| 3 | | The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: ___________ |
| 5 | | "I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W) |
| 3 | | "Earlier I told you the names of three things. Can you tell me what those were?" |
| 2 | | Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them. |
| 1 | | "Repeat the phrase: 'No ifs, ands, or buts.'" |
| 3 | | "Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.) |
| 1 | | "Please read this and do what it says." (Written instruction is "Close your eyes.") |
| 1 | | "Make up and write a sentence about anything." (This sentence must contain a noun and a verb.) |

| | | |
|---|---|---|
| 1 | | "Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.)  |
| 30 | | TOTAL |

(Adapted from Rovner & Folstein, 1987)

# THE WORKING MEMORY QUESTIONNAIRE

Questions are presented here in the order given to each patient. For each question, patients have to choose one of the following response boxes:

- Not at all
- A little
- Moderately
- A lot
- Extremely
- Not relevant

1. Do you feel that you tire quickly during the day?
2. Do you find it difficult to carry out a project such as choosing and organizing your holidays?
3. Do you have problems with remembering sequences of numbers, for example, when you have to note down a telephone number?
4. Do you need to make an effort to concentrate in order to follow a conversation in which you are participating with many other people?
5. Do you find it difficult to remember the name of a person who has just been introduced to you?
6. When you shop, do you often spend more than the budget you set for yourself? (Aside from the change of currency to the euro!)
7. Do you have difficulty remembering what you have read?
8. When you are interrupted during an activity by a loud noise (door slam, car horn) do you have difficulty in getting back to the activity?
9. Do you find it difficult to carry out an activity with chronological steps (cooking, sewing, DIY)?
10. Do nearby conversations disturb you during a conversation with another person?
11. Do you need to re-read a sentence several times to understand a simple text?
12. Do you have difficulty in organizing your time with regard to appointments and your daily activities?
13. Do you find it difficult to do two (or several) things at the same time such as?
    - DIY and listening to the radio at the same time?
    - Cooking and listening to the radio at the same time?
14. When you are carrying out an activity, if you realize that you are making a mistake, do you find it difficult to change strategy?
15. Do you have difficulty understanding what you read?
16. Do you feel that fatigue excessively reduces your concentration?
17. When you pay cash for an item, do you have difficulty in realizing if you have been given the correct change? (Aside from the change of currency to the euro!)
18. Do you find it difficult to follow the different steps of a user's guide (putting kit furniture together, installing a new electrical device)?
19. Do you find it difficult to carry out an activity in the presence of background noise (traffic, radio or television)?
20. Are you particularly disturbed if an unexpected event interrupts your day or what you are in the process of doing?
21. If a character in a text is designated in different ways (he, him), do you have difficulty in understanding the story?
22. Do you feel embarrassed when you have a conversation with an unfamiliar person?
23. Do you find that you hesitate for a long time before buying even a common item? (Aside from the change of currency to the euro!)
24. Do you feel that you are very slow to carry out your usual activities?
25. Do you have to look at a written phone number many times before dialing a number that you don't know off by heart?
26. Do you have difficulty in managing your paper work, sending social security papers, paying bills, etc.?
27. If somebody speaks quickly to you, do you find it difficult to remember what you were told or asked?
28. Do you find that you tire quickly during an activity which demands a lot of attention (for example, reading)?
29. After doing your shopping, are you surprised to find that you have bought many useless items?
30. Do you find it difficult to participate in a conversation with several people at once?

# PROSPECTIVE-RETROSPECTIVE MEMORY QUESTIONNAIRE

In order to understand why people, make memory mistakes, we need to find out about the kinds of mistakes people make, and how often they are made in normal everyday life. We would like you to tell us how often these kinds of things happen to you. Please indicate by ticking the appropriate box.

Please make sure you answer all of the questions on both sides of the sheet even if they don't seem entirely applicable to your situation.

Please provide the following details about yourself.
Age: ………; Male/Female: …….

How many years of formal education have you had?

