Beyond Completion: Exploring the Persistence of Intentions in Prospective Memory

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By

A Snigdha Mohana (206141001)

Department of Humanities and Social Sciences

Indian Institute of Technology Guwahati

Department of Humanities and Social Sciences

Indian Institute of Technology Guwahati, Guwahati

India

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Indian Institute of Technology Guwahati

Department of Humanities and Social Sciences
Guwahati 781039
Assam, India

DECLARATION

I hereby declare that the thesis entitled "**Beyond Completion: Exploring the Persistence of Intentions in Prospective Memory**" 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 **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 | **A Snigdha Mohana**
June 2025 | (Roll No. 206141001)

Indian Institute of Technology Guwahati

Department of Humanities and Social Sciences
Guwahati 781039
Assam, India

CERTIFICATE

This is to certify that Ms. A Snigdha Mohana has prepared the thesis entitled "**Beyond Completion: Exploring the Persistence of Intentions in Prospective Memory**" for the degree of Doctor of Philosophy at the Indian Institute of Technology Guwahati. The work was carried out under my supervision and in strict conformity with the rules laid down for the purpose. It is the result of her investigation and has not been submitted either in whole or in part to any other university/institution for a research degree.

IIT Guwahati
June 2025

Dr. Naveen Kashyap
(Professor)
Thesis Supervisor

Dedication

To my parents, whose support gave me the rare luxury of always looking forward, never behind.

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IIT Guwahati **A Snigdha Mohana**

June 2025 **(206141001)**

ABSTRACT

Prospective memory (PM)- the ability to execute planned actions at some appropriate time in the future- is essential for adaptive, goal-directed behaviour. As vital as this ability is, it is equally essential to inhibit an action associated with a plan or intention once it is completed, cancelled or becomes irrelevant. However, it seems that such is not the case always. And not inhibiting irrelevant actions can have real-world consequences for safety and efficiency. While extensive research has focused on the successful encoding and retrieval of future intentions, relatively little is known about what happens to completed or non-relevant intentions. The process of inhibiting non-relevant or completed intentions is called intention deactivation and the consequences of ineffective deactivation are called aftereffects.

This thesis systematically investigates the cognitive mechanisms underlying intention deactivation and the persistence of intentions beyond their relevance. Using a series of behavioural experiments with event-based paradigms, we examine how factors such as encoding novel intentions, the status of the intention- whether it is suspended or completed, task similarity, and delay from task completion impact the process of deactivation and the resulting aftereffects.

Across multiple experiments, experimental manipulations included (a) repeated cycles paradigm with new intentions encoded and made non relevant in each cycle, (b) encoding of novel prospective tasks, (c) manipulating status of intention completion, (d) manipulating time of non-relevant cue occurrence, and (e) varying task similarity between old and new tasks. Outcomes were measures as mean commission error rates and slowing of response on non-relevant targets.

We find that unlike general forgetting in retrospective memory, deactivation in prospective memory is a more active and effortful process shaped by task completion, similarity between tasks and how our attentional and inhibitory processes are engaged in effective deactivation. We find support for the newly proposed dual-mechanisms account of prospective memory with both inhibition and retrieval jointly determining the fate of intentions beyond their relevance. We find that intention completion may serve as a crucial bottleneck in deactivation processes. That is, completed intentions exhibit better deactivation that suspended intentions, and are more susceptible to overwriting like mechanisms by new intentions. We also find that task similarity or overlap determines the strength and finality of intention deactivation. We found no effects of delay on persistence of intentions beyond their utility.

Overall, the results of this thesis contribute to the understanding of the processes behind intention deactivation and the cognitive flexibility required to live efficient lives.

Keywords: *Prospective Memory, Intention Deactivation, Aftereffects, Suspended Cues, Novel intention, Commission Errors*

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CONFERENCE PUBLICATIONS AND WORKSHOPS

4th WINTER SCHOOL ON COGNITIVE MODELLING, IIT MANDI
Sept 2022

Workshop Certification

NATIONAL ACADEMY OF PSYCHOLOGY, AHMEDABAD UNIVERSITY
March 2023

Facial Attractiveness Judgements are Influenced by Completeness of Stimuli and Age Differences

iBrain- APPLICATION OF EYE-TRACKING IN COGNITIVE SCIENCE
Aug 2023

Workshop Certification

NATIONAL ACADEMY OF PSYCHOLOGY, GITAM UNIVERSITY
Feb 2024

Semantic Associates from DRM lists can lead to False Alarms in Prospective Memory Tasks

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CHAPTER 01: INTRODUCTION

'Everything in life is memory, save for the thin edge of the present' – Micheal Gazzinga

1. Thesis Outline

One can easily bring to mind a memory of accidentally mailing an email attachment twice or embarrassing oneself by telling the same story twice at a party. These kinds of errors are referred to as repetition errors because they are performed repeatedly when not necessary. Such errors bring to light two important facets of memory: the ability to keep a record of acts already performed and the ability to turn off intentions to perform acts when unnecessary. This thesis attempts to focus on the latter.

This ability to turn off an intention when it is no longer relevant is called intention deactivation, and it is one of the lesser-explored facets in the area of prospective memory. Prospective memory refers to encoding an intention to perform a particular action at some point in the future (Einstein & McDaniel, 1990). Some event or occurrence will later trigger this intention, and the action will be executed. Prospective memory has been the research focus for memory researchers for the past few decades. However, most findings are relevant to the success or failure of prospective memory actions and the factors impacting successful prospective memory.

An intention that is no longer relevant has either been executed appropriately, or cancelled due to some logistical difficulty such that it shall not be executed anymore, or is postponed till some future time. The ability to effectively forget such no-longer-relevant intentions is called *deactivation*. Furthermore, the influence exerted by these no longer relevant intentions that have been successfully executed or cancelled are called *aftereffects* in literature (Moschl et al., 2020). While the terms deactivation and aftereffects are often used interchangeably in this work and many others, deactivation is the process of releasing the intention from active processing. And aftereffects are the outcome of such a process not executed fully or efficiently. Aftereffects can manifest as interference with ongoing tasks or as commission errors. *Interference* is when intention-related material hampers other tasks and is usually recorded as response slowing. *Commission errors* are the erroneous repetition of an action in response to a cue that is no longer to be pursued.

A detailed exploration of the literature on the subject supports some form of persisting activation of no-longer relevant intentions, resulting in aftereffects. This is seen specifically in paradigms that focus purely on cue-action links, which is the link between the prospective memory cue and its corresponding action or response. The studies in this dissertation aim to explore what happens to these cue-action links after they have served their purpose. We attempt to examine how certain factors impact these aftereffects and the process of deactivation.

These factors include examining the effect of multiple intentions one after the other to simulate a real-life situation where we are constantly monitoring multiple intentions and have to execute them one after the other. A new prospective intention is encoded in every cycle of the paradigm, creating increased demands on our cognitive control and inhibitory processes. These processes keep aftereffects from occurring. We examine the impact of encoding a novel prospective memory task or as we refer to it, encoding of a secondary intention. Few studies have used such a factor, and to our knowledge, no study has used it with a control group for direct comparison.

Other factors explored in this thesis include testing the role of task similarity between the primary and secondary intentions to see if this impacts aftereffects. We also manipulate intention status; the intention could either be suspended (encoded but never had the chance to execute and became non-relevant) or be completed (encoded and executed). Time course effects in the form of delay after intention completion are also studied by presenting no-longer-relevant cues either early or later in the experiment and measuring aftereffects.

In summary, this thesis attempts to explore how we turn off intentions and what happens if such a process less than perfect.

1.1 Introduction to Memory

Our memories make us who we are. There is something about memories that makes them feel very personal and defining. It is vital to every functional aspect of our lives, from reminiscing to learning to planning for the future and maintaining social relationships. Memory as a field diversifies into many sub-branches, each seemingly studied with its own distinctive approach. Like with other cognitive processes, we do not see how remarkable memory is until we face with problems in that ability.

If we had evolved without the abilities of memory, each day would either be novel and exciting, or strange and scary. But we probably would not have a lot of time to find out which is more prevalent as we wouldn't survive very long. The ability of memory evolved as it is immensely advantageous. It helped us remember where food sources were and what threats usually look and smell like. It helped us remember each other and foster social connections. New information and skills acquired remained in memory making us who we are. Overall, memory is an indispensable cognitive ability that serves us in more ways than one.

The history of our understandings of memory began with its likening to a wax tablet or an aviary by Plato. He first introduced the concept of 'recollection' and provided an abstract understanding of memory making. A memory is likened to an imprint on the wax tablet that can later be recollected. The difficulty of recollection was evidenced in the example of birds flying in an aviary and one attempting to catch the right bird, or finding the right book in a library. With the concept of 'anamnesis', he argued that memory was a feature of the soul, recollecting knowledge and learning of basic forms which was present in it even before birth.

Christian thinkers added a spiritual twist to this by referring to this innate memory of the soul as the sense of God. These understandings were later developed by Aristotle who argued that memory can only correspond to the past and hence always contains within it some time elapsed. He also distinguished between remembering and recollection and emphasized that good memory does not guarantee that one is quick at recollecting it.

This was followed by the Stoics and their invention of memory enhancing techniques or ‘mnemonics’. Mnemonics were memory aids used to improve our natural facilities of memory like the method of loci, where we place things that we want to remember in a familiar location like different rooms in our house and later recollect it by walking through the house in our mind and ‘seeing’ the things there. Rationalist understandings made memory take a backstage by deeming it unreliable. Rationalists like Locke, Hume and Kant saw memory as a passive, fleeting and imperfect faculty that should be scrutinized and verified instead of being accepted as it is.

But philosophers like Hegel drove memory back to forefront by emphasizing both its functional importance (‘mechanical memory’ as referred to by Hegel) and its role in development of one’s self-identity. He argued that memory even contributed to shaping human progress by being a part of our historical understandings or as he called it ‘the spirit’. Poets like Wordsworth contributed to the romanticizing of memory as a creative faculty full of emotion and depth of meaning. This romanticization of memory may have contributed to the later constructive understandings of memory.

While these philosophical perspectives laid the foundations of memory, the systematic and scientific study of memory can be traced back to the work of Hermann Ebbinghaus (1885). He conducted experiments on himself using nonsense syllables and gave us the ‘forgetting curve’. Bartlett (1932), on the other hand used stories to experiment on memory for meaningful content and found that our memory is usually not very reliable, fragmented and depends on the gist. He argued that memory is constructive in nature, where recollection mean regenerating a representation instead of passively producing a perfect copy. The works of Ebbinghaus and Bartlett are also discussed majorly as being the founding stones of two opposing schools of memory. The works of Ebbinghaus and those who followed him subscribed to the storehouse metaphor, where they evaluated memory in an input and storage-bound fashion. On the contrary, Bartlett and his followers focused on a more output-bound approach that focused less on quantity and more on gist or semantic accuracy in memory.

William James (1890) introduced the concept of memory stores in his seminal work. He distinguished between 'Primary Memory' which corresponds to short-term or memories in active processing, and 'Secondary Memory' which refers to more stable, or long-term retention. Following in the idea of different memory stores, Atkinson and Shiffrin (1968) gave the multi-store-model of Memory. They hypothesized that memory was processed in a linear fashion starting with the sensory store which is modality specific (echoic, iconic), where information is registered for a very brief time followed by the short-term memory which holds the information for 20-30 seconds. This store is limited in capacity and can only store 7 ± 2 items at a time (Miller, 1956). The information is finally transmitted into long-term memory by rehearsal where information remains for rest of time, and this store is considered to be potentially limitless in capacity.

After this came the working memory model as formulated by Baddeley (1974) from the argument that a unitary short-term store may not adequately represent the depth of active memory functioning in daily life. Working memory is a type of short-term memory but instead of one unitary store, it is made up of three subcomponents and information stored here is in active processing (Baddeley & Hitch, 1974). The three components of working memory are the central executive, which is simply a pool of resources that does not deal with storage or retrieval, but with only allocating resources to the other two subsystems for information processing. The phonological loop processes auditory and verbal information, while the visuospatial sketchpad processes visual information. Evidence for this tripartite model came from studies that showed modality specific interference (Baddeley & Hitch, 1974; Logie et al., 1990; Allen et al., 1978; Saults & Cowan, 2007; Matthijssen et al., 2018). A new subsystem called the episodic buffer was introduced and seen to aid in integration of modalities and transfer of information from the working memory into long-term memory (Baddeley, 2000).

In opposition to the storehouse models, Craik and Lockhart (1972) argued that rehearsal alone does not guarantee transfer into long-term memory (Craik & Watkins, 1973), and words embedded in the context of the sentence are better remembered than words presented alone (Craik & Tulving, 1975). Based on these findings, they proposed that memories depend on levels or depth of processing and differentiated between shallow and deep processing and also between structural, phonological and semantic processing.

Model	**Proponents**	**Components**
Dual-Store Model	William James	Primary Memory and Secondary Memory
Multi-Store Model	Atkinson & Shiffrin	Sensory Memory, Short-Term Memory and Long-Term Memory
Levels of Processing Model	Craik & Lockhart	Shallow Processing and Deep Processing
Working Memory Model	Baddeley & Hitch	Central Executive, Phonological loop, Visuospatial Sketchpad, and Episodic Buffer

Table 1.1: Models of general memory stores and their proponents

Across models, one can agree without argument that every model talks about the three basic processes that are defining of memory. They are encoding, storage, and retrieval of information. One other process is important, especially when we talk about errors in memory:

forgetting. Experimental evidence using memory diaries shows that the majority of what we forget can broadly be categorized as 'future intentions' (Crovitz & Daniel, 1984).

1.2 Intentions

The action component of volition, which is the decision to take a certain action, is called an intent. Although not fully inseparable, intent can be seen as the result of volition. It is when we have chosen a path of action to execute some will, or to reach some goal. An intent turns into an intention when there is some retrospective knowledge and planning attached to it (Brand, 1984). An intent can form spontaneously like a ringing phone may make you choose the action of picking it up. An intention requires prior consideration. Intentions are directives given to the self to perform certain behaviours. They shape and are shaped by our attention, thoughts and goals (Lewin, 1926; Bratman, 1987).

It is not always the case that intentions or memory for them will guarantee their execution (Kvavilashvili, 1987; Dobbs & Rule, 1987). But this may simply be an indicator that there is more to successful intention completion than having the intention itself. Many lines of research converge on the idea that intentions are the key determinants of behaviour (Abraham, Sheeran & Johnston, 1998; Maddux, 1999). Models like the theory of reasoned action (Fishbein, 1979) and the theory of planned behaviour (Ajzen, 1985) emphasize the role of intentions in future action/behaviour. A meta-analysis of 47 experiments found that a medium-to-large change in intention leads to a small-to-medium change in corresponding behaviour (Webb & Sheeran, 2006). We can confidently remark that intentions have predictive value for corresponding behaviours.

Intentions can be immediately acted on or delayed. Delayed intentions involve a time gap between when the intention is formed and when the action can take place (Smith, 2008). Imagine the intention of passing a message to your boss who is currently on leave. In this intention, there is substantial delay involved, and the intention cannot possibly remain in focus during this delay. This poses a unique challenge where we must later remember to perform this intention when your boss comes back without any external prompting. So, there is a need for self-initiation of the intention later when it is appropriate to act on it. The ability of executing such previously formed intentions at later intervals is called *prospective memory*. This is what is the defining feature that makes prospective memory a separate cognitive facet which is not only dependent on our previous plan or retrospective representation of the intention (Crowder, 1996), but also on recognition of the appropriate context and self-initiation of the action to be performed.

1.3 Prospective Memory

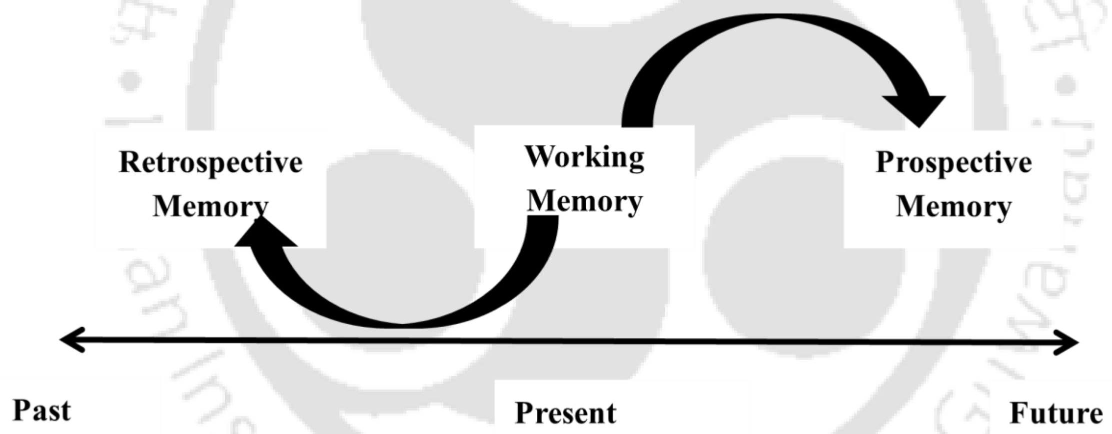


Figure 1.1: Temporal Classification of Memory: Retrospective, Working, and Prospective Memory

If we were to classify memory temporally, we would have retrospective memory corresponding to all memories of past events and experiences. All the knowledge acquired and anything that requires you to look back in time to obtain any information. Prospective memory or memory for the future, corresponds to memory of planned intentions to perform some action in the future. The origins of prospective memory can be traced back to an APA conference in 1975 where Meacham and Leiman presented their work which was later published as a book chapter titled 'Remembering to perform future actions' (1982). They used the term 'prospective remembering' to signify remembering that has implications for some action to be carried out in the future. This may mean that the field is still juvenile. But we must acknowledge that it has seen rapid growth in the decades following its inception and that it is a unique cognitive capacity has been tested to precision. Prospective Memory is the ability to perform previously formed action plans at an appropriate moment in the future (McDaniel & Einstein, 2007). It encompasses our ability to form an intention that is to be executed later after a delay. There is a very real-world demand for performance of such intentions where there is delay between when they are formed and when they are to be performed. Like taking a medication every eight hours or picking up your children from school at the correct time.

Prospective memory abilities are vital to daily life from the smallest of tasks to more complex and life-threatening situations (Dismukes, 2012; Rummel & McDaniel, 2019). Missing out on blood pressure medication even a handful times can result in increased risk for heart disease (Nelson et al., 2006). Even a sizeable chunk of airplane accidents can be traced back to prospective errors (Dismukes, 2008). Prospective memory deficiencies are one of the main symptoms of clinical diseases such as Parkinson's, multiple sclerosis, schizophrenia, autism, stroke, and ADHD (Altgassen et al., 2010; Costa et al., 2018; Rouleau et al., 2020; Hogan et al., 2020).

An example of everyday prospective memory may include forming an intention to call and check-on your friend after your morning workout. We often form such intentions the night before. This example highlights what are said to be the two key aspects of prospective memory. The first is the delay between when we form the intention and when we actually get to execute it. Real-life is complicated with several situational and logistical concerns making executing an intention immediately difficult. This delay between when an intention is formed and the time at which it can be performed is called a ‘retention interval’. The second aspect that makes prospective memory a unique ability is the self-initiation of action. Unlike in retrospective memory where most retrieval is externally prompted; prospective memory actions are self-initiated when we spot the trigger in the appropriate context. This context during which it is appropriate that the action should be initiated and executed is called the ‘performance interval’.

Based on what it is that sets of the action in motion (also known as prospective cue or trigger), prospective memory can be categorized into several variations (Kvavilashvili & Ellis, 1996). Intentions in prospective memory can either be event-based or be time-based. In event-based prospective memory, the cue that triggers the action is an event. For instance, your favourite shoe is torn, and you have to stop at a shoe-mending store when you see one. Since the trigger here is the event of such a store being spotted, this is event-based prospective memory. On the other hand, in time-based prospective memory, the action has to be performed at a certain time, like going to a doctors’ appointment at 7 PM. Apart from this, a newer type is activity-based prospective memory. Here the trigger to perform the action is the coming to end or the beginning of an activity. The transition between the activities marks the context to perform the prospective action, though it is arguable that it is no different from event-based prospective memory.

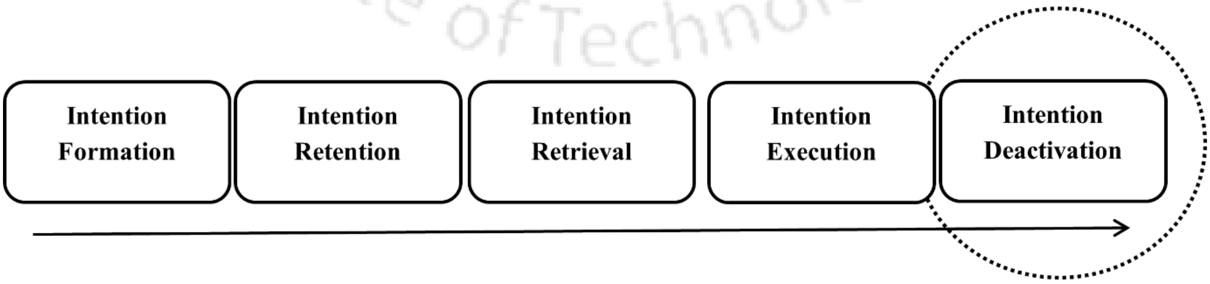


Figure 1.2: A re-imagined depiction of the phase models of Prospective Memory as given by Ellis (1996) to include component of intention deactivation

The phase models of prospective memory have led to the formation of steps or phases necessary for successful intention completion. These models (Ellis, 1996) divide the prospective memory process into four phases that begin with the first phase, intention encoding. The first phase entails the formation of the intention, with the retrospective memory component of what the target cue is, and what the intended action is. The second phase, intention retention is also part of the retrospective component which entails the storage of the intention in memory. It does not remain in the focus of working memory because we are occupied in some concurrent activity. Intention retrieval, or the third phase is when the trigger (an event or time) is noticed, and the intention is brought to consciousness. This is done during the ‘performance interval’ which is the context in which it is appropriate for the intention to be retrieved. This involves the self-initiation of a memory search or spontaneous retrieval based on strong association between prospective cue and corresponding action. Finally, the fourth phase is intention execution. While these phase models emphasized task completion, the aspects of output monitoring (monitoring our own previous actions to readjust our goals) and deactivation of intentions after task completion are left out.

We have highlighted the conceptualization of prospective memory, the types of prospective memory and the steps or phases of prospective memory. We have emphasized the importance of prospective memory in real-life situations but measurement of prospective memory comes with a few challenges. In attempting to tackle these challenges, we arrive at the Dual-Task Paradigm.

1.3.1 The Dual-Task Paradigm

Instead of asking participants to recall previously taught material or other outwardly prompted recall that constitutes retrospective recall, Prospective Memory experiments ask them to remember to carry out a particular activity when an associated trigger appears. Semi-naturalistic studies were the first to be conducted in this area (Meacham & Singer, 1977;

Kvavilashvili, 1987; West, 1988). Intentions were embedded into real-life environments like participants having to call the experimenter at 4PM. These studies were foundational in our understanding of prospective memory and provided us with evident ecological validity.

However, some of the obvious critical drawbacks were the absence of experimental control (McDaniel & Einstein, 2007), and the limited range of scores that might not be sensible to accommodate heterogeneous and diverse PM performances (Rendell & Henry, 2009). Real-life prospective memory performance could only be measured on a binary scale of success or failure without providing any knowledge into the more nuanced factors in this capacity. Failures in prospective memory can represent a spectrum of possibilities from prospective failure (inability to act at the appropriate time), retrospective failure (inability to remember what to do), and a myriad of possibilities in between like attentional lacking and inhibitory failures. Environmental distractors and the inability to effectively manipulate independent variables also resulted in the lack of an objective measure of PM performance.

Consequently, the systematic study of PM did not start prior to the development of the dual-task paradigm by Einstein and McDaniel (1990). The paradigm begins with an encoding phase where the intention is formed. This is followed by a distractor task. The distractor task is meant to create a delay between intention formation and the *performance interval*, which is the context where the prospective task can be performed. The distractor task ensures that the participants cannot actively rehearse the prospective memory intention thereby making it a vigilance task. The dual-task paradigm as the name suggests involves two tasks, the ongoing task and the prospective memory task. For the prospective task, the standard procedure was that when participants come across infrequent occurrences of particular targets that act as retrieval cues (like the word "Blue"), they are instructed to carry out an intended action (like pressing the Q key). To replicate real-life scenarios of being busy with ongoing activities (like driving home from work) while also needing to remember to carry out an intention, the PM task is embedded within an ongoing task (OT) in laboratory settings (e.g., lexical decision task-LDT, or image rating task). The stimuli in this case have characteristics that are necessary to complete the OT on each trial. However, in certain instances, it also has characteristics (PM target) that show when a planned intention should be fulfilled.

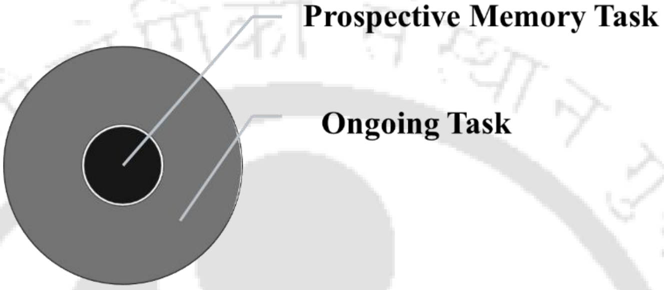


Figure 1.3: Schematic Representation of Dual-Task Paradigm

The dual-task paradigm not only offers abundant experimental control but also is the only paradigm to give a straightforward measurement of Prospective Memory Hit Rate, or the ratio of the number of correct PM responses to total number of PM occurrences. This paradigm offers several advantages for studying prospective memory. First of all, it offers robust experimental control, enabling researchers to successfully isolate and modify factors. It enables more reliable measurements of prospective memory performance and can simulate aspects of real-world settings, making the findings more ecologically valid. Finally, and importantly, it allows for a nuanced investigation of various underlying processes involved in prospective memory—such as spontaneous retrieval, strategic monitoring, and task interference (Smith, 2003; Scullin et al., 2009).

1.3.2 Theories and Models of Prospective Memory

Research has led to several theories that attempt to explain how we encode, store, retrieve and execute future intentions. The main assumption that pits these models or theories against each other is if prospective memory abilities are more a result of conscious resource consuming processes or are more automatic in nature. As the models evolve, we see that some focus more on prospective cue or trigger detection, while some others focus on retrieval processes. The first ever model of prospective memory was a two-component model given by Norman and Shallice (1986). Of the two components, Contention Scheduling (CS) is used to trigger actions in routine activities. It is responsible for ensuring that we perform frequently encountered tasks like walking or brushing our teeth, without conscious effort. And the second component, Supervisory Attention System (SAS) monitors the environment for unique target events, overrides automatic responses and increases activation for any helpful related schemas. Together, both lead to appropriate motor action or execution of intention.

The SAS model focuses more on intention retrieval and execution, probably because it was not particularly developed keeping in mind delayed intentions. This model was not developed to explain prospective memory, but it is one of the foundational understandings of how we direct our attention to remember and execute everyday actions.

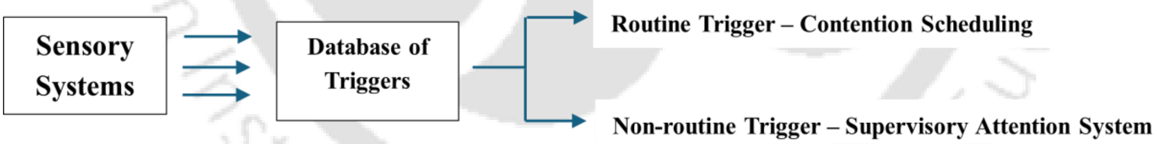


Figure 1.4: Representation of Two-Component Model by Norman and Shallice (1968)

Preparatory Attention and Memory (PAM) is the next two-process theory, and the first made particularly for explaining prospective memory. It posits that in order for a prospective cue to be noticed, preparatory attentional processes must be engaged from the time that we encode the intention. This requires some resource spending which can take away resources from the ongoing task and hindering its performance. This is followed by the retrospective component of memory of what the action to be performed is (Smith, 2003). This theory posits that the limitation of attentional resources means that for successful prospective memory performance we need all our focus on the task till task completion, and divided attention decreases performance. Divided attention leads to a ‘cost’ to the ongoing task where the performance on the non-prospective task is worse when performed along with the prospective memory task rather than performed alone (Smith, 2003; Einstein & McDaniel 2005; Marsh et al., 2002; West, Krompinger & Bowry, 2005). This cost was especially salient in trials preceding successful prospective memory targets and not in those prospective memory targets that were misses (West, Krompinger & Bowry, 2005). This theory looks at PM as an effortful and resource-consuming process. All of these findings support the PAM theory of prospective memory.

Einstein and McDaniel (1990) asked participants about their thoughts related to the prospective intention and most participants reported that the intention popped into their mind every now and then, instead of constantly being there. This, along with few other studies like that of Reese and Cherry (2002) found that unlike postulated by the PAM model, the intention is not constantly being monitored. A more nuanced approach began with the Multi-Process View (MPV), which recognized that while some prospective memory tasks may require monitoring processes, it is possible that the appearance of the target cue can spontaneously trigger the appropriate action (Einstein & McDaniel, 2005).

In the multi-process theory, it is argued that engaging in preparatory processes for long durations can use up heavy amounts of attentional resources which is maladaptive. Instead, it proposes a dual-pathway model where intentions can be retrieved via two distinct mechanisms. The pathways are strategic monitoring and spontaneous retrieval, and which is used depends on several contextual factors. The strategic monitoring processes are deployed based on target cue characteristics like focality. Non-focal tasks like remembering to make a call at 7PM while also engaging in cleaning activities (or any activity that does not direct our attention to time) will require us to actively monitor the time to be able to do so effectively. These cues hence lead to more costs to the ongoing task and usually poorer PM Performance. On the other hand, Prospective memory performance is high when the target cue is focal, meaning the ongoing task directs attention to the target cue, and participants rely on bottom-up processes to spontaneously retrieve the intended action. For example- spotting a particular pre-defined word while reading. These are two paths proposed to explain how the multi-process view operates.

The multi-process view is more encompassing of a broader range of possibilities, but its limitations lie in its inability to delineate the mechanisms underlying its functioning. There is no conclusive evidence to point out if spontaneous retrieval occurs because of associative priming (Meier, Zimmermann & Perrig, 2006) or due to attentional capture by a salient cue. To counter such limitations some sub-theories were proposed as supporting mechanisms for the MPV.

Reflexive-Associative Theory of Prospective Memory states that an association is created between the target cue and the intended action. When the cue appears later it automatically triggers retrieval of the prospective intention, almost like a reflex (Smith & Bayen, 2004; Smith & Bayen, 2006; McDaniel et al., 2004). The Discrepancy-plus-Search hypothesis posits that the target cue that is discrepant from the other ongoing trials is noticed, followed by a controlled memory search for the full intention and then we perform the intended action (McDaniel & Einstein, 2007). This explains well the superior PM performance for cues that are salient or occur unexpectedly. The pathway that is used dominantly may depend on cue-characteristics like focality or salience. An extension of the MPV as a dynamic model explaining both the bottom-up and top-down processes is proposed to explain different phases of prospective memory from intention formation, intention retention, and intention retrieval.

