A critical evaluation of interference-based accounts of forgetting via studies of minimal interference

Jamie D. McGhee

Thesis presented for the degree of

Doctor of Philosophy in Experimental Psychology and Cognitive Neuroscience

The University of Edinburgh

2019

Declaration

I declare that this thesis is my own composition, and that the work has not been submitted for any other degree or professional qualification. The work presented in this thesis has been executed by myself, except where explicitly stated otherwise.

Chapter 2 and Chapter 4

Data collection for the adult sample tested in Experiment 2 (Chapter 2), and the amnesic patient sample tested in Experiment 5 (Chapter 4) was completed by Cedric Mosconi. This was performed under the supervision of Nicoletta Beschin, who sourced the patient background data. Experimental instructions and testing materials were developed and provided by me.

Chapter 5

Multiple tasks used in Experiment 6 (i.e., lexical decision task, cue-word learning and word-pair learning tasks, PM test) were developed by myself using PsychoPy2, with guidance from Alisdair Tullo.

Chapter 6

Data collection for Experiment 7 was conducted by Isis Segura, under the supervision of Sabine Pompéia. Data analysis, alongside the formation of relevant tables and figures, was conducted by Isis Segura, with substantial input from myself, alongside Sergio Della Sala and Nelson Cowan. The post-encoding interpolated task used in this experiment (i.e., Spot-the-Difference task) was developed by myself, with minor alterations made by Isis Segura.

Abstract

There is a growing consensus that the forgetting of information from long-term memory occurs as a result of interference. Interference is experienced when the encountering of extraneous stimuli impedes the retention and later recall of a desired memory. Interfering stimuli may be encountered before (i.e., proactive interference) or after (i.e., retroactive interference) the encoding of a given memory. The minimisation of interference via wakeful rest has been seen to improve retention of newly acquired episodic memory (Dewar, Pesallaccia, Cowan, Provinciali, & Della Sala, 2012; Alber, Della Sala, & Dewar, 2014; Ecker, Tay, & Brown, 2015a; Ecker, Brown, & Lewandowsky, 2015b). However, conceptions of how interference elicits forgetting – and how its minimisation may promote successful retention - vary across different theoretical accounts.

According to consolidation theory (Müller & Pilzecker, 1900; Wixted, 2004; Dudai, 2004), forgetting is elicited by the disruption of early consolidative processes following post-encoding engagement in further sensory stimulation. It is believed that the interruption of this process is avoided when encoding is immediately followed by a period of wakeful rest, in which disruptive sensory stimulation is vastly reduced.

Alternatively, the temporal distinctiveness theory (Brown, Neath, & Chater, 2007) posits that forgetting is incurred following the reduced distinctiveness of a specific memory at retrieval, which is partly mediated by the proximity of neighbouring memories encountered either before or after target acquisition. Under this account, if a target memory is temporally isolated by either pre- or post-encoding intervals of

rest then the increased distinctiveness of this memory will improve retrieval.

Over the course of this thesis, I aim to explore the possible benefits of minimal proactive and retroactive interference across seven experiments as a means of critically evaluating the accountability of these theories in explaining forgetting across a spectrum of memory ability.

In Chapter 1, I review the literature exploring the effects of interference and benefits resulting from wakeful rest seen across both healthy populations and patients with anterograde amnesia. I also outline the mechanisms proposed by both the consolidation theory and the temporal distinctiveness theory and highlight key deviations.

In Chapter 2, I explore two experiments (Experiment 1 and 2) which aimed to assess whether healthy younger and older adults retained more prose material when encoding was preceded and/or followed by wakeful rest. We found that both healthy younger and older adults groups were able to retain substantial amounts of prose information irrespective of whether they rested wakefully or engaged in an effortful task before or after prose encoding. I conclude that healthy adults may benefit from the use of retrieval strategies that are applicable only in the retention of prose material specifically. I propose that the maintenance of interference-resilient cues derived from salient story ideas allowed for the circumvention of interference effects following pre- and post-encoding activity.

In Chapter 3, I explore this idea further via two experiments which assessed whether healthy older adults would continue to demonstrate a lack of interference effects if the to-be-retained material did not readily allow for the use of facilitatory retrieval strategies. The same paradigm used in

Experiment 1 and 2 was adopted, with the exception of different to-be-retained material (i.e., lists of unrelated words) and the use of a more intensive version of the Spot-the-Difference task. In Experiment 3, healthy older adults were seen to forget significantly more wordlist items following both pre- and post-encoding engagement in a more demanding Spot-the-Difference task. While an observed individual pre-encoding wakeful rest benefit provided support for the temporal distinctiveness theory in Experiment 3, Experiment 4 demonstrated that this evidence was likely the result of cross-list interference, with results indicating no interference effects within a between-subjects design.

In Chapter 4, I reflect on another experiment which adopts the same paradigm used in Experiment 1 and 2 in order to assess whether patients presenting with anterograde amnesia would show improved retention of prose material following pre- and/or post-encoding wakeful rest (Experiment 5). In Experiment 5, amnesic patients retained significantly more prose material across conditions in which wakeful rest followed encoding. However, a superadditive decline was observed following both pre- and post-encoding engagement in a spot-the-difference task within a single condition. Given the absence of an individual pre-encoding wakeful rest benefit in this experiment, it was concluded that the results provided evidence in support of the consolidation theory as the more accountable theory of forgetting.

In Chapter 5, I cover Experiment 6 which aimed to see whether the consistent benefits of post-encoding wakeful rest to the retention of episodic information from long-term memory could also be observed in tests of prospective memory (PM). In this experiment, both healthy younger and older adults were able to successfully identify cues and recall associated items irrespective of whether wakeful rest followed PM test instruction. However, I highlight that assessing the benefits of post-study wakeful rest in a typical study of PM is significantly limited by the employment of multiple learning trials. Given that participants are repeatedly exposed and tested on the target material during the initial learning phase of the experiment, I conclude that the target material has likely been adequately stabilised in long-term memory prior to the occurrence of post-encoding activity.

In Chapter 6, I discuss the final experiment that intended to see whether the administration of benzodiazepines (BZs) across a sample of healthy adults would result in observed memory performances that mirror specific profiles of anterograde amnesia. Additionally, the study intended to establish whether forgetting following drug-induced amnesia would be alleviated by post-encoding wakeful rest. While BZs ingestion did result in poorer recall of prose material learned after drug administration, forgetting was not reduced following post-encoding wakeful rest as typically seen in many amnesic patients. Given this, I conclude that the administration of BZs results in a temporary state of severe anterograde amnesia, in which an ability to benefit from the minimisation of sensory stimulation following is briefly unavailable.

In Chapter 7, I provide a general discussion of the findings from all seven experiments. In this discussion, I assert that the consolidation theory provides a more viable explanation of forgetting among individuals with anterograde amnesia. However, I acknowledge practical constraints of investigating interference effects and the observed limits of wakeful rest benefits. Mainly, how wakeful rest benefits are difficult to assess across healthy populations under certain conditions (i.e., learned materials facilitate retrieval strategies, Experiment

1 and 2; interpolated tasks do not elicit interference alone, Experiment 3 and 4; learned materials can be stabilized prior to further sensory stimulation, Experiment 6).

Lay Abstract

Throughout our daily lives, we often find ourselves forgetting information that we once remembered. For example, you may have forgotten the name of a new colleague at work, or forgot to pick up an intended item during a shopping trip. For well over a century, researchers have attempted to explain why we forget. Many agree that forgetting is caused by interference. When we engage with information or tasks before or after forming a new memory, this can disrupt our ability to successfully retain and recall that memory at a later point. Research has found that if you limit your exposure to additional information or tasks through a brief period of rest, you can decrease the amount of information you forget. However, there is division surrounding the underlying mechanisms that are responsible for this benefit.

According to the consolidation theory, taking part in an effortful task shortly after learning something new can interrupt the early consolidation of that information and its transfer into long-term memory. Consolidation involves the progressive strengthening of new memories which are initially weak in nature and prone to being lost if the process is impeded prematurely. Resting after new learning can prevent this process from being disrupted.

However, according to the temporal distinctiveness theory, resting after new learning does not aid consolidation, but rather the later retrieval of memories. This account proposes that our ability to retrieve information successfully is determined by how distinct a memory is at the point of retrieval. If you rest immediately after learning something new, you improve the distinctiveness of that memory. However, if

additionally memories are formed immediately before or shortly after new learning, the desired memory is more difficult to distinguish from the others when tested later.

One way of determining which theory better explains forgetting is to assess the possible benefits of rest when it precedes and/or follows new learning. Across a number of experiments that have tested the retention of information among different groups (younger and older adults, people with memory impairments following brain damage or the administration of sleeping pills), I have established that the consolidation theory is a more reliable explanation overall.

While healthy younger and older adults appeared to retain information over 10 minutes in the absence of rest either before or after learning, patients with memory impairments following brain damage demonstrated improved retention when learning was followed by rest. However, resting before new learning did not lead to the same reductions in forgetting. Since the temporal distinctiveness theory would expect less forgetting following a rest before learning, it appears that this explanation is unsupported by the data. However, assessing the theories of forgetting through studies exploring the benefits of rest is not always reliable. Both healthy younger and older adults are able to remember stories and pairs of words, irrespective of whether they rest or take part in effortful tasks before and/or after learning. Additionally, people with memory impairments following the consumption of sleeping pills do not benefit from rest following learning either.

While it appears that forgetting may be largely caused by the disruption of consolidation following an effortful task after learning, there are a number of ways in which this interference can be mitigated by healthy adults beyond a brief instance of rest.

Acknowledgements

First of all, I want to take this opportunity to show my absolute appreciation for my primary supervisor Sergio Della Sala. From my years as an undergraduate student at The University of Edinburgh to now, Sergio has continued to be a truly outstanding supervisor. The knowledge and experience I have gained thanks to him is priceless. I honestly could not have asked for a better supervisor.

I also wish to give a huge thanks to my secondary supervisor Nelson Cowan. While geographically distant, Nelson has never felt too far away. His invaluable support throughout over the years has been really appreciated. I would also like to thank my other supervisor Maria Brandimonte for giving me this opportunity to start with. This process has not only taught me so much about memory, but has taught me valuable lessons about myself that will never be forgotten.

I need to give a massive thanks to both Nicoletta Beschin and Cedric Mosconi for their fantastic work in collecting patient data in Italy. Additionally, I would like to thank Sabine Pompéia and Isis Segura for giving me the opportunity to work collaboratively with them on the benzodiazepines study.

I would also like to give a big thanks to all of the participants who volunteered their time to take part in the experiments discussed in this thesis. Their willingness to participate and eagerness to learn more about my work always put a smile on my face.