Have you suffered from brain or head injury resulting in hospitalization **(Y/N)?**

Please give brief details

Please answer all of the questions as accurately as possible.

| | Very Often | Quite Often | Sometimes | Rarely | Never |
|---|---|---|---|---|---|
| Do you decide to do something in a few minutes time and then forget to do it? | | | | | |
| Do you fail to recognise a place you have visited before? | | | | | |
| Do you fail to do something you were supposed to do a few minutes later even though it's there in front of you, like take a pill or turn off the kettle? | | | | | |
| Do you forget something that you were told a few minutes before? | | | | | |
| Do you forget appointments if you are not prompted by someone else or by a reminder such as a calendar or diary? | | | | | |
| Do you fail to recognise a character in a radio or television show from scene to scene? | | | | | |
| Do you forget to buy something you planned to buy, like a birthday card, even when you see the shop? | | | | | |
| Do you fail to recall things that have happened to you in the last few days? | | | | | |
| Do you repeat the same story to the same person on different occasions? | | | | | |
| Do you intend to take something with you, before leaving a room or going out, but minutes later | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| leave it behind, even though it's there in front of you? | | | | | |
| Do you mislay something that you have just put down, like a magazine or glasses? | | | | | |
| Do you fail to mention or give something to a visitor that you were asked to pass on? | | | | | |
| Do you look at something without realising you have seen it moments before? | | | | | |
| If you tried to contact a friend or relative who was out, would you forget to try again later? | | | | | |
| Do you forget what you watched on television the previous day? | | | | | |
| Do you forget to tell someone something you had meant to mention a few minutes ago? | | | | | |

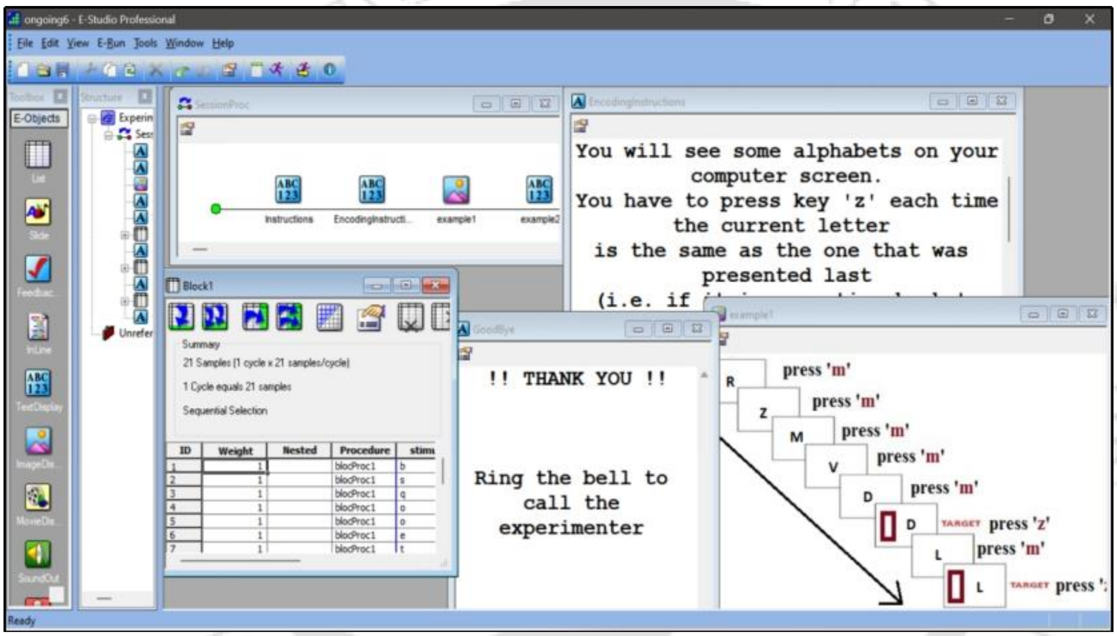
# Appendix B

## Equipment's Specification

# E-PRIME 2.0 PROFESSIONAL

E-Prime® is a software package which is used for the stimulus presentation in psychological and cognitive science experiments. This software system used to collect behavioral data and also helps in their analysis. It provides millisecond precision timing to ensure the accuracy of data. E-Prime® has a good online support website: http://www.pstnet.com/support/login.asp Here, you can find examples of different type of experiments, their problem solutions and frequently asked questions which helps you in resolving your query.