The last and the latest theory explaining how prospective memory functions is the Delay Theory. This theory posits that we set higher thresholds for processing PM related targets such that there is enough time for processing any PM-related information, thereby improving PM performance. Heathcote et al. (2015) found that participants used this strategy (a strategic and self-imposed dealy) especially in tasks where multiple different processing pathways (semantic and syllabic) were to be used. It was also seen in another experiment that performance on both focal and non-focal tasks was similar when participants were forced to respond with a certain delay. This delay allowed them to accumulate more information and improved performance (Loft & Remington, 2013).

However, there are findings challenging this delay and accumulation model where we find that delay alone does not always result in superior PM performance and cannot compensate adequately for factors like lack of salience and focality in all cases (Anderson & McDaniel, 2019).

Theory	Proponents and Year	Key Features
SAS Theory	Norman and Shallice, 1986	Focuses on Automatic and controlled processing of information. Not PM specific
PAM Theory	Smith, 2003	Accounts well for costs in other tasks but overestimates the role of monitoring.
MPV Theory	McDaniel and Einstein, 2000	Accounts for cases of both monitoring and spontaneous retrieval but does not specify

		underlying mechanisms clearly
Delay Theory	Loft and Remington, 2013	Accounts for time-based effects and forgetting but cannot explain differences in performance based on cue-characteristics.

Table 1.2: Models of prospective memory and their proponents

One aspect of prospective memory that is not addressed in any of the theories above or in the phase models is what happens to these intentions once they serve their purpose. *Intention deactivation* is the loss of intention and intention-related material from active processing after it has been executed. Research on intention deactivation examines whether the processes related to intention material prior to its execution are still active after it has been successfully executed. Another terminology used closely with intention deactivation is '*aftereffects*'. Aftereffects can refer to the lingering impact of previously executed intentions or actions on subsequent cognitive processes. A lot of research has been directed to studying the conditions suitable for successful intention execution (Hicks, Marsh & Cook, 2005; Nowinski & Dismukes, 2005; Kliegel, McDaniel, Einstein, 2000; Gollwitzer, 1999; Gollwitzer & Sheeran, 2006; Altgassen et al., 2010; Spindola et al., 2011; Heffernan & O'Neil, 2013; Smith & Hunt, 2014). But there is limited understanding of what happens to a prospective intention after its completion and if there are any aftereffects. The ability to deactivate or disregard completed prospective memory intentions is a substantial yet frequently disregarded facet of prospective memory.

1.3.3 From Prospective Remembering to Forgetting

Despite the considerable focus on encoding, maintaining, and recalling intended actions, the act of forgetting prospective intentions holds equal importance for efficient and adaptable behaviour. Once an intention is completed, we should be able to inhibit the related action. Failure in this ability is what leads to errors of repetition or commission errors. The early understandings of Prospective forgetting were rooted in the PAM theory, and it was thought that a failure in disengaging the monitoring processes even after intention completion is what leads to erroneous repetitions of non-relevant tasks (commission errors) or other costs. However, as we have already established, having an intention on mind is not always associated with costs (Einstein et al., 1998; McDaniel et al., 2004). From the spontaneous retrieval framework, we see that a strong PM cue and action link can lead to spontaneous retrieval and erroneous execution of the task even in the absence of any preparatory monitoring (Einstein & McDaniel, 2005; Marsh, Hicks & Cook, 2006).

Studies on the phenomenon of Intention Superiority effect (ISE) argues that intention and intention-related material are stored in a privileged state of activation compared to other neutral information only before intention completion or goal-achievement (Goschke & Kuhl, 1993; Penningroth, 2011). However, some other studies on activation levels of intention material and the intention superiority effect also show a deficit in prospective forgetting because intention-related-material remains in higher activation even after intention completion owing to its special status (Marsh, Hicks & Bink, 1998; Forster et al., 2005).

Even in some of the foundational work on prospective memory that used semi-naturalistic paradigms, we saw that prospective memory has with it a sort of immunity to forgetting and did not follow the steep curves of forgetting displayed by retrospective memory (Wilkins & Baddeley, 1978). Some early laboratory studies also found that retention interval differences did not lead to a lot of performance differences in prospective memory (Einstein et al., 1995; Guynn, McDaniel & Einstein, 1998). Though early studies on PM focused only on the omission of a PM occurrence, real-world occurrences of accidental repetitions led to the curiosity backing the commission error paradigms. Commission errors are the erroneous repetitions of a previously completed, or cancelled intention. They reflect an executive failure of being able to inhibit an action associated with a cue that is not relevant. Over time, there have been an abundance of findings reporting the occurrence of commission errors especially in event-based paradigms (Scullin et al., 2011; Scullin et al., 2012; Scullin & Bugg, 2013; Bugg & Scullin, 2013; Walser et al., 2012). These studies lead to the current interest and growing focus on the aspects of intention deactivation.

So it is clear to us that intentions often continue to occupy our working memory capacities beyond the point of utility as the intentions are either completed, suspended or cancelled. Especially in older adults, people with chronic illnesses and those who work in safety critical contexts, it is very important to forget completed and non-relevant intentions. We see in several studies of aviation and safety that pilots executed already completed actions from a checklist especially when interrupted causing operational disruptions (Dismukes, 2008; Dodhia & Dismukes, 2009). Studies on medication adherence also show increased patient risk related to overmedication and persistent double-dosing (Ihle et al., 2017; Zogg et al., 2012). Even instructional and learning outcomes are hampered due to such repetition errors (Kristensen et al., 2024; Tamrazi & Wiskow, 2023). Hence, the ability to forget a PM intention is very critical to adaptive and efficient daily life functioning. We refer to this necessary forgetting as intention deactivation and to the consequences of lack of such a forgetting as aftereffects.

1.3.4 Paradigms for Investigating Intention Deactivation and Aftereffects

To measure intention deactivation, it is essential for a paradigm to have at least two blocks. Since intention deactivation usually follows intention completion or the completion of a prospective task, any paradigm designed to measure deactivation and aftereffects should involve a standard prospective memory task plus another task in which the targets from the standard task reappear and aftereffects can be measured. So, despite having multiple paradigms, the uniting thread between them all is that there will be at least two blocks. The first block will be the one where the original prospective memory task is encoded and executed like any other standard event-based prospective memory task. This is either referred to as the active-phase or the PM block in different studies. After this comes the next part where the intentions from the active phase reappear but are non-relevant and hence should not be executed. This is called the finished-phase or Test Block in different studies. It is in this phase that we measure aftereffects by examining how participants respond to the reoccurring non-relevant cues.

Broadly speaking, all the paradigms that assess deactivation and aftereffects can be classified in two ways. One, they can either be script-based paradigms, or event-based paradigms. Script-based paradigms were used in early studies on activation status of intentions or action scripts. Since most scripts used simple motor actions, like setting a table, later activation was measured using not just that script but also other closely related action scripts. In these paradigms, researchers also compared the activation of completed scripts with cancelled or other neutral action scripts which were never to be performed.

Event-based paradigms used much simpler cue-action links that could focus more on the PM task and less on the semantics or content of what to do. Event-based paradigms measured continued retrieval of older intentions by means of repetition or commission errors. They also compare no-longer relevant cues to other neutral ongoing task trials to assess intention deactivation.

Two, they can be either single-cycle or repeated-cycle paradigms. A single-cycle paradigm has only one active-phase followed by a finished phase and aftereffects are measured during it. The commission error paradigm which is the first of its kind methodology used in research on intention deactivation is an event-based paradigm with a single-cycle of active and finished-phases. The no-longer-relevant cues from the active-phase reappear in the finished-phase and aftereffects are measured.

On the other hand, in a repeated-cycles paradigm participants alternate between active and finished phases over several cycles. Even this can go one of two ways. Either all finished phases can be ongoing task only and restart a fresh cycle, or it can be a continuous experiment block after block where each finished-phase transforms into the active-phase with another active intention. The repeated-cycles paradigm is one of the few paradigms in which the effects of encoding a novel prospective memory intention can be studied.

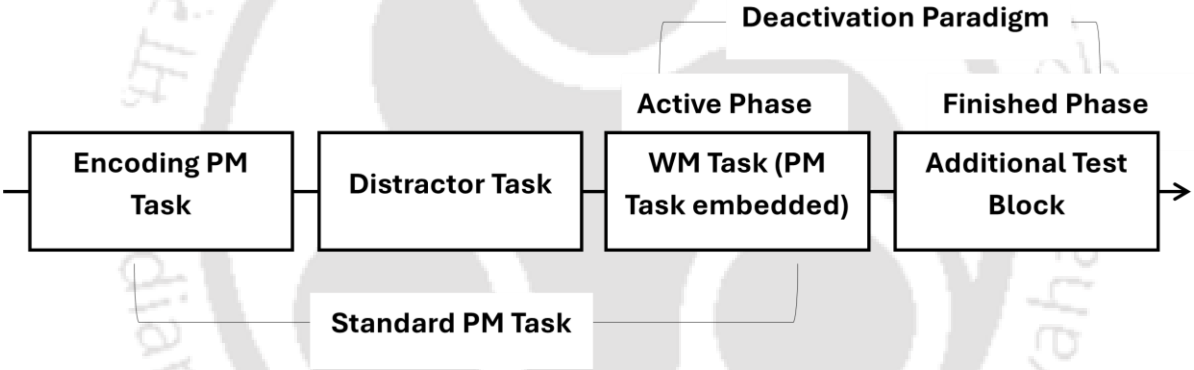


Figure 1.5: Flow Chart Depiction of Paradigm examining Intention Deactivation and Aftereffects

1.4 Intention Deactivation and Aftereffects

To adequately define intention deactivation may be a challenge in itself. In its simplest form it is the turning off, or removing from memory, of an intention that is completed or has served its utility. Though we have used the term prospective forgetting for it in some previous sections, we have also highlighted that it does not behave in ways similar to retrospective forgetting that is passive and often rapid. Unlike retrospective forgetting, intention deactivation seems to be a deliberate and controlled process that is impacted by several factors like cue-action association strength, habituality of action and context among others. To separate deactivation from other terms like forgetting, we have to understand a few things. The first is that non-relevant intentions continue to impact our performance even when we are fully aware that they are no longer active. Even after participants are explicitly instructed of task completion and their understanding of all instructions is verified, non-relevant cues continue to result in slower response times and even commission errors (Marsh et al., 1998; Scullin et al., 2012).

We also come across the terms inhibition and active suppression in some studies. Inhibition is the ability to suppress or override information that is not relevant to us anymore. In process, it is the decrease in level of activation of some information to make it less accessible. In measurement, it can be noticed as a response time lag on cue or cue-related material. Inhibition can be both automatic or more deliberate. Evidence for inhibition like processes can especially be seen in studies with ageing populations as they lack inhibitory control (Bugg et al., 2016; Scullin et al., 2011; Maylor et al., 2002).

Active suppression is a more deliberate and controlled process whereby we intentionally push intention-related material out of working memory. Evidence for such processes is seen when using the think-no think paradigm where we see that active suppression is a cognitive control process which leads to reduced later recall of concerned material (Anderson & Green, 2001). In prospective memory studies on ageing populations, we see deficits in active suppression because of lack of executive control capacities in older adults (Bugg et al., 2016).

The final process discussed in this literature is that of continued retrieval, where the cue-action linking is strong resulting in spontaneous retrieval even after task completion. Thus in the presence of a salient cue and strong cue-action linking, intention deactivation is a more continues control processes where we have to repeatedly regulate our responses at each occurrence. All findings of commission errors can be taken as evidence for continued retrieval of no-longer relevant intentions (Scullin et al., 2012; Walser et al., 2012; Pink & Dodson, 2013). Overall, we can conclude that intention deactivation is very different from common forgetting, is not a passive process, and encompasses within it several mechanisms like automatic inhibition, active suppression and continued retrieval.

The outcomes of an ineffective deactivation process are aftereffects. The inability to effectively forget an intention or 'deactivate' an intention, that has served its purpose can result in aftereffects. This persisting activation of intentions is the reason why we make errors like taking a medication twice or narrating the same story to a friend twice. Our daily life is complicated with several changing plans and dynamic variables making adaptation and reconsolidation of memories and plans necessary. And we see evidence both in support of and against our abilities in doing so effectively. We see in these studies examining the processes of reconsolidation that when memory traces are reactivated, like it happens at intention execution, it creates a window for the modification of the memory itself. This gives us an opportunity to update the status of the memory as not-relevant (Walker et al., 2003). However, we see in some studies that our reconsolidation mechanisms are not very effective, and we may fail to update intention statuses event after reactivation or new learning opposing the older intention (Hardwicke et al., 2016). Given such a state of findings, effective deactivation seems evasive even though it is a most helpful ability that should be examined and understood.

In a typical laboratory paradigm, aftereffects can be observed in two ways. Intention interference in terms of slower reaction times to intention related target cues due to spontaneous retrieval processes even when the intention is completed or non-relevant. And commission errors in terms of erroneous repetition of an action in response to a non-relevant cue related to an intention. Intention Interference is a cue-driven process that occurs because some aspect of the of the intention is spontaneously detected and retrieved. This occurs because the activation level of intention related material is higher than baseline causing it to be more accessible.

The idea that highly activated intention-related content, even if it is no longer relevant, can cause slower reaction times rather than faster ones may appear counter-intuitive. This phenomenon of intention interference, arises because of the conflict it causes in cognitive processing rather than because of difficulty in accessing the cue. A previously relevant prospective memory (PM) cue can involuntarily draw attention and cause the completed intention to be retrieved when the person encounters it and the associated intention is still highly activated (Marsh, Hicks, & Bink, 1998; Scullin, Bugg, & McDaniel, 2012). As the system considers whether to act or suppress the now irrelevant reaction, this spontaneous retrieval process pauses the current task and briefly uses cognitive resources (Einstein & McDaniel, 2005; Pink & Dodson, 2013), creating a response slowing due to switching of attentions and task sets. Because of this temporary task conflict and the requirement for inhibition, the behavioural result is slower reaction times rather than faster ones.

This illustrates the drawbacks of intention interference: performance is hampered since the mind has to work hard to repress the unimportant but still reachable intention. Failure of this control could lead to a commission error, which is the actual execution of a completed purpose, rather than mere interference (Scullin et al., 2011; Bugg & Scullin, 2013). As a result, interference results from the ongoing accessibility of an intention colliding with the requirements of a new task environment rather than from low activation, as might be predicted in conventional memory paradigms.

Commission errors are the result of continued retrieval and execution of a no-longer relevant intention. A non-relevant intention is mistakenly performed again. These can arise from spontaneous retrieval and interfere with current tasks. When we perform an intention, we should attach a 'stop-tag' to it, which signals that the intention should not be performed again. However, if such a tag is not attached during reconsolidation of the intention, it can result in commission errors (Bugg & Scullin, 2013).

In terms of measurement, Intention Interference is measured by an increase in response time on the particular trial that is measured either in seconds or milliseconds. Commission errors reflect a binary accuracy measure where it is incorrect to make a repetition error.

Though the use of all this terminology is very recent, similar conceptualizations are seen in the ageing and lifespan development research on prospective memory. Studies on perseveration show that patients with frontal lobe damage are worse in the ability of shifting attention away from previously relevant dimensions (Owen et al., 1993). Proactive Interference studies also examined performance impairments due to interference from older non-relevant information (Underwood, 1957). Even research on the phases of prospective memory and lifespan development shows that our inhibitory abilities, needed for deactivation like processes, change throughout the lifetime following an inverted-U curve (Kliegel et al., 2008).

Early studies by Zeigarnik (1938) show that unsatisfied intentions are retained differently in memory and have higher activation compared to baseline. There is heightened accessibility of even intention-related concepts (Holton, 2009). Older studies that deal with intention completion and activation status, measured response latencies and found that completed intentions were actively inhibited. This was evidenced by faster response latencies of completed intentions and slower response latencies of suspended or partially completed intentions (Marsh, Hicks, & Bink, 1998; Scullin, Einstein, & McDaniel, 2009). Similar to completed intentions, even cancelled intentions displayed a similar style of inhibition after cancellation (Marsh, Hicks, & Bryan, 1999). Findings from Forster et al., (2005) also show that accessibility of target-related material is higher when the task is yet to be fulfilled and decreases after the task is fulfilled. Even instructions given for motor skill learning showed superior activation on later recognition tests till the motor action is initiated (Badets et al., 2006). Other script-based experiments using aggressive actions and related words found that performing the script reduced accessibility of the related words but only watching the action led to increased accessibility for related material (Denzler et al., 2009; Denzler, Hafner & Forster, 2011).

All these findings are in line with the 'Intention-superiority effect', where there is more activation and faster access to content related to an intention, and this is seen to disappear or reduce after intention completion (Goschke & Kuhl, 1993; Meilan, 2008). One important detail to note is that most studies that examined the intention superiority effect or produced results of active suppression (inhibition) or deactivation post task completion used script-based prospective memory paradigms.

Despite the fact that PM deactivation allows us to adjust to shifting circumstances, there is strong evidence that intentions can occasionally stay active. In other words, participants may suffer intention interference and may perform the PM action incorrectly because of failing to forget (i.e., "turn-off") an irrelevant intention. In the last decade, focus shifted to event-based paradigms and research grew more interested in age effects of prospective memory. Studies on ageing populations were the first to show some evidence of aftereffects in prospective memory. Though there was no erroneous repetition or commission errors recorded, older adults showed slower performance on intention words (Cohen, Dixon, & Lindsay, 2005).

Similar findings were seen in Scullin et al., (2011), and highlight how normal ageing might not impair spontaneous retrieval but impair inhibitory functioning. Penningroth (2011) also found sustained activation of intention related material even after task completion. The first study to observe commission errors was also the first to use what we will refer to here forth as the 'commission error paradigm'. This paradigm begins with an active phase where the prospective task occurs, followed by a finished phase where the non-relevant intentions reappear, and aftereffects are measured. Scullin, Bugg, & McDaniel (2012), found that similar to their previous studies, when the ongoing task was different between both phases, there were no commission errors recorded. However, commission errors were recorded in task-match (similar ongoing task for both phases) conditions, especially for salient cues. A salient cue is one that stands out among other trials because of perceptual characteristics like larger font size or bright font colour, leading to more automatic processing (Zhang et al., 2021). Older adults also made significantly more such erroneous repetitions.

In an experiment with a control condition without a prospective task, Scullin and Bugg (2013) found that evidence for the spontaneous retrieval of finished intentions even without any monitoring. They also had delay as a variable and analysis of response times indicated higher risk of commission errors in longer delay condition. This was attributed to be a function of fatigue but there were no differences in percentage of commission errors between short and long delay conditions as would be expected because of the lack of fatigue in short delay condition. Similar results in support of spontaneous retrieval of completed intentions were found in a neuroimaging study (Beck et al., 2014).

Cue-characteristics like salience and focality have a great impact on intention deactivation. A focal cue is one whose processing aligns with the attentional demands of the current ongoing task (Scullin et al., 2010). Experiments that use non-salient and non-focal cues usually result in deactivation (Cona et al., 2016; Cohen et al., 2017; Moschl et al., 2020; Mello et al., 2024).On the contrary, there are also findings of continued retrieval and commission errors even with targets that are non-salient and non-focal, especially with older adults and those with Alzheimer's (El Haj et al., 2018; Gilbert, Hadjipavlou & Raoelison, 2013). Bugg, Scullin and McDaniel (2013) used the commission error paradigm with implementation encoding and found that commission errors doubled across age groups. Implementation intentions involve forming explicit plans of when, where and how one would perform an action in the future, and is usually made in an 'If X-Then Y' format. Boywitt et al., (2015) also found that older adults were more prone to making commission errors. However, few studies found that commission errors do not significantly differ by age and found that forgetting practice, along with implementation intention to not respond to target words reduces commission errors (Steeper, 2018). Also, routinely occurring or habitual cues resulted in more commission errors, especially in divided attention conditions (Pink & Dodson, 2013).

Knight et al. (2011) found that when participants were outside of the appropriate responding context (i.e., the initial phase), they exhibited slower latencies to lures that exactly matched the features of their intention compared with other types of lures and control words. Findings on context also show that intention deactivation is more difficult to achieve if there is more contextual overlap between the active-phase and finished-phase (Scullin et al., 2012). Rummel et al. (2012) found that giving participants a PM intention caused interference on trials directly following such PM lures. Besides finding a general slowing on trials following a PM lure, they also found that this lure-induced interference was significantly increased after implementation-intention encoding. Mullet et al. (2013) also found evidence for spontaneous retrieval after task completion or suspension, but only for exact cues and not semantic lures.

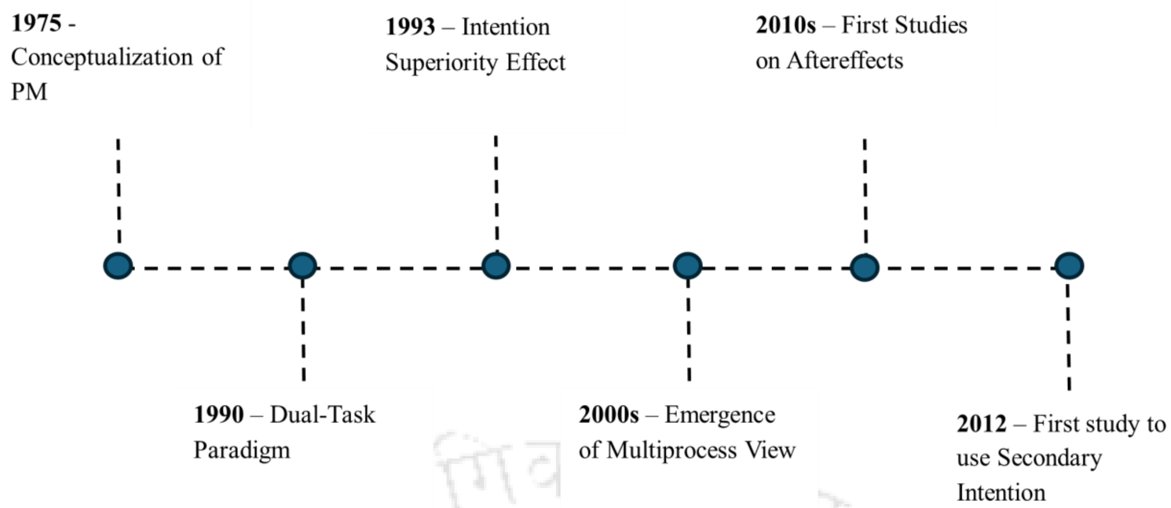


Figure 1.6: Timeline- Milestones in the study of Prospective Memory and Intention Deactivation

In summary, we find that intention deactivation is hampered by a variety of factors including:

- Implementation Intention encoding
- Older participant age
- Divided attention conditions
- Habitual or repetitive cues
- Spontaneous retrieval because of Salient Cues and Context Similarity
- Fatigue caused by delay

While spontaneous retrieval serves an adaptive function, a downside of it is that retrieval is triggered in non-appropriate contexts and even after completion leading to potentially disastrous aftereffects.

1.5 Theories of Intention Deactivation

There are two dominant explanations for intention deactivation or the phenomenon of aftereffects. The observation that intentions often persist when not relevant and have negative consequences to other tasks has been observed and documented only in the last decade (Scullin et al., 2012).

One possibility is that aftereffects may reflect an inhibition of completed intentions, that is, intention completion results in decrease in the activation status of intention or its related material and leads to its move towards a neutral level (baseline), and sometimes even below it. This is supported by findings of a below baseline activation of the content of action scripts after script completion (Marsh et al., 1998) or cancellation in script-based paradigms (Marsh et al., 1999). We also see below baseline activation of semantic associates of PM cues in event-based PM paradigms (Förster et al., 2005; Denzler et al., 2009, 2011). This below baseline activation was also observed after performing a series of unrelated actions (e.g., distributing cutlery, sharpening a pencil, pouring water; Marsh et al., 1999) that were not part of an overarching action script describing a coherent activity.

Research on motor action patterns also shows that performing complex motor patterns that were not acquired via verbal instructions may lead to reduced activation of the primary action (Badets et al., 2006; Badets & Osiurak, 2015). One study by Förster et al. (2005) additionally suggested that inhibition of a completed intention was stronger when participants had a high expectation to encounter a PM cue and successful intention completion was incentivized and also suggested that inhibition was gradually released over time. Few studies suggested an immediate return to baseline activation (Meilán, 2008), and some that memory accessibility of everyday-life intentions changes upon intention completion (Freeman & Ellis, 2003; Maylor et al., 2000).

Another possibility is that aftereffects result from continued retrieval of completed intentions. According to this account, intentions continue to be retrieved even after completion leading to costs to the ongoing tasks and making participants more prone to commission errors. This account is supported by the multi-process view of prospective memory. It is supported by findings of commission errors and slower ongoing task performance in response to no-longer-relevant PM cues in event-based PM paradigms, (Scullin & Bugg, 2013; Walser et al., 2012) and a computational model of PM (Gilbert, Hadjipavlou, & Raoelison, 2013). It is further corroborated by findings of repeated thoughts about the finished PM task after encountering no-longer-relevant PM cues (Anderson & Einstein, 2017) and activation during no-longer-relevant PM trials in brain areas that are also activated by PM cues during active phases (Beck, Ruge, Walser, & Goschke, 2014).

The majority of the reviewed studies with no-longer-relevant PM cues provide support for predictions derived from the continued retrieval account and the inhibition account seems to explain only some sort of semantic content-based inhibition. So, the occurrence or size of aftereffects should be modulated by factors that foster or attenuate retrieval of active intentions according to popular views of PM functioning (McDaniel et al., 2015). Specifically, the strength or integrity of stimulus–response associations between a PM cue and an intended action (Bugg, Scullin, & McDaniel, 2013), the context match between active and finished phases, the salience of PM cues, and the processing overlap between the PM task and ongoing task seem to play an important role in the occurrence of aftereffects. That is, salient PM cues with a strong association to the intended action and the matching of ongoing tasks in active and finished phases have been shown to exacerbate aftereffects (Bugg et al., 2013; Scullin et al., 2012).

These factors can also explain why some studies did not observe aftereffects (e.g., Scullin et al., 2009). In such studies, features of the PM task did not encourage or barely encouraged spontaneous intention retrieval (McDaniel et al., 2015). For instance, Cohen et al. (2017) observed no aftereffects when PM cues were non-salient and required additional processing (non-focal) than ongoing-task stimuli. Similarly, Scullin et al. (2011, 2009) observed no aftereffects when PM cues were non-salient words in an image rating task and aftereffects were measured during a subsequent (mismatching) lexical decision task. Furthermore, several studies support the notion that aftereffects result from a combination of continued intention retrieval and failed cognitive control (i.e., response suppression). For instance, aftereffects increased under high cognitive control demands (divided attention) during finished phases (Schaper & Grundgeiger, 2017) or when participants showed impaired cognitive control abilities (Scullin et al., 2011).

Overall, results show that though intentions are sometimes completely deactivated or inhibited, they can also continue to be retrieved after completion. In other words, some deactivation can occur, which allows us to flexibly adapt to novel situations and goals, but also parts of a completed intention seem to remain active. These findings seem to fit well with everyday experiences of being able to focus on ongoing tasks and future tasks most of the time without being (overly) distracted by recollecting tasks that we have already performed.

Intention deactivation is not an all-or-nothing process. While some mechanisms may promote inhibition, leading to a reduction in accessibility of intention-related information, other factors can lead to the continued retrieval of completed intentions. Thus, rather than a dichotomy, intention deactivation appears to exist on a continuum, influenced by factors such as intention status, task similarity and cognitive control. The dual-mechanisms account (Moschl et al., 2020) suggests that aftereffects arise from both the continued retrieval of completed intentions and the success or failure of cognitive control processes in suppressing those intentions. It integrates both the dominant frameworks under one roof and offers a better explanation for the diverse results we notice in different paradigms and populations. However, the specific conditions under which retrieval dominates, or control is most effective, remain unclear.

Also, to understand the nature of aftereffects in prospective memory we must remember that in naturalistic settings most intentions we form are not created in isolation. They are either part of overarching goals or represent a step in a complex plan. Hence it is important to study intention deactivation in paradigms where other intentions are to be retained and executed.

1.6 Intention Deactivation, Novel Intentions and Overwriting

Despite all the findings in support of the intention superiority effect making it clear that incomplete intentions have heightened activation, less is known about the activation status of completed intentions. As much is evident that immediate deactivation of non-relevant intentions, though adaptive does not always what happen. Imagine your own life, where you start a work day by opening you work email only to see 10 different requests that have to performed parallelly or in rapid succession, most of which you cannot attend to immediately and must form detailed plans to execute. Such intentions/actions are connected to each other or are all part of a list of things to do (Kliegel, Mackinlay & Jager, 2008).

In everyday life we have to execute several future intentions one after the other. So, deactivation and aftereffects should be examined in a paradigm that requires the retention and retrieval of other new intentions. The first studies involving encoding of such novel intentions in the finished-phase, or as we refer to it, 'secondary intentions', were based on post-fulfilment inhibition or backward inhibition. Backward inhibition is the process of suppressing of recently completed task information to reduce interference from it when we move on to a new task. Libermann et al (2007), in their experiments found that participants supress accessible memories of non-relevant tasks when encountered with new targets. Backward inhibition is also observed when participants performance suffers when they switched back to a recently abandoned task because of some residual inhibition (Mayr & Keele, 2000). These can be noted as the basis for studies on 'overwriting' where a new intention leads to retroactive interference or the blocking of an older intention. Recent studies explore the phenomenon of overwriting of intentions where it is conceivable that the establishment of a new prospective memory (PM) task representation could potentially overwrite various components, such as the PM cue, intended action, the association between PM cue and intended action, and the abstract representation of intention. This occurs because the new intentions components might compete for cognitive resources with the older intention. This process may alter the activation level of the completed intention representation.

Walser et al. (2012) were the first to investigate such a phenomenon by developing a repeated prospective memory paradigm, where a new PM cue was initiated in every repeated cycle, but old cues reappeared in later cycles to measure aftereffects. They found that repeat PM cues led to more aftereffects than simple oddball trials used as distractors. Aftereffects for completed intentions were higher in conditions where new prospective tasks were to be performed than when standalone ongoing task was to be performed. Anderson and Einstein (2017) found significantly higher persisting activation in the post-target response-times for the condition with new PM task in finished phase. Kurtz et al. (2022) used a mouse-tracking paradigm and found that aftereffects occur as a spontaneous reflexive action which were heightened in the presence of a novel PM task.

These findings provide support to the possibility that the novel prospective task heightens aftereffects by creating a state of active retrieval where all deviant stimuli may trigger retrieval mode because of monitoring engagement (Guynn, 2003). Retrieval mode is a cognitive task set that predisposes one to treat stimuli as a cue for retrieving certain stored action scripts or other information. Early studies using PET scans show heightened activation in the right prefrontal cortex when participants are supposed to retrieve something regardless of whether the retrieval is successful (Cabeza et al., 1997; Nyberg et al., 1995). Especially, intention related material already displays intention superiority effect or stronger and longer lasting activation in comparison to other retrospective material (Goschke & Kuhl, 1993; 1996). However, these are only a handful of studies and no systematic attempt at understanding overwriting from new prospective intentions or continued retrieval because of retrieval mode was made.

On the flip side, Walter, Goschke and Fischer (2014) found that in conditions with high working memory load, aftereffects were reduced. This could be because of an overwriting like process where attentional resources are diverted to another task thereby effectively deactivating older task representations. Other studies showed that while low and high levels of cognitive load did not cause a significant increase in commission errors, moderate levels of load did (Matos et al., 2020). These findings and our general understanding of retroactive interference in recognition paradigms seem to indicate that a new task may decrease aftereffects by process of overwriting. However, this has not been tested in prospective memory paradigms in relation to prospective intentions.