I have to thank both of my parents and my close family members for their unwavering support over the last few years (and throughout my entire life more generally). Even through difficult times, they always found their own way to make me feel supported.

Lastly, I would like to thank my partner Jillian for her endless support and encouragement over the years. I have no idea where I would be without you. I love you!

Table of Contents

Chapter 1:

General introduction

1.1 Forgetting

Why do we forget things we once remembered? A definitive answer to this question has continued to elude psychologists ever since the early nineteenth century (Herbart, 1816; 1825; Ebbinghaus, 1885/1964; Bigham, 1894; see Postman, 1968; Murray, 1976). Past attempts to characterise and investigate the possible mechanisms that underpin forgetting have often sparked theoretical divide (Müller & Pilzecker, 1900; Underwood, 1957; Wixted, 2004; Brown, Neath, & Chater, 2007), despite a gradual converging consensus that interference is profoundly implicated in everyday forgetting (see Wixted, 2004). Even efforts to define what we mean by forgetting in rudimentary terms has been a point of contention among the scientific community (Sills & Merton, 1968). Most researchers have settled on the notion that forgetting entails the failure to recall or recognise something that was previously learned (Munn, 1962; Tulving, 1974).

For the majority of us, forgetting is an inescapable reality of our everyday lives; ranging from the inconsequential (e.g., inability to remember where you placed your mobile phone, or difficulty in recalling the name of someone you just recently met) to the severe (e.g., not remembering to take vital medication at a prescribed time). It is a reasonable assumption that we forget far more information than what we subsequently commit to memory, with most of what we experience throughout our lives being forgotten. While this idea may leave many reflecting negatively on the process of forgetting, it is important to consider that forgetting serves multiple positive functions in our lives (the regulation of emotions, the acquisition of knowledge, etc.; see Nørby, 2015).

Given the pervasiveness of forgetting, it comes as no surprise that it is a prominent subject of psychological study. Much of the past research on forgetting has explored the inability to remember information from declarative long-term memory (LTM; Tulving, 1972; 1985; Squire, 1987; see Squire, 2004); more specifically, episodic memory. Episodic memory is a subdivision of declarative LTM that involves the human capacity to retain information of "episodes" (i.e., events, experiences, and situations acquired throughout life). This involves remembering what happened during a given episode, where a specific episode occurred, and when a specific episode transpired (Tulving, 2002). This ability enables us to mentally travel back in time and re-live moments from our past. As a form of explicit memory, episodic memory is believed to involve the encoding, consolidation, and retrieval of events (Wenger & Shing, 2016). Theories regarding the forgetting of episodic content and other information from LTM have linked it to the interference of some of these crucial stages of memory formation. While these theoretical endeavours are yet to reliably lead us to a satisfying answer to the opening question, the scientific pursuit of a viable explanation of forgetting has continually expanded our overall understanding of human memory.

1.2 The Origins of Experimental Research into Forgetting

The pioneering research of Hermann Ebbinghaus and his observation of the classic “forgetting curve” marked the first major demonstration that experimental studies of forgetting could provide informative insights into memory. Ebbinghaus (1885/1964) was the first to establish a temporal course of forgetting through his use of the “savings method”, which entailed the assessment of his own relearning of perfectly memorised lists of nonsense syllables (i.e., consonant-vowel-consonant nonword items).

When tasked with relearning syllable lists across numerous delay intervals (20 minutes, 1 hour, 9 hours, 1 day, 2 days, 6 days and 31 days), Ebbinghaus found that a substantial degree of forgetting occurred rapidly during the immediate minutes and hours following initial learning. This was characterised by a notable increase in the number of trials required and the time taken across earlier intervals (20 minute interval – 9 hour interval) to successfully relearn lists of nonsense syllables to a level that matched original learning (i.e., two successive, faultless recalls of the list). However, this rapid rate of forgetting was seen to decelerate and plateau as time passed, with the number of trials required for adequate relearning inclining at a much slower rate between 2 days and 31 days (see Figure 1.1).

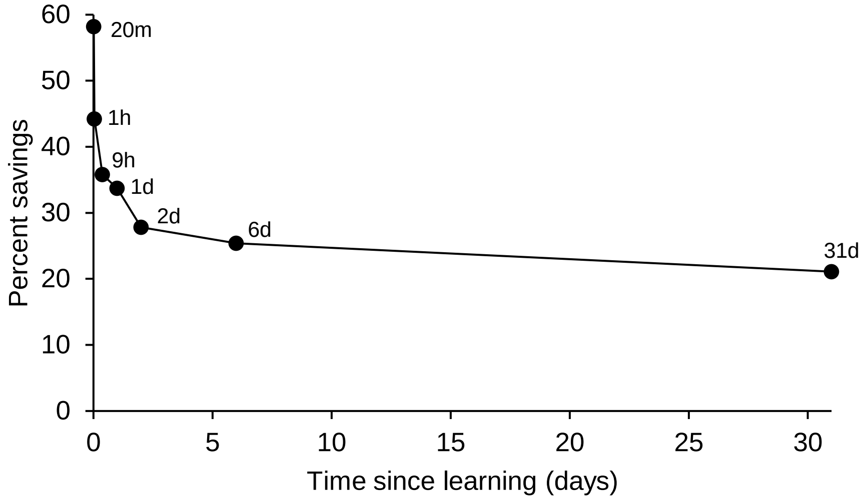

Figure 1.1. Ebbinghaus' (1885/1964) forgetting curve (data sourced from Murre & Dros, 2015). Percent savings = (OL – RL)/OL x 100, where OL = number of trials (elapsed time) needed to learn the syllable list originally, RL = number of trials (elapsed time) needed to relearn the syllable list.

The rate of forgetting seen by Ebbinghaus (i.e., continually diminishing rate of forgetting over time) remains a common observation in memory research over 100 years later (see Rubin & Wenzel, 1999). This pattern has been seen consistently across healthy populations, despite the use of a variety of experimental procedures and measurements of retention over extended delay intervals (Slamecka & McElree, 1983; Bahrick, 1984; Rubin, 1989; Rubin, Hinton, & Wenzel, 1999). Moreover, direct replications of Ebbinghaus' original study have led to similar observations (Heller, Mack, & Seitz, 1991; Murre & Dros, 2015).

1.3 Forgetting: A Sole Product of the Passage of Time

One of the most notable yet divisive assertions made at the time following Ebbinghaus' establishment of the forgetting curve was the notion that forgetting occurs solely as a function of the passing of time. This principle formed the foundation of the Law of Disuse, (Thorndike, 1913; see McGeoch, 1932), which drew primary support from Ebbinghaus' findings.

According to the Law of Disuse, memory traces are believed to progressively fade over time if left unreinforced following an absence of further usage (Woodworth, 1929; Gates, 1930; Pratt, 1934a; 1936b). However, this concept – which Ebbinghaus briefly reflected upon within his own work – was soon met with mounting scrutiny and contradictory evidence (Bigham, 1894; Müller & Pilzecker, 1900; Jenkins & Dallenbach, 1924; Skaggs, 1925; see McGeoch, 1932). A study by Jenkins and Dallenbach (1924) provided pivotal evidence revoking the notion that forgetting was solely determined by the elapsing of time. They found that the recall of learned syllables was substantially poorer when the period between learning and later recollection consisted of normal everyday activity, as opposed to sleep. Differential degrees of forgetting were seen despite the fixed elapsing of time between learning and later recall across both conditions. Such a finding would not be expected if the passive effects of time alone were the determining factor of memory degradation, as outlined in the Law of Disuse.

Jenkins and Dallenbach (1924) further argued that the observed benefits to retention following the reduction of interpolated material – which was achieved via post-learning sleep - could additionally explain an often overlooked irregularity in Ebbinghaus' own findings. Inspection of

Ebbinghaus' forgetting curve reveals a temporary deceleration in the rate of forgetting that can be seen between the 9 hour and 24 hour intervals. Given that the period between these assessments predominantly consisted of sleep, Jenkins and Dallenbach (1924) posited that the observed slowing of forgetting was likely a result of reduced exposure to interpolated material during this time.

Skaggs (1925) and McGeoch (1932) provided further arguments against the principles underlying the Law of Disuse, referencing both Jenkin and Dallenbach's research and observed instances of superior recall following a delay (known as reminiscence; Ballard, 1913; Williams, 1926). McGeoch (1932) went as far to refer to the proposition that time is a major condition of forgetting in itself as "logically meaningless" (p. 25) given that no analogy exists among other scientific phenomena. Following the accumulation of opposing findings and alternative viewpoints, the Law of Disuse and other similar theories of forgetting (e.g., Decay Theory; Brown, 1958) were thereafter considered unviable explanations of forgetting with respects to LTM (though its relevance in short-term memory, or STM, is still widely debated; see Ricker, Vergauwe, & Cowan, 2016). However, given that this concept inadvertently led to the conduction of influential studies which shaped accounts of forgetting that are prominent today, its indirect importance to the theoretical understanding of forgetting should not be ignored.

With consideration to the impacts of such research on later accounts of forgetting, further attention should be directed towards the work of John Bigham. Bigham (1894) was the earliest researcher to disagree with the relationship between forgetting and time that would later be promoted by the Law of Disuse. He posited that the elapsing of time from initial learning to later reproduction in everyday life typically involved the encountering of “optical or acoustical impressions” (Bigham, 1894, p. 458). He believed that the mere passage of time was not an important condition to forgetting in itself; instead proposing that forgetting may be primarily elicited by exposure to subsequent auditory and visual information which typically fills retention periods in normal everyday living.

Bigham’s claims were substantiated by his observations of increased recall errors and longer recall durations when the learning of different to-be-retained material (i.e., visually- and verbally-presented numbers, colours, words, nonsense syllables) was followed by the visual or verbal presentation of newspaper articles in comparison to unfilled post-learning intervals lasting no longer than 60 seconds. Additionally, he saw an increase in the number of recall errors as a result of normal everyday activity (relative to the sample tested, which consisted of university students) when comparing tests conducted two hours and 24 hours after learning.

1.4 Forgetting: A Product of Interference

While Bigham’s early contribution to the study of forgetting is often underappreciated, his original proposition that interpolated activity between learning and later recall may play a fundamental role in forgetting soon became a major focal point in memory research. His study marked the first empirical demonstration of “retroactive inhibition” (a term later coined by Müller and Pilzecker, 1900), whereby the ability to retain or recall a recently encoded memory (e.g., words, nonsense syllables, etc.) is inhibited or interfered with by the subsequent encountering of interpolated activity (e.g., reading a newspaper article) between acquisition and reproduction. His methodology of assessing the negative effects of post-learning interpolated material to retention at varying intervals – as well as the effects of post-learning rest - became a commonly adopted practice which is still used to some extent across more recent studies of minimal interference (Müller & Pilzecker, 1900; Skaggs, 1925; Dewar, Garcia, Cowan, & Della Sala, 2009; Ecker, Tay, & Brown, 2015a; Sosic-Vasic, Hille, Kröner, Spitzer, & Kornmeier, 2018).