Following image is showing the main experimental page of E-Prime file.



## DREEM HEADBAND

To study the sleep characteristics, we used DREEM HEADBAND. The DH device is a wireless headband worn during sleep which records, stores, and automatically analyzes physiological data in real time with-out any connection (e.g. Bluetooth, Wi-Fi, etc.). Following the recording, the DH connects to a mobile device (e.g. smart phone and tablet) via Bluetooth to transfer aggregated metrics to a dedicated mobile application and via Wi-Fi to transfer raw data to the sponsor's servers. Five types of physiological signals are recorded via three types of sensors embedded in the device: (1) brain cortical activity via five EEG dry electrodes yielding seven derivations (FpZ-O1, FpZ-O2, FpZ-F7, F8-F7, F7-O1, F8-O2, FpZ-F8; 250 Hz with a 0.4–35 Hz bandpass filter); (2–4) movements, position, and breathing frequency via a 3D accelerometer located over the head; and (5) heart rate via a red-infrared pulse oximeter located in the frontal band. The EEG electrodes are made of high consistency silicone with soft, flexible protrusions on electrodes at the back of the head enabling them to acquire signal from the scalp through hair. An audio system delivering sounds via bone conduction transducers is integrated in the frontal band but was not active in this study. The DH is composed of foam and fabric with an elastic band behind the head making it adjustable such that it is tight enough to be secure, but loose enough to minimize discomfort.


**FIGURE IV: DREEM HEADBAND**

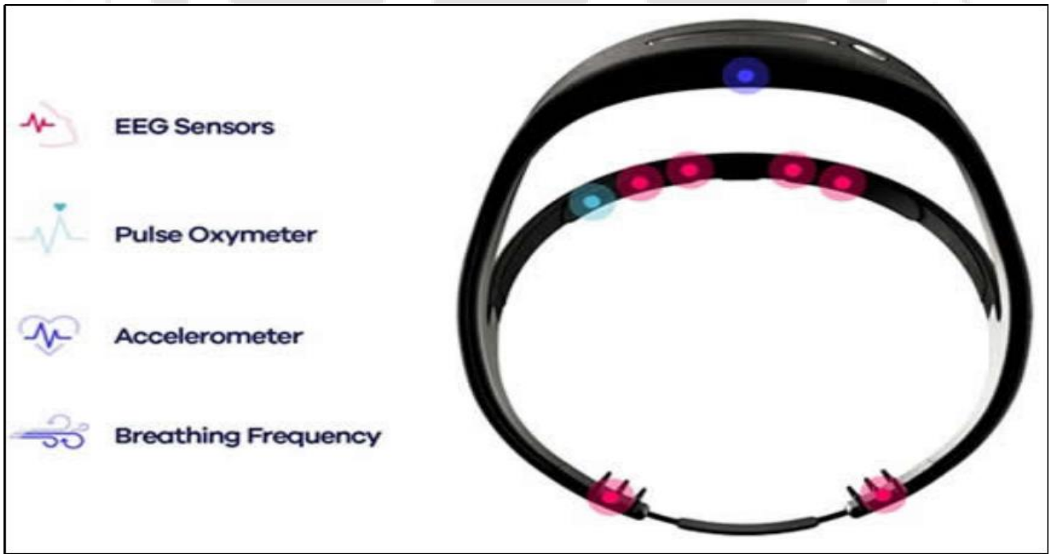



**FIGURE V: Placement of EEG Sensors and Accelerometer in Dreem Headband**