Studies that manipulate retention interval or ongoing task delays show that as delay increases, later prospective memory performance worsens. Delay in most cases can be conflated with other tasks that may take up cognitive resources and overwrite task sets. This is seen in Loftus (1971) where lesser intervening questions (less retroactive interference) lead to better prospective performance and in other studies that manipulated task delays (Hicks et al., 2000; Martin et al., 2011). Other findings by Müller and Pilzecker (1900) also support that retroactive interference by new list learning impairs memory of old list material. Such results make it pertinent to examine the plausible effects of retroactive interference leading to better deactivation because of new tasks interfering with old task representation and lessening of prospective aftereffects.

Some methodological limitations with the few studies of aftereffects and novel intentions are changes in context between active and finished-phase tasks, and changes in cue focality and salience. Focality is degree of overlap in processing between different tasks or different task stimuli. These kinds of context and processing changes are seen to influence the aftereffects of prospective memory. Also, findings from Walser et al., (2014) and general memory studies (Berman, Jonides & Lewis, 2009) support that interference results in more deactivation of older representations, than mere decay with passage of time.

1.7 Intention Deactivation and Intention-Status

The status of an intention can differ significantly—it might be unfinished and actively maintained, temporarily put on hold for future action, retracted after being encoded, partially fulfilled, or entirely carried out. These various statuses affect how cues related to intentions are processed when they are encountered in a later, irrelevant context. A suspended intention is one that has been encoded but not yet acted upon, typically because the right opportunity has not yet presented itself. It remains momentarily relevant and is thus not fully deactivated. Conversely, a completed intention—one that has been carried out—should theoretically be completely deactivated. However, research indicates that this is frequently not the case (Möschl et al., 2020). Interestingly, even intentions that have been cancelled, which are encoded and then specifically revoked, can still influence cognition and behaviour.

This raises important questions about how activation and deactivation mechanisms differ across intention statuses—completed, suspended, partially completed, or cancelled. For example, Scullin et al. (2009) discovered that spontaneous retrieval and commission errors occur during suspended phases but not after intentions have been fulfilled. However, in older adults, lingering effects were noted for both suspended and completed intentions (Scullin et al., 2011), indicating potential age-related challenges in intention deactivation.

The varying levels of activation may stem from the presence or absence of episodic tags that indicate completion. Completed intentions might benefit from enhanced episodic traces, which facilitate the creation of a “stop-tag” (Bugg & Scullin, 2013). In contrast, suspended or cancelled intentions do not possess the mental closure associated with actions that have been completed, resulting in ongoing activation. This aligns with the Zeigarnik effect (1938), which posits that incomplete tasks remain more accessible in memory than completed ones.

While both suspended and cancelled intentions remain unfulfilled, they differ significantly. Suspended intentions are temporarily paused, waiting for the chance to be completed. In contrast, cancelled intentions are intentionally discarded after being formed, with no anticipation of future cues or actions. Therefore, one might assume that cancelled intentions would deactivate similarly to completed intentions. However, research shows a different result: cancelled intentions tend to have higher commission error rates than those that are completed (Bugg & Scullin, 2013). This indicates that lingering cognitive tension, without any resolution, keeps these intentions in a more activated state. In support of this, Bugg and Scullin (2013) discovered that participants who did not encounter the PM target cue were more prone to make commission errors compared to those who were presented with the cue four times.

Interestingly, they discovered that practicing forgetting might alleviate these effects—possibly by activating processes similar to reconsolidation. According to Nader and Hardt (2009), recalling a memory could destabilize its trace, making it more vulnerable to modifications or suppression. Bugg, Scullin, and Rauvola (2016) built upon these results involving older adults, who displayed aftereffects even in the condition with four targets.

On the other hand, it seems that cue-action links are strengthened by performing the intention. Studies using the go/no-go paradigm find that the strength of response that is prepotent because of previous cue-action linking determines inhibitory failures that manifest as commission errors and interference (Garavan, Ross, & Stein, 1999; Roberts, Hager, & Heron, 1994). Performance of the action in response to the cue solidifies memory for the cue-action association and may make deactivation difficult. Pink and Dodson (2013) find that repetition of cue-action links leads to more commission errors. Marsh et al. (2002; 2007) also show that habitual tasks with more repetitions result in more aftereffects in terms of commission errors.

Hence, it can be concluded that the effects of intention status on aftereffects are not very clear. And there seems to be a paradoxical pattern where not engaging in intention completion hampers deactivation, while at the same time, multiple cue-action linkings (performing intention multiple times) also hampers deactivation.

Another interesting distinction that we attempt to bring to light with this thesis is one between ‘suspended instructions’ and ‘suspended targets’. Most studies in this area deal with suspended instruction, wherein participants are told that the intention is temporarily on hold. Since this is an instructional manipulation and this thesis attempts to focus on the cue-action links and their strength, we use suspended targets. That is, the targets were encoded but there was no opportunity to execute them as the cues never appeared during the active phase of the task. This is also a major lacunae in research as studies using suspended targets instead of suspended instructions are scarce.

1.8 Intention Deactivation and Delay from intention completion

Intention deactivation and the intensity of aftereffects are also framed as a function of the amount of delay from intention completion. The lingering impacts of fulfilled intentions, like increased response times (RTs) to recurring PM cues due to intention interference may only be noticeable immediately after the completion of intentions, as observed in McNerney and West's research (2007). However, these effects might diminish over longer intervals (Scullin et al., 2009; 2011). The notion of delay-dependent intention deactivation is based in studies showing similar forgetting curves for various other memory contents. General prospective memory performance is seen to worsen with delay (Meier et al., 2006), so it is plausible that the same effects of delay may apply to a completed intention being retrieved less and less as delay increases. Drop in performance as delay increases is also seen in other studies (Bradimonte & Passolunghi, 1994; Einstein et al., 2005). However, there are also studies that show no effect of delay on prospective performance (Einstein et al., 1995; Nigro & Cicogna, 2000). Similar results are seen with delays as long as 20 minutes and intention interference still persist (Loft et al., 2008).

Walser et al. (2012) found a greater number of errors occurred during PM repeated trials with shorter delays to intention completion compared to longer delays. In their experiment, they manipulated delay as delay from intention completion in the form that the half of the non-relevant cues occurring early in the finished-phase and the other half occurring later or towards the end. Even fMRI studies on spontaneous retrieval show that repeated cues that appear early on in the post-PM phase re-activated areas similar to general prospective responding (Beck et al., 2014). On the other hand, there was no variance in the likelihood of commission errors between short and long delay intervals in Scullin and Bugg (2013). Walser et al. (2014) found that across experiments it is repeated exposure to non-relevant stimuli that decreases aftereffects by creating new cue-action links that replace older links, and temporal delay does not decrease aftereffects.

Overall, findings about the effect of time delay and presentation interval on aftereffects are inconclusive and ridden with paradigm differences. There is support for delay dependent deactivation in principle but it may be that other factors like cue salience, task importance or status of the intention may override the effects of delay.

1.9 Intention Deactivation and Task Similarity

Another factor that modulates intention deactivation and aftereffects is task similarity or overlap. If there are two tasks that are to be performed simultaneously, or in rapid succession one after the other, tasks that use similar cognitive resources might produce more error because of sharing of the limited resources. Size and type of aftereffects may depend on whether a new task competing for resources in encoded and what kind of task it is. When an old cue-category is identical to a new prospective task cue-category, there will be competition for the limited processing resources and visual attention (Desimone & Duncan, 1995). For instance, if both cues (old and new) are meaningful words processed semantically, the higher overlap may lead to more errors than if the new task was non-semantic, like an image-rating task.

Novel prospective tasks with significant categorical or dimensional overlap are seen to increase the likelihood of erroneous repetition of older non-relevant tasks (Walser et al., 2017). Aftereffects were highest in condition when the target cue-category matched with the new target in the finished phase even when the response key was switched for the new prospective task. A switch in PM cue-category also switches attention from the old task set, reducing erroneous aftereffects. However, the use of repeated-cycles paradigm and the confusion effects of using repeated or multiple non-relevant cues may impact results.

It is also seen that context information is part of a task set (Landeira-Fernandez, 1996; Waszak, Hommel, & Allport, 2003), and a context similarity may support retrieval of uncompleted (McDaniel, Robinson-Riegler, & Einstein, 1998) as well as completed (Scullin et al., 2012) intentions. Most studies that use the repeated-cycles paradigm create a change in the context (the ongoing task in which PM is embedded) between phases or cycles. This change in context may impact aftereffects and also lacks the real-world challenge of usually remaining in the same context when the need to inhibit non-relevant intentions occur. So, in our thesis, we keep the context of the ongoing task in which our targets are embedded the same.

We all see that no study till now has examined erroneous spontaneous retrieval for both completed and suspended targets in the same experimental framework. The role of intention status in deactivation in cycles where newer intention should be retained and executed while inhibiting older intentions, especially when the intentions are similar in underlying processing is a lacuna that is to be addressed.

1.10 Summary:

Navigating through a busy daily life requires the brain to dynamically switch between goals—prioritizing new tasks while letting go of completed ones. This cognitive flexibility relies on mechanisms that not only activate relevant intentions but also deactivate those that are no longer needed. While executive control processes are known to regulate this transition by identifying obsolete goals and redirecting cognitive resources to current ones, the question remains: how do we truly “let go” of intentions, and what are the conditions under which this occurs?

Although forgetting has historically been viewed as a cognitive failure, recent theoretical advances suggest that forgetting may serve an adaptive role in the deactivation of irrelevant intentions. Several studies posit that forgetting could be instrumental in suppressing or inhibiting lingering prospective memories, allowing the cognitive system to reduce interference and remain task-focused (Dewar et al., 2007; Walser et al., 2017; Wixted, 2004). However, this hypothesis has yet to be systematically examined in the context of prospective memory. While the role of forgetting in retrospective memory has been extensively studied, its implications for PM deactivation is an area ripe for exploration.

For one we see that the status of intention completion has clear effects on how intention related information is processed. Suspended targets retain some kind of latent activation predisposing them to have higher aftereffects. However, the difference between deactivation processes for suspended and completed targets is not systematically examined in deactivation paradigms.

Secondly, encoding of novel prospective intentions to overwrite old intentions might seem a logical possibility. But no study so far shows direct support for it in the aftereffects and deactivation literature. Next, is the fact that this overwriting or the lack of it may very likely depend on task overlap. It is especially important to examine this factor in conditions where the context remains the same. Because in most real life instances, the need to deactivate or inhibit intentions is because we remain in contexts where intention triggers are still accessible.

We also see that delay may hamper performance and may result in better deactivation. However, some other studies report that the deactivation is because of repeated cue presentation leading to reconsolidation and updating intention status better and that delay is not responsible for deactivation.

We also see the accounts of inhibition and continued retrieval with findings aligning with both views. A growing body of neurocognitive and behavioural research offers fresh perspectives on the active role of inhibition in managing memory interference. For instance, the active suppression paradigm has shown that individuals can willingly inhibit the retrieval of unwanted memories, recruiting neural mechanisms associated with cognitive control (e.g., prefrontal regions) to limit memory accessibility (Anderson & Hanslmayr, 2014; Benoit & Anderson, 2012). Similarly, Wixted (2004, 2005) argues that forgetting is not always a passive failure of retention but may involve effortful suppression of irrelevant information. These findings raise the possibility that completed intentions are not merely passively forgotten over time but are actively suppressed to reduce competition for limited resources. As Scullin and Bugg (2013) and Walser et al. (2014) suggest, deactivation depends on several factors like ongoing task demands, cue salience, cognitive control abilities, and exposure to new cue-action contingencies. The effectiveness of deactivation thus hinges not on one factor alone.

Adding to this is the diversity in experimental paradigms used to study prospective memory. Script-based paradigms, which often examine more action-based tasks (e.g., remembering to perform an action like setting the table), offer insights into how the content of intentions influences their persistence. But event-based paradigms focus more on the cue-action link, and the mechanisms of decay or replacement. They provide more support in isolating the processes by which intentions are triggered, suppressed, reactivated, or deactivated, and less about how the content of the intention matters. Hence, event-based paradigms shall remain the focus here.

In summary, the deactivation of completed intentions is not a uniform or immediate process. Instead, it is a complex, multivariate phenomenon influenced by time, interference, inhibition, cue characteristics, and the structure of the intention itself. In the studies comprising this thesis, we attempt to examine some of the variables impacting intention deactivation and the conditions under which such deactivation is most effective. We compare different competing accounts of both deactivation and continued retrieval to try and understand this very critical ability required for effective daily functioning.

1.11 Research Agenda

Based on the findings in literature, intentions do not efficiently deactivate after serving a purpose and have lasting effects on tasks that come later. These effects manifest in the form of intention interference and commission errors for no-longer relevant targets. There are many lacunae in our understanding of these aftereffects and the conditions in which they occur. The present thesis makes an attempt at bridging some of the gaps in our understanding of prospective memory deactivation and aftereffects.

For one, we focus on an event-based paradigm because we attempt to explore the journey of a cue-action link and how it goes through the process of deactivation. We also see in literature that script-based paradigms do not usually observe aftereffects. Script-based paradigms are more focused on the semantic content which is especially sensitive to individual knowledge differences and life experiences, and seems subject to effective inhibition. We also focus on the role of novel prospective intentions in intention deactivation. The very few studies in this area are ridden with paradigm differences. Especially all studies that used a repeated-cycle paradigm (except Walser et al., 2017) do not have a novel intention in the finished phase. Instead they use multiple cycles if active and finished phases, where the finished phase is ongoing-task only. This is an incomplete representation of how real-world prospective memory works where we must deactivate and manage multiple intentions while continuing to retain and execute new intentions.

There is another distinction in Prospective memory literature that is not adequately highlighted. This is the difference between suspended instructions and suspended targets of prospective memory. Most research focuses on suspended instructions where participants are instructed that the prospective memory task is currently on hold. This is an instructional manipulation and there is no focus on cue presentation or the strength of the cue-action link. On the other hand, suspended targets are those that are encoded, but there is simply no opportunity to execute them. Just like a completed intention, these targets are also followed by task completion instructions, so as to discourage any active monitoring. This is something that occurs a lot in real life where many intentions (actions) have to be revised as completed even though we never actually perform them when working with teams or on complex tasks. Another gap in research is how delay from task completion impacts deactivation in such paradigms. There are studies that test the effect of delay by manipulating time gap between active-phase and finished phase and on the other hand, there are studies that manipulate the delay between encoding an intention and actually having the opportunity to execute it. However, very few studies conceptualize delay not as a time delay but more of a presentation delay where the non-relevant targets appear early on or later in the experiment by when there is better chance for updating and reconsolidation of our intentions due to a change in task set or mental set.

Lastly, we also explore the role of task similarity between old and new intentions and how that impacts prospective memory deactivation. There is only one study that examines the role of task similarity but even that study is accompanied with the drawbacks of using a typical event based paradigm where the finished phase consists only of the ongoing task, and having a context change between both phases. In our thesis, we manipulate task similarity in blocks where there is another prospective task that must retained and executed.

Key Terminology	**Definitions**
Deactivation	The *process* of disengaging or turning-off, a completed or no-longer relevant intention. This means the intention is not pursued actively and/or is actively inhibited.
Aftereffects	Aftereffects can be defined as the *outcome* of inefficient or incomplete deactivation of no-longer relevant intentions. They represent a conceptual umbrella term and operationally manifest as intention interference and commission errors

Commission Errors	Incorrect performance on a no-longer relevant intention is termed a commission error. It is considered an error and can occur for both completed and suspended/Cancelled targets
Interference	The phenomenon where intention-related material causes a cost to other tasks. This manifests as slower response times when the target word is encountered.

Table 1.3: Key terminology used in the thesis and their definitions

In summary, the studies in this thesis investigate the effects of encoding a novel prospective memory (PM) task on aftereffects or deactivation in prospective memory. Encoding a new PM task may potentially overwrite the old intention representations. However, this may depend on the intensity of demands the new task places on our limited cognitive resources. On one hand, the novel PM task may heighten aftereffects by creating a state of active retrieval where all deviant stimuli may trigger spontaneous retrieval. On the other, overwriting like mechanisms may lead to a decrease in aftereffects. We see that proactive interference has an impact on prospective memory but no examination of retroactive interference in such a paradigm has occurred. We fill that gap by using a new intention representation in a prospective memory paradigm where it is already seen that the continued retrieval of the older non-relevant intention hampers performance on the new task or other associated tasks, but there may be conditions that reverse this phenomenon. In this thesis, we explore three such conditions. They are Intention Status, Task similarity between old and novel prospective task, and the amount of delay from intention completion.

We explore if the state of deactivation depends on if the target was suspended or completed. This status of the intention is seen to be an important variable in literature and is very pertinent to real-life as most of our daily goals are part of bigger plans that are always only partially fulfilled. Bugg et al. (2013) found that task interruption creates a tension leading suspended cues to have higher recall and commission errors in comparison to completed or repeat cues. This along with several other studies in line with the Zeigarnik effect support the view that suspended or cancelled or partially completed targets are of higher activation status that completed targets. On the other hand, Pink and Dodson (2013) find that repetition of cue-action links leads to more commission errors. Marsh et al. (2002; 2007) also show that habitual tasks with more repetitions result in more aftereffects in terms of commission errors. These views support the idea that repetition strengthens memory traces and makes deactivation difficult. We attempt to find support for either possibility by testing if cue status has an impact on prospective memory aftereffects.

We also examine the effect of delay from task completion and if cue-action associations are stronger immediately after task completion and subject to decay with time. We manipulate time delay by early or late presentation of non-relevant target cues and examine their impact on aftereffects.

Finally, we also explore the role of task similarity in prospective memory aftereffects. When an old prospective memory cue-category is similar to a new prospective task, there will be a competition for the limited processing resources. A switch in PM cue-category also switches attention from the old task set reducing erroneous aftereffects. However, the use of a repeated-cycles paradigm could lead to confusion due to multiple presentations on non-relevant targets and there are also differences is salience and focality in studies so far. We create different levels of task similarity and dissimilarity by changing target cue category and by changing response keys.

So, the broad questions guiding this thesis are as follows:

1. How does the encoding of a novel prospective memory task affect previous intentions and their deactivation?

Rationale: Only few studies have used multiple intentions in prospective memory paradigms and none, to our knowledge used a control group for comparison. The influence that retroactive interference can play in such a paradigm is largely unexplored presenting as a significant research gap. This is a very pertinent question to address as it brings the laboratory paradigm closer to real-life scenarios where we rarely deal with solitary intentions.

2. How does intention status (suspended vs. completed) impact intention deactivation and aftereffects?

Rationale: There are conflicting findings about activation levels of intentions based on their status of completion. While some suggest higher activation for suspended cues, other suggest that completed and repetitive actions display more aftereffects. These findings do not align and this poses as a relevant gap to be addressed. Clarifying how intention status impacts deactivation may provide some very useful insights into understanding how we are usually capable to successful intention management and updation.

3. What role does delay play in determining the strength of cue-action associations and their deactivation?

Rationale: Forgetting theories of decay and Interference have forever been pitted against each other but the temporal dynamics of cue-action associations in the context of PM aftereffects has simply not been investigated. Even the few findings that exist present with a lot of contradiction. Some suggest that delay diminishes aftereffects, while other suggest that these aftereffects are resilient to the effects of time.

4. How does task similarity between old and new prospective memory task influence aftereffects and deactivation of non-relevant task.

Rationale: In understanding the role of context on PM aftereffects, cue focality, salience of target cues and the use of a repeated cycle paradigm were key components so far. These may have an impact on how prospective targets are processed. However, task similarity may also impact how PM targets are processed due to shared cognitive resources. We attempt in our study to isolate these effects by using cue-category similarity and response-type similarity as the independent variables.

CHAPTER 02: RESEARCH AIMS AND GENERAL METHODOLOGY

2.1 Research Objectives

We have reviewed the history of prospective memory, research literature on deactivation of intentions, and later impact of non-relevant intentions as aftereffects in the previous chapter. Based on the findings of the chapter, the main questions guiding our experiments were structured. In line with the research questions, the following will be the objectives of this thesis.

1) Encoding Novel Intentions:
    a. To compare aftereffects in groups with and without novel intention encoding in the finished phase
    b. Whether encoding Novel Intentions impacts intention deactivation positively or negatively
    c. Whether repeated cycle paradigms with novel intentions in each cycle result in increased aftereffects in later cycles compared to earlier cycles

2) Intention-Status
    a. Whether completing an intention impacts aftereffects differently than a cancelled or suspended intention
    b. Whether stronger cue-action links that are formed by performing the intention, lead to more aftereffects

3) Time-course effects
    a. Whether manipulating delay from intention completion impacts intention Deactivation

b. Whether non-relevant cues presented early in the finished phase display higher aftereffects than those presented later in the experiment.

c. Whether delay from intention completion impacts intentions of different status; suspended and completed targets, differently.

4) Task Similarity

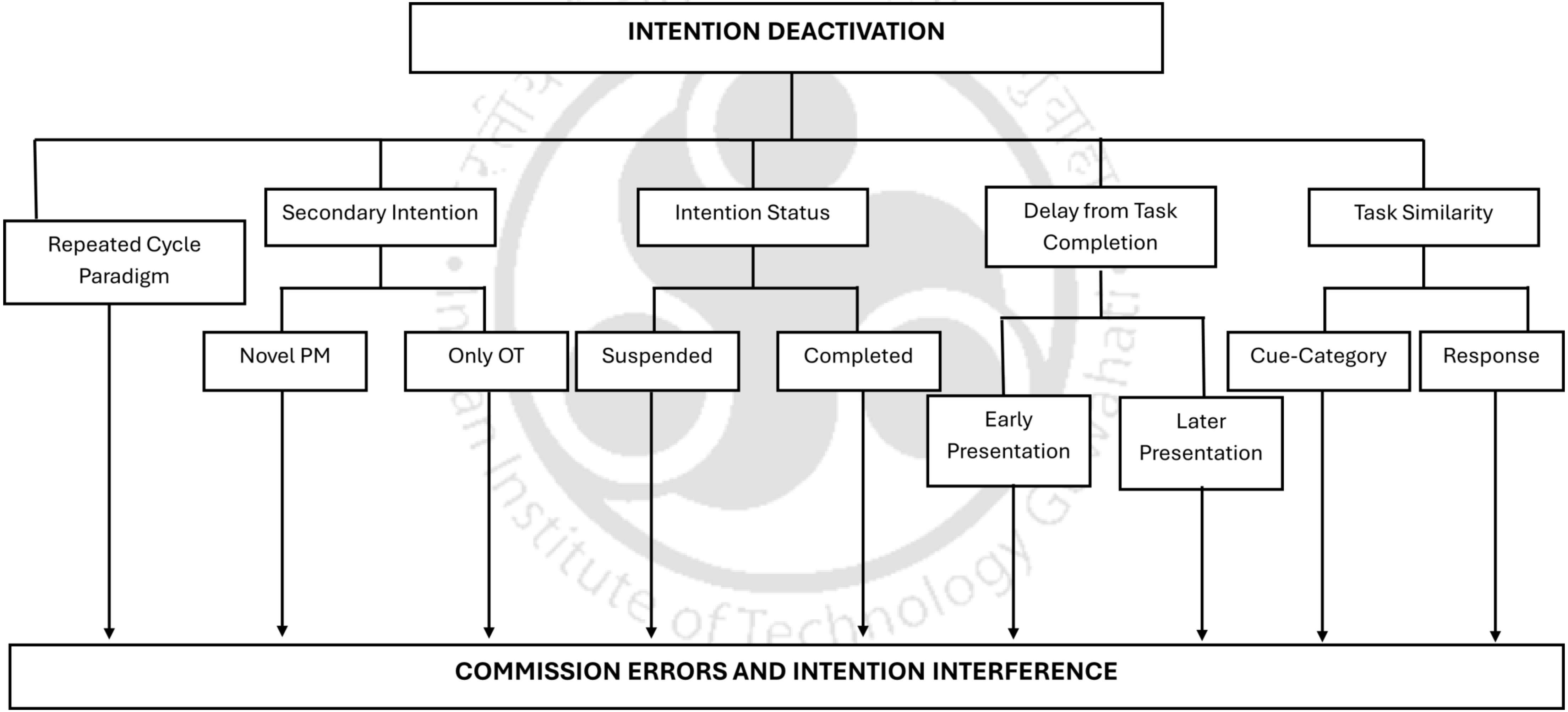
a. Whether overlap or similarity between tasks plays an important role in prospective memory aftereffects

b. Whether change in stimulus category supports prospective memory deactivation. That is; if the initial prospective target is a word and the novel prospective target is a word too, it represents cue-category similarity. If the novel target is a symbol, it represents cue-category dissimilarity.

c. Whether change in response key supports prospective memory deactivation

d. Whether the impact of task overlap on aftereffects is different for suspended and completed targets

RESEARCH DESIGN



2.2 General Methodology

In this section, we briefly outline the various tools and equipment we have used in the present thesis. Additionally, we also define how the tool / equipment was used in the present thesis. This section aims to minimize unnecessary repetitions and redundancies caused by repeated reference to common tools and equipment included in the thesis

2.2.1 *Participants*

A total of 190 participants were recruited across all the studies included in this thesis. All were undergraduate students with ages ranging from 18 to 24 [N=190; Mean=19.78; SD=1.48], from Indian Institute of technology Guwahati, who volunteered for the experiments in the exchange of partial credit towards a course requirement. Each participant was tested individually in sessions that lasted approximately 40-60 minutes per experiment. All the participants completed few questionnaires, i.e. a personal data form including questions about their age, gender, eyesight and so forth. along with informed consent form, and the mini-mental state examination.

Inclusion Criteria: Young Adults with normal or corrected to normal vision, The participants had no diagnosed psychiatric abnormalities or history of drug use. They had normal score on the pre-testing questionnaires and signed and informed consent sheet.

Exclusion criteria: Participants with mild to moderate neurological/psychiatric conditions, and mild to moderate addictions in any form were excluded. Some participants were excluded at the level of the practice phase because despite multiple instructions, they took too long to respond to each trial. And any participant could request to step back from the experiment at any time and for their data to not be used during analysis.

2.2.2 *Questionnaires*

1. **Mini-Mental Status Examination**- The Mini-Mental State Examination (MMSE) is a widely used 30-point questionnaire designed to assess cognitive impairment. It encompasses various cognitive functions, including orientation to time and place, registration (immediate memory), attention and calculation, recall, language skills, and the ability to follow simple commands. The test typically takes about 5 to 10 minutes to administer and does not require specialized equipment or training.

   In the present thesis: We used it to screen subjects for any major cognitive impairments. The mean score was 27.52 ± 1.69 and indicated that none of the participants had any kind of impairment.

2.2.3 *Stimuli*

Word stimuli for the ongoing task, which was an abstractness/concreteness rating task, were selected from the English Lexicon Project (ELP) database (Balota et al., 2007). The English Lexicon Project is a comprehensive database that provides standardized behavioural and descriptive data for a vast set of words and nonwords. The database encompasses various lexical characteristics and behavioural measures, including reaction times and accuracy rates for both lexical decisions and naming tasks. The ELP was chosen for its robust and well-validated data, ensuring that the selected stimuli had reliable and established psycholinguistic properties.

The first experiment of this thesis used a repeated cycles paradigm which consisted of a total of 160 trials across 4 cycles. All these words were selected from the ELP database. Apart from this, three unique lists of words were created for the practice, active, and finished phases of the experiment: 10 words for the practice phase, 40 words for the active phase, and 60 words for the finished phase. The word lengths were between six to twelve letters and all words were of above average frequency in Freq_HAL ratings (Lund & Burgess, 1996). HAL (Hyperspace Analogue to Language) frequency ratings are a set of word frequency norms developed to provide a more accurate measure of word usage in English compared to previous frequency norms. The HAL frequency norms are based on an analysis of approximately 131 million words, making it a larger word corpus than older norms like the Kucera-Francis norms. The HAL ratings were preferred because they provide a more contemporary and ecologically valid measure of word frequency, reflecting current language usage patterns. Using above-average frequency words ensured that participants were familiar with the stimuli, reducing the likelihood of unfamiliarity influencing abstractness/concreteness ratings.

Eight words, in four pairs of two were selected as the prospective cues in each cycle of our first experiment using the repeated-cycle paradigm. For all other experiments, Six words were selected as prospective memory (PM) targets. Three of these PM target words did not appear in the active phase to assess the impact of prior exposure on PM performance. The suspended and completed target words were carefully matched on the number of syllables and word frequency to control for potential confounding variables related to linguistic complexity and familiarity. This matching process ensured that any observed differences in PM performance could be more confidently attributed to the experimental manipulations rather than inherent differences in the target words themselves.

Additionally, for Experiment 4, symbols were used as prospective targets in one of the conditions to investigate the effect of stimulus type on PM performance. The symbols were selected to be visually distinct and easily recognizable to participants.

2.2.4 *Tools*

E-Prime 2.0 (Psychology Software Tools, Inc.) is a software application designed for the design, execution, and analysis of behavioural experiments. Widely used in research settings, E-Prime enables researchers to create experimental paradigms with millisecond precision timing, ensuring high accuracy in data collection and analysis. The software supports a wide range of stimulus types, including text, images, audio, and video, allowing for versatile experimental designs. E-Prime also allows sending and receiving triggers with external devices, including eye trackers, fMRI, and EEG.

2.2.5 *General Task Design*

The experiment was designed on E-Prime2.0, a presentation software used in the field of behavioural sciences. We use an adapted version of the active phase-finished phase paradigm introduced by Scullin et al., (2012). The experimental paradigm was divided into two phases, plus a practice phase. There are two task processes within the experiment, the ongoing task and the prospective memory task.

Ongoing Task: The ongoing task serves as the context in which the prospective cues are embedded. It mimics a real-life environment where participants are engaged in an activity when they have to execute a future intention. In the case of our experiment, the ongoing task is an abstractness/concreteness word rating task. The words are presented on white background in black font, and separated by a fixation cross. The response is a keypad response using the keys 'A' for abstractness and 'C' for concreteness.

Prospective Memory Task: The prospective memory task is an event-based task. The prospective cues are also meaningful words. A prospective memory hit is when participants press the appropriate key ('L' key) in response to the target appearing during the ongoing task. There are a total of 6 prospective targets. Three of these appear in the active-phase of the experiment. These targets are considered completed after the end of the active-phase. The other three targets, which did not appear during the active-phase, are called suspended targets. Both completed and suspended targets reappear later in the finished phase but are non-relevant and participants should not respond with the prospective response to them anymore.

Practice Phase and Distractor Task: Each experimental session begins with instructions for the ongoing task. After giving these instructions, the participants were subjected to a practice phase of 10 trials so that they could understand the structure of the experiment. This practice was meant to ensure the participants understood the task and to encourage them not to take too long to respond. After this, cue learning for the active-phase begins. This phase can also be referred to as prospective encoding. A word list consisting of six words selected as prospective memory targets were presented on the software one at a time for a duration of 2000ms. After each word, a fixation cross was displayed for 500ms. The entire list was displayed 3 times. This encoding phase ended with instructions given to the participant that if any of the memorised words were to appear on a later task, they must press 'L' (instead of a/c). After encoding was complete, participants were made to write down the given instructions in their own words to verify that they had correctly understood them.

A distractor task followed this. The distractor task used in this experiment was a flip-and-match card game. For any participant to finish all three levels of the game took 9-10 minutes. This task is meant to ensure that any active rehearsal of the prospective memory intention does not take place, so that it does not become a vigilance task. After the distractor task, the subjects were instructed to pay attention to the word stimuli displayed on the screen and press *A* for an abstract word and *C* for a concrete word using the keys of the keyboard.