The exploration of the detrimental properties of engaging with material following recent learning became a staple of theoretical considerations at the turn of the twentieth century with the formation of interference-based theories of forgetting. The continued study of retroactive (and later proactive) inhibition effects on retention, alongside comparisons of retention under pre- and/or post-learning rest, represents a significant portion of the experimental efforts to decipher the mechanisms underpinning forgetting. A selection of these works will be discussed over the course of this chapter, alongside the prominent theories which have been proposed to account for them.

1.5 Consolidation Theory of Memory

The first prominent interference-based account of forgetting to surface – namely, the consolidation theory - stemmed from the influential works of Georg Elias Müller and Alfons Pilzecker (1900). Across a series of experiments, Müller and Pilzecker (1900) aimed to investigate the mechanisms underlying associative memory and retrieval. Largely inspired by the earlier works of Ebbinghaus, the goals of their initial experiments were to establish the minimal number of learning repetitions needed for successful cued recall of nonsense syllables and to assess how recall accuracy and duration was affected by different fixed numbers of learning repetitions.

However, following the observation of certain phenomena (i.e., “perseveration tendencies”, and reduced retention following its disruption), the focus of subsequent experiments was redirected towards the exploration of what they called “rückwirkende Hemmung”, also known as “retroactive inhibition” or “retroactive interference”. The latter term of retroactive interference (RI) represents the more widely used expression that will be adopted throughout the remainder of the thesis. The exploration of RI led to the coining of the term “consolidirung” or consolidation, and the formation of the consolidation theory (see Lechner, Squire, & Byrne, 1999; Dewar, Cowan, & Della Sala, 2007 for summary).

1.5.1 Forgetting: The Interference of Consolidation

Müller and Pilzecker’s (1900) experiments broadly involved the “method of hits”, an early precursor to the frequently used paired-associate (PA) paradigm, or the A-B, A-C paradigm (discussed later). This method entailed the assessment of cued recall of learned lists of paired nonsense syllables (the syllables used were similar in nature to the items used by Ebbinghaus). Retention was assessed across a number of post-learning conditions; the most notable conditions employed in later experiments being those in which the period between the learning and later recall of syllable lists consisted of mental exertion or rest (bearing similarities to the procedure used by Bigham).

In their early investigations, participant feedback revealed that items from recently learned lists of paired nonsense syllables would frequently return to the attention of subjects involuntarily during subsequent retention intervals. Müller and Pilzecker referred to these occurrences as “perseveration tendencies”, whereby memories would spontaneously re-emerge into consciousness. The term “perseveration” was derived from the field of clinical neuropsychology where it is still used to define the immediate or delayed repetition of a previously performed action that is no longer relevant to the situation (Gurd, Kischka, & Marshall, 2010).

Müller and Pilzecker argued that a number of errors and performance patterns observed across numerous experiments were further evidence of these perseveration processes in action (see Murray, 1978). They found that later lists often took longer to learn if a previously learned syllable list consisted of shared cues (described as “effectual inhibition”), primarily due to the returning of previous associations to the attention of participants (described as “associative by-excitation”). Additionally, the incorrect recall of a previously learned syllable sometimes followed the presentation of a different cue from the same list, as well as a cue from a different list learned later on.

As a means of suppressing the rehearsal of learned items following the observation of spontaneous perseverations, participants were given materials to read during retention intervals across a number of experiments. However, this was soon seen to have a marked detrimental impact on later cued recall. It was from this that Müller and Pilzecker hypothesised that perseveration tendencies are vital to memory formation and retention – linking its role to the consolidation of memories. They proposed that perseverations facilitated the formation of representations in memory and the further strengthening of corresponding associations established during initial encoding via the continuation of gradually weakening physiological processes. While their discussion of the underlying neural processes of consolidation were vague, these were further elaborated in the years to follow (see Wixted 2004; Dudai, 2004; Dudai, Karni, & Born, 2015; discussed later).

Given their assumption that consolidation is a crucial process in the formation of LTM, they proposed that the interference of perseveration tendencies via post-learning mental exertion may lead to subsequent increases in forgetting. Conversely, in the absence of further mental exertion following memory acquisition (during a period of quiet, wakeful rest), retention should be relatively spared following a lack of consolidation interference.

To explore this, they assessed the retention of a list of 6 nonsense syllable pairs when learning was followed by: (a) the immediate presentation of a subsequent syllable list (after 34 seconds), or (b) an unfilled post-learning retention interval (between 7-8 minutes) comprised of wakeful rest in a quiet environment where sensory stimulation had been markedly reduced. Additionally, they conducted a similar experiment in which the delay between the original list and the interpolated list was extended to 1 minute and the retention interval was extended to 24 hours. Across these experiments, they observed poorer performances across tests of cued recall when a further list was encountered during the retention interval as opposed to when rest followed learning.

These results reaffirmed the findings originally made by Bigham (1894); interpolated mental activity or “work” can retroactively impair the later recall of recently formed memories, and that this negative impact is enduring over time. However, if new learning was followed by minimal activity (achieved via wakeful rest), the minimisation of RI can result in uninterrupted consolidation and thus improved retention.

These results were further supported by the findings of another investigation which revealed that the encountering of an interpolated list was more detrimental to the retention of the original list (tested 90 minutes later) when presented soon after learning (after 17 seconds), as opposed to after a brief delay (6 minutes). This finding represented the first direct demonstration that the degree of RI experienced by an individual is partly determined by how soon interpolated activity is encountered after new learning, alluding to a temporal gradient of RI (which will be explored later). Following from this, Müller and Pilzecker reasoned that recently formed memory traces may be more susceptible to RI in their infancy, becoming more resilient to later interference as they mature over time due to the stabilising properties of uninterrupted consolidation. This explanation provides us with a means of understanding the pattern of forgetting illustrated by Ebbinghaus' (1885/1964) forgetting curve (i.e., initial rapid rate of forgetting of "young" memory traces that progressively lessens over time as "older", more robust memory traces remain).

Later experiments established that decreases in retention of a list of syllables could still be observed, even when the interpolated task following learning consisted of material that was unrelated to the to-be-retained material (i.e., describing paintings of landscapes following the learning of a syllable list). Again, when the post-learning period between learning and recall (in this experiment, lasted 6 minutes) consisted of an interpolated task, retention was significantly poorer. This finding led them to propose that *any* mental exertion following learning (also known as "diversion RI" or "nonspecific RI"; see Dewar et al., 2007, Keppel, 1968) results in the similar disruption of consolidation and subsequent increases in forgetting, regardless of the similarity of the interpolated material to the memorandum.

Given all these results, Müller and Pilzecker concluded that the processes underlying memory consolidation are susceptible to disruption by further mental exertion (diversion RI) immediately following learning due to the interruption of perseveration of the original memory. However, susceptibility to RI would weaken over time (as soon as 6 minutes) as memory traces mature and strengthen following undisrupted consolidation.

1.5.2 Consolidation Theory: Later Contributions from Neuroscience and Neuropsychology

As will be discussed later, many experimental psychologists considered alternative theories to forgetting following notable difficulties in replicating the interference effects outlined in Müller and Pilzecker’s (1900) seminal work (i.e., diversion RI; see Britt, 1935 for review of early opposing research). However, the lack of immediate behavioural data supporting the consolidation theory of memory and forgetting did little to discourage interdisciplinary attention from the fields of neuroscience and neuropsychology in the years to follow. Over the last 30 years specifically, both neuroscientific work on humans and nonhuman-animals, as well as neuropsychological research on amnesic patients, have elucidated the underlying physiological processes of consolidation and its importance to memory formation and retention.

Research among these fields have solidified the idea that newly formed memory traces are highly vulnerable to RI (elicited behaviourally by the post-learning introduction of mental exertion, chemically via the administration of protein synthesis inhibitors, physically via selective anatomical lesions to medial temporal lobe structures in animals; see Wixted, 2004). This has been attributed to the specific susceptibility of early consolidative processes (i.e., “synaptic” consolidation involving short and early long-term plasticity; see Clopath, 2012) to subsequent disruption (as observed by Müller & Pilzecker, 1900). The proceeding discussion of past research will pertain to this phenomena, given that a significant portion of forgetting is typically seen to occur within this time-frame (Ebbinghaus, 1885/1964; Müller & Pilzecker, 1900).

The clinical research of Théodule Ribot - which predated Müller and Pilzecker’s (1900) investigations of RI - was the first to allude to the possibility that recently formed memory traces are initially fragile and prone to forgetting, becoming increasingly resilient to interference over time following stabilisation (Ribot, 1881,1882/1977). Ribot (1881, 1882/1977) found that some patients with cerebral atrophy resulting in anterograde amnesia (AA: the inability to commit new information to LTM, despite often preserved STM; Baddeley & Warrington, 1970; see Kopelman, 2002) also presented with retrograde amnesia (RA: the forgetting of past memories preceding brain damage). Upon further investigation of individuals presenting with “global” organic amnesia, he recognised that the deterioration of past memories followed a temporal gradient. More specifically, he found that memories formed in the recent past were more likely to be forgotten than distant memories.

The Law of Regression, or Ribot’s Law, was subsequently proposed to characterise this temporal gradient of RA. This gradient has been consistently observed since

(Sanders & Warrington, 1971; Squire, Slater, & Chace, 1975; Squire, 1975), particularly in cases involving medial temporal lobe (MTL) damage (Reed & Squire, 1998; Kapur & Brooks, 1999; Manns, Hopkins, & Squire, 2003). This is exemplified best by the case study of patient Henry Molaison (HM) that was conducted by William Scoville and Brenda Milner (1957; see Rempel-Clower, Zola, Squire, & Amaral, 1996; Squire, 2009; Squire & Wixted, 2011 for summary). Following a bilateral medial temporal lobectomy to mitigate debilitating epileptic seizures, Scoville and Milner (1957) identified that HM demonstrated both AA and temporally graded RA. While remote memories from HM's past were seen to be relatively spared, more recent episodic memories were not. This has additionally been supported across prospective nonhuman-animal studies that have observed RA that is temporally graded in nature following hippocampal lesions (Jarrard, 1975; Squire, 1992; Squire, Clark, & Knowlton, 2001; Bartko, Cowell, Winters, Bussey, & Saksida, 2010). Later research on amnesic patients has revealed that the scope of temporally graded RA often broadens (e.g., increased forgetting of even remote episodic memories encoded 50 years prior to atrophy) when brain damage has extended beyond the hippocampus (as seen in patients with large MTL lesions, conjoint perirhinal-entorhinal cortex lesions; see Squire & Alvarez, 1995; Nadel & Moscovitch, 1997; Reed & Squire, 1998).

While RA research has illustrated the primary role of the medial temporal lobe – more specifically, the hippocampus and the adjacent perirhinal, entorhinal, and parahippocampal cortices (see Squire, 2009) – in the initial formation and early stabilisation of newly acquired memories (Squire & Zola-Morgan, 1991; Squire, 1992), more recent patient research on individuals presenting with AA has provided additional insights

(Cowan, Beschin, & Della Sala, 2004; Della Sala, Cowan, Beschin, & Perini, 2005; Dewar et al., 2009; Dewar, Della Sala, Beschin, & Cowan, 2010; Dewar, Pesallaccia, Cowan, Provinciali, & Della Sala, 2012a; Alber, Della Sala, & Dewar, 2014).

A study by Dewar and colleagues (2009) found that the proportion of items retained from a list of 15 unrelated words (assessed immediately, then after a retention period of 9 minutes) was significantly poorer among patients presenting with AA when post-learning sensory stimulation (visual images encountered within a 3-minute picture naming task) occurred either immediately or 3 minutes after learning. However, if the interpolated material was delayed by a 6 minute period consisting of wakeful rest - or replaced entirely by a 9-minute interval of wakeful rest - retention was seen to improve greatly. This study marked the demonstration of temporally graded RI among amnesic patients that had only been previously observed across a limited number of past studies of healthy adults (Müller & Pilzecker, 1900; Skaggs, 1925; see Sosic-Vasic et al., 2018) and nonhuman-animals (Agranoff, Davis, & Brink, 1966; Izquierdo, Schröder, Netto, & Medina, 1999; see Dudai, 2004; Wixted, 2004). This work contributes to a mounting literature that patients with AA (and to a lesser degree, healthy adults) possess a susceptibility to RI that can be substantially mitigated following a brief instance of post-encoding wakeful rest (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2010; Dewar et al., 2012a; Alber et al., 2014).

But what specific role does the hippocampus and other neighbouring structures play in early memory formation, and how may hippocampal damage result in an increased vulnerability to RI in patients with AA? It has been established that early consolidative processes - known by a number of names (e.g., synaptic, fast, cellular, and local consolidation) - occur predominantly between synapses and cellular nodes located within the highly plastic neuronal circuits of the hippocampus (see Dudai, 2004; Carr, Jadhav, & Frank, 2011; Dudai et al., 2015; Craig, Dewar, & Della Sala, 2015). Synaptic consolidation involves the stimulus-induced activation of intracellular signalling transduction cascades, which results in the posttranslational modification of synaptic proteins, the modulation of gene expression and the subsequent synthesis of gene products that alter the strength of synaptic connections (see Dudai, 2004; Dudai et al., 2015).

It is commonly assumed that synaptic consolidation concludes within a time-frame of hours following its induction (Dudai et al., 2015), resulting in the stabilisation of memory traces that are thereafter resilient to a variety of amnesic agents (mental exertion during interpolated post-learning tasks, pharmacological agents, etc.). However, given the findings from some patient studies (i.e. Dewar et al., 2009), new memory traces may become significantly more protected from subsequent interference after a 6-minute period of uninterrupted consolidation after encoding. Synaptic consolidation is present across a range of non-human animals, as seen following neuroscientific investigations of both invertebrates (e.g., *Aplysia*) and vertebrates (e.g., mice) (see Kandel, Dudai, & Mayford, 2014 for review). Our knowledge of synaptic consolidation processes and its association with the hippocampus has been largely influenced by the study of hippocampal long-term potentiation (LTP; Bliss & Lømo, 1973; Martin, Grimwood, & Morris., 2000; Martin & Morris 2002). Hippocampal LTP is a prominent physiological model for the early stabilisation of memories that entails the enduring enhancement of synaptic transmission that occurs during encoding as a result of the short, high frequency stimulation of post-synaptic neurons (see Wixted, 2004; Craig et al., 2015). It has been proposed that subsequent LTP induction following the encountering of post-learning material may disrupt the maintenance of LTP for previously encoded memories, if incurred immediately after acquisition (Xu, Anwyl, & Rowan, 1998; Izquierdo et al., 1999; Mednick, Cai, Shuman, Anagostaras, & Wixted, 2011). Alongside the interference of hippocampal LTP, RI is also proposed to occur due to the disruption of “offline replay”, which involves the sequential reactivation of hippocampal representations that occurs during wakefulness (Peigneux et al., 2004; Foster & Wilson, 2006; Tambini, Ketz, & Davachi, 2010; Carr, Jadhav, & Frank, 2011; Lewis & Durrant, 2011; see Craig et al., 2015).

1.6 Forgetting: The Interference of Retrieval

While significant developments to our understanding of forgetting and early LTM formation were achieved across neuropsychological and neuroscientific studies of early consolidation and RI in recent years, progress has been much slower across the field of experimental psychology. Many researchers had varying degrees of success when investigating the phenomena of RI in the years following the publication of Müller and Pilzecker’s (1900) study.

Heine (1914) was in the minority who observed RI effects on previously learned nonsense syllables following the post-learning encountering of dissimilar interpolated material (i.e., pictures, lists of numbers, consonants), with reduced recall in comparison to a condition whereby rest followed learning (see Tolman, 1918 for summary). However, this and other supportive research at the time (Jenkins & Dallenbach, 1924) failed to explore whether the use of interpolated tasks consisting of similar material to the target material would result in even poorer retention. The exploration of similarity RI effects (i.e., RI following the post-learning introduction of interpolated material that is similar semantically and/or in terms of modality to the memorandum) became a common investigation during the early- to mid-twentieth century (Webb, 1917; Robinson, 1920; Skaggs, 1925; Lund, 1926; Whitely, 1927; McGeoch & McDonald, 1931; see Britt, 1935). This occurred as a result of early observations of inconsistent or absent RI effects following dissimilar interpolated activity (DeCamp, 1915; Tolman, 1918; Whitely, 1924).

A notable caveat of Müller and Pilzecker's (1900) work lies in their assertion that post-encoding mental exertion alone (diversion RI) is a key culprit of later forgetting. It can be argued that this principle was not reliably established across their experiments (see Dewar et al., 2007). The unrelated interpolated task used in later investigations (i.e., verbal description of three landscape pictures following the learning of nonsense syllables) entailed both a verbal and intentional learning component that matched the memorandum. The shared modality between the interpolated task and the target material (visual presentation of material that had to be subsequently verbalised), and the fact that participants were required to actively remember both materials, may have interfered with the later recall of syllables beyond the mere exertion of mental effort. In fact, the previously discussed work by Bigham (1894) demonstrated this modality-specific interference effect. Within his first experiment, recall of visually presented syllables was poorer when followed by visually presented interpolated material when compared to material from a different modality (i.e., auditory material). The same was also observed when both the memorandum and the interpolated material were auditory. While not explicitly discussed by Bigham himself, later researchers began to allude to the possibility of this effect (Tate, 1913; Strong, 1914). Similar findings to those made by Bigham were observed across a number of studies which assessed retention across conditions in which the similarity of the interpolated activity to the memorandum had been directly manipulated (Robinson, 1920; Skaggs, 1925; Lund, 1926; Whitely, 1927; Harden, 1929; McGeoch & McDonald, 1931; Johnson, 1933; Gibson & Gibson, 1934; Dey, 1969).

Across a series of experiments, Robinson (1920) assessed the retention of learned information following the encountering of different interpolated tasks. In the first experiment, the retention of a list of 8 four-digit numbers was assessed following a brief delay interval (ranging between 3-5 minutes). During this delay interval, participants either: (a) learned more four-digit numbers, (b) learned a list of 20 consonants, (c) learned a poem, (d) took part in a mathematical task consisting of the multiplication of four-digit numbers, or (e) read a story. Recall was substantially lower when learning was followed by the further presentation of another list of numbers in comparison to the four remaining conditions. It is important to note that retention was comparable among the other conditions.

In a similar experiment, Robinson again assessed retention of four-digit lists following a range of post-encoding interpolated activities. These activities either involved: (a) the learning of more four-digit numbers, (b) the learning of 32 digits, (c) a mathematical task consisting of the multiplication of different two-digit numbers, (d) looking at pictures, or (e) reading newspaper articles. Both experiments demonstrated a clear similarity RI effect, with reduced forgetting following dissimilar interpolated tasks (diversion RI). Robinson noted that the magnitude of RI is a product of both similarity of process or operation, as well as similarity of content. He stated that similar content alone did not result in increased RI (as seen with interpolated mathematical tasks consisting of similar material).

In a third investigation, Robinson assessed the retention of chessboard arrangements (via a reconstruction test, whereby the ability to later replicate arrangement of 6 chess pieces independently was judged) following interpolated activities consisting of: (a) studying a subsequent chessboard arrangement, (b) a mathematical task (i.e., multiplication), or (c) reading. After each one of these types of activity the subject were asked to place the 6 chessmen in their original position. This experiment demonstrated higher degrees of forgetting following similar material, but showed that dissimilar material could elicit RI, albeit to a lesser extent.

Adopting a similar design to the last experiment, Skaggs (1925) made comparable observations of reduced retention as a product of increased similarity. However, he does not refute the existence of diversion RI outright; instead, Skaggs highlighted that similarity RI effects elicited via post-learning engagement with similar material may contribute to an enhanced degree of forgetting on top of diversion RI that is encountered following any post-learning activity.

With the continued observations of similarity RI effects over the next few decades (Lund, 1926; Whitely, 1927; Harden, 1929; McGeoch & McDonald, 1931; Johnson, 1933; Gibson & Gibson, 1934; Dey, 1969), interpretations of interference effects moved towards mechanisms that entailed the disruption of retrieval (Melton & McQueen, 1940). One regarded account was the cue-overload theory (Watkins & Watkins, 1975; 1976). Rooted in the earlier response competition theory (McGeoch, 1942), a key component of the cue-overload account was the notion that forgetting results from retrieval competition between memory traces that are simultaneously activated by similar cues at retrieval. This follows from the prevailing view that the retrieval of information from episodic memory is mediated by cues (see Tulving & Pearlstone, 1966; Watkins & Watkins, 1976). The consistent observation of similarity RI effects were progressively being interpreted as retrieval competition at play, with cues triggering the concurrent activation of multiple memory traces that are highly similar across a number of dimensions (Watkins & Watkins, 1976). Interestingly, a similar concept can be traced back to the Law of Associative Inhibition that was outlined by Müller and Schumann (1894), whereby a profound difficulty to form associations between two items (say, A-C) is experienced when one of these items has been previously associated with a different item learned previously (say, A-B) (see Kline, 1921; McGeoch, 1942; Neath & Surprenant, 2015).