Active Phase: The active phase refers to the period during which individuals are actively engaged in a working-memory task, in this case an abstractness/concreteness word rating task along with a prospective memory task that requires them to remember to perform a future action. . It comprised of a total of 40 trials with 3 of the prospective targets embedded in the ongoing task. The targets occurred at fixed positions in the list (12th, 25th and 38th). Each trial word appeared in the center of the screen in black font on a white background. The trials were separated by a fixation screen that provided an inter stimulus interval of 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words were either ‘A’ or ‘C’, and for those trials containing target words, it was keypress ‘L’. A prospective hit was recorded only if ‘L’ was pressed immediately in response to a target word.

Encoding Novel Intentions: The end of the active phase was followed by finished-phase instructions. In these instructions, the participants were told that the prospective memory task was over and they no longer had to perform that task or react to those target words. In conditions where a novel prospective task is encoded, it is encoded after this finished-task instructions. The encoding process is exactly similar to the prospective encoding for the active phase. The list of targets are displayed one by one, each appearing for 2000ms with a fixation of 500ms in between. The list is played thrice before it is checked if it has memorised by the participants.

Finished Phase: The finished-phase comprised of a total of 60 trials, and both suspended (the three cues from the old prospective cue list that did not appear during the active-phase) and completed prospective cues from the active-phase reappeared during this phase. In this phase also, targets appeared in fixed positions across trials (9^{th}, 18^{th}, 25^{th}, 38^{th},46^{th}, and 54^{th}). Each trial word appeared in the center of the screen in black font on a white background. The trials were separated by a fixation screen that provided an inter stimulus interval of 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words, and target words which are no longer relevant were only ongoing task responses ‘A’ or ‘C’. If participants responded by pressing ‘L’, when encountered with the no-longer-relevant target words, it would be counted as a commission error.

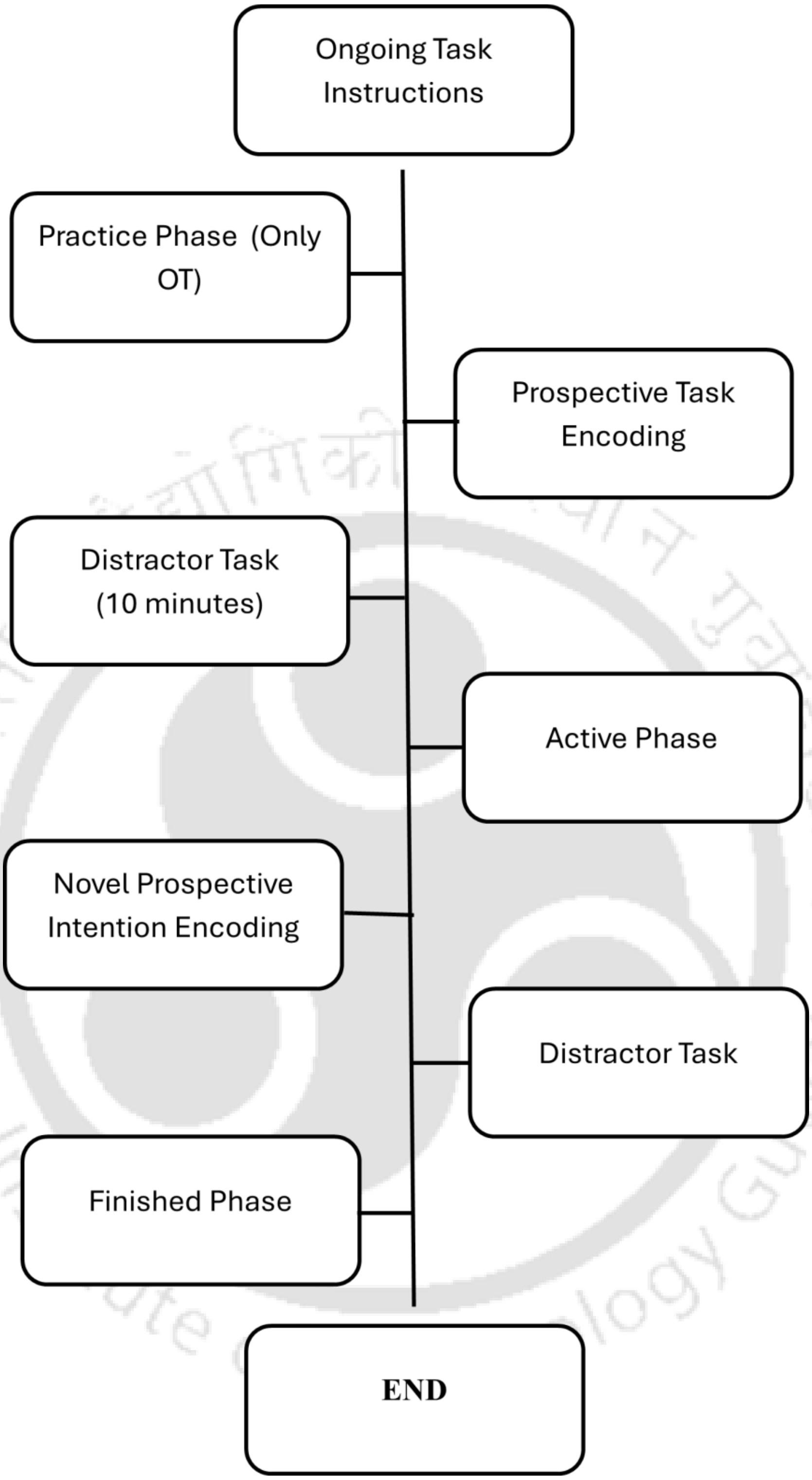


Figure 2.2: General Methodology- Task Flow

CHAPTER 03: BEHAVIOURAL EXPERIMENTS

3.1. EXPERIMENT 01: Repeated-Cycles Paradigm and Intention Deactivation

In this experiment, we use a repeated cycle paradigm, with new PM cues encoded in each new block. In most experiments that use a repeated-cycle paradigm, the finished phases are ongoing task only. However, real life situations often demand we deactivate an intention effectively while also simultaneously monitoring for new and active intentions that are to be performed. So, we use a repeated cycle paradigm, where there are PM tasks in both active phase and finished phase, with multiple cycles. Also, studies so far focus only on aftereffects for the PM block immediately preceding the current task. In our study, we repeat cues of not only the immediately preceding block, but even those performed before it and test for aftereffects.

Inhibiting not one but multiple non-relevant intentions may cause increased load on our inhibitory control abilities and lead to failures. But it may also be that new and different task encodings in each new block may reduce carry-over effects from older cycles.

Cycle	Cues in active-phase	Non-relevant cues in finished-phase
1	PM1	None
2	PM2	PM1
3	PM3	PM2 + PM1
4	PM4	PM3 + PM2 + PM1

Table 3.1: Tabular representation of exploratory nested design to measure aftereffects beyond those of only immediately preceding cycles/blocks

OBJECTIVE 01: To evaluate the effect of encoding novel intentions through repeated cycles on intention deactivation in terms of commission errors and intention interference.

HYPOTHESIS:

a) We hypothesize that participants will incur more commission errors in later cycles

b) We hypothesize that participants will incur more Intention Interference in later cycles

DESIGN:

We use a within-subject design where all our participants were subjected to four cycles of a repeated-cycle paradigm, with novel PM intentions encoded in each cycle. The repeated-measures design involves a single factor, with four levels. The independent variable was block or cycle (Block 1, Block2, Block3, Block 4). Another factor of interest though not outwardly manipulated is the origin cycle of non-relevant cues. As we present all non-relevant cues and not just those from the immediately preceding cycles, there are 6 levels of non-relevant cue origin divided among cycles. Cycle 2 has embedded within it non-relevant cues only originating from cycle 1. However, cycle 3 has non-relevant cues from both cycle 2 and cycle 1 reappear. The final cycle has non-relevant cues from all three previous cycles reappear.

CYCLE	NON-RELEVANT CUE ORIGIN	LABEL
2	Cycle 1 (PM1)	L1
3	Cycle 2 (PM2)	L2
3	Cycle 1 (PM1)	L3
4	Cycle 3 (PM3)	L4
4	Cycle 2 (PM2)	L5
4	Cycle 1 (PM1)	L6

Table 3.2: Aftereffects across conditions (Level labels used for analysis using one-way repeated measures ANOVA

Prospective memory performance and ongoing task performance is measured across cycles. Apart from this, the dependent variables were aftereffects measured as intention interference (response time) and commission errors (Accuracy), were measure from Block 2 onwards. Statistical analysis was conducted using one-way repeated measures ANOVA for prospective memory performance, reaction time on ongoing tasks, reaction time on non-relevant targets and response accuracy (commission errors) on non-relevant targets.

METHODOLOGY:

Participants

Ten healthy participants of the age group between 18 to 22 (19.6 ± 1.42) years volunteered for the experiment. Volunteers were undergraduate students of IIT Guwahati who were part of a psychology course. All participants filled a basic demographic information sheet and signed an informed consent sheet.

Material

Repeated-Cycles Commission Error Paradigm was used (Walser et al., 2017). Four lists of 40 words were used as the ongoing task stimuli. The word stimuli were taken from the English Lexicon Project (ELP). The word length was between six to twelve letters and all words were of above average frequency in Freq_HAL ratings (Lund & Burgess, 1996). The HAL (Hyperspace Analogue to Language) frequency ratings are a set of word frequency norms developed to provide a more accurate measure of word usage in English compared to previous frequency norms. The HAL frequency norms are based on approximately 131 million words making it the largest word corpus and preferred over older norms like the Kucera-Francis norming.

Procedure

The experiment was made on E-Prime (Version 2.0). It uses a within-subject repeated measures design. We use a paradigm similar to the one used by Walser and Collegues (2017) where there is an active PM task in both phases. The session begins with instructions for the ongoing task (word-rating task). The subjects were instructed to pay attention to the word stimuli displayed on the screen and press A for an abstract word and C for a concrete word using the keys of the keyboard. Each word stimulus presentation was separated by a fixation screen that appeared for 1500ms. The participants could take as long as needed to respond but were encouraged to do so as quickly and accurately as possible. A practice phase with 10 trials was conducted to ensure familiarization.

This is followed by prospective memory encoding. Two words that serve as prospective memory cues are displayed on the screen one after the other. Each word appeared for 2000ms with an inter-stimulus fixation of 500ms. The list appeared thrice. This encoding phase ended with instructions given to the participant that if any of the memorised words were to appear on a later task, they must press ‘L’ (instead of A/C). Some additional instructions were also given directing participants to expect such encoding at the end of each cycle illustrated by markers like, ‘End of Phase 1’. Each such marker was followed by the encoding of two new prospective targets that were relevant for the next phase. Also the end of each phase came with finish task instructions that the prospective task from the previous phase is now complete and no-longer relevant for the future.

After making sure that the participants have understood the instructions and memorised the cues, an active-phase commences. This consists of 40 trials (38 standard trials, 2 PM trials). Each trial is separated by a fixation cross that appears for 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words were either ‘A’ or ‘C’, and for those trials containing target words, it was keypress ‘L’. A prospective hit was recorded only if ‘L’ was pressed immediately in response to a target word. A miss was recorded if participants failed to press ‘L’ key for a target word, and in later phases, a commission error was recorded every time a participant pressed the prospective response key (L) for any of the older non-relevant targets.

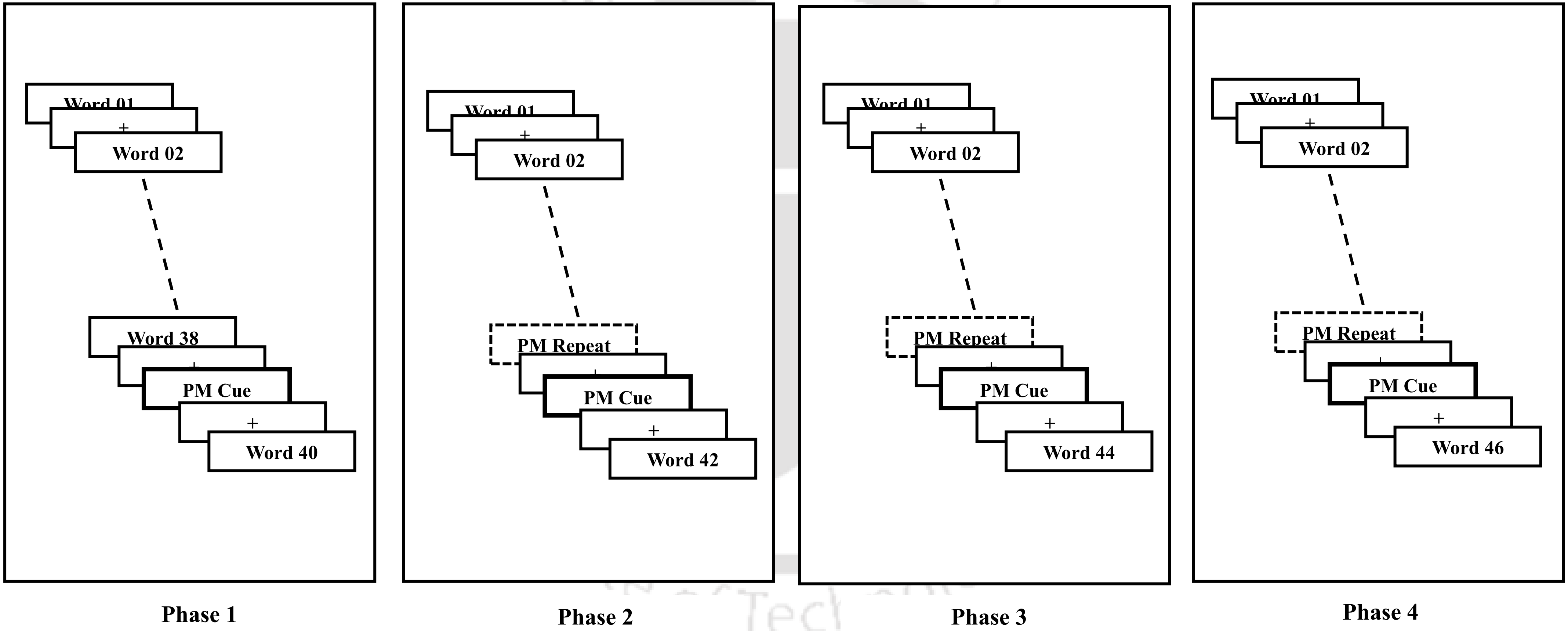
All phases ended with finish task instructions during which the participants were told that the prospective task was over and that the target words were no longer relevant. This was followed by a Finished-phase or simply the next phase during which two new more targets were encoded as prospective memory cues that would appear later in the task.

Following phases contained two additional trials that were added to accommodate the $PM_{Repeated}$ trials. Phase 2 consisted of 42 trials (38 standard trials, 2 PM trials, 2 $PM_{Repeated}$ trials). Phase 3 consisted of 44 trials (38 standard trials) with $PM_{Repeated}$ trials from both phase 1 and phase 2 re-appearing to measure intention deactivation.

The entire experimental session had 4 such cycles with new prospective memory targets encoded and made non-relevant each time. In the 2^{nd}, 3^{rd} and 4^{th} cycles, both the newly encoded targets and the no-longer relevant targets from all the previous phases were encountered by the participants. Testing of aftereffects was done in the finished phases.

Figure 3.1: Schematic Representation of Experimental Paradigm Consisting of Multiple Cycles of Finished-Phase Paradigm.

The PM Repeat Cues appearing in each phase are the non-relevant cues from the previous phase.



RESULTS:

All statistical analysis were conducted using one-way repeated measures ANOVAs. Since the experiment consisted of 4 cycles, the effect of cycle on reaction time for ongoing task and prospective memory accuracy were calculated.

Ongoing task: A One-way Repeated ANOVA comparing response times across cycles found significant differences, $F_{(3,27)}= 5.82$, $p< 0.05$, $\eta^2 = 0.39$. Post-hoc comparisons using Bonferroni pairwise comparison revealed one significant difference. Response times on ongoing task in the second cycle (M=979.40ms) were significantly different from the third cycle (M=1161.10ms), with a mean difference of 181.70ms ($p<0.05$).

Prospective Memory Task: In analysis of PM accuracy, our results find that there is no significant difference between Accuracy for prospective memory targets across cycles [$F_{(3,27)}=0.14$, $p>0.05$, $\eta^2 = 0.02$]. Same is for response times on PM targets across cycles.

The next set of analysis also used one-way repeated measures ANOVAs. But here there were six levels of the independent variable, non-relevant cue origin across cycles.

Commission error rate: There is no significant differences in commission error rates [$F_{(5,45)}=1.28$, $p>0.05$, $\eta^2 = 0.12$].

Intention Interference: Repeated ANOVA for response times on non-relevant targets of different origin cycles were analysed. There were no significant differences found. [$F(5,45)=0.98$, $p>0.05$, $\eta^2 = 0.09$].

Table 3.3: Mean Reaction Times for Ongoing Task Trials across Cycles

	CYCLE 1	CYCLE 2	CYCLE 3	CYCLE 4
RESPONSE TIME	913.90 ± 324.54	979.40 ± 197.49	1161.10 ± 95.64	1359.20 ± 312.54

Table 3.4 : Mean Recation Times for Prospective memory targets across Cycles

	CYCLE 1	CYCLE 2	CYCLE 3	CYCLE 4
RESPONSE TIME	1171.45 ± 187.48	1164.10 ± 161.93	1172.70 ± 201.47	1150.70 ± 146.61

Table 3.5: Mean proportion Commission errors across levels

L1	L2	L3	L4	L5	L6
0.15 ± 0.24	0.10 ± 0.21	0.05 ± 0.15	0.10 ± 0.21	0.05 ± 0.15	0.05 ± 0.15

Table 3.6: Mean reaction time on non-relevant targets across conditions

L1	L2	L3	L4	L5	L6
1270.80 ± 44.94	1198.40 ± 91.33	1237.90 ± 123.86	1268.40 ± 123.60	1284.65 ± 108.25	1230.85 ± 43.40

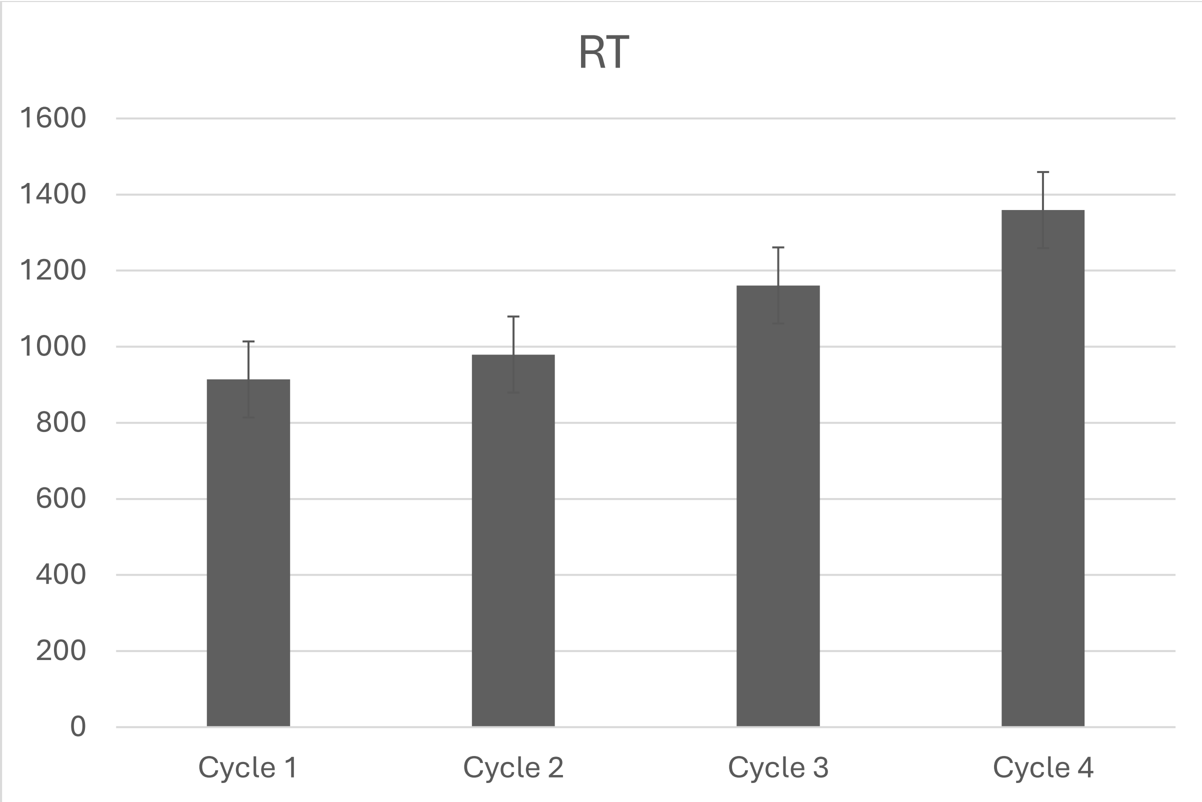


Figure 3.2 : Mean reaction time (RT) for ongoing task across cycles

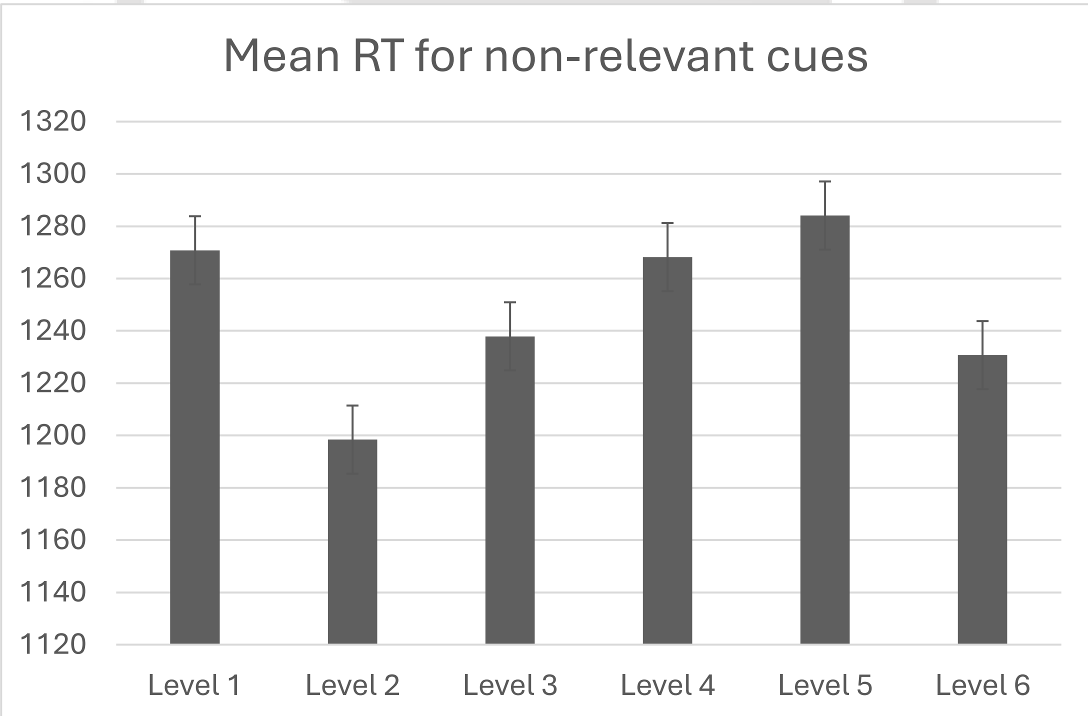


Figure 3.3: Response times (RT) for non relevant targets across levels of origin in all 'finished-phases'

DISCUSSION:

This study aimed to examine the impact of encoding multiple novel PM intentions in a repeated cycle paradigm, where participants continue to hold in their memory a to-be-executed intention even in the finished-phases of the experiment. This paradigm (see Walser et al., 2017) highlights the importance of actively updating and adjusting our actions to changing needs as it happens in real-life.

We used a within-subject design where performance of participants on ongoing task, prospective memory task, and their aftereffects (commission error rate) were measured across 4 cycles of active-phase and finished-phases. The analysis was done using one-way repeated measures ANOVA. We analysed response times for ongoing task, which is the word rating task. We also used the same analysis to compare prospective memory accuracy and commission error rates across cycles.

We found a significant difference in mean reaction time on ongoing task trials. Pairwise analysis showed that there were significant differences in ongoing task response times between the second cycle and the third cycle. The mean reaction time increases as participants progress from one cycle to the next. This may be attributed to fatigue due to the increased number of trials encountered as each cycle is completed. We see that mean reaction time is highest in the last phase for ongoing task trials. As participants progress through multiple cycles of the ongoing task, their performance may be influenced by exhaustion or decreased attentional resources.

In our analysis of prospective memory accuracy, we found that there was no significant difference between cycles and that prospective task accuracy was almost at ceiling in all cases. Even Commission error rates do not differ significantly across cycles when participants use such a repeated-cycles paradigm.

These findings suggest that the use of a repeated cycle paradigm may not be necessary or advantageous. The lack of substantial variation between active phase (1^{st} cycle) and Finished PM phases indicates that participants' ability to remember and execute intended actions remains relatively consistent across cycles.

Given these findings, researchers may want to reconsider the use of repeated cycle paradigms in PM studies, as they do not appear to offer additional insights beyond those obtained from single-cycle designs. Instead, focusing on a single cycle also gives a clearer picture of deactivation which may be hampered in the confusion of multiple cycles.

3.2. EXPERIMENT 02: Intention Status and Intention Deactivation

In this experiment we use a mixed design, with the commission error paradigm (single cycle, active phase-finished phase). A new PM intention is encoded in the finished phase to examine the impact of novel intentions on prospective memory aftereffects. However, we use a control group with no novel intention encoding for enhanced experimental control. To our knowledge, there is no study clearly differentiating between such conditions.

We also use intention status (suspended vs completed) as the within-subject variable to assess if intention completion results in better deactivation. Very few studies use suspended cues in the true sense of a non-executed PM cue and not as suspended task instructions. We attempt to bridge that gap with our experiment.

OBJECTIVE 01: To evaluate the effect of encoding novel intentions and the effect of intention status using commission errors paradigm, on intention deactivation in terms of commission errors and intention interference.

HYPOTHESIS:

a) We Hypothesize that intention interference will be significantly different between condition with novel PM intention and control condition

b) We Hypothesize commission error rates will be significantly different between condition with novel PM intention and control condition

c) We hypothesize that suspended cues will result in more aftereffects across both conditions

VARIABLES:

Independent variables: Secondary Intention (No novel intention and Novel intention)

Intention Status (Suspended and Completed)

Dependent variables: Response times

Commission errors (Accuracy).

DESIGN:

A 2x2 Mixed design is employed. The between-subject independent variable of condition has two levels (Novel PM task Condition, Control Condition). The first group encoded a novel prospective intention in the finished-phase, and the control group did not encode any additional task. The within-subject independent variable was intention status, with two levels (Suspended, Completed). The intention could either be suspended (encoded but never had a chance to be performed in the active phase) or completed (encoded and performed in the active phase).

The dependent variables were aftereffects measured as intention interference (response time lag on non-relevant targets) and commission errors (Accuracy) on non-relevant targets that reappear in the finished-phase. Statistical analysis was conducted using a Mixed ANOVA for reaction time on non-relevant targets and response accuracy (commission errors) on non-relevant targets.

METHODOLOGY:

Participants

A total of 60 participants were recruited to participate in the study. All of them were students who volunteered in return for course credit on an undergraduate psychology course. They were all within the age range of 18-24 years (M = 19.46 years; SD = 1.39). They were split into experimental and control groups using alternating pseudo-random assignment. The experimental sessions lasted an hour and the participants had normal or corrected to normal vision.

Material

Word stimuli for the ongoing task which was an abstractness/concreteness rating task were selected from the English Lexicon Project database (Balota et al., 2007). We created three unique lists of 10, 40, and 60 words each for the practice-phase, active-phase, and the finished-phase respectively. The word length was between six to twelve letters and all words were of above average frequency in Freq_HAL ratings (Lund & Burgess, 1996). Six words were selected as prospective memory targets, three of which did not appear in the active phase. The suspended and completed target words were matched on number of syllables and word frequency.

Procedure:

The experiment was designed on E-Prime2.0, a presentation software used in the field of behavioural sciences. We use an adapted version of the active phase-finished phase paradigm introduced by Scullin et al., (2012). This is also called the commission error paradigm and is consists of a standard prospective memory task along with an additional task at the end where commission errors or aftereffects are measured.

The experimental paradigm was divided into two phases. The active phase refers to the period during which individuals are actively engaged in a working-memory task, in this case an abstractness/concreteness word rating task along with a prospective memory task that requires them to remember to perform a future action. Because of this, it is also referred to as the PM Block. This phase represents a standard event based prospective memory task where the participant is engaged with an ongoing task and has to execute an additional PM task that occurs infrequently and is embedded in the ongoing working memory task.

The finished phase occurs after the primary task is completed. This is the additional task in the paradigm apart from the standard prospective memory task. In this phase, participants are instructed that the prospective task is finished and is no longer relevant during this phase. Then the no-longer relevant cues reappear, and aftereffects are measured. Because of this, it is also referred to as the Test Block.

The experiment begins with instructions for the ongoing task. The subjects were instructed to pay attention to the word stimuli displayed on the screen and press A for an abstract word and C for a concrete word using the keys of the keyboard. Each word stimulus presentation was separated by a fixation screen that appeared for 1500ms. The participants could take as long as needed to respond but were encouraged to do so as quickly and accurately as possible. After giving these instructions, the participants were subjected to a practice phase of 10 trials so that they could understand the structure of the experiment.

Encoding Prospective Task: Following the practice phase, cue learning for the prospective memory task embedded in the active-phase begins. A word list consisting of six words selected as prospective memory targets were presented on the software one at a time for a duration of 2000ms. After each word, a fixation cross was displayed for 500ms. The entire list was displayed 3 times. This encoding phase ended with instructions given to the participant that if any of the memorised words were to appear on a later task, they must press ‘L’ (instead of A/C). After the encoding was complete, participants were made to write down the instructions given in their own words, along with the word list, to verify that they had correctly understood them.

A distractor task followed intention encoding. The distractor task used in this experiment was a flip-and-match card game. For any participant to finish all three levels of the game took 9-10 minutes.

Active Phase: The active phase commenced with the embedded prospective task. It is comprised of a total of 40 trials with 3 of the prospective targets embedded in the ongoing task. The prospective targets occurred at fixed positions in the list (12th, 25th and 38th). Each trial word appeared in the center of the screen in black font on a white background. The trials were separated by a fixation screen that provided an inter stimulus interval of 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words were either 'A' or 'C', and for those trials containing target words, it was keypress 'L'. A prospective hit was recorded only if 'L' was pressed immediately in response to a target word.

Encoding Novel Intentions: The completion of the active-phase was followed by finished-phase instructions. All participants were instructed that the prospective task was now complete, and they do not have to remember or perform it anymore. At this juncture, participants were divided into experimental and control groups. The experimental group then encoded a new prospective memory task. Three new prospective targets were encoded similar to cue-learning during the active-phase. The list of targets was displayed thrice, and it was ensured that participants memorised the target words. There was no additional task encoded by the participants of the control group. This was followed again by a distractor task for both groups.

Finished Phase: The finished-phase comprised of a total of 60 trials, and both suspended (the three cues from the old prospective cue list that did not appear during the active-phase) and completed prospective cues from the active-phase reappeared during this phase. These targets also appeared in fixed positions across trials (9th, 18th, 25th, 38th,46th, and 54th). Each trial word appeared in the center of the screen in black font on a white background. The trials were separated by a fixation screen that provided an inter stimulus interval of 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words, and target words which are no longer relevant were only ongoing task responses 'A' or 'C'. If participants responded by pressing 'L', when encountered with the no-longer-relevant target words, it would be counted as a commission error. Aftereffects were measured in terms of response delays and commission errors.