Evidence for retrieval interference, as outlined in the cue-overload theory, is mainly derived from experiments that utilise the A-B, A-C paradigm (Skaggs, 1933; McGeoch & Nolen, 1933; Postman & Alper, 1946; Briggs, 1954). Across this paradigm, one group of participants (i.e., the experimental group) would learn an A-B list of cue-associate word pairs (e.g., canary-queen, timber-silver, basket-oxygen, etc.). A-B learning would later be followed by the learning of a second A-C list of word pairs. The A-C word pairs would consist of the same cue words, but alternative associate words (e.g., canary-hobby, timber-nurse, basket-world, etc.). Another group (i.e., the control group) would learn the A-B list, followed later by a C-D list that consisted of distinct cue-associate word pairs. Both groups are then assessed on tests of cued-recall for their retention of the associate words from either the first or second list (i.e. B or C items for experimental group, B or D items for control group) when given the cues (i.e., A items for experimental group, A or C items for control group). Typically, studies utilising this paradigm found that the experimental group recalled far fewer items when compared to the control group, indicating retrieval is impeded as more items become associated with the same cue.

An important property of this theory is that it can account for forgetting resulting from RI, and simultaneously explain forgetting that occurs when interpolated activity preceding new learning results in the decreased retention of the more recently encoded information (also known as proactive interference or PI; Underwood, 1957; Watkins & Watkins, 1976). In fact, PI resulting from the previous learning of information was, at one time, believed to be the main source of forgetting following notable works by Benton Underwood.

Underwood (1957) highlighted that the observed variability of RI seen across numerous studies (focusing particularly on Ebbinghaus-inspired studies which assessed relearning following a 24-hour period of normal everyday activity; i.e., Cheng, 1929; Hovland, 1940; Youtz, 1941; Williams, 1950; Weiss & Margolius, 1954) alluded towards an alternative interfering effect in action. Through his analysis of pre-encoding activity (correlating number of lists learned prior to target list encoding with later recall of target list), he found that the recall of different episodic information decreased as the number of pre-encoded lists increased (also see Greenberg & Underwood, 1950; Wipf & Webb, 1962; House, Smith, & Zeaman, 1964; Keppel, Postman, & Zavortink, 1968). He concluded that the degree of forgetting seen across typical studies of interference could be more aptly determined by the pre-encoding activity of participants prior to learning.

These findings were substantiated by the results of a number of patient studies which aimed to assess the effects of prior learning on the subsequent recall of more recently acquired information. Utilising the AB-AC paradigm, Winocur and Weiskrantz (1976) found that patients with AA were unable to successfully retrieve semantically-related words from a recently learned list when a previous list with shared cues was presented 30 minutes earlier. Additionally, intrusions from the earlier list were more frequently observed during cued-recall of the second lists within the patient group when compared to healthy controls. These results were replicated when semantic similarity among items from separate lists was changed to acoustical similarity (i.e. rhyming; see Stern, 1981). They posited that the memory impairment of patients with AA was likely due to their failure to retrieve the relevant information from LTM.

This finding was corroborated by the studies of Warrington and Weiskrantz (1970; 1974) who established that patients with AA were better able to recall episodic content when provided with cues that reduce competing responses at retrieval. In one study (Warrington and Weiskrantz, 1974), they manipulated the degree to which a retrieval cue restricted the number of response alternatives (i.e., intrusions from previously acquired material) as a means of assessing whether this would aid later retrieval of recently learned word lists. They saw that amnesic patients were more successful in retrieving word items when the presented cues only applied to a smaller sub-set of previously learned words. A similar susceptibility to PI, following the pre-encoding presentation of similar stimuli, has also been observed across patients with executive dysfunction following damage to the frontal lobes (see Shimamura, Jurica, Mangels, Gershberg, & Knight, 1995; Baldo & Shimamura, 2002).

However, cue-overload theories and accounts of forgetting that viewed PI as a primary cause soon fell out of favour with researchers following a number of different contradictory observations. First of all, the notion that everyday forgetting is mainly elicited by PI and response competition at retrieval was rejected following demonstrations that these effects could only be observed within the confines of laboratory experiments (Underwood & Postman, 1960; Underwood & Ekstrand, 1967). In a study by Underwood and Postman (1960), they found that the pre-experimental learning history of participants elicited no PI on learned lists of three-letter words (presumed to be heavily associated with words learned prior to experiment) when compared to learned lists of three-letter non-words (no presumed association with words learned prior to the experiment). Secondly, the notion that forgetting in amnesic patients is due to an inability to restrict the availability of competing responses (further evidence of PI effects) was later rejected on the grounds that retention following the experimental reduction of competing responses was not seen to improve significantly at later retrieval (Warrington & Weiskrantz, 1978).

1.7 Forgetting: The Interference of Temporal Distinctiveness

Although the role of PI in everyday forgetting was largely rejected following these studies (alongside a growing literature revitalising the primary effects of RI to forgetting in amnesic patients; Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2009; 2010; 2012a; Alber et al., 2014), more recent accounts that present an alternative viewpoint of retrieval-based forgetting have attempted to form a more encompassing view of episodic memory loss that can explain both RI and PI effects. One such account is the temporal distinctiveness theory outlined by Brown, Neath, and Chater (2007).

Within this theory, it is proposed that episodic memories are positioned on a temporal dimension (among other dimensions in psychological space), and that this dimension is pivotal in guiding retrieval (see Brown & Chater, 2001). A factor which determines the success of later retrieval is the distinctiveness of a given memory on this temporal dimension. The distinctiveness of a memory is mediated by the temporal distance between its acquisition and later retrieval, with more recently encoded memories being more distinct than memories that were encoded further in the past. Distinctiveness is concurrently moderated by the relative temporal proximity of memories with respect to one another, growing closer as the interval between acquisition and recall lengthens (logarithmic compression: see Bjork & Whitten, 1974; Crowder, 1976; Brown et al., 2007). Given this, memories are more likely to be indistinct, and difficult to retrieve later, if encoding is immediately preceded and/or followed by the encoding of other information (encountered during interpolated tasks). Conversely, if episodic memories occupy a space on the temporal dimension that is isolated (i.e., no nearby episodic memory traces), the distinguishability of the memory at retrieval is markedly increased.

The idea of distinctiveness with respects to memory is not a new concept (see Murdock, 1960; Baddeley, 1976; Crowder, 1976). However, recent research has indicated that temporal isolation benefits exist for episodic items that are freely recalled (see Brown, Morin, & Lewandowsky, 2006; also Morin, Brown, & Lewandowsky, 2010; Ecker, Brown, & Lewandowsky, 2015a). Furthermore, a study by Ecker and colleagues (2015b) saw that the recall of episodic content was significantly improved in a sample of healthy adults when a target list of words was temporally isolated from neighbouring lists via longer pre- and post-encoding periods of low mental activity (Ecker, Tay, & Brown, 2015b). This study confirmed that the benefits of temporal isolation, previously observed between individual items within a list (Brown et al., 2006), could be observed between different lists. Additionally, it partly supported the idea that these effects could be observed over relatively longer retention intervals (i.e., 2-4 minutes, as opposed to mere seconds; see Ecker et al., 2015a; 2015b).

1.8 <u>Conclusion and Aims of the Thesis</u>

Studies of forgetting spanning beyond a century have elucidated fundamental properties of episodic memory formation and its loss from LTM. Classic research has outlined that much of the episodic information we initially retain is subsequently lost within the immediate moments following learning (i.e., minutes to hours; Ebbinghaus, 1885/1964; see Rubin & Wenzel, 1999). The prevailing notion over the years suggests that the loss of episodic information from LTM is caused by interference, whereby engagement in other activity directly preceding or following target memory acquisition impedes our ability to recall the target memory at a later time. However, there remains conflicting theoretical accounts that are prominent today that attempt to explain these phenomena.

The aim of this thesis is to explore the possible effects of both RI and PI on episodic memory retention over a crucial period of time in which interference is heavily disruptive (i.e., 10 minutes; Müller & Pilzecker, 1900; Cowan et al., 2004). Furthermore, the thesis aims to disseminate potential benefits following the minimisation of PI and RI via brief instances of pre- and post-encoding wakeful rest. The exploration of PI/RI effects, and benefits following pre- and post-encoding wakeful rest, will be predominantly conducted using a single experimental paradigm that entails the simultaneous manipulation of pre- and post-encoding activity (Experiments 1-5). This will allow for individual effects to be disentangled, and allow for a more reliable evaluation of prominent theoretical perspectives of forgetting (i.e., interference of consolidation, interference of temporal distinctiveness).

Each account (i.e., the consolidation theory and temporal distinctiveness theory) would predict a differential pattern of memory performance across a set of conditions in which the activity during delay intervals preceding and following the encoding of episodic content (which would theoretically elicit PI and RI) had been manipulated (see Page 62 for detailed description of these specific conditions). Table 1 illustrates a series of predictions that each theory would posit that correspond to differences and similarities in memory performances across such conditions. These will effectively act as hypotheses that will be subsequently tested across a series of experiments (Experiments 1-5).

Table 1. Predictions of memory performance across conditions consisting of filled and/or unfilled pre- and post-encoding delay intervals between the consolidation and temporal distinctiveness theory.

Consolidation Theory	Temporal Distinctiveness Theory
UU = FU*	UU > FU*
UU > UF	UU > UF
UU > FF	UU > FF
FU > UF*	FU = UF*
FU > FF	FU > FF
UF = FF*	UF > FF*

Note. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval, * = contrasting predictions between the consolidation theory and temporal distinctiveness theory

According to the consolidation theory and consolidation interference accounts of forgetting (i.e., Müller and Pilzecker, 1900; Wixted, 2004; Dudai, 2004), notable reductions in retention would be expected across conditions which consist of filled post-encoding delay intervals. The increased loss of episodic information from LTM across such conditions would be expected as a result of the immediate disruption of early consolidative processes (i.e., synaptic consolidation) following post-encoding engagement in further sensory stimulation. Under this account, improved retention of episodic content would be observed across conditions which consist of post-encoding wakeful rest. Within such conditions, it is believed that the minimisation of RI would allow for the crucial stabilisation of newly formed memory traces that enable them to be resilient to further interference in the future (Müller & Pilzecker, 1900).

Many studies have demonstrated notable benefits to episodic memory retention following brief instances of post-encoding wakeful rest, which allows for potentially interfering material to be substantially reduced (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2007; 2009; Dewar, Alber, Butler, Cowan, & Della Sala, 2012b; Alber et al., 2014). This has not only been observed across healthy populations (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2007; 2009; 2012b; Alber et al., 2014; Craig, Della Sala, & Dewar, 2014; Brokaw et al., 2016), but also across samples of patients with AA (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2009; 2010; 2012a; Alber et al., 2014). Neuroscientific work has further elaborated the underlying mechanisms of this benefit of minimising RI (i.e., absence of subsequent LTP, no disruption of “offline replay”; see Craig et al., 2015) that support the role of consolidation and its interference at the heart of everyday forgetting.

With concerns to the predictions made by the temporal distinctiveness theory, there are some key deviations. Bi-directional temporal isolation (i.e., theoretically achieved via the absence of an effortful task before and after the learning of to-be-retained material) may result in a notable increase in retention beyond that seen when episodic content is only partially temporally isolated (i.e., wakeful rest either before or after learning). According to the temporal distinctiveness theory and temporal interference accounts of forgetting (Brown, Neath, & Chater, 2007), forgetting results from the reduced distinctiveness of a specific memory on a temporal dimension.

This is partly mediated by the proximity of neighbouring memories. By removing these memories, the distinctiveness of the target memory is drastically improved at the point of retrieval. However, this prediction and its implications notably deviate from the consolidation theory in a number of ways.

Firstly, consolidation theory would expect comparable retention across conditions in which RI has been minimised following post-encoding wakeful rest, irrespective of whether PI has also been reduced following pre-encoding wakeful rest. Secondly, there is an assumption that partial temporal isolation – which is achieved via the sole reduction of PI via pre-encoding wakeful rest or the sole reduction of RI via post-encoding wakeful rest – would result in comparable improvements in retention. Again, consolidation theory does not align with this prediction; instead, predicting that retention would be significantly improved following the reduction of RI only. A third deviation in the predictions made by the temporal distinctiveness theory is the improved retention following partial temporal isolation that is achieved via pre-encoding wakeful rest alone when compared to the retention of episodic content which is flanked by engagement in effortful tasks both before and after encoding. With respect to the consolidation theory, both conditions would elicit the same degree of increased forgetting due to the presence of immediate post-encoding activity which would theoretically disrupt consolidation.

These predictions will be assessed across various samples that differ with respects to their presumed episodic memory ability (healthy younger and older adults, Experiments 1-4; patients with AA, Experiment 5). This will provide a more encompassing picture of forgetting across this paradigm more generally, allowing the evaluation of the competing theories of forgetting among different populations. Moreover, selective investigations exploring separate interference effects will be made across underexplored subdivisions of memory (i.e., prospective memory; Experiment 6), as well as upon unique samples (i.e., healthy adults with drug-induced amnesia, Experiment 7), to further elucidate our understanding of the effects of interference and its role across a wider range of situations.

Chapter 2:

Accountability of interference-based theories of forgetting among healthy populations

2.1 <u>Introduction</u>

With respect to the forgetting of information from episodic LTM in healthy adults, the underlying roles of both RI and PI continue to be debated. As mentioned in Chapter 1, further demonstration of diversion RI effects were scarce (Heine, 1914; Jenkins & Dallenbach, 1924) following Müller and Pilzecker (1900) work. Instead, the prolific observation of similarity RI effects (see Robinson, 1920; McGeoch & McDonald, 1931), and a later concern with the effects of PI (Underwood, 1957), dominated the forgetting literature (see Wixted, 2004). This heralded a period in which retrieval-based interference accounts of forgetting were highly regarded as reliable perspectives of everyday forgetting among healthy populations (McGeoch, 1942; Watkins & Watkins, 1975; 1976). However, this line of research came to a dead end following the revelation that retrieval interference - believed to be predominantly elicited via PI – is difficult to observe beyond laboratory experiments (Underwood & Postman, 1960; Underwood & Ekstrand, 1967).

While investigations into forgetting and interference of episodic LTM in healthy adults underwent a period of stagnation, the field subsequently experienced a resurgence following the revival of a largely-neglected experimental practice – the studied benefits of minimal interference (see Dewar et al., 2007).

The assessment of retention following a short, sustained period of wakeful rest – in which participants have a wakened respite from further sensory stimulation in a quiet, darkened room - was a fundamental staple of Müller and Pilzecker's (1900) early investigations. An important feature of their findings was the notable benefit to LTM retention following very brief post-encoding instances of wakeful rest (as short as 6 minutes). However, much of the successive research following this work failed to investigate these wakeful rest benefits further (Robinson, 1920; Skaggs, 1925; McGeoch & McDonald, 1931; Dey, 1969; see Dewar et al., 2007). In its place, studies were predominantly focused on the nature of the interpolated material and its effects on later retrieval (see Britt, 1935). While arguably justified given the lack of empirical evidence supporting Müller and Pilzecker's (1900) findings at the time, the shifted focus resulted in a striking absence of research exploring minimal interference via wakeful rest. However, recent neuropsychological research on patients with AA has inadvertently rejuvenated the general exploration of wakeful rest benefits to retention in healthy populations (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2007).

Cowan and colleagues (2004) found that the retention of verbal material (15-item wordlist) after a post-encoding delay interval of 10 minutes was significantly better among a control sample of healthy adults when it was unfilled with wakeful rest (31%), as opposed to being filled with neuropsychological testing (19%). A similar, significant benefit of wakeful rest was also observed when the retention of alternative verbal material (i.e., prose passages) was assessed following a delay interval of 1 hour (Cowan et al., 2004; also Della Sala et al., 2005).

However, the superior retention following post-encoding wakeful rest was notably lower over this period (7% and 9% difference in retention between conditions in Cowan et al., 2004, and Della Sala et al., 2005, respectively). Regardless, numerous studies since have established similarly small, yet significant benefits of post-encoding wakeful rest in both healthy younger and older adults (Dewar et al., 2007; 2009); with the benefits of a brief instance of rest (15 minutes) persisting following a later test of retention 7 days later (Dewar et al., 2012b; Alber et al., 2014).

From the perspective of consolidation theory, these wakeful rest benefits were accredited to the reduced disruption of early consolidative processes during the immediate minutes following encoding (Müller and Pilzecker, 1900; Wixted, 2004; Dudai, 2004). Further elaboration of the possible mechanisms underlying consolidation interference came following neuroscientific research, leading to the proposal that the reduction of RI during an unfilled post-encoding period results in the elimination of subsequent LTP of interpolated information that may directly disrupt earlier LTP processes or deplete limited cognitive resources (Wixted, 2004; Mednick et al., 2011). Along the same vein, the act of engaging with post-encoding activities may directly interfere with the process of “offline replay”, a process that may be interlaced with LTP that involves the automatic reactivation of traces in the hippocampus (Craig et al., 2015). While behavioural studies of healthy adults may not directly address these neuroscientific claims, they nevertheless emphasise the specific importance of post-encoding activity and a vulnerability to forgetting that occurs during this period.

Following the renewed interest and establishment of post-encoding wakeful rest benefits in healthy adults, consolidation-based explanations were met with immediate opposition. One notable counterargument highlighted the potential role of STM maintenance and the use of rehearsal strategies. According to this viewpoint, improvements to retention following post-encoding wakeful rest could be the result of uninterrupted maintenance of episodic information within STM via conscious subvocal rehearsal (Cowan, 2001; Logie & D'Esposito, 2007). This is a valid assertion to be made, given that an unfilled post-encoding interval could allow for attention to be focused towards the to-be-retained information during this time. However, a number of notable findings indicate that such an explanation cannot solely account for the observed benefits.

Firstly, deception is typically employed so that participants do not anticipate future tests of delayed recall (Della Sala et al., 2005; Dewar et al., 2009; 2012b). Participants are often not informed that their memory for target material will be assessed at later points in the experiment. As a result, the probability that participants will maintain information in STM is much lower, given that the information is no longer going to be assessed and is thus irrelevant to later performance.

In the event that efforts to actively rehearse are undertaken, the length of the delay intervals between learning and later recall in some studies (i.e., 7 days; Dewar et al., 2012b; Alber et al., 2014) make it highly unlikely that these processes can be successfully sustained.. Additionally, such studies have typically employed distractor tasks prior to the testing of delayed free-recall, or delayed interpolated activities, which effectively extinguish any information being preserved in STM in the event that such efforts were undertaken (Dewar et al., 2009, 2012b; Alber et al., 2014). Furthermore, post-encoding wakeful rest has been seen to improve the recognition of information that is presumably non-rehearsable, such as nonword and non-verbal material (Craig, Dewar, Harris, Della Sala, & Wolbers, 2015, 2016a; Craig et al., 2016b).

While the benefits associated with the minimisation of RI via post-encoding wakeful rest have been commonly linked with the facilitation of consolidative processes (with the dismissal of rehearsal-based accounts), alternative theories have proposed a different set of underlying mechanisms. As mentioned in Chapter 1, temporal distinctiveness theories of memory (Brown et al., 2007) would suggest that the benefits observed following post-encoding wakeful rest in healthy adults are not the result of uninterrupted consolidation, but are instead a by-product of temporal isolation and improved retrieval. A period of post-encoding wakeful rest is believed to result in the absence of any neighbouring memories on the temporal dimension between the acquisition of the target memory (i.e., verbal material) and recall. Given this, the retrievability of the target material is markedly improved following the increased distinctiveness of the memorandum on the temporal dimension (Brown et al., 2007).

An intriguing quality of this account is the idea that temporal isolation following pre-encoding wakeful rest could theoretically lead to similar improvements in retrieval (Brown et al., 2007; Ecker et al., 2015a; 2015b). And indeed, studies exploring whether the pre- and post-encoding temporal isolation of a target memory facilitates improved retrieval have found just that (Ecker et al., 2015a; 2015b).

While there is theoretical uncertainty surrounding the underlying processes responsible for observed wakeful rest benefits, there is additional ambiguity concerning possible age-related differences in interference effects across healthy populations. It is known that as we age, our performance on a number of cognitive tasks progressively deteriorates in tandem with notable changes in our brain (Dennis & Cabeza, 2008). However, these changes do not necessarily result in increased vulnerability to interference (and a pronounced benefit following its minimisation via wakeful rest).