Though other studies with focal cues accept prospective responses as accurate even two trials after cue presentation, we record only on cue response as accurate as most laboratory based prospective tasks have ceiling level accuracy anyway.

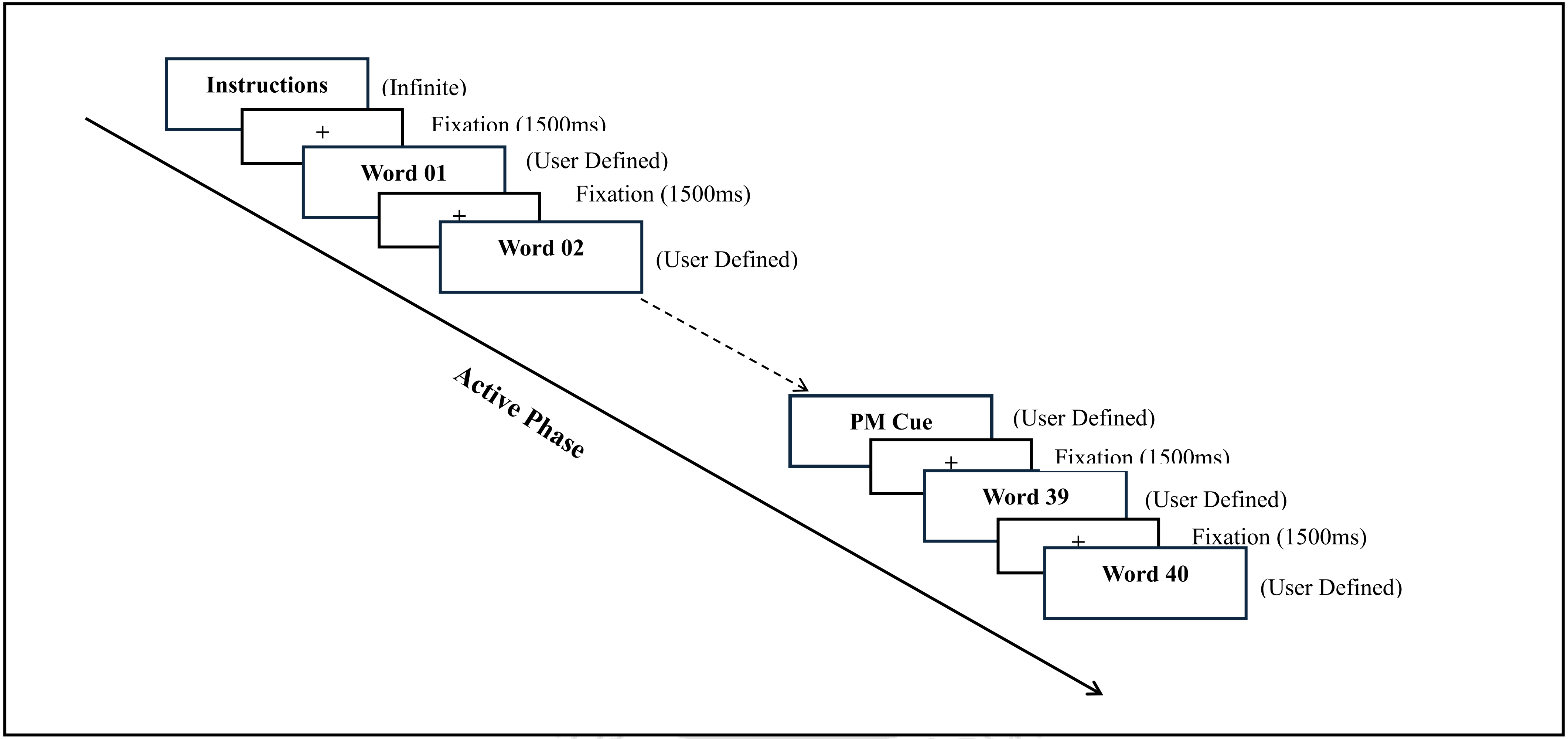


Figure 3.4: Schematic Representation of Task Flow of Active Phase

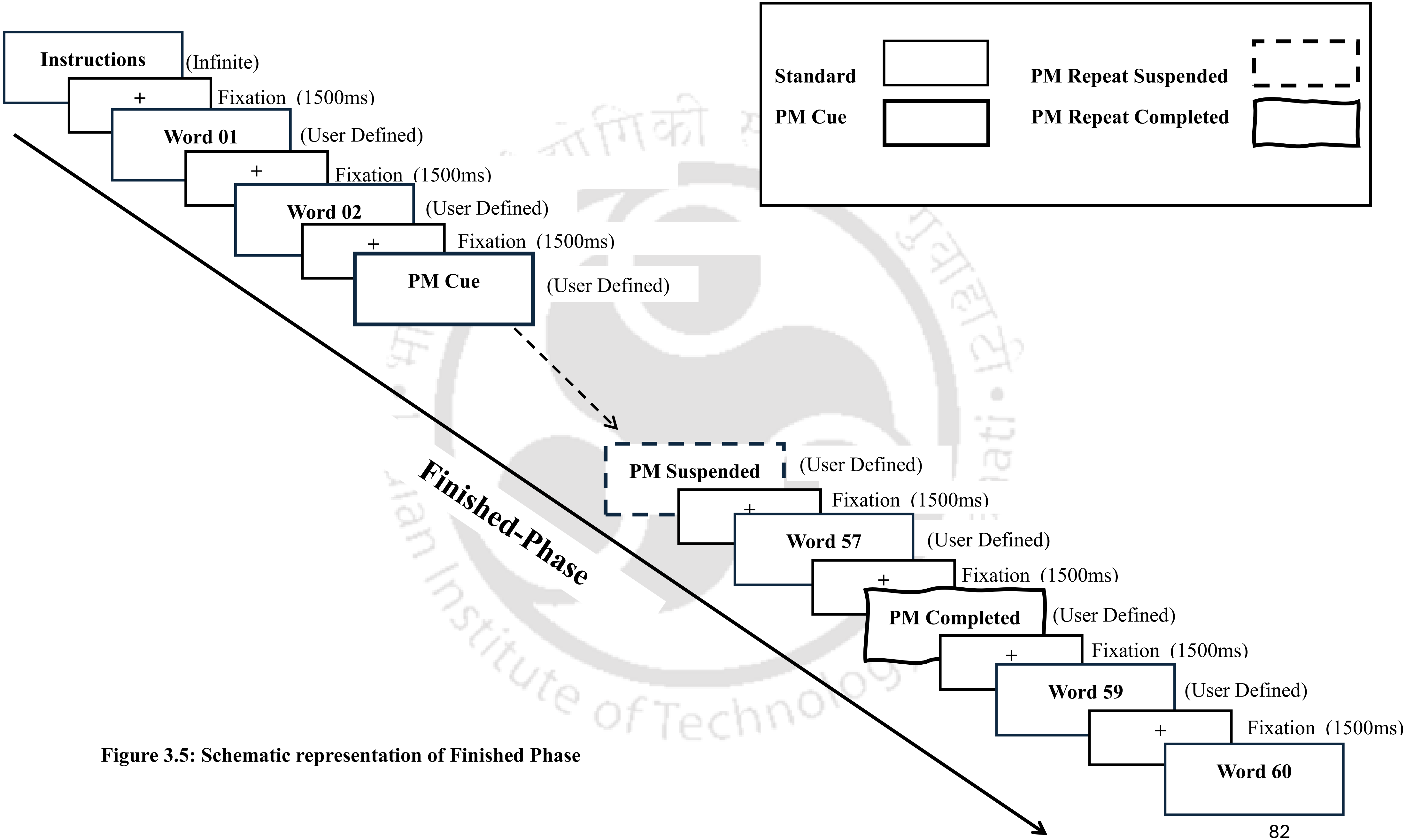


Figure 3.5: Schematic representation of Finished Phase

RESULTS:

Active Phase- Prospective memory target accuracy rate in the active-phase was at ceiling as in most laboratory-based paradigms (M=0.95) and there was no difference in performance between the experimental and control groups, t(178) = -1.335, p = .18.

Finished Phase- A mixed ANOVA was conducted to examine the effects of encoding a novel prospective memory task (the between-subjects variable) and cue-type (the within-subjects variable) on aftereffects in response times. The analysis revealed a significant interaction effect between condition (experimental, control) and cue-type ($F_{(1,58)}$=11.59, p<0.01, η^2= 0.16), indicating that encoding a secondary prospective intention had varied impact on suspended and completed targets. Completed targets displayed slower response latencies, especially for experimental condition where a novel prospective task was encoded (M=1378ms). Suspended targets in experimental condition had the lowest mean response time (M=1170ms) and participants had lower RT for suspended targets in control condition also (M=1299ms).

This can also be interpreted from the significant main effect of cue-type (suspended, completed), the within-subject factor at $F_{(1,58)}$=16.76, p< 0.01, η^2 =0.22; indicating that there were significant differences in aftereffects depending on whether the participants previously encountered the target or not. The between-subjects factor showed no significance (F=1.68, p>0.05, $\eta^2 = 0.02$), suggesting that experimental and control conditions did not differ significantly in terms of response latencies.

We also examined the mean proportion of commission errors in a 2x2 mixed ANOVA and found a significant effect of cue-type ($F_{(1,58)}$= 10.03, p<0.05, $\eta^2 = 0.14$). The highest commission error rate was seen in condition where novel prsopective task was encoded for suspended targets (M=0.16) and lowest for completed targets in the same experimental condition (M=0.03). Both interaction effects and effect of condition were insignificant (p_s>0.05).

Table 3.7: Mean Reaction Times for Non-relevant PM Trials across conditions

	Suspended	Completed
Experimental	1170.66 ± 231.96	1378.20 ± 78.60
Control	1299.73 ± 119.35	1319.51 ± 124.45

Table 3.8: Mean proportion of Commission Errors for Non-relevant PM Trials across conditions

	Suspended	Completed
Experimental	0.16 ± 0.22	0.03 ± 0.10
Control	0.12 ± 0.20	0.07 ± 0.14

Discussion

The purpose of the present experiment was to examine the influence of a secondary intention on aftereffects for suspended and completed targets in the finished/test phase. Our study aligns with previous literature in supporting the view of persisting activation even in non-relevant conditions. The experiment revealed that the aftereffects of completed intention depended acutely on cue-type. Participants responded slower for completed targets than targets that did not occur before. This slowing was especially observed in the experimental condition where a novel prospective memory task was encoded. Commission errors on the other hand were also seen to be dependent on cue-type. Completed targets had lower mean commission error rates than suspended targets in both experimental and control conditions. This could be because the activation level of intention-related memories may reduce after intention-completion, resulting in more time required to respond to such stimuli and lesser commission errors. This is in line with the inhibition account of aftereffects (Forster et al., 2005).

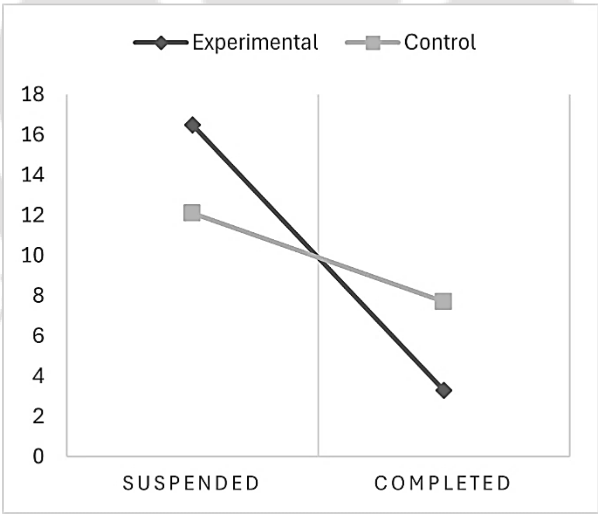


Figure 3.6: Mean percentage of commission errors on nonrelevant targets in experimental and control conditions

Response latencies for suspended targets were lower with participants responding faster to these targets. This finding coupled with the higher mean commission error rates of suspended targets supports the Zeigarnik effect (1938), that interrupted or incomplete tasks maintain a higher level of activation due to the pending action against them. Commission error rates being higher for suspended targets may be attributed to anticipatory monitoring as participants monitor for the target during active phase but the target does not occur. This finding reflects that of Bugg et al., (2013) who found more commission errors in a zero-target condition than a four-target PM condition. Our findings also align with Scullin et al., (2009), who reported evidence for sustained intention interference resulting in spontaneous retrieval for suspended targets but not for finished targets. They also attribute this increased activation to an episodic stop-tag which is absent in suspended targets as they have never been performed.

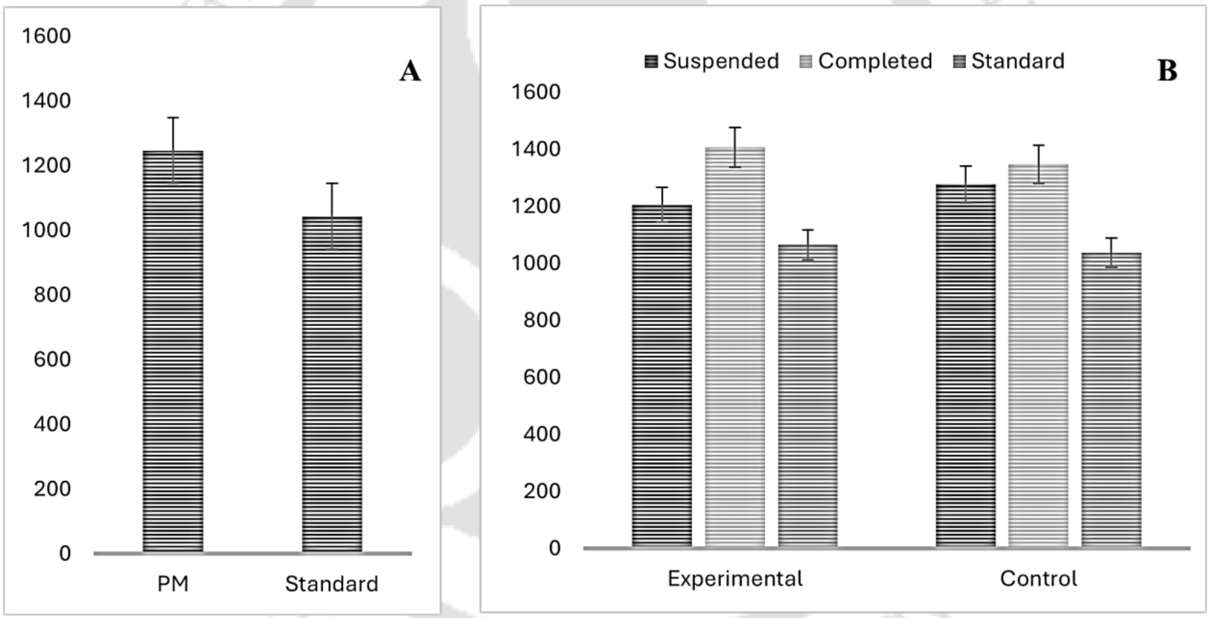


Figure 3.7: A Mean response times (RT) by trial type in active-phase. B. Mean response time by trial type in finished-phase for experimental and control groups

If we attempt to look at our findings comprehensively, we see that encoding a novel prospective memory task seems to benefit only completed targets but hamper deactivation of suspended targets. We also see an inverse relationship between commission errors and response latencies. This may be because of the additional inhibitory processes involved in preventing commission errors. This is also in line with other findings in literature that indicate that preventing commission errors may be a resource consuming process as more commission errors occur in conditions of divided attention, stress, fatigue and impaired cognitive control (Pink and dodson,2013; Scullin Bugg 2013; Boywitt, Rummel, Meiser, 2014).

3.3. EXPERIMENT 03: Intention Status, Time-course Effects and Intention Deactivation

In this experiment, we used a mixed design with the commission error paradigm (single cycle, active phase-finished phase). A new PM intention is encoded in the finished phase to examine the impact of novel intentions on prospective memory aftereffects. There is also a control group that does not encode a novel intention. The non-relevant targets from the active-phase appear either early in the finished-phase, immediately after task completion, or appear later in the task. We attempt to evaluate how this delay or time-course effects impacts prospective memory aftereffects.

Additionally, we also manipulate intention status, where both suspended and completed intentions are used to investigate if they behave differently under these conditions.

OBJECTIVE 01: To evaluate the impact of delay from task completion on intention deactivation.

OBJECTIVE 02: To evaluate whether suspended intention behaves differently from intention that had undergone overt intention completion over a course of delay from task completion.

HYPOTHESIS:

a) We hypothesize that prospective memory aftereffects will be significantly higher for non-relevant cues appearing early or immediately after task completion.

b) We hypothesis that non-relevant suspended cues that occur early or immediately after task completion will display the highest aftereffects.

c) We hypothesize that encoding a novel intention will reduce aftereffects especially for non- relevant cues that occur later in the finished-phase or with a delay from task completion.

VARIABLES:

Independent variables: Time-Course Effects (Early and Delayed presentation)

Secondary Intention (No novel intention and Novel intention)

Intention Status (Suspended and Completed)

Dependent variables: Response times

Commission error (Accuracy)

DESIGN:

A 2x2x2 Mixed design is employed. The first between-subject independent variable is temporal delay or delay from task completion. Some participants were presented with the non-relevant cues in the first half of the finished phase. This was the early condition. Other participants were presented with the non-relevant cues in the later half of the finished phase. This is the delayed condition. The other between-subject variable is the encoding of a novel prospective intention. This divided them into experimental and control groups. The experimental group encoded a novel prospective intention in the finished-phase and the control group did not. The within-subject variable is is intention status. The intention could either be suspended (encoded but never had a chance to be performed in the active phase) or completed (encoded and performed in the active phase).

Statistical analysis was conducted using a Mixed ANOVA for reaction time on non-relevant targets and response accuracy (commission errors) on non-relevant targets.

METHODOLOGY:

Participants

A total of 60 participants were recruited to participate in the study. All of them were university students who volunteered in return for course credit on an undergraduate psychology course. They were all within the age range of 18-24 years (M = 21.12 years; SD = 1.91). They were split into experimental and control groups using alternating psuedo-random assignment. The experimental sessions lasted an hour, and the participants had normal or corrected to normal vision.

Material

Word stimuli for the ongoing task which was an abstractness/concreteness rating task were selected from the English Lexicon Project database (Balota et al., 2007). We created three unique lists of 10, 40, and 80 words each for the practice-phase, active-phase, and the finished-phase respectively. The word length was between six to twelve letters and all words were of above average frequency in Freq_HAL ratings (Lund & Burgess, 1996). Six words were selected as prospective memory targets, four of which did not appear in the active phase. The suspended and completed target words were matched on number of syllables and word frequency.

Procedure

The experiment was designed on E-Prime2.0, a presentation software used in the field of behavioural sciences. We use an adapted version of the active phase-finished phase paradigm introduced by Scullin et al., (2012), similar to Experiment 2. This is also called the commission error paradigm and is consists of a standard prospective memory task along with an additional task at the end where commission errors or aftereffects are measured.

The experimental paradigm was divided into two phases. The active phase refers to the period during which individuals are actively engaged in a working-memory task, in this case an abstractness/concreteness word rating task along with a prospective memory task that requires them to remember to perform a future action. Because of this, it is also referred to as the PM Block. This phase represents a standard event based prospective memory task where the participant is engaged with an ongoing task and has to execute an additional PM task that occurs infrequently and is embedded in the ongoing working memory task.

The finished phase occurs after the primary task is completed. This is the additional task in the paradigm apart from the standard prospective memory task. In this phase, participants are instructed that the prospective task is finished and is no longer relevant during this phase. Then the no-longer relevant cues reappear, and aftereffects are measured. Because of this, it is also referred to as the Test Block.

The experiment begins with instructions for the ongoing task. The subjects were instructed to pay attention to the word stimuli displayed on the screen and press A for an abstract word and C for a concrete word using the keys of the keyboard. Each word stimulus presentation was separated by a fixation screen that appeared for 1500ms. The participants could take as long as needed to respond but were encouraged to do so as quickly and accurately as possible. After giving these instructions, the participants were subjected to a practice phase of 10 trials so that they could understand the structure of the experiment.

Encoding Prospective Task: After the practice phase, cue learning for the prospective memory task embedded in the active-phase begins. A word list consisting of eight words selected as prospective memory targets were presented on the software one at a time for a duration of 2000ms. After each word, a fixation cross was displayed for 500ms. The entire list was displayed 3 times. This encoding phase ended with instructions given to the participant that if any of the memorised words were to appear on a later task, they must press ‘L’ (instead of a/c). After the encoding was complete, participants were made to write down the instructions given in their own words to verify that they had correctly understood them.

A distractor task followed the encoding phase. The distractor task used in this experiment was a flip-and-match card game. For any participant to finish all three levels of the game took 9-10 minutes.

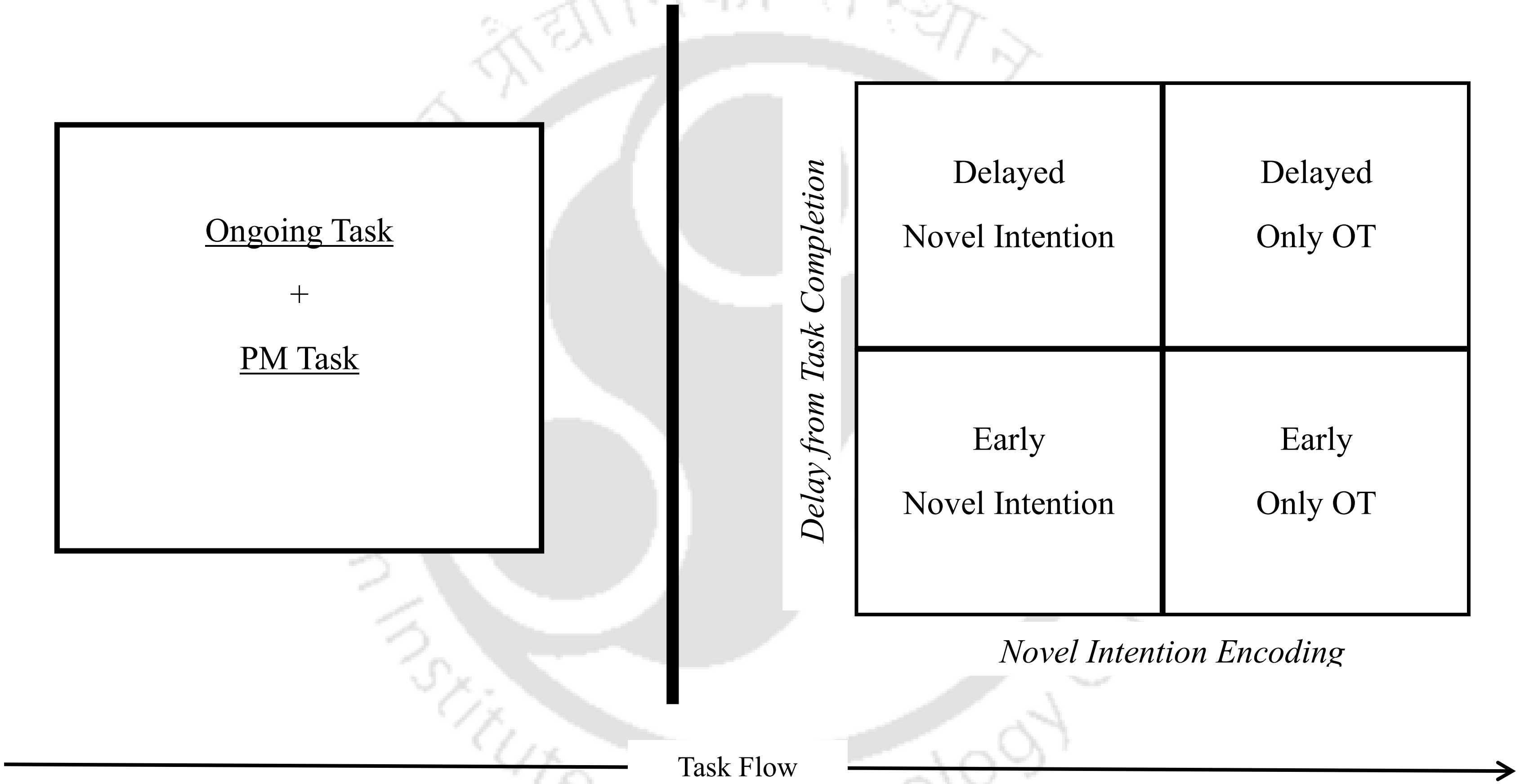
Active Phase: The active phase commenced with the embedded prospective task. It is comprised of a total of 40 trials with 2 of the prospective targets embedded in the ongoing task. The prospective targets occurred at fixed positions in the list (18^{th} and 36^{th}). Each trial word appeared in the center of the screen in black font on a white background. The trials were separated by a fixation screen that provided an inter stimulus interval of 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words were either ‘A’ or ‘C’, and for those trials containing target words, it was keypress ‘L’. A prospective hit was recorded only if ‘L’ was pressed immediately in response to a target word.

Encoding Novel Intentions: The completion of the active-phase was followed by finished-phase instructions. All participants were instructed that the prospective task was now complete, and they do not have to remember or perform it anymore. At this juncture, participants were divided into experimental and control groups. The experimental group then encoded a new prospective memory task. Three new prospective targets were encoded similar to cue-learning during the active-phase. The list of targets was displayed thrice, and it was ensured that participants memorised the target words. There was no additional task encoded by the participants of the control group. This was followed again by a distractor task for both groups.

Finished Phase: The finished-phase for this experiment consisted of more number of total trials since there was a need to divide the experiment into two halfs (early/delayed) and present non-relevant cues in either early or delayed presentation. It comprised of a total of 80 trials. Both suspended (cues from the old prospective cue list that did not appear during the active-phase) and completed prospective cues from the active-phase reappeared during this phase. These targets also appeared in fixed positions across trials. The non-relevant cues appearing early in the experiment are positioned at the 9th, 15th, 22th, and 30th trials in the task. The cues that appear later in the experiment (delayed) are positioned at 48th,54th,61st, and 69th trials of the task flow.

Each trial word appeared in the center of the screen in black font on a white background. The trials were separated by a fixation screen that provided an inter stimulus interval of 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words, and target words which are no longer relevant were only ongoing task responses ‘A’ or ‘C’. If participants responded by pressing ‘L’, when encountered with the no-longer-relevant target words, it would be counted as a commission error. Aftereffects were measured in terms of response delays and commission errors.

Figure 3.8: Schematic representation of Experimental Task Flow – Experiment 3



Results:

Here also we employed a mixed ANOVA to examine the effects of early and delayed presentation of non-relevant cues in the finished phase of the experiment to analyse the effects of temporal delay on prospective aftereffects. We also manipulated novel intention encoding and Intention-Status on aftereffects in event-based prospective memory paradigm. The analysis of response latencies revealed significant main effect of the within-subjects factor, Intention Status on our dependent variables [$F_{(1,56)}$=291.41, p< 0.01, $\eta^2 = 0.89$]. The between-subject factors of Temporal Delay and Novel Intention Encoding did not have any significance.

There was no interaction in the between-subjects variables [F=0.27, p>0.05, $\eta^2 = 0.00$]. There was also no significant interaction between Intention Status and Temporal Delay [F=0.20, p>0.05 $\eta^2 = 0.00$], Intention Status and Novel Intention Encoding [F=0.29, p>0.05, $\eta^2 = 0.00$], and no three way interaction between Intention Status, Temporal Delay and Novel intention Encoding [$\mathrm{F} = 0.02, \mathrm{p} > 0.01,\ \eta^2 = 0.00$]

Accuracy and Commission errors were also analysed. Similar to the pattern seen in reponse latencies, there was a main effect of Intention Status was significant [$F_{(1,56)}$=11.30, p<0.05, $\eta^2 = 0.16$]. The between-subject variable of time was significant at $F_{(1,56)}$=6.68, p<0.05, $\eta^2 = 0.10$. No interaction effects were significant and there was no effect of encoding novel intention.

Table 3.9: Mean reaction time (RT) for suspended non-relevant targets across conditions

	Experimental	Control
Early	1236.33 ± 80.72	1244.13 ± 80.69
Delayed	1240.46 ± 96.92	1260.86 ± 86.28

Table 3.10: Mean reaction time (RT) for completed non-relevant targets across conditions

	Experimental	Control
Early	1036.30 ± 40.17	1030.36 ± 36.30
Delayed	1028.90 ± 34.69	1035.43 ± 41.61

Table 3.11: Mean proportion of commission errors for completed non-relevant targets across conditions

	Experimental	Control
Early	0.16 ± 0.24	0.10 ± 0.20
Delayed	0	0

Table 3.12: Mean proportion of commission errors for suspended non-relevant targets across conditions

	Experimental	Control
Early	0.26 ± 0.37	0.23 ± 0.25
Delayed	0.20 ± 0.25	0.13 ± 0.22

Discussion:

In this study, we aimed to examine how delay from task completion impacts intention deactivation. Along with this we also manipulated the encoding of a new prospective task and intention Status to see if they differentially impact aftereffects and deactivation in prospective memory. We reviewed studies where most time delay was conceptualized as the difference in the length of the retention interval or the gap between intention encoding and the inception of the context in which the intention can be executed. Another observation was that most these studies deal with gaps that range from 20 minutes to 24 hours but very few studies focus on the more immediate processing of intentions. These studies suffer the drawback of the multiple possibilities of impinging variables that can occur in this long time gap. As a dissertation that is focused on the cue-action link aspect, we attempt to look at the shorter and more immediate duration after task completion in hopes that it may provide a more nuanced perspective.

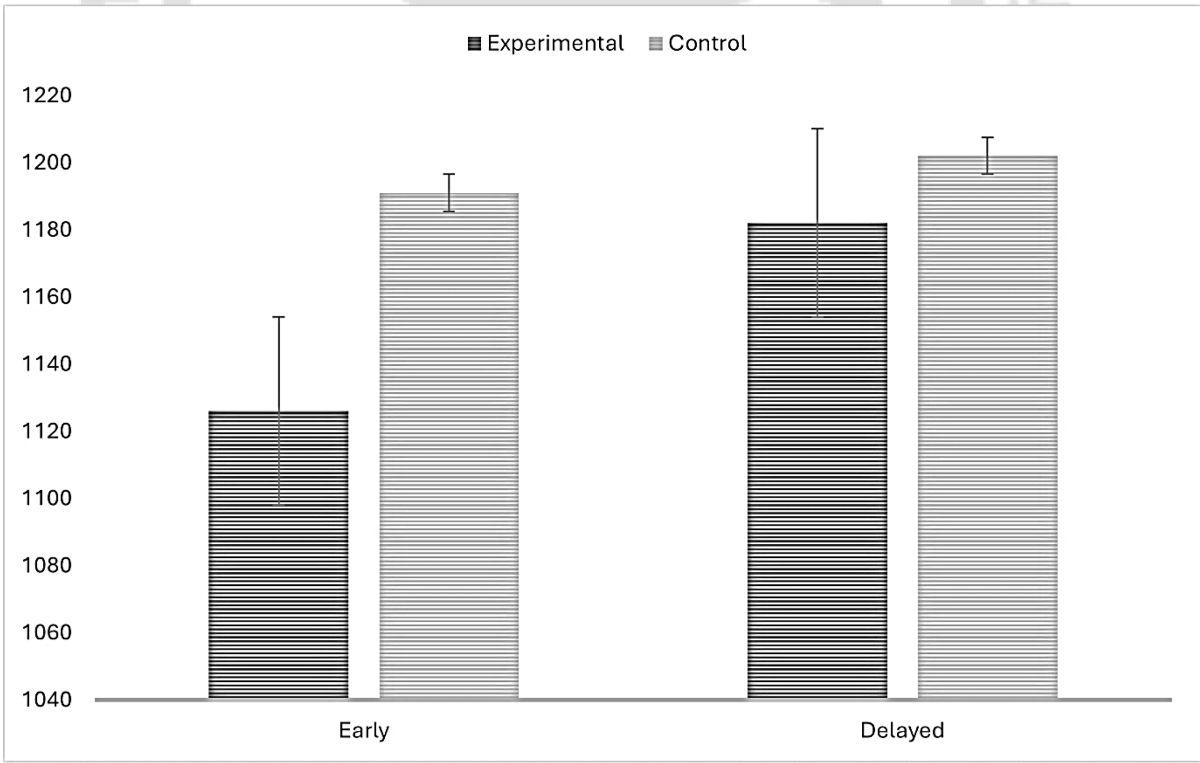


Figure 3.9: Mean response time (RT) of suspended non-relevant targets across conditions.

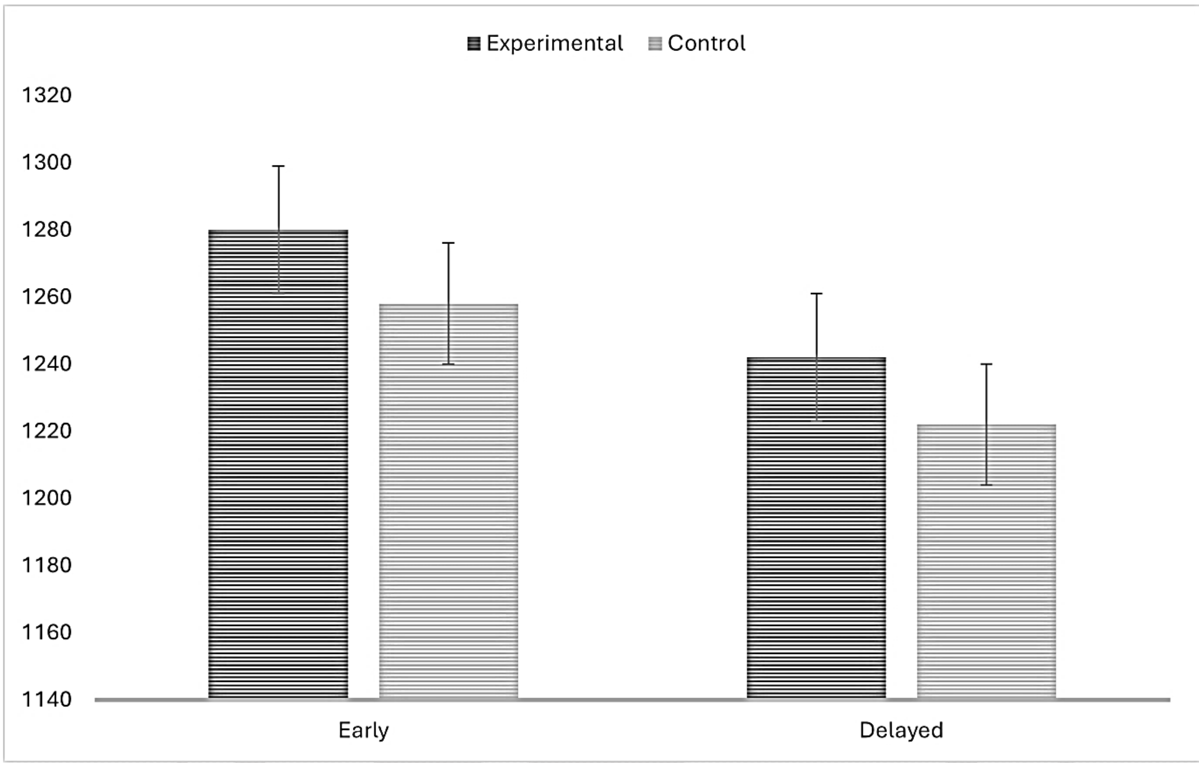


Figure 3.10 : Mean response time (RT) of completed non-relevant targets across conditions.

Contrary to our hypotheses, Temporal Delay did not significantly impact response times on non-relevant targets. This suggests that the timing of non-relevant cue presentation being presented immediately after task completion or with some delay from task completion may not impact how the cue-action link deactivates. This is line with other findings (Walser et al., 2014) that there is no role of delay in reducing prospective memory aftereffects. However, we see a siginificant effect of time delay when analysing commission errors for non-relevant targets across conditions. With lesser commission errors reported in the delayed conditions, especially for completed targets, it may be that intention completion may be necessary for deactivation as we see in the findings of our previous experiment. It can also be interpreted that delay may make deactivation easier. This is in line with the decay-based theories and also with findings that suggest that memory is impacted by mere passage of time.

We also find that the presence of a new intention may not be as influential as initially thought. However, the lack of significant effects for some variables might be due to our low sample size and insufficient statistical power. The significant main effect of Intention Status aligns with findings from Experiment 2. This consistent result across experiments strengthens the evidence that the status of an intention (completed vs. suspended) plays a crucial role in aftereffects.

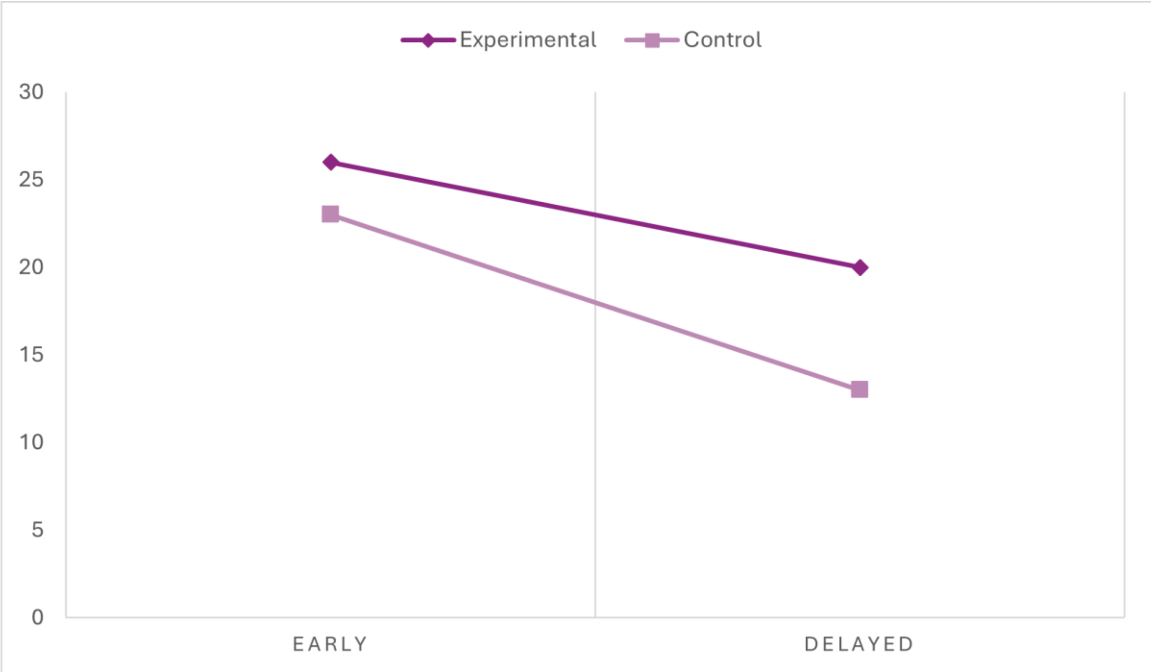


Figure 3.11: Mean proportion commission error rates of suspended targets across conditions

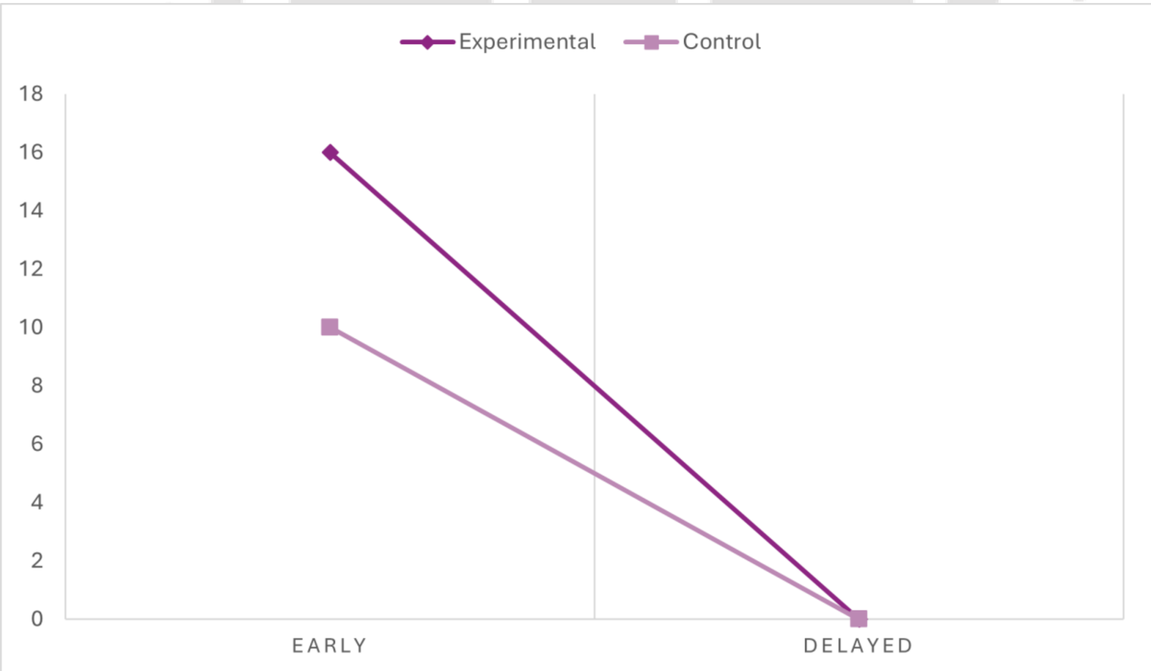


Figure 3.12: Mean proportion commission error rates of completed targets across conditions.

3.4. EXPERIMENT 04: Intention Status, Task Similarity and Intention Deactivation

In this experiment, we used a mixed design and the commission error paradigm with novel PM intention encoded for all groups in the finished phase. We manipulated task similarity in two ways and examined its impact on aftereffects. Cue-category similarity is manipulated by either the novel intention target belonging to the same category as the old intention (words-words), or to a different category (words-symbols). The other way is response-key similarity. It is manipulated by either using the same response keys for the old and novel intention ('L' keypress), or different response keys, with a new response key for the novel intention ('L' Key - SPACEBAR key).

Additionally, we also use intention status (suspended vs completed) as a within-subject variable. With these variables, we attempt to explore the role of task similarity/dissimilarity on prospective memory aftereffects.

OBJECTIVE 01: To study the impact of similarity between old and new prospective tasks on aftereffects.

OBJECTIVE 02: To evaluate the effect of intention status on intention deactivation under different conditions of task similarity.

HYPOTHESIS:

a) We hypothesize that Cue-Category Similarity between initial prospective task and novel prospective task will increase aftereffects.

b) We hypothesize that Response Similarity between initial prospective task and novel prospective task will increase aftereffects.

c) We hypothesize that the Condition with both Cue-Category Similarity and Response Similarity will increase aftereffects most in comparison to other conditions.

d) We hypothesize that suspended targets will behave differently than completed targets

VARIABLES:

Independent variables: Cue-Category (Words and Symbols)

Response Keys (Key 'L' and Key 'SPACE')

Intention Status (Completed and Suspended)

Dependent variables: Intention Interference (Response times)

Commission errors (Accuracy)

DESIGN:

A 2x2x2 Mixed design is employed. The first between-subject independent variable is cue-category (repetition vs switch). Participants are divided into groups, with one group have similar cue category in both the active and finished phases (word-word), and the other having cue-category dissimilarity across both phases (word-symbol). The other between-subject variable is response similarity (repetition vs switch). One group of participants used the same response key for both the prospective tasks ('L' key) and the other group encoded a new response key along with the novel prospective task ('L' Key- 'SPACE' Key). The within subject variable is intention status (suspended vs completed). The intention could either be encoded but never performed in the active phase, or encoded and performed in the active phase.

Statistical analysis was conducted using a Mixed ANOVA for reaction time on non-relevant targets and response accuracy (commission errors) on non-relevant targets.

METHODOLOGY:

Participants

A total of 60 participants were recruited to participate in the study. All of them were university students who volunteered in return for course credit on an undergraduate psychology course. They were all within the age range of 18-23 years (M = 20.41 years; SD = 1.80). They were split into experimental and control groups using alternating pseudo-random assignment. The experimental sessions lasted an hour, and the participants had normal or corrected to normal vision.

Material

Word stimuli were the same as in the other experiments. For the ongoing task which was an abstractness/concreteness rating task were selected from the English Lexicon Project database (Balota et al., 2007). We created three unique lists of 10, 40, and 60 words each for the practice-phase, active-phase, and the finished-phase respectively. The word length was between six to twelve letters and all words were of above average frequency in Freq_HAL ratings (Lund & Burgess, 1996). Six words were selected as prospective memory targets, three of which did not appear in the active phase. The suspended and completed target words were matched on number of syllables and word frequency.

Procedure:

The experiment was designed on E-Prime2.0, a presentation software used in the field of behavioural sciences. We use an adapted version of the active phase-finished phase paradigm introduced by Scullin et al., (2012), similar to Experiment 2. This is also called the commission error paradigm and is consists of a standard prospective memory task along with an additional task at the end where commission errors or aftereffects are measured.

The experimental paradigm was divided into two phases. The active phase refers to the period during which individuals are actively engaged in a working-memory task, in this case an abstractness/concreteness word rating task along with a prospective memory task that requires them to remember to perform a future action. Because of this, it is also referred to as the PM Block. This phase represents a standard event based prospective memory task where the participant is engaged with an ongoing task and has to execute an additional PM task that occurs infrequently and is embedded in the ongoing working memory task.

The finished phase occurs after the primary task is completed. This is the additional task in the paradigm apart from the standard prospective memory task. In this phase, participants are instructed that the prospective task is finished and is no longer relevant during this phase. Then the no-longer relevant cues reappear, and aftereffects are measured. Because of this, it is also referred to as the Test Block.

Encoding Prospective Task: Cue learning for the prospective memory task embedded in the active-phase begins. A word list consisting of six words selected as prospective memory targets were presented on the software one at a time for a duration of 2000ms. After each word, a fixation cross was displayed for 500ms. The entire list was displayed 3 times. This encoding phase ended with instructions given to the participant that if any of the memorised words were to appear on a later task, they must press 'L' (instead of a/c). After encoding was complete, participants were made to write down the instructions given in their own words to verify that they had correctly understood them.

A distractor task followed this. The distractor task used in this experiment was a flip-and-match card game. For any participant to finish all three levels of the game took 9-10 minutes.

Active Phase: The active phase commenced with the embedded prospective task. It is comprised of a total of 40 trials with 3 of the prospective targets embedded in the ongoing task.

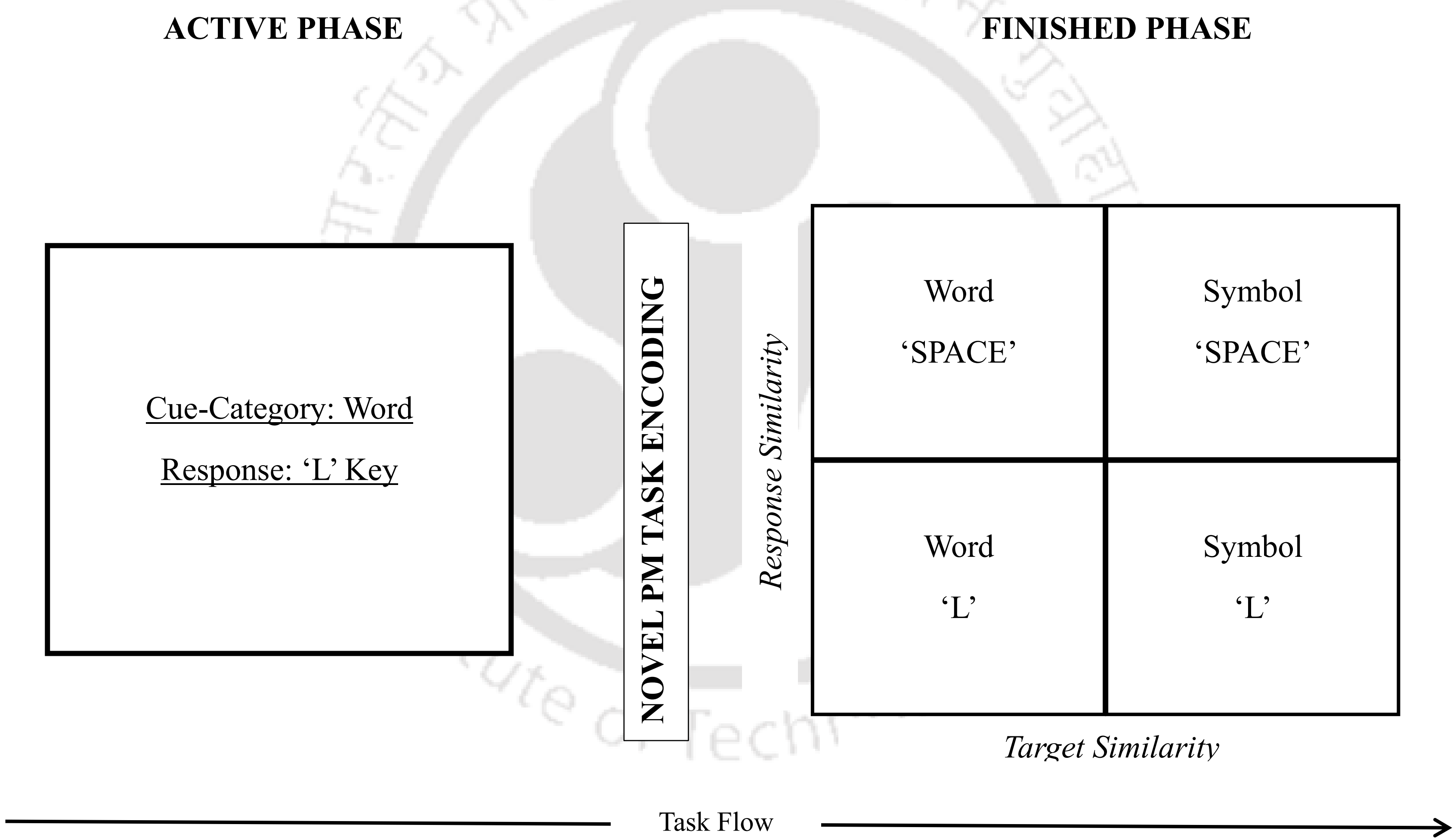
The prospective targets occurred at fixed positions in the list (12th, 25th and 38th). Each trial word appeared in the centre of the screen in black font on a white background. The trials were separated by a fixation screen that provided an inter stimulus interval of 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words were either ‘A’ or ‘C’, and for those trials containing target words, it was keypress ‘L’. A prospective hit was recorded only if ‘L’ was pressed immediately in response to a target word.

Encoding Novel Intentions: The completion of the active-phase was followed by finished-phase instructions. All participants were instructed that the prospective task was now complete, and they do not have to remember or perform it anymore. Here, in the finished-phase, we varied task similarity using a 2 (cue-category similarity: words-words vs words-symbols) x 2 (response similarity: response repetition vs repetition switch) design. All groups encode a novel intention, of either category and response key. The encoding process was similar to the active phase. The three new targets appeared one after the other for 2000ms separated by fixation cross for 500ms. This list appeared thrice along with new task instructions of how to respond to the targets. Then participants were asked to write down the instructions in their own words. This is followed again by a distractor task for all groups.

Finished Phase: The finished-phase comprised of a total of 60 trials, and both suspended (the three cues from the old prospective cue list that did not appear during the active-phase) and completed prospective cues from the active-phase reappeared during this phase. These targets also appeared in fixed positions across trials (9th, 18th, 25th, 38th,46th, and 54th). Each trial word appeared in the centre of the screen in black font on a white background. The trials were separated by a fixation screen that provided an inter stimulus interval of 1500ms. The experiment was self-paced. The appropriate responses for the trials containing non-target words, and target words which are no longer relevant were only ongoing task responses ‘A’ or

'C'. If participants responded by pressing 'L', when encountered with the no-longer-relevant target words, it would be counted as a commission error. Aftereffects were measured in terms of response delays and commission errors. The new prospective targets also appeared in the finished phase. They were also placed at fixed positions across trials (13th and 31st).

Figure 3.13: Schematic representation of Experimental Task Flow – Experiment 4



Results:

Here also we employed a mixed ANOVA to examine the effects of target and response similarity, along with cue-type on aftereffects in event-based prospective memory paradigm. The analysis revealed significant interaction effects between cue-type and target similarity ($F_{(1,56)}$=13.65, p< 0.001, $\eta^2 = 0.27$) and significant main effect of cue-type at $F_{(1,56)}$=58.21, p<0.001, $\eta^2 = 0.24$. Response latencies for suspended targets, especially in the target switch-response switch condition were much slower (M=1419ms) than completed targets (M=1520ms). RTs were slowest for completed targets in the target match-response match condition (M=1546ms), and not significantly different even when response key was switched (M=1541ms). Main effect analysis also showed significant effects of target similarity (F=28.86, p< 0.001, $\eta^2 = 0.14$) but no significant effect of response similarity.

We also analysed commission errors rates. There was a significant difference between suspended and completed cues in mean proportion of commission errors ($F_{(1,56)}$=17.00, p<0.05, $\eta^2 = 0.23$).

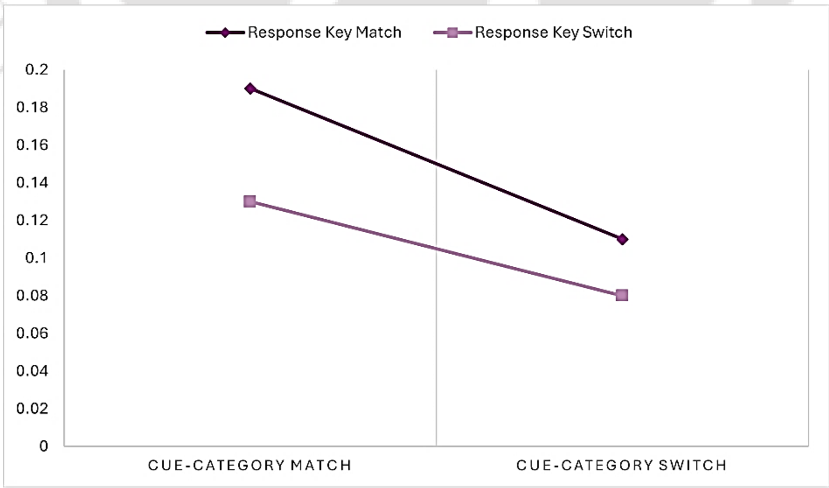


Figure 3.14: Mean proportion commission errors of suspended non-relevant targets across conditions

Suspended cues had higher mean commission error rates, especially in target match-response match condition (M=0.19), than in conditions with target and response dissimilarity (M=0.08). Completed targets on the other hand had zero commission errors in target-reponse switch condition and a considerably lower mean commission error rate even in target match-reponse match condition (M=0.06).

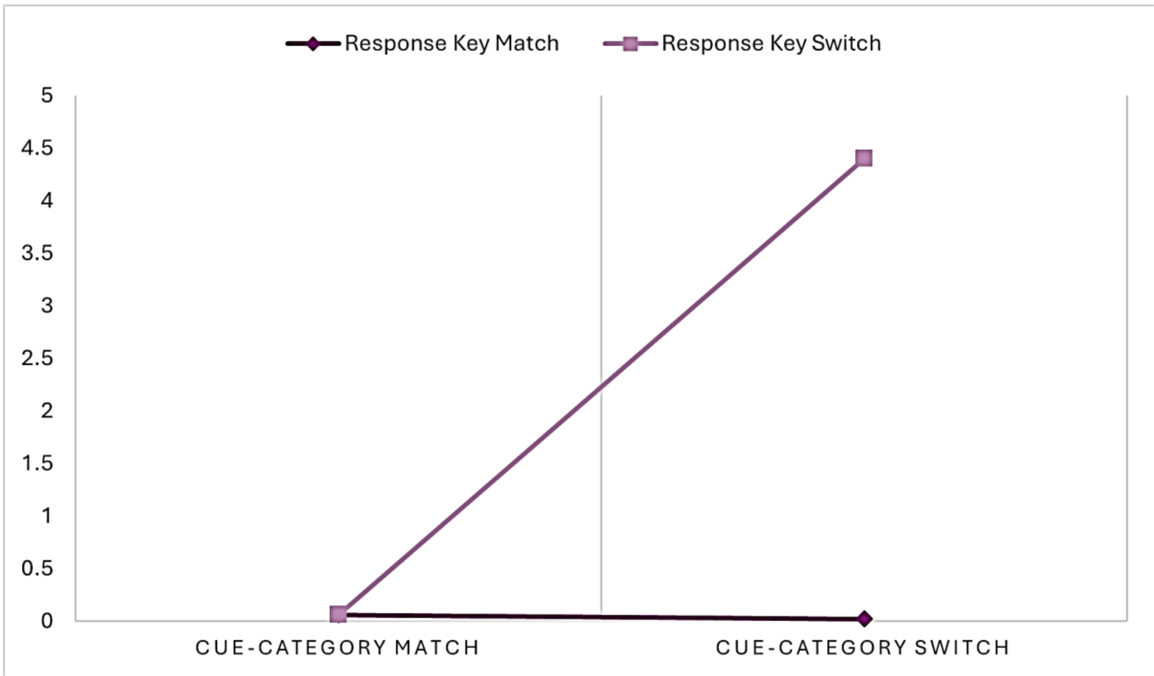


Figure 3.15: Mean proportion of commission errors for completed non-relevant targets across conditions

There was no significance of any between-subject variables and any interaction effects. A new type of error occurred where participants in the reponse switch conditions responded by pressing the spacebar key for older non-relevant targets. These special type of commission errors were not included in the analysis as they represented a very small percentage in any condition.

Table 3.13: Mean Reaction Times across conditions for Suspended non-relevant PM Targets

	Response Key Similarity	Response key Dissimilarity
Cue Category Similarity	1511.11 ± 108.04	1507.46 ± 102.40
Cue- Category Dissimilarity	1424.06 ± 61.19	1419.13 ± 59.86

Table 3.14: Mean Reaction Times across conditions for Completed non-relevant PM Targets

	Response Key Similarity	Response key Dissimilarity
Cue Category Similarity	1546.15 ± 72.04	1541.73 ± 94.09
Cue- Category Dissimilarity	1522.40 ± 113.96	1520.24 ± 96.63

Table 3.15: Mean Commission Error Rates across conditions for Suspended non-relevant PM Targets

	Response Key Similarity	Response key Dissimilarity
Cue Category Similarity	0.19 ± 0.24	0.13 ± 0.20
Cue- Category Dissimilarity	0.11 ± 0.20	0.08 ± 0.15

Table 3.16: Mean Commission Error Rates across conditions for Completed non-relevant PM Targets

	Response Key Similarity	Response key Dissimilarity
Cue Category Similarity	0.06 ± 0.13	0.06 ± 0.18
Cue- Category Dissimilarity	0.02 ± 0.08	00

Discussion:

In this study, we aimed to examine how similarity between old and new prospective tasks influences aftereffects and deactivation in prospective memory. We hypothesized that greater dissimilarity between the tasks will reduce the likelihood of aftereffects by diverting attention and creating a new task set. Similar tasks will increase aftereffects due to monitoring and processing overlaps (Guynn, 2003).

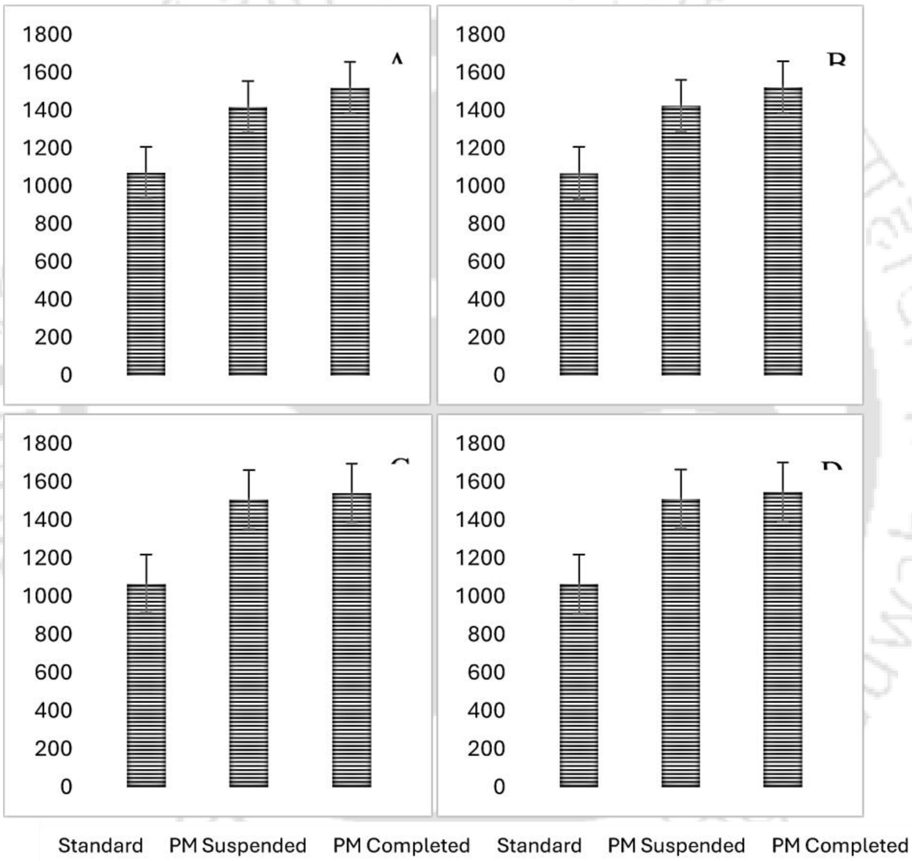


Figure 3.16: A. Target match-Response match mean RTs across trial types. B. Target match-Response switch mean RTs across trial types. C. Target switch-Response match mean RTs across trial types. D. Target switch-Response switch mean RTs across trial types.

As predicted, we see that task similarity significantly influences aftereffects in prospective memory, but we see that these effects are uniquely linked only to target similarity and not much of the variance can be attributed to response similarity. We see slower response latencies in target-matched conditions for both type of targets. Participants respond faster and have better accuracy in conditions where the novel prospective task targets are dissimilar. Response similarity did not have an effect with similar performance in response match and response switch conditions. Though task sets are stored as a unit, the unit may have a representative component, in this case the target stimulus. Hence only the target stimulus component may be persisting in later non-relevant conditions. On the other hand, it may also be that the lower number of cue-action associations (lesser target trials) in our experiment may have led to a weaker cue-action link because of which change in response key does not elicit a great impact on performance.