Craig and colleagues (2016b) compared delayed performance on a test of spatial memory (i.e., cognitive map test) between healthy younger and older adults when learning was followed by wakeful rest or an interpolated task (i.e. spot-the-difference task). They found that while healthy older adults performed significantly poorer on some aspects of delayed testing (i.e., accuracy on a test of spatial memory; see Craig et al., 2016b), older adults did not demonstrate a pronounced benefit of post-encoding wakeful rest when compared to the younger adult group. Comparative benefits of post-encoding wakeful rest between these age groups have been observed since (see Martini, Zamarian, Sachse, Martini, & Delazer, 2018). However, older adults have demonstrated an increased susceptibility to RI following the post-encoding encountering of subsequent tasks (Martini et al., 2018). While there are few studies that have assessed the differential effects of RI and its minimisation on healthy younger and older adults, there are no studies that have attempted to simultaneously compare the effects of both PI and RI among these two groups.

In order to reliably evaluate the accountability of prominent theories (i.e., consolidation theory, temporal distinctiveness theory), the coinciding assessment of RI and PI effects needs to be conducted across various populations - including both groups of healthy younger and older adults - to further elucidate possible differences.

In addition to this, key differences between the methodologies used to explore benefits following the minimisation of RI and PI need to be distinguished and addressed.

Firstly, the recent research which has provided supportive evidence in favour of temporal distinctiveness theories of memory (through the simultaneous demonstration of minimal PI and RI rest benefits; Ecker et al., 2015a; 2015b) have assessed retention over very short intervals (ranging from seconds, to four minutes). This is markedly shorter than the intervals utilised in studies which have solely assessed the benefits of post-encoding rest (ranging between 9 minutes and 7 days; Dewar et al., 2009; 2012b). A divisive principle of the temporal distinctiveness theory outlined by Brown and colleagues (2007) is the notion that STM and LTM are not distinct. As such, it follows that benefits of temporal isolation seen over short delays (i.e., seconds) should theoretically scale up to much longer retention intervals (as employed by studies investigating minimal RI only). However, no study has attempted to concurrently assess the benefits of minimal RI and minimal PI on the retention of episodic information over a period that have been theoretically proposed to allow for a suitable degree of synaptic consolidation to take place (i.e., minimum of 6 minutes; Müller and Pilzecker, 1900; Dewar et al., 2009).

Additionally, there are inconsistencies surrounding the use of “rest” periods. Across the studies which have favoured temporal distinctiveness (i.e. Ecker et al., 2015a; 2015b), rest intervals consisting of low mental activity (i.e., tone-detection task comprising of two tones) were used. Similar tone-detection tasks encountered during a post-encoding delay interval have elicited increased forgetting in healthy adults (Dewar et al., 2007), although this is arguably inconsistent (see Dewar et al., 2010). Given this, it seems plausible that such activity does not minimise interfering stimulation to the same degree as wakeful rest in an environment void of incoming sensory stimulation (Wixted, 2004; Dewar et al., 2009; Mednick et al., 2011). While the use of low activity is justified on the basis of inhibiting rehearsal, alternative measures can be deployed to reduce the likelihood of STM maintenance (i.e., deception, distractor tasks, etc.) whilst simultaneously allowing for rest that is void of external stimulation.

Through addressing the methodological discrepancies between the outlined studies, there is a possibility that minimal RI and PI benefits can be concurrently assessed across a paradigm that allows for a more reliable evaluation of the discussed theories. The current experiment intends to achieve this through the assessment of both healthy younger and older adults.

2.2 Experiment 1

2.2.1 Aims

The current experiment aimed to assess whether the filling of pre- and/or post-encoding delay intervals with a mentally effortful task would result in the decreased retention of newly acquired episodic information (prose material). This was done in order to test the differential predictions of each theory (consolidation theory and temporal distinctiveness theory; see Table 1 on Page 50 for these predictions) and to establish which account provides a more representative understanding of forgetting within this paradigm.

Healthy groups of younger and older adults were tested as a means of establishing possible age-related differences in memory performance within this paradigm. More specifically, the experiment intended to reveal whether healthy older adults are more susceptible to interference following *and* preceding new learning.

2.2.2 Methods

2.2.2.1 Participants

Twenty-four younger adults (11m/13f, mean age = 19.54 years, age range = 18 - 23 years; mean education = 15.08 years, education range = 14 - 18 years) and twenty-four older adults (12m/12f, mean age = 69.33 years, age range = 64 - 75 years; mean education = 15.63 years, education range = 11 - 22 years) were tested. Both groups were healthy, with normal motor skills and normal or corrected eyesight and hearing. In addition, all participants had no pre-existing cognitive impairments or any history of brain damage. All participants were native-English speakers, and were subsequently tested in English. All participants were tested in the neuropsychology lab within the Psychology Department at the University of Edinburgh. Participants from the younger adult group were comprised of undergraduate Psychology students who were recruited via email. Participants from the older adult group were all members of the Volunteer Panel, and were recruited via telephone.

2.2.2.2 Procedure

Figure 2.1 illustrates the experimental procedure. All participants underwent four conditions. Each of the four conditions entailed the following: (a) an unfilled pre-encoding delay interval consisting of wakeful rest and an unfilled post-encoding delay interval consisting of wakeful rest – labelled UU condition; (b) a filled pre-encoding delay interval consisting of a spot-the-difference task and a filled post-encoding delay interval consisting of a spot-the-difference task – labelled FF condition; (c) an unfilled pre-encoding delay interval consisting of wakeful rest but a filled post-encoding delay interval consisting of a spot-the-difference task – labelled UF condition; and (d) a filled pre-encoding delay interval consisting of a spot-the-difference task but an unfilled post-encoding delay interval consisting of wakeful rest – labelled FU condition. The two-letter abbreviations corresponding to the conditions will be frequently referred to throughout the thesis (namely during Chapters 2 - 4). The first letter corresponds to the pre-encoding delay interval, and the second letter corresponds to the post-encoding delay interval. Within these abbreviations, U represents unfilled (i.e., wakeful rest) and F represents filled (i.e., Spot-the-Difference task).

These conditions were spread across two separate testing sessions. The second testing session took place within seven days of the first testing session. This was done so that participants would have a maintained familiarity with the tasks encountered in the experiment. Separate testing sessions were employed to alleviate potential fatigue effects that could have been incurred following the completion of multiple conditions in a single session. Such effects have been highlighted in previous research investigating temporal isolation effects (Ecker et al., 2015). Each session consisted of two of the four conditions.

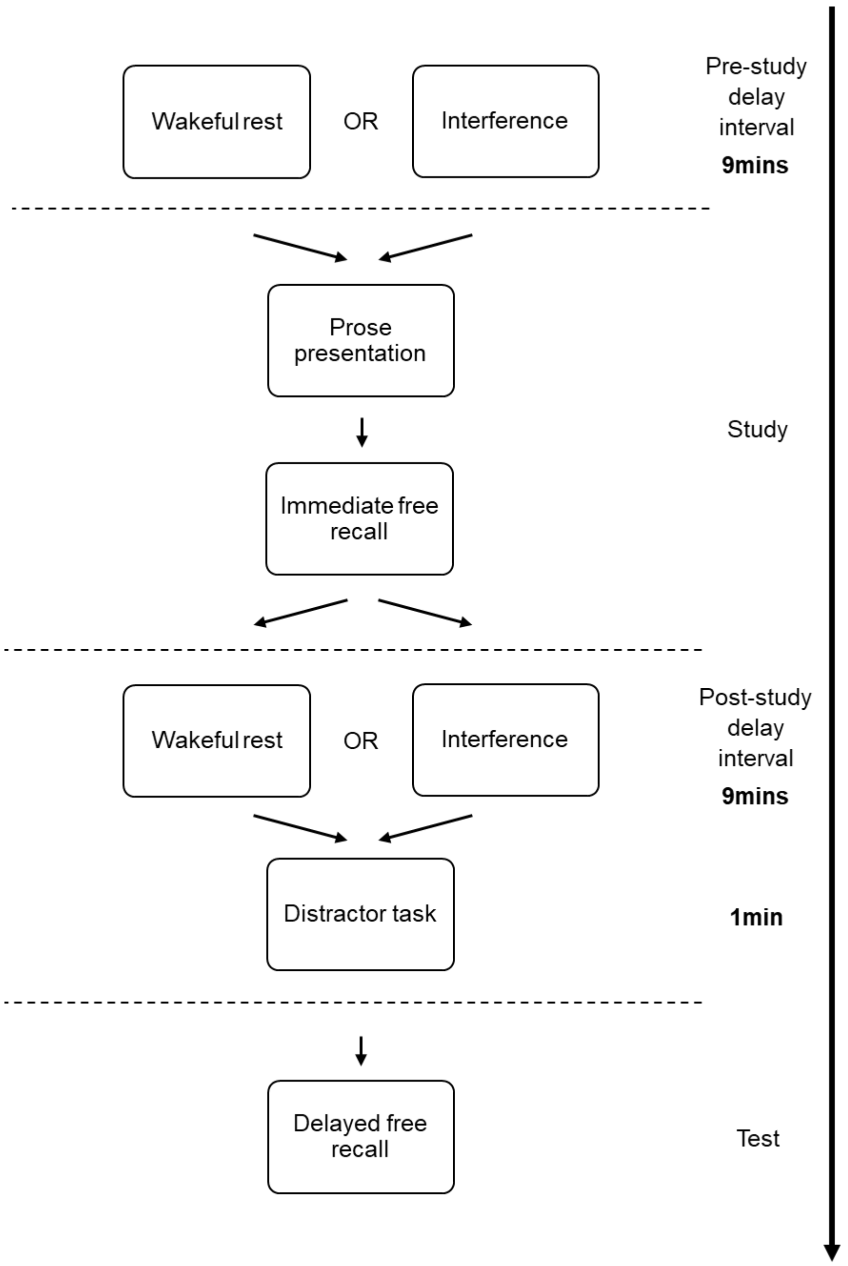

Figure 2.1. Experimental procedure. Interference and distractor task consisted of a spot-the-difference task.

2.2.2.3 To-Be-Retained Material

All participants were presented with a prose passage after the 9-minute pre-encoding delay interval within each condition, totalling four prose passages throughout the course of the experiment. The prose passages were presented verbally to the participants by the experimenter. All participants were instructed to listen carefully to each prose passage, as immediate free-recall would occur directly after presentation. During immediate free-recall, all participants were asked to recall as much of the prose passage as they could remember. Participants were instructed to recall the prose passages verbatim to the best of their ability.

The four prose passages were taken from the Rivermead Behavioural Memory Test (RBMT; Wilson, Cockburn, & Baddeley, 1985) (see Appendix A). Each prose passage consisted of 21 story idea units. Only story idea units that were recalled verbatim were scored as correct within the current experiment. Story ideas which were partially recalled (i.e., use of approximations, omissions of minor details or subtle errors) were given half-marks. Half-marks were allocated in accordance to a scoring rubric that was developed from the brief guidelines set by the RBMT (Wilson et al., 1985; see Appendix B).