Similar to the findings our first experiment, we see that cue-type or status has a strong influence on aftereffects. Completed targets had slower response latencies than suspended targets. This could be because of an increased activation due to a Zeigarnik-like effect (1938) or higher intention interference as seen in other studies (Scullin et al., 2009). Commission errors rates are higher for suspended targets, especially in target match conditions. In line with our previous results, an inverse relationship is seen between commission errors and response latencies.

CHAPTER 4: CONCLUSION

The present thesis aims primarily at examining how an intention that has been executed or has served its purpose by being cancelled or suspended becomes inactive. This is important so as to not cause a negative impact like performance costs to other tasks or erroneous repetitions of a completed task. An intention-response link is also called a cue-action link in prospective memory and the process by which this link is made inactive after it serves it's utility is called intention deactivation. Intention deactivation refers to the 'turning off' of non-relevant intentions and is a gravely important facet of prospective memory that has only recently started receiving the attention that it is due.

It is because of these deactivation capabilities that we are able to execute intentions that are constantly updated, cancelled, or put-off for later because of our dynamic environments. In the lack of effective deactivation, intentions can persist and lead to a very wide range of problems. You may narrate the same story at an office party leading to some embarrassment or you may have negative health consequences because of double dosing on a medication (Kimmel et al., 2007).

Even most patients diagnosed with clinical disorders like Parkinsons, multiple sclerosis, Schizophrenia, Autism, ADHD and especially frontal lobe lesions display prospective memory deactivation deficits as one of the major symptoms (Altgassen et al., 2010; Costa et al., 2018; Rouleau et al., 2020; Hogan et al., 2020). Such deficits highlight the critical role of deactivation in everyday normal functioning.

The consequences of ineffective intention deactivation are not limited to clinical populations. In studies on aviation and other workplace studies also show that prospective memory failure of this sort may have implications for operational and safety disruptions (Dismukes et al., 2007; 2008; 2012).

Ineffective deactivation, as we witnessed in research literature results in aftereffects. Aftereffects manifest as Intention Interference and Commission errors. Intention Interference is measure by increase in response time (RT) on the re-appearance of non-relevant targets. And commission errors are measured as a binary accuracy measure where a PM response to a non-relevant or completed target is considered an error. The main condition under which we examine deactivation and such aftereffects is when a novel intention is encoded. Additionally, we also explore the role of intention status on prospective memory deactivation. Intentions could either be executed and marked as complete, or simply suspended, a case where there is never an opportunity to execute an intention, but the task is finished. We also tested the effects of delay from task completion on aftereffects and deactivation. Finally, we explored if task similarity between completed intentions and novel intentions has an impact of prospective memory aftereffects.

This thesis tests the two opposing accounts that are used in explaining intention deactivation, inhibition vs continued retrieval. The inhibition account states that intention completion results in decrease in the activation status of intention or its related material to move towards a neutral level (baseline), and sometimes even below it. This is supported by findings of a below baseline activation of the content of action scripts after script completion (Marsh et al., 1998), cancellation in script-based paradigms (Marsh et al., 1999) and several others (Förster et al., 2005; Denzler et al., 2009, 2011; Marsh et al., 1999; Badets et al., 2006; Badets & Osiurak, 2015; Meilán, 2008; Freeman & Ellis, 2003; Maylor et al., 2000; Maylor et al, 2001). The continued retrieval account on the other hand, states that intentions continue to be retrieved even after completion leading to costs to the ongoing tasks and making participants more prone to commission errors. This account is in line with the multi-process view of prospective memory. It is supported by findings of commission errors and slower ongoing task performance in response to no-longer-relevant PM cues in event-based PM paradigms

(Scullin & Bugg, 2013; Walser et al., 2012; Gilbert, Hadjipavlou, & Raoelison, 2013; Anderson & Einstein, 2017; Beck, Ruge, Walser, & Goschke, 2014; McDaniel et al., 2015; Schaper & Grundgeiger, 2017; Scullin et al., 2011).

The findings across experiments shed some light on the complex nature of intention deactivation and its underlying processes. In this chapter, we will integrate and interpret the key findings from all the experiments of this thesis, discuss implications and limitations, and suggest directions for future research.

4.1 Answers to Research Questions

The first research question was to examine how encoding a novel prospective memory intention impacts prospective memory deactivation. For examining this, we used an event-based prospective memory task for two reasons. Event-based prospective tasks focus on cue-action associations and not on the semantic content of the intention (Einstein & McDaniel, 1990; Förster et al., 2005; Scullin & Bugg, 2013; Scullin et al., 2012; Walser et al., 2012; Anderson & Einstein, 2017). Also, previous research suggests that intention deactivation is more immediate for script-based content and there are no findings of aftereffects for such paradigms (Marsh et al., 1998; Marsh et al., 1999; Badet et al., 2006; Melian, 2008).

Across our experiments, we find that novel prospective memory encoding may not severly impair or enhance intention deactivation in itself. Our first experiment employed a repeated-cycles paradigm to investigate how encoding multiple novel intentions across cycles affects prospective memory performance and aftereffects. Contrary to our hypothesis, we found no significant differences in commission error rates across cycles, suggesting that the repeated encoding of novel intentions does not necessarily lead to increased aftereffects in later cycles. The lack of variation in commission error rates across cycles indicates that participants' ability to deactivate intentions remains relatively consistent, regardless of the number of intentions they have previously encoded and executed. Experiment 1 showed that repeatedly encoding novel intentions across multiple cycles did not progressively increase aftereffects. This challenges the notion that cognitive load from multiple intentions necessarily accumulates and burdens our inhibitory resources thereby impairing deactivation. Instead, it suggests that our cognitive system may be relatively efficient at managing the deactivation of completed intentions even when new intentions are continuously formed.

These findings can be interpreted as being in contrast to the findings of current literature (Walser et al., 2012; Walser et al., 2017; Anderson & Einstein, 2017; Kurtz et al, 2022) which suggest that aftereffects occur as a spontaneous reflexive action which were heightened in the presence of a novel PM task. They support the view that the novel prospective task heightens aftereffects by creating a state of active retrieval where all deviant stimuli may trigger retrieval mode because of monitoring engagement (Guynn, 2003). However, we do not see such results in our experiments.

In our second experiment, we directly examined the effect of encoding a novel intention on the deactivation of previously relevant intentions. As there was no benefit of a repeated cycles paradigm, with no accumalating impact on aftereffects on novel intentions encoded repeatedly in all new cycles, from the second experiment onwards we use a single-cycle paradigm. In this experiment we used a mixed design with the between subject variable of condition. Those in the experimental condition encode a novel intention in the finished-phase, and those in the control condition do not encode any additional tasks. The within-subject variable of cue-type has two levels. Suspended targets are those that do not appear in the active-phase, hence there is no oppurtunity to complete the intention. And completed targets are those that appear in the active-phase and are executed. We found a significant interaction between condition (experimental vs. control) and cue-type (suspended vs. completed), indicating that encoding a secondary intention had differential effects on suspended and completed targets. Specifically, completed targets showed slower response latencies, particularly in the experimental condition where a novel prospective task was encoded. This suggests that encoding a new intention may decrease the activation of completed intentions.

Interestingly, suspended targets showed faster response times but higher commission error rates compared to completed targets, especially in the experimental condition. This pattern aligns with the Zeigarnik effect (1938), which posits that incomplete tasks maintain higher activation levels due to unresolved tension. The higher commission error rates for suspended targets suggest that these intentions remain more accessible in memory, making them more prone to erroneous retrieval when encountered in non-relevant contexts. Experiment 2 demonstrated that encoding a novel intention can have differential effects based on intention status, enhancing inhibition for completed intentions while potentially interfering with the deactivation of suspended intentions. This suggests that novel intentions do not uniformly facilitate or impede deactivation but interact with other factors in determining aftereffects.

Here we can interpret our findings as both in tandem and slightly in contrast with previous research findings owing to our differing methodology. Encoding of a novel intention may both impair deactivation, as seen for suspended targets in our experiments and in literature (Walser et al., 2012; Walser et al., 2017; Anderson & Einstein, 2017; Kurtz et al, 2022) and also enhance deactivation as seen for completed targets (Loftus, 1971; Martin et al., 2011; Walser et al., 2014; Matos et al., 2020). From our findings, we can argue that overt intention completion might be a necessary condition for better updation of intentions in complex prospective memory (Kliegel et al., 2008).

The second research question was to examine how intetion status impacts prospective memory deactivation. We highlight a key difference in this thesis between 'suspended instructions' and 'suspended targets'. Most existing research focuses on suspended instructions (Scullin et al., 2009; Marsh et al., 1999; Scullin et al., 2011), where participants are informed that their intention is momentarily paused as an instructional manipulation but the targets still appear. However, since this thesis concentrates on the connections between cues and actions and the strength of those connections, we addressed suspended targets instead (Bugg & Scullin, 2013). Suspended targets are those that are encoded as prospective memory targets but do not appear in the appropriate context.

Across all experiments, we consistently found significant effects of intention status on aftereffects. Suspended intentions (those that were encoded but never executed) generally showed higher commission error rates but faster response times compared to completed intentions (those that were encoded and executed). This pattern suggests that suspended and completed intentions are represented differently in memory and undergo different deactivation processes. The higher commission error rates for suspended intentions support the Zeigarnik effect and suggest that intentions that have not been fulfilled maintain higher activation levels, making them more susceptible to erroneous retrieval. This may be because suspended intentions lack the episodic "stop-tag" that is created when an intention is successfully executed, as suggested by Scullin et al. (2009).

Completed intentions, on the other hand, showed slower response times but lower commission error rates, particularly in conditions where a novel intention was encoded. This pattern is consistent with the inhibition account of aftereffects (Forster et al., 2005), which posits that completed intentions undergo inhibition post-execution, reducing their accessibility in memory. The slower response times may also reflect the additional cognitive resources required to inhibit the completed intention when it is encountered in a non-relevant context.

Our experiments employed a mixed design to investigate how encoding a novel prospective intention influences the deactivation of previous intentions, while also examining the differential effects of intention status (suspended versus completed). In our second experiment, we addressed a significant gap in existing research by including a control group that did not encode a novel intention in the finished phase, providing a clearer picture of how secondary intentions impact deactivation processes of different cue types. The results revealed a main effect of cue-type on both intention interfernce and commission errors. Completed targets exhibited slower response latencies, particularly in the experimental condition where a novel prospective task was encoded. Conversely, suspended targets showed faster response times across both experimental and control conditions. Commission error rates were also primarily influenced by cue-type, with suspended targets displaying higher error rates than completed targets, especially in the experimental condition with novel intention encoding.

These findings suggest a differential impact of novel intention encoding based on the status of previous intentions. For completed intentions, encoding a novel task appeared to enhance inhibition processes, resulting in slower responses but fewer commission errors. For suspended intentions, the novel task seemed to interfere with deactivation, leading to more commission errors despite faster response times. This pattern aligns with a dual-mechanism account of aftereffects, where both continued retrieval and inhibitory processes influence deactivation outcomes (Moschl et al., 2020).

Even in our third experiment, we observed a significant effect of cue-type or intention status, with suspended and completed intentions continuing to show differential patterns of aftereffects consistent with Experiment 2. The consistent effect of intention status across both Experiments 2 and 3 strengthens the evidence that the completed versus suspended nature of an intention plays a crucial role in determining its subsequent deactivation pathway.

The final experiment also found that ommission error rates were again higher for suspended targets, especially in conditions with high task similarity (target match-response match), while completed targets showed minimal commission errors, particularly in conditions with low similarity (target-response switch).

Overall, we see that this question received the most consistent findings across our experiments. In all studies where intention status was manipulated, we observed significant differences between completed and suspended intentions in terms of aftereffects. Completed intentions generally showed slower response times but fewer commission errors, while suspended intentions exhibited faster response times but higher commission error rates. Hence, there was also a consistent pattern of highe response times corresponding with lower proportion of commission errors.

These findings align with two seemingly contradictory accounts in the literature. The slower response times for completed intentions support an inhibition account, suggesting that execution of an intention leads to active suppression of the intention representation, resulting in slower response time when it is re-encountered. The higher commission error rates for suspended intentions align with the Zeigarnik effect (1938), which posits that interrupted or incomplete tasks maintain higher activation levels due to an unresolved tension. Our results suggest that intention completion provides a sort of mental marker that enhances inhibitory processes, helping to prevent erroneous repetition of the action. Suspended intentions lack this stop-tag, making them more susceptible to spontaneous retrieval when their associated cues are encountered. This interpretation is consistent with findings from previous studies (Scullin et al., 2009; Bugg et al., 2013) which reported higher commission errors for intentions that had never been executed.

The consistent pattern across our experiments strengthens the conclusion that intention status is a critical determinant of deactivation outcomes, and is more influential than factors such as temporal delay or novel intention encoding in determining how effectively an intention will be deactivated.

The third research question was an exploration into the role of time or delay from task completion on prospective memory deactivation. The non-relevant targets from the completed task re-appear at varied delays from task completion and we measure aftereffects for these non-relevant targets. Research exists that examines the impact of delay by altering the time interval between the active phase and the completed phase. Additionally, some studies focus on the delay between the formation of an intention and the actual opportunity to carry it out (Scullin et al., 2009; 2011; Meier et al., 2006; Bradimonte & Passolunghi, 1994; Einstein et al., 2005; Einstein et al., 1995; Nigro & Cicogna, 2000; Loft et al., 2008; Walser et al., 2014). However, there are only a limited number of studies that view delay not simply as a temporal gap but rather as a presentation delay, where irrelevant targets are shown either earlier or later in the experiment, allowing for a greater opportunity to update and reconsolidate our intentions while still involved in the task (Walser et al., 2012; Scullin & Bugg, 2013; Beck et al., 2014).

Our third experiment investigated how delay from task completion affects intention deactivation. Contrary to our hypothesis, we found no significant effect of temporal delay on aftereffects in terms on intention interference, suggesting that the timing of non-relevant cue presentation (immediately after task completion vs. delayed) does not substantially impact how cue-action links deactivate. This finding is consistent with previous research by Walser et al. (2014), who also reported no role of delay in reducing prospective memory aftereffects. The lack of significant effects for temporal delay challenges the notion that intention deactivation follows a time-dependent decay process. Instead, it suggests that other factors, such as intention status and task similarity, may play more crucial roles in determining the extent of aftereffects. This has important implications for understanding how we manage multiple intentions in everyday life, as it suggests that simply allowing time to pass may not be sufficient for effectively deactivating completed intentions.

This result challenges the notion that the passage of time alone facilitates intention deactivation. Rather, it suggests that deactivation may be more dependent on cognitive processes such as inhibition and context updating than on temporal decay. This finding challenges traditional decay theories of forgetting, which would predict diminished aftereffects with increased delay. Instead, it aligns better with interference-based accounts, suggesting that what matters more for deactivation is not how much time has passed since completion, but rather what cognitive processes have occurred during that time. The absence of temporal delay effects is consistent with some previous studies (Walser et al., 2014; Scullin & Bugg, 2013) which also found that aftereffects were relatively resistant to time passage. This suggests that once formed, cue-action associations remain relatively stable unless actively inhibited or interfered with by other processes.

However, for commission errors, we find that delay has a significant main effect. This dissociation in findings may indicate that cue-detection might be a more spontaneous and automatic process that is not sensitive to the effects of time. Hence, the non-significant impact of delay on RTs in our experiment. However, commission errors are a result of more deliberate control based processes which may be sensitive to time based decay. It is also pertinent to note that the number of trials in our experiments are very low. This coupled with our limited sample size could be one of the reasons for an insignificant time effect on intention interfernce.

The final research question addresses the role of task similarity in the deactivation of prospective memory intentions. Novel prospective tasks with significant categorical or processing overlap are seen to increase the likelihood of erroneous repetition of older non-relevant tasks (Walser et al., 2017). We use a paradigm where we manipulate task similarity in blocks where there is another prospective task that has to retained and executed.

Our fourth experiment examined how task similarity between old and new prospective tasks influences aftereffects. We manipulated both cue-category similarity (words-words vs. words-symbols) and response similarity (same response key vs. different response key) to investigate their effects on intention deactivation.

We found significant effects of cue-category similarity on both response times and commission error rates. Specifically, when the cue categories of the old and new intentions were similar (both using words), participants showed slower response times and higher commission error rates compared to when the cue categories were different (words vs. symbols). This suggests that similarity in cue processing demands increases interference between old and new intentions, making it more difficult to effectively deactivate the old intention. Interestingly, response similarity did not have a significant main effect on aftereffects, indicating that the cognitive processes involved in cue detection may be more critical for intention deactivation than those involved in response execution. This finding aligns with the multi-process view of prospective memory, which emphasizes the importance of cue detection processes in prospective remembering.

When a new intention utilizes the same stimulus category as an old intention, it creates competition for attentional resources and makes it more difficult to distinguish between relevant and non-relevant cues. This is consistent with attention allocation theories that propose limited cognitive resources must be distributed across competing task demands.

Response similarity having less impact than cue-category similarity, suggests that the perceptual and semantic features of prospective cues may be more critical for deactivation than the motor response associated with them. This highlights the importance of considering the specific dimensions of task similarity when studying intention deactivation. The interaction between task similarity and intention status further reinforces the role of overt intention completion in the complex nature of deactivation processes.

These findings highlight the importance of context and processing overlap in intention deactivation. High similarity between old and new tasks appeared to interfere with the deactivation process, particularly for suspended intentions. In contrast, completed intentions seemed more resistant to similarity effects, especially when both the cue category and response requirements differed between old and new tasks. From this, we could suggest that intention completion may create more robust deactivation mechanisms that can withstand interference from similar tasks. In a way, task completion shields us from other variables that impair deactivation.

4.2 Summary

The findings from this thesis have several important implications for theories of prospective memory and intention deactivation. First, they challenge simplistic views of deactivation as either pure inhibition or continued retrieval, instead supporting a dual-mechanisms account (Moschl et al., 2020) where both processes contribute to aftereffects. The differential patterns observed for completed versus suspended intentions suggest that these two types of intentions may follow different deactivation pathways. From all our findings, we can conclude that overt completion of an intention may serve like somewhat of a bottleneck for effective deactivation. And suspended intention continue to retrieved as they are bypassed at this crucial bottleneck.

Our results also contribute to the debate between decay and interference theories of forgetting in prospective memory. The mixed effects of temporal delay effects in Experiment 3 suggests that pure decay mechanisms may be insufficient to explain intention deactivation. Instead, the strong effects of intention status and task similarity point to the importance of interference and inhibitory processes in determining deactivation outcomes.

The findings regarding novel intention encoding provide nuanced insights into how retroactive interference operates in prospective memory. Rather than simply overwriting old intentions, new intentions appear to interact with existing ones in complex ways that depend on factors such as intention status and task similarity. This calls into question the convetional theories of how intentions are processed and deactivated, and supports more dynamic accounts that recognize the differeing underlying processes that operate on different kinds of intentions in varied contexts.

Our experiments also extend theoretical understanding of the Zeigarnik effect in the context of prospective memory. The higher commission error rates for suspended intentions across multiple experiments provide substantial evidence that uncompleted intentions remain more activated in memory, making them more susceptible to erroneous retrieval when the associated cues are encountered. This suggests that intention completion provides not just episodic memory of having performed the action (the stop-tag), but also engages inhibitory mechanisms that help prevent its future repetition. And suspended intention remain like ghosts of the past that refuse to let go as they do not have a stop-tag attached to them

The role of task similarity in modulating aftereffects aligns with theories of attention allocation and cognitive control. When new and old intentions share processing pathways (as in cue-category similarity), they compete for limited cognitive resources and for visual attention, potentially reducing the effectiveness of inhibitory control and increasing aftereffects. This highlights the importance of considering how attention is allocated across competing intention representations in understanding deactivation processes.

4.3 Limitations and Future Directions

Despite its contributions, this research has several limitations that should be acknowledged. First, all experiments were conducted with young, healthy university students, limiting the generalizability of findings to other age groups or clinical populations. Future research should examine whether the patterns of deactivation and aftereffects observed here extend to older adults, children, or individuals with cognitive impairments. Also, we used a relatively simple word-based prospective memory task in a laboratory setting. Real-world intentions are often more complex, embedded in hierarchies and rich contexts, and associated with personally significant outcomes. Ecological validity could be enhanced by examining intention deactivation in more naturalistic settings or with more complex, personally relevant intentions as motivation and consequence may be important factors. Though our focus was a cue-action link based exploration, more complex and meaningful intentions of real-life may behave differently. The temporal delays examined in Experiment 3 were relatively short, occurring within a single experimental session. Future studies could investigate longer delays spanning days or weeks to better understand how consolidation processes might influence intention deactivation over extended periods.

Lastly, while we examined commission errors and response latencies as measures of aftereffects, additional measures such as eye-tracking or neuroimaging could provide more nuanced insights into the cognitive processes underlying intention deactivation. For example, examining patterns of neural activation when encountering non-relevant cues could help distinguish between retrieval and inhibition accounts.

Future research can focus on investigating the neural correlates of intention deactivation. For example, examining activation in prefrontal regions associated with inhibitory control when encountering completed versus suspended intentions could help clarify the role of inhibition in deactivation processes (Beck et al., 2014). Individual differences can also be explored to determine if certain populations like older adults are more prone to commission errors (Bugg & Scullin, 2016). But factors such as working memory capacities, inhibitory control, and metacognitive monitoring capacities or output monitoring capacities might also influence individual differences in the ability to deactivate completed intentions. Intentions that are part of goal hierarchies, like superordinate and subordinate goals embedded within goal hierarchies and how deactivation functions in such designs can also be examined by future research.

4.4 Closing Remarks

Beyond their theoretical significance, our findings have practical implications for everyday memory management and for populations with cognitive impairments. The consistent effect of intention status suggests that actually executing an intention, even once, may be critical for its subsequent deactivation. This has implications for task management strategies, suggesting that when possible, it may be beneficial to complete intentions rather than suspend them to reduce the likelihood of erroneous repetition. Our research also has implications for understanding prospective memory failures in clinical populations. The increased aftereffects observed for suspended intentions might help explain why individuals with impaired cognitive control, such as older adults or those with executive function deficits, often struggle with repetitive behaviours. These populations may have particular difficulty deactivating intentions that have not been fully completed. In workplace settings where prospective memory demands are high, such as aviation or healthcare, our findings suggest that task design should consider intention deactivation as an important factor. For example, providing clear closure for completed tasks and minimizing the similarity between concurrent prospective tasks might reduce the likelihood of commission errors that could have serious consequences.

This thesis has attempted to systematically investigate the processes underlying intention deactivation in prospective memory, examining how factors such as novel intention encoding, intention status, temporal delay, and task similarity influence the aftereffects of no-longer-relevant intentions. Through a series of carefully designed experiments, we have demonstrated that intention deactivation is not a simple all-or-nothing process, but rather represents a complicated interaction between inhibitory control, cue-retrieval processes, and contextual updating and reconsolidation. In conclusion, this thesis contributes to our understanding of how the human cognitive system manages the deactivation of no-longer-relevant intentions, a process that is crucial for adaptive functioning in a world where goals and priorities are constantly shifting. By highlighting the roles of intention status, task similarity, and active inhibition in deactivation processes, it enhances our theoretical understanding of prospective memory and provides practical insights for improving intention management in everyday life. Our ability to remember to perform actions in the future—prospective memory—is undoubtedly crucial for daily functioning. However, equally important is our ability to disengage from intentions once they have served their purpose. As this thesis demonstrates, this disengagement is not a passive fading away of memory remnants but an active and deliberate process influenced by multiple factors. Understanding these factors not only advances our theoretical knowledge of memory and cognitive control but also offers practical insights for enhancing goal management in contexts ranging from everyday task planning to specialized environments where prospective memory failures can have serious consequences.

The journey of an intention, from its formation through execution to eventual deactivation, reveals much about the dynamic and adaptive nature of human cognition. By shedding light on the final stage of this journey—deactivation—this thesis, we hope, contributes to a more complete understanding of how we navigate the complex landscape of past, present, and future-oriented memory and cognition that defines our mental lives.

REFERENCES

Abraham, C., Sheeran, P., & Johnston, M. (1998). From health beliefs to self-regulation: Theoretical advances in the psychology of action control. *Psychology and Health*, *13*(4), 569-591.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. *Action control: From cognition to behavior/Springer*.

Allen, T.W., Marcell, M.M. & Anderson, P. Modality-specific interference with verbal and nonverbal stimulus information. Memory & Cognition 6, 184–188 (1978). https://doi.org/10.3758/BF03197444

Altgassen, M., Schmitz-Hübsch, M., & Kliegel, M. (2010). Event-based prospective memory performance in autism spectrum disorder. *Journal of Neurodevelopmental Disorders*, *2*, 2-8.

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

Anderson, F. T., & McDaniel, M. A. (2019). Retrieval in prospective memory: Multiple processes or just delay?. *Quarterly Journal of Experimental Psychology*, *72*(9), 2197-2207.

Anderson, M. C., & Green, C. (2001). Suppressing unwanted memories by executive control. Nature, 410(6826), 366-369.

Anderson, M. C., & Hanslmayr, S. (2014). Neural mechanisms of motivated forgetting. *Trends in Cognitive Sciences, 18*(6), 279–292.

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.

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

Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of learning and motivation*, *8*, 47-89.

Badets, A., & Osiurak, F. (2015). A goal-based mechanism for delayed motor intention: Considerations from motor skills, tool use and action memory. *Psychological Research*, *79*(3), 345-360.

Badets, A., Blandin, Y., Bouquet, C. A., & Shea, C. H. (2006). The intention superiority effect in motor skill learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(3), 491.

Balota, D. A., Yap, M. J., Hutchison, K. A., Cortese, M. J., Kessler, B., Loftis, B., ... & Treiman, R. (2007). The English lexicon project. *Behavior research methods*, *39*, 445-459.

Bartlett, F. C. (1932). Remembering: An experimental and social study. Cambridge: Cambridge University.

Beck, S. M., Ruge, H., Walser, M., & Goschke, T. (2014). The functional neuroanatomy of spontaneous retrieval and strategic monitoring of delayed intentions. *Neuropsychologia*, *52*, 37-50.

Benoit, R. G., & Anderson, M. C. (2012). Opposing mechanisms support the voluntary forgetting of unwanted memories. *Neuron*, *76*(2), 450-460.

Berman, M. G., Jonides, J., & Lewis, R. L. (2009). In search of decay in verbal short-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(2), 317.

Boywitt CD, Rummel J, & Meiser T (2015). Commission errors of active intentions: The roles of aging, cognitive load, and practice. Aging, Neuropsychology, and Cognition, 22(5), 560–576. 10.1080/13825585.2014.1002446

Brand, M. (1984). *Intending and acting: Toward a naturalized action theory* (p. 237). Cambridge, MA: MIT press.

Brandimonte, M. A., & Passolunghi, M. C. (1994). The effect of cue-familiarity, cue-distinctiveness, and retention interval on prospective remembering. *The Quarterly Journal of Experimental Psychology*, *47*(3), 565-587.

Bratman, M. (1987). Intention, plans, and practical reason.

Bugg, J. M., & Scullin, M. K. (2013). Controlling intentions: The surprising ease of stopping after going relative to stopping after never having gone. *Psychological Science*, 24(12), 2463-2471.

Bugg, J. M., & Streeper, E. (2019). Fate of suspended and completed prospective memory intentions. In Prospective memory (pp. 44-59). Routledge.

Bugg, J. M., Scullin, M. K., & McDaniel, M. A. (2013). Strengthening encoding via implementation intention formation increases prospective memory commission errors. *Psychonomic bulletin & review*, *20*, 522-527.

Bugg, J. M., Scullin, M. K., & Rauvola, R. S. (2016). Forgetting no-longer-relevant prospective memory intentions is (sometimes) harder with age but easier with forgetting practice. *Psychology and Aging*, 31(4), 358.

Cabeza, R., Kapur, S., Craik, F. I., McIntosh, A. R., Houle, S., & Tulving, E. (1997). Functional neuroanatomy of recall and recognition: A PET study of episodic memory. *Journal of cognitive neuroscience*, *9*(2), 254-265.

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., Gordon, A., Jaudas, A., Hefer, C., & Dreisbach, G. (2017). Let it go: the flexible engagement and disengagement of monitoring processes in a non-focal prospective memory task. *Psychological research*, *81*, 366-377.

Cona, G., Bisiacchi, P. S., Sartori, G., & Scarpazza, C. (2016). Effects of cue focality on the neural mechanisms of prospective memory: A meta-analysis of neuroimaging studies. *Scientific reports*, *6*(1), 25983.

Costa, A., Caltagirone, C., & Carlesimo, G. A. (2018). Prospective memory functioning in individuals with Parkinson's disease: a systematic review. *The Clinical Neuropsychologist*, *32*(5), 937-959.

Cottini, M., & Meier, B. (2020). Prospective memory monitoring and aftereffects of deactivated intentions across the lifespan. Cognitive Development, 53, 100844.

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., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. Journal of experimental Psychology: general, 104(3), 268.

Craik, F. I., & Watkins, M. J. (1973). The role of rehearsal in short-term memory. Journal of verbal learning and verbal behavior, 12(6), 599-607.

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.

Crowder, R. G. (1996). Commentary: The trouble with prospective memory: A provocation.

Denzler, M., Förster, J., & Liberman, N. (2009). How goal-fulfillment decreases aggression. *Journal of Experimental Social Psychology*, *45*(1), 90-100.

Denzler, M., Häfner, M., & Förster, J. (2011). He just wants to play: How goals determine the influence of violent computer games on aggression. *Personality and Social Psychology Bulletin*, *37*(12), 1644-1654.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual review of neuroscience*, *18*(1), 193-222.

Dewar, M. T., Cowan, N., & Della Sala, S. (2007). Forgetting due to retroactive interference: A fusion of Müller and Pilzecker's (1900) early insights into everyday forgetting and recent research on anterograde amnesia. *Cortex*, *43*(5), 616-634.

Dismukes, R. K. (2008). Prospective memory in aviation and everyday settings. *Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives*, *411428*.

Dismukes, R. K. (2010). Understanding and analyzing human error in real-world operations. In *Human factors in aviation* (pp. 335-374). Academic Press.

Dismukes, R. K. (2012). Prospective memory in workplace and everyday situations. *Current Directions in Psychological Science*, *21*(4), 215-220.

Dismukes, R. K., & Nowinski, J. (2007). Prospective memory, concurrent task management, and pilot error. *Attention: From theory to practice*, *4*, 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.

Dodhia, R. M., & Dismukes, R. K. (2009). Interruptions create prospective memory tasks. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *23*(1), 73-89.

Ebbinghaus, H. (1885). *Über das gedächtnis: untersuchungen zur experimentellen psychologie*. Duncker & Humblot.

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. (2005). Prospective memory: Multiple retrieval processes. *Current Directions in Psychological Science*, *14*(6), 286-290.

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., 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., Smith, R. E., & Shaw, P. (1998). Habitual prospective memory and aging: Remembering intentions and forgetting actions. *Psychological science*, *9*(4), 284-288.

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.

El Haj, M., Coello, Y., Kapogiannis, D., Gallouj, K., & Antoine, P. (2017). Negative prospective memory in Alzheimer's disease:"Do not perform that action". *Journal of Alzheimer's Disease*, *61*(2), 663-672.

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., Kvavilashvili, L., & Milne, A. (1999). Experimental tests of prospective remembering: The influence of cue-event frequency on performance. *British Journal of Psychology*, *90*(1), 9-23.

Fishbein, M. (1979). A theory of reasoned action: some applications and implications.

Förster, J., Liberman, N., & Higgins, E. T. (2005). Accessibility from active and fulfilled goals. *Journal of Experimental Social Psychology*, *41*(3), 220-239.