Scoring took place after testing using audio recordings of free-recall to ensure accuracy. This also enabled the checking of the initial scoring against the scoring of a second rater who was blind to the intentions of the experiment. Inter-rater reliability (IRR) was computed using two-way random, consistency, average-measures intraclass correlations coefficient (ICC: McGraw & Wong, 1996). This was conducted as a means of assessing the degree that raters provided consistency in their scoring of prose free-recall among the groups across all experimental conditions. The second rater scored a random selection of participants, totalling half of the overall sample (n = 32). An equal number of participants from each condition and age group were scored by the second rater. Table 2.1 highlights the ICC between the two scores of immediate and delayed free-recall across all conditions among both groups. Mean ICC across immediate and delayed free-recall scores was in the excellent range for both groups (ICC = .958 for immediate in young, ICC = .959 for immediate in older, ICC = .967 for delayed in young, ICC = .943 for delayed in older; Cicchetti, 1994; Hallgren, 2012). These findings indicated that raters had a high degree of agreement. Given this, the original scores were subsequently used in later analyses. Reported findings did not vary significantly depending on which set of scores was used.

Table 2.1. Intra-class correlations coefficient (ICCs) of mean immediate (Imm) and delayed (Del) free-recall scores between two raters for both healthy younger and older adult groups across all experimental conditions.

	ICC			
Condition	Healthy Younger Adults		Healthy Older Adults	
	Imm	Del	Imm	Del
UU	.986	.987	.958	.966
FU	.953	.954	.966	.969
UF	.944	.962	.968	.915
FF	.950	.966	.944	.922

Note. Imm = immediate free-recall, Del = delayed free-recall; UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Delayed free-recall of each prose passage was also assessed. An individual test would occur at the end of each condition once the 1-minute Spot-the-Difference task immediately following the 9-minute post-study delay interval had been completed. Individual tests following each condition were chosen – in place of a single test assessing retention of all passages - to ensure that the temporal distance between presentation and delayed free-recall was consistent across all conditions.

Delayed free-recall came as a surprise to participants during the conditions within the first testing session (i.e., first and second condition). Participants were initially briefed at the beginning of the first testing session that the experiment was interested in assessing visual processing abilities via the Spot-the-Difference task. More specifically, participants were informed that the experiment was interested in how visual processing abilities may be influenced by other cognitive processes (i.e., the auditory processing of short stories). This was done both to disguise the memory component of the experiment and to justify the inclusion of prose passages and the assessment of immediate free-recall within the experiment. After the 1-minute Spot-the-Difference task within the first condition, participants were told that a malfunction with the recording device had resulted in a distorted recording of immediate free-recall (i.e., a nearby operating desk fan had led to an inaudible recording). The experimenter asked each participant to once again recall as much of the prose passage as they could remember in order to obtain a usable recording.

Since delayed free-recall was seen as a one-time occurrence employed to address a technical error in the first condition, it was assumed that anticipation of another delayed free-recall test for the new prose passage within the second condition would remain low. The elimination of the problem in the first condition (i.e., turning off the desk fan) made this more convincing. Given this, delayed free-recall within the second condition would again come as a surprise to participants.

Unlike previous studies assessing retention following post-encoding wakeful rest, the decision was made to leave memory performance uncapped. Uncapped proportion retention was calculated by dividing the number of items recalled during the delayed free-recall test by the number of items recalled during the immediate free-recall test. Typically, proportion retention is capped. When the number of items recalled during a delayed test of free-recall exceeds the number recalled during an immediate test, the score is capped at 1. The reasoning behind this capping measure is that items not recalled during an immediate test have likely not been suitably encoded, and can therefore not be reliably assessed in later tests.

However, a number of observations have been made in the past where groups of healthy adults recalled more items during a delayed test when compared to an earlier test (Ballard, 1913; Williams; 1926). This phenomena, known as reminiscence, is not fully understood. A possibility remains that instances of reminiscence among healthy adults could be more frequent under certain conditions (i.e., pre- and/or post-encoding wakeful rest), possibly due to the promotion of consolidation or temporal distinctiveness. If this is the case, capping scores may be counterproductive and work to undermine the true variance of performances across conditions within the current paradigm. This may result in notable differences being difficult to discern. This issue is more prominent when assessing healthy adult samples, given that such groups often perform at ceiling irrespective of post-encoding conditions within studies of minimal RI (see Della Sala et al., 2005; Dewar et al., 2007; 2010; 2012a). The use of uncapped proportion retention among healthy samples therefore provides a more representative, unaltered account of forgetting at the point of delayed recall. By analysing uncapped scores, a truer picture of the variance among mean performances that are approaching ceiling can be attained and evaluated.

2.2.2.4 Delay Intervals

Across the four conditions, pre-encoding and post-encoding delay intervals immediately preceding and following the presentation/immediate free-recall assessment of each prose passage were either filled or unfilled. These intervals lasted for a duration of 9 minutes. This duration was chosen as a means of striking a medium between the intervals used in previous temporal distinctiveness studies (no longer than 4 minutes: see Ecker, Tay & Lewandowsky, 2014) and the minimum period of time in which benefits to long-term retention of episodic content have been observed across both amnesic patients and healthy controls in minimal RI studies supporting consolidation theory (9 minutes: see Dewar et al., 2009). A 9-minute post-encoding delay interval more than doubles the retention period seen in studies lending support to temporal distinctiveness accounts. By assessing both the effects of PI and RI on the retention of episodic content over 9 minutes, it can be established whether the concept regarding scaling of temporal isolation benefits can be seen over an extended period that does not far exceed previous investigations.

2.2.2.4.1 *Filled delay intervals*

Filled delay intervals consisted of a mentally effortful Spot-the-Difference task. The selection of a Spot-the-Difference task as a means of generating interference within the current experiment (and all other experiments detailed in this thesis) was motivated by a number of factors.

Past research investigating RI and the benefits of post-encoding wakeful rest to the retention of episodic content have demonstrated that engaging visual tasks – particularly, Spot-the-Difference tasks - can consistently elicit interference across a wide range of samples (healthy younger adults: Dewar et al., 2007; Sacripante, McIntosh, & Della Sala, 2019; healthy older adults: Dewar et al., 2012; Alber et al., 2014; patients with anterograde amnesia: Alber et al., 2014). The scope of this interference effect is a reliable indication of its suitability as an effortful task that poses a reasonable challenge for cognitively healthy participants to complete, whilst not being overly difficult for participants who present with cognitive deficits that may extend beyond LTM. This cannot be concluded for some less engaging tasks (i.e., tone detection tasks) which have been seen to elicit interference in amnesic patients but not in healthy controls (see Dewar et al., 2010).

Another notable reason for the selection of a Spot-the-Difference task is based on the type of interference it is believed to elicit. Within the current paradigm, a Spot-the-Difference task may elicit non-specific interference, given that it is a visual task consisting of images unrelated semantically and in terms of modality to the to-be-retained material (i.e., verbally presented prose passages, or verbally presented word-lists as seen across Experiments 3-4 in Chapter 4). If the interference task was also verbal, or consisting of material that was semantically related to the memoranda, there remains a possibility that retrieval interference may occur as a result of material similarity. However, this form of interference is believed to not be representative of everyday forgetting (Dewar et al., 2007; 2010). Additionally, it is not directly explained by either the consolidation or temporal distinctiveness accounts. Given this, it is a more appropriate choice to utilise a task that may elicit non-specific interference as a means of assessing a more common form of forgetting for which the respective theories are attempting to account for.

Within the Spot-the-Difference task, participants were presented with picture pairs sequentially on a computer screen for 25 seconds each. The original image was always presented to participants on the left side of the computer screen and the altered image was always presented to participants on the right side of the computer screen to avoid confusion. Participants were tasked with identifying two subtle differences between each pair of pictures during the allotted 25s. Following this, a 5s feedback phase occurred in which the differences were highlighted with red circles on the altered pictures. The feedback phase was included to maintain consistent participant engagement in the task. Participants may have wrongfully questioned the presence of differences between the images if they were unable to identify them. This may have resulted in task disengagement, whereby participants are no longer actively processing the new material. This would lead to the dissipation of the interfering properties of the task overall. By highlighting the differences, participants were ensured that the differences were present. In addition, the inclusion of a feedback phase reduces task-irrelevant thinking (Varma et al., 2017).

Participants were required to identify the subtle differences by pointing them out to the experimenter without talking to ensure the task was purely visual. The pictures – photographs of complex real-world scenes (e.g., landscapes, animals and people) – were not directly related semantically to the prose passage material.

Before the experiment, participants completed a practice trial consisting of 2 picture pairs in order to establish familiarity with the task. Future trials faced during the delay intervals consisted of 18 picture pairs and took 9 minutes to complete. This was explained to participants during the practice trial.

The Spot-the-Difference task was also used as a distractor task within the current experiment. A short distractor task was employed prior to each test of delayed free-recall across all conditions to ensure that any conscious subvocal rehearsal occuring during post-study wakeful rest would be interrupted. The interruption of any rehearsal strategies prior to delayed free-recall was presumed to result in the extinguishing of information being maintained within STM. The distractor task consisted of 2 picture pairs and lasted for 1 minute. Participants were not informed that this task was a distractor task to avoid the anticipation of delayed free-recall.

Overall performance of participants within each trial was scored based on the total number of correctly identified differences divided by the total number of differences (36 differences within each condition trial, 4 differences within each distractor trial). The experimenter scored the individual performance of the participant on each picture pair within each trial using the Spot-the-Difference task scoring sheet, marking 0, 1, or 2 depending on how many differences were spotted during the allotted 25s.

2.2.2.4.2 *Unfilled delay intervals*

Unfilled delay intervals consisted of wakeful rest. During unfilled delay intervals, participants would rest quietly in a darkened room void of any further sensory stimulation.

2.2.2.5 Post-Session Debriefing

At the end of each session, participants were asked to complete a short questionnaire. The questionnaires were used to gain a deeper understanding of the potential rehearsal behaviour of participants during each session. The questionnaire initially asked non-directive open-ended questions (e.g. “What do you remember about what you had to do in this experiment?”) before moving onto more directive closed questions (e.g. “Did you find yourself thinking about the stories during the experiment?”). The main purpose of the questionnaire was to gain a more accurate account of whether or not conscious subvocal rehearsal occurred during the experiment; and more specifically, under what conditions (i.e., as a response to anticipated delayed recall, story items may have randomly popped into participants’ heads, etc.). The questionnaire was presented to participants on paper for them to complete by hand.

2.2.2.6 Counterbalancing

In addition to using distractor