Freeman, J. E., & Ellis, J. A. (2003). The intention-superiority effect for naturally occurring activities: The role of intention accessibility in everyday prospective remembering in young and older adults. *International Journal of Psychology*, *38*(4), 215-228.

Freeman, J. E., & Ellis, J. A. (2003). The representation of delayed intentions: A prospective subject-performed task?. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29(5), 976.

Garavan, H., Ross, T. J., & Stein, E. A. (1999). Right hemispheric dominance of inhibitory control: an event-related functional MRI study. *Proceedings of the National Academy of Sciences*, *96*(14), 8301-8306.

Gilbert, S. J., Hadjipavlou, N., & Raoelison, M. (2013). Automaticity and control in prospective memory: A computational model. *PloS one*, *8*(3), e59852.

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

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.

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

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., & Einstein, G. O. (1998). Prospective memory: When reminders fail. *Memory & cognition*, *26*(2), 287-298.

Hardwicke, T. E., Taqi, M., & Shanks, D. R. (2016). Postretrieval new learning does not reliably induce human memory updating via reconsolidation. *Proceedings of the National Academy of Sciences*, *113*(19), 5206-5211.

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

Heffernan, T. M., & O′ Neill, T. S. (2013). Everyday Prospective Memory and Executive Function Deficits Associated with Exposure to Second-Hand Smoke. *Journal of Addiction*, *2013*(1), 160486.

Hicks, J. L., Marsh, R. L., & Cook, G. I. (2005). Task interference in time-based, event-based, and dual intention prospective memory conditions. *Journal of Memory and Language*, *53*(3), 430-444.

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.

Hogan, C., Cornwell, P., Fleming, J., & Shum, D. H. (2020). The assessment and prediction of prospective memory after stroke. *Journal of the International Neuropsychological Society*, *26*(9), 873-882.

Holton, R. (2009). *Willing, wanting, waiting*. Oxford University Press.

Ihle, A., Inauen, J., Scholz, U., König, C., Holzer, B., Zimmerli, L., Battegay, E., Tobias, R., & Kliegel, M. (2017). Prospective and retrospective memory are differentially related to self-rated omission and commission errors in medication adherence in multimorbidity. Applied Neuropsychology. Adult, 24(6), 505–511. https://doi.org/10.1080/23279095.2016.1209675

James, W. (1890). The principles of. *Psychology*, *2*, 94.

Kimmel, S. E., Chen, Z., Price, M., Parker, C. S., Metlay, J. P., Christie, J. D., ... & Gross, R. (2007). The influence of patient adherence on anticoagulation control with warfarin: results from the International Normalized Ratio Adherence and Genetics (IN-RANGE) Study. *Archives of internal medicine*, *167*(3), 229-235.

Kliegel, M., Mackinlay, R., & Jäger, T. (2008). Complex prospective memory: development across the lifespan and the role of task interruption. *Developmental psychology*, *44*(2), 612.

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.

Kliegel, M., McDaniel, M. A., & Einstein, G. O. (2007). *Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives*. Psychology Press.

Knight, J. B., Meeks, J. T., Marsh, R. L., Cook, G. I., Brewer, G. A., & Hicks, J. L. (2011). An observation on the spontaneous noticing of prospective memory event-based cues. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*(2), 298.

Kristensen, J. K., Torkildsen, J. v. K., & Andersson, B. (2024). Repeated mistakes in app-based language learning: Persistence and relation to learning gains. Computers & Education, 210, 104966. https://doi.org/10.1016/j.compedu.2023.104966

Kucera, H., & Francis, W. N. (1967). Computational analysis of present-day American English. *Providence, RI: Brown University Press.*

Kurtz, M., Scherbaum, S., Walser, M., Kanske, P., & Möschl, M. (2022). Dissociating sub-processes of aftereffects of completed intentions and costs to the ongoing task in prospective memory: A mouse-tracking approach. *Memory & Cognition*, 50(7), 1590-1613.

Kvavilashvili L (1987). Remembering intention as a distinct form of memory. British Journal of Psychology, 78(4), 507–518. 10.1111/j.2044-8295.1987.tb02265.x

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

Landeira-Fernandez, J. (1996). Context and Pavlovian conditioning. *Brazilian Journal of Medical and Biological Research*, *29*(2), 149-173.

Lewin, K. (1926). Vorsatz, wille und bedürfnis. *Psychologische Forschung*, *7*(1), 330-385.

Liberman, N., Förster, J., & Higgins, E. T. (2007). Set/reset or inhibition after goal fulfillment? A fair test between two mechanisms producing assimilation and contrast. *Journal of Experimental Social Psychology*, *43*, 258-264.

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., Kearney, R., & Remington, R. (2008). Is task interference in event-based prospective memory dependent on cue presentation?. *Memory & Cognition*, *36*, 139-148.

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

Logie, R. H., Zucco, G. M., & Baddeley, A. D. (1990). Interference with visual short-term memory. Acta psychologica, 75(1), 55-74.

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-occurrence. *Behavior research methods, instruments, & computers*, *28*(2), 203-208.

Maddux, J. E. (1999). Expectancies and the social–cognitive perspective: Basic principles, processes, and variables.

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. (2006). Task interference from prospective memories covaries with contextual associations of fulfilling them. *Memory & cognition*, *34*, 1037-1045.

Marsh, R. L., Hicks, J. L., & Watson, V. (2002). The dynamics of intention retrieval and coordination of action in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*(4), 652.

Marsh, R. L., Hicks, J. L., Cook, G. I., & Mayhorn, C. B. (2007). Comparing older and younger adults in an event-based prospective memory paradigm containing an output monitoring component. *Aging, Neuropsychology, and Cognition*, *14*(2), 168-188.

Marsh, R. L., Hicks, J. L., Hancock, T. W., & Munsayac, K. (2002). Investigating the output monitoring component of event-based prospective memory performance. *Memory & Cognition*, 30(2), 302-311.

Martin, B. A., Brown, N. L., & Hicks, J. L. (2011). Ongoing task delays affect prospective memory more powerfully than filler task delays. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *65*(1), 48.

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.

Matthijssen, S. J. M. A., van Schie, K., & van den Hout, M. A. (2018). The Effect of modality specific interference on working memory in recalling aversive auditory and visual memories*. Cognition and Emotion, 33(6), 1169–1180. https://doi.org/10.1080/02699931.2018.1547271

Maylor, E. A., Darby, R. J., & Sala, S. D. (2000). Retrieval of performed versus to-be-performed tasks: A naturalistic study of the intention-superiority effect in normal aging and dementia. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *14*(7), S83-S98.

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.

Maylor, E.A., Chater, N. & Brown, G.D.A. Scale invariance in the retrieval of retrospective and prospective memories. *Psychonomic Bulletin & Review* 8, 162–167 (2001). https://doi.org/10.3758/BF03196153

Mayr, U., & Keele, S. W. (2000). Changing internal constraints on action: the role of backward inhibition. *Journal of Experimental Psychology: General*, *129*(1), 4.

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.

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), 605–614. https://doi.org/10.1037/0278-7393.30.3.605

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.

Meacham, J. A., & Singer, J. (1977). Incentive effects in prospective remembering. *The Journal of Psychology: Interdisciplinary and Applied, 97*(2), 191–197. https://doi.org/10.1080/00223980.1977.9923962

Meacham, Jack & Leiman, B.. (1982). Remembering to perform future actions.

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.

Meilán, J. J. (2008). Activation and deactivation processes in the postponed intention paradigm. *Psychologia*, *51*(1), 89-97.

Mello, B., Matos, P., & Albuquerque, P. B. (2024). The role of cue salience in prospective memory commission errors in nonperformed nonfocal tasks. *Cognitive Processing*, *25*(3), 395-402.

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.

Möschl, M., Fischer, R., Bugg, J. M., Scullin, M. K., Goschke, T., & Walser, M. (2020). Aftereffects and deactivation of completed prospective memory intentions: A systematic review. *Psychological Bulletin*, 146(3), 245.

Müller, G. E., & Pilzecker, A. (1900). *Experimentelle beiträge zur lehre vom gedächtniss* (Vol. 1). Ja 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.

Nader, K., & Hardt, O. (2009). A single standard for memory: the case for reconsolidation. *Nature Reviews Neuroscience*, *10*(3), 224-234.

Nelson, M. R., Reid, C. M., Ryan, P., Willson, K., & Yelland, L. (2006). Self-reported adherence with medication and cardiovascular disease outcomes in the Second Australian National Blood Pressure Study (ANBP2). *Medical Journal of Australia*, *185*(9), 487-489.

Nigro, G., & Cicogna, P. C. (2000). Does delay affect prospective memory performance?. *European psychologist*, *5*(3), 228.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In *Consciousness and self-regulation: Advances in research and theory volume 4* (pp. 1-18). Boston, MA: Springer US.

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.

Nyberg, L., Tulving, E., Habib, R., Nilsson, L. G., Kapur, S., Houle, S., ... & McIntosh, A. R. (1995). Functional brain maps of retrieval mode and recovery of episodic information. *NeuroReport*, *7*(1), 249-252.

Owen, A. M., Roberts, A. C., Hodges, J. R., & Robbins, T. W. (1993). Contrasting mechanisms of impaired attentional set-shifting in patients with frontal lobe damage or Parkinson's disease. *Brain*, *116*(5), 1159-1175.

Penningroth, S. L. (2011). When does the intention-superiority effect occur? Activation patterns before and after task completion, and moderating variables. *Journal of Cognitive Psychology*, *23*(1), 140-156.

Pink, J. E., & Dodson, C. S. (2013). Negative prospective memory: Remembering not to perform an action. *Psychonomic Bulletin & Review*, *20*, 184-190.

Reese, C. M., & Cherry, K. E. (2002). The effects of age, ability, and memory monitoring on prospective memory task performance. *Aging, Neuropsychology, and Cognition*, *9*(2), 98-113.

Rendell, P. G., & Henry, J. D. (2009). A review of Virtual Week for prospective memory assessment: Clinical implications. *Brain impairment*, *10*(1), 14-22.

Roberts, R. J., Hager, L. D., & Heron, C. (1994). Prefrontal cognitive processes: Working memory and inhibition in the antisaccade task. *Journal of Experimental Psychology: General*, *123*(4), 374.

Rouleau, I., Dagenais, E., Tremblay, A., Demers, M., Roger, É., Jobin, C., & Duquette, P. (2020). Prospective memory impairment in multiple sclerosis: a review. *Prospective Memory in Clinical Populations*, 182-196.

Rummel, J., & McDaniel, M.A. (Eds.). (2019). Prospective Memory (1st ed.). Routledge. https://doi.org/10.4324/9781351000154

Rummel, J., Einstein, G. O., & Rampey, H. (2012). Implementation-intention encoding in a prospective memory task enhances spontaneous retrieval of intentions. *Memory*, *20*(8), 803-817.

Saults, J. S., & Cowan, N. (2007). A central capacity limit to the simultaneous storage of visual and auditory arrays in working memory. Journal of Experimental Psychology: General, 136(4), 663.

Schaper, P., & Grundgeiger, T. (2017). Commission errors in delay–execute prospective memory tasks. *Quarterly Journal of Experimental Psychology*, *70*(8), 1423-1438.

Schult, J. C., & Steffens, M. C. (2013). Tuned for the future: Intentions are only accessible when a retrieval opportunity is near. Memory & cognition, 41, 1252-1260.

Schult, J. C., & Steffens, M. C. (2013). Tuned for the future: Intentions are only accessible when a retrieval opportunity is near. Memory & cognition, 41, 1252-1260.

Scullin, M. K., & Bugg, J. M. (2013). Failing to forget: Prospective memory commission errors can result from spontaneous retrieval and impaired executive control. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 39(3), 965–971.

Scullin, M. K., Bugg, J. M., & McDaniel, M. A. (2012). Whoops, I did it again: commission errors in prospective memory. *Psychology and Aging*, 27(1), 46.

Scullin, M. K., Bugg, J. M., McDaniel, M. A., & Einstein, G. O. (2011). Prospective memory and aging: Preserved spontaneous retrieval, but impaired deactivation, in older adults. Memory & Cognition, 39, 1232-1240.

Scullin, M. K., Einstein, G. O., & McDaniel, M. A. (2009). Evidence for spontaneous retrieval of suspended but not finished prospective memories. *Memory & Cognition*, *37*, 425-433.

Scullin, M. K., McDaniel, M. A., Shelton, J. T., & Lee, J. H. (2010). Focal/nonfocal cue effects in prospective memory: Monitoring difficulty or different retrieval processes?. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(3), 736.

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. (2008). Connecting the past and the future: Attention, memory, and delayed intentions. In M. Kliegel, M. A. McDaniel, & G. O. Einstein (Eds.), *Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives* (pp. 29–52). Taylor & Francis Group/Lawrence Erlbaum Associates.

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), 756–777. https://doi.org/10.1037/0278-7393.30.4.756

Smith, R. E., & Bayen, U. J. (2006). The source of adult age differences in event-based prospective memory: a multinomial modeling approach. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(3), 623.

Smith, R. E., & Hunt, R. R. (2014). Prospective memory in young and older adults: The effects of task importance and ongoing task load. *Aging, Neuropsychology, and Cognition*, *21*(4), 411-431.

Spíndola, L., & Brucki, S. M. D. (2011). Prospective memory in Alzheimer's disease and Mild Cognitive Impairment. *Dementia & Neuropsychologia*, *5*(2), 64-68.

Streeper, E. (2018). Just Don't Do It!: A Comparison of Strategies for Reducing Commission Errors in Older and Younger Adults.

Tamrazi, S., & Wiskow, K. M. (2023). Effects of omission and commission errors during tact instruction. Journal of Applied Behavior Analysis, 56(4), 720–728. https://doi.org/10.1002/jaba.1020

Terry, W. S. (1988). Everyday forgetting: Data from a diary study. *Psychological reports*, *62*(1), 299-303.

Underwood, B. J. (1957). Interference and forgetting. *Psychological review*, *64*(1), 49.

Walker, M., Brakefield, T., Allan Hobson, J. *et al.* Dissociable stages of human memory consolidation and reconsolidation. *Nature* **425**, 616–620 (2003). https://doi.org/10.1038/nature01930

Walser, M., Fischer, R., & Goschke, T. (2012). The failure of deactivating intentions: aftereffects of completed intentions in the repeated prospective memory cue paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 38(4), 1030.

Walser, M., Goschke, T., & Fischer, R. (2014). The difficulty of letting go: Moderators of the deactivation of completed intentions. *Psychological Research*, *78*, 574-583.

Walser, M., Goschke, T., Möschl, M., & Fischer, R. (2017). Intention deactivation: Effects of prospective memory task similarity on aftereffects of completed intentions. *Psychological research*, 81(5), 961-981.

Walser, M., Plessow, F., Goschke, T., & Fischer, R. (2014). The role of temporal delay and repeated prospective memory cue exposure on the deactivation of completed intentions. *Psychological Research*, *78*, 584-596.

Waszak, F., Hommel, B., & Allport, A. (2003). Task-switching and long-term priming: Role of episodic stimulus–task bindings in task-shift costs. *Cognitive psychology*, *46*(4), 361-413.

Webb, T. L., & Sheeran, P. (2006). Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychological bulletin*, *132*(2), 249.

West, R. L. (1988). Prospective memory and aging. *Practical aspects of memory: Current research and issues*, 155-160.

West, R., Krompinger, J., & Bowry, R. (2005). Disruptions of preparatory attention contribute to failures of prospective memory. *Psychonomic bulletin & review*, *12*, 502-507.

West, R., McNerney, M. W., & Travers, S. (2007). Gone but not forgotten: The effects of cancelled intentions on the neural correlates of prospective memory. *International Journal of Psychophysiology*, *64*(3), 215-225.

Wilkins, A. J., & Baddeley, A. (1978). Remembering to recall in everyday life: an approach to absentmindedness. In *Practical aspects of memory* (pp. 27-34). Academic Press.

Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annu. Rev. Psychol.*, *55*(1), 235-269.

Wixted, J. T. (2005). A theory about why we forget what we once knew. *Current Directions in Psychological Science*, *14*(1), 6-9.

Zeigarnik, B. (1938). On finished and unfinished tasks.

Zhang, J., Xue, T., & Zhang, Z. (2021). Salient cues facilitate automatic processes in prospective memory. *NeuroReport*, *32*(10), 864-868.

Zogg, J. B., Woods, S. P., Sauceda, J. A., Wiebe, J. S., & Simoni, J. M. (2012). The Role of Prospective Memory in Medication Adherence: A Review of an Emerging Literature. Journal of Behavioral Medicine, 35(1), 47–62. https://doi.org/10.1007/s10865-011-9341-9

Appendix A

Questionnaires used in the Study

INFORMED CONSENT FORM

We invite you to take part in a research study conducted at the Sleep and Cognition Laboratory, IIT Guwahati. The purpose of this research is to examine memory performance under certain conditions created in the laboratory. It will be conducted by Snigdha Mohana Ayyagari, a research scholar at the Department of HSS, under the Guidance of Dr Naveen Kashyap, Professor, Department of HSS, IIT Guwahati.

The experiment comprises a behavioural study which will be conducted on a computer. Therefore, it is non-invasive and has no risks involved. Some demographic details will be collected from the participants, but all the information collected will be kept strictly confidential. The participants who volunteer retain the right to back out from the study at any point in time. If such a request is made by any participant, the data from their experimental sessions will not be used for analysis.

We seek your consent to be part of above-mentioned study. You participation is completely voluntary, and you have the right to refuse consent. If you have any doubts about the study and the procedure involved, please feel free to clarify.

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 anytime during the study without giving any reason. I am aware that by participating in this study, I will have to give time to the investigator for assessment."

Signature of Participant — Signature of Investigator

Name: — A Snigdha Mohana

Hostel:

Contact:

Date:

GENERAL DEMOGRAPHIC QUESTIONAAIRE

Name:

Age:

Gender:

Academic Qualification:

Spectacles: Yes / No

Smoking Habit: Yes / No

Drinking Habit: Yes / No

Do you suffer from Chronic Illness?

....

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

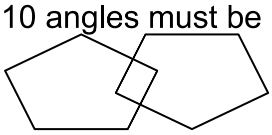
....

Do you take any medications/Drugs?

....

THE MINI-MENTAL STATE EXAMINATION

Patient's Name: ______________________________ Date: ___________

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

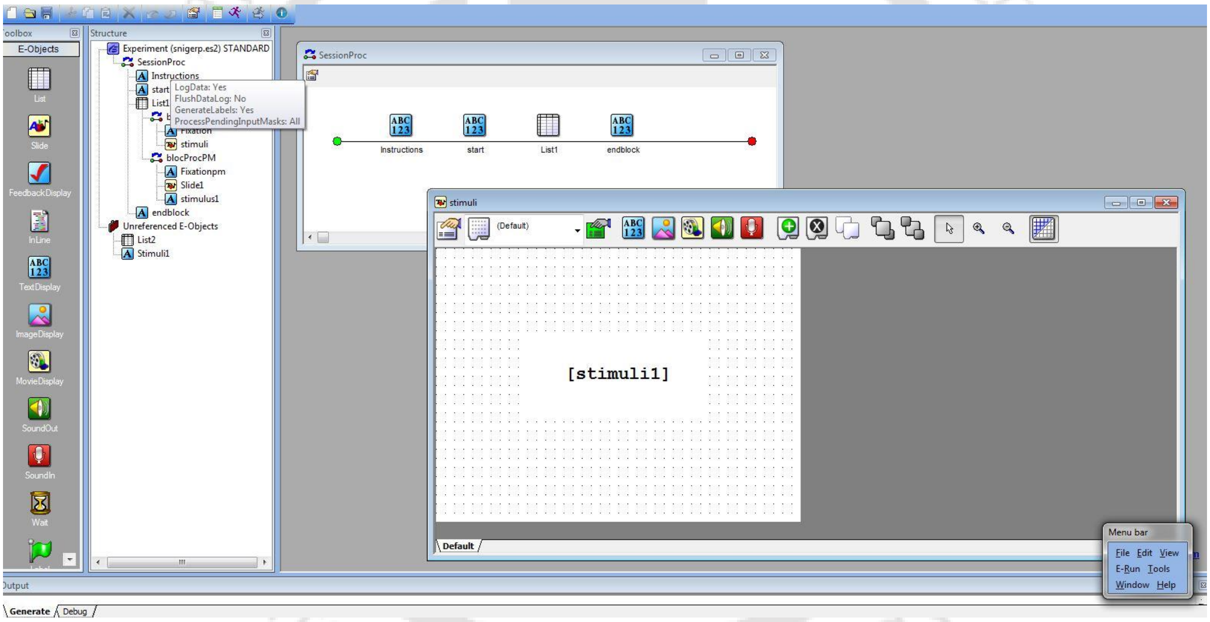
Appendix B

Equipment used in the Thesis

E-PRIME 2.0 PROFESSIONAL

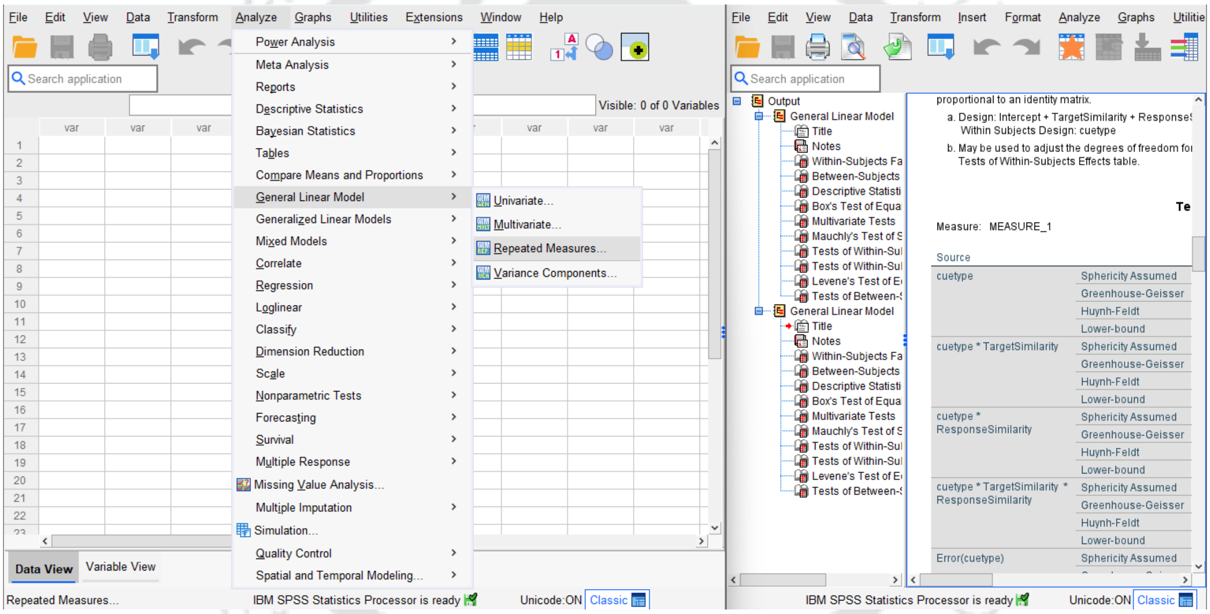
The software program E-Prime® is used to deliver stimuli in investigations related to psychology and cognitive science. This software system aids in the analysis of behavioural data and is used to gather it. It offers millisecond precise timing to guarantee data accuracy.

An excellent online help page for E-Prime® can be found at http://www.pstnet.com/support/login.asp. Examples of many experiment types, their solutions to problems, and answers to commonly asked questions can all be found here to assist investigators using this software.



IBM SPSS Version 29

IBM® SPSS® Statistics is the world's leading statistical software that is used to solve business and research problems by using ad hoc analysis, hypothesis testing, and predictive analytics. It helps comprehend data, anticipate and analyze patterns, validate assumptions and draw reliable conclusions. In this thesis SPSS was used for all statistical analysis including descriptives ANOVAs and post-hoc tests.



Appendix C

Word Lists

S.NO	WORD	LENGTH	NO. OF SYLLABLES	FREQ_HAL
1	*Demonstrated*	12	4	≈ 10000
2	*Consequences*	12	4	≈ 10000
3	*Categories*	10	4	≈ 10000
4	*Ridiculous*	10	4	≈ 10000
5	*Afternoon*	9	3	≈ 10000
6	*Suffering*	9	3	≈ 10000
7	*Involve*	7	2	≈ 10000
8	*Consent*	7	2	≈ 10000

S.NO	WORD	LENGTH	NO. OF SYLLABLES	FREQ_HAL
1	Commerce	8	2	≈ 10000
2	Suicide	7	3	≈ 10000
3	Agenda	6	3	≈ 10000
4	Enforcement	11	3	≈ 10000
5	Barely	6	2	≈ 10000
6	Nonsense	8	2	≈ 10000
7	Nowhere	7	2	≈ 10000
8	Frequent	8	2	≈ 10000
9	Overseas	8	3	≈ 10000
10	Deliver	7	3	≈ 10000

S.NO	WORD	LENGTH	NO. OF SYLLABLES	FREQ_HAL
1	Conducted	9	3	≈ 10000
2	Cooperation	11	5	≈ 10000
3	Produces	8	3	≈ 10000
4	Alliance	8	2	≈ 10000
5	Advantages	10	4	≈ 10000
6	Promised	8	2	≈ 10000
7	Burning	7	2	≈ 10000
8	Descriptions	12	3	≈ 10000
9	Purchasing	10	3	≈ 10000
10	Conventional	12	4	≈ 10000
11	Passes	6	2	≈ 10000
12	Commitment	10	3	≈ 10000
13	Recovery	8	4	≈ 10000

14	Struggle	8	2	≈ 10000
15	Stones	6	1	≈ 10000
16	Cheers	6	1	≈ 10000
17	Streets	7	1	≈ 10000
18	Announce	8	2	≈ 10000
19	Precisely	9	3	≈ 10000
20	Elected	7	3	≈ 10000
21	Clothing	8	2	≈ 10000
22	Scenario	8	4	≈ 10000
23	Balanced	8	2	≈ 10000
24	Narrow	6	2	≈ 10000
25	Capture	7	2	≈ 10000
26	Rubber	6	2	≈ 10000
27	Atmosphere	10	3	≈ 10000
28	Junior	6	2	≈ 10000
29	Reasoning	9	3	≈ 10000
30	Instrument	10	3	≈ 10000
31	Repeated	8	3	≈ 10000
32	Petition	8	3	≈ 10000
33	Displayed	9	2	≈ 10000
34	Mystery	7	3	≈ 10000
35	Emphasis	8	3	≈ 10000
36	Approval	8	3	≈ 10000
37	Artificial	10	4	≈ 10000
38	Serves	6	1	≈ 10000
39	Loading	7	2	≈ 10000
40	Grateful	8	2	≈ 10000
41	Spoken	6	2	≈ 10000
42	Substantial	11	3	≈ 10000
43	Publish	7	2	≈ 10000
44	Covering	8	3	≈ 10000
45	Sealed	6	1	≈ 10000
46	Upgraded	8	3	≈ 10000
47	Explore	7	2	≈ 10000
48	Quantity	8	3	≈ 10000
49	Gravity	7	3	≈ 10000
50	Nearby	6	2	≈ 10000
51	Maintaining	11	3	≈ 10000
52	Observed	8	2	≈ 10000
53	Depend	6	2	≈ 10000
54	Partners	8	2	≈ 10000
55	Edited	6	3	≈ 10000
56	Modify	6	3	≈ 10000

57	Fastest	7	2	≈ 10000
58	Driven	6	2	≈ 10000
59	Thrown	6	1	≈ 10000
60	Entity	6	3	≈ 10000
61	Switching	9	2	≈ 10000
62	Explains	8	2	≈ 10000
63	Industries	10	3	≈ 10000
64	Justify	7	3	≈ 10000
65	Talent	6	2	≈ 10000
66	Refers	6	2	≈ 10000
67	Converted	9	3	≈ 10000
68	Represents	10	3	≈ 10000
69	Apparent	8	3	≈ 10000
70	Literally	9	4	≈ 10000
71	Commonly	8	3	≈ 10000
72	Creates	7	2	≈ 10000
73	Voices	6	2	≈ 10000
74	Assault	7	2	≈ 10000
75	Expense	7	2	≈ 10000
76	Accuracy	8	4	≈ 10000
77	Associate	9	4	≈ 10000
78	Roughly	7	2	≈ 10000
79	Satisfied	9	3	≈ 10000
80	Confirm	7	2	≈ 10000
81	Locked	6	1	≈ 10000
82	Denied	6	2	≈ 10000
83	Specialist	10	3	≈ 10000
84	Alternate	9	3	≈ 10000
85	Notion	6	2	≈ 10000
86	Restore	7	2	≈ 10000
87	Younger	7	2	≈ 10000
88	Contacts	8	2	≈ 10000
89	Strictly	8	2	≈ 10000
90	Portland	8	2	≈ 10000
91	Twenty	6	2	≈ 10000
92	Accessible	10	4	≈ 10000
93	Pocket	6	2	≈ 10000
94	Desirable	9	4	≈ 10000
95	Impressed	9	2	≈ 10000
96	Suggests	8	2	≈ 10000
97	Breaks	6	1	≈ 10000
98	Hanging	7	2	≈ 10000
99	Springs	7	1	≈ 10000

100	Envelope	8	3	≈ 10000
101	Fantastic	9	3	≈ 10000
102	Investigate	11	4	≈ 10000
103	Assumption	10	3	≈ 10000
104	Linked	6	1	≈ 10000
105	Eternal	7	3	≈ 10000
106	Declared	8	2	≈ 10000
107	Assigned	8	2	≈ 10000
108	Ignorant	8	3	≈ 10000
109	Console	7	2	≈ 10000
110	Restrictions	12	3	≈ 10000
111	Complicated	11	4	≈ 10000
112	Contest	7	2	≈ 10000
113	Drinking	8	2	≈ 10000
114	Serving	7	2	≈ 10000
115	Enhanced	8	2	≈ 11000
116	Submission	10	3	≈ 11000
117	Intellectual	12	4	≈ 11000
118	Worried	7	2	≈ 11000
119	Signals	7	2	≈ 11000
120	Whoever	7	3	≈ 11000
121	Forgotten	9	3	≈ 11000
122	Paradise	8	3	≈ 11000
123	Optional	8	3	≈ 11000
124	Racist	6	2	≈ 11000
125	Rocket	6	2	≈ 11000
126	Warren	6	2	≈ 11000
127	Criteria	8	3	≈ 11000
128	Prepare	7	2	≈ 11000
129	Properties	10	3	≈ 11000
130	Incoming	8	3	≈ 11000
131	Offensive	9	3	≈ 11000
132	Joined	6	1	≈ 11000
133	Regulations	11	4	≈ 11000
134	Discover	8	3	≈ 11000
135	Pulling	7	2	≈ 11000
136	Managers	8	3	≈ 11000
137	Intend	6	2	≈ 11000
138	Rational	8	2	≈ 11000
139	Assumed	7	2	≈ 11000
140	Samples	7	2	≈ 11000
141	Masters	7	2	≈ 11000
142	Accident	8	3	≈ 11000

143	Severe	6	2	≈ 11000
144	Measures	8	2	≈ 11000
145	Worlds	6	1	≈ 11000
146	Involving	9	3	≈ 11000
147	Recognition	11	4	≈ 11000
148	Garden	6	2	≈ 11000
149	Legitimate	10	4	≈ 11000
150	Rapidly	7	3	≈ 11000
151	Segment	7	2	≈ 11000
152	Conduct	7	2	≈ 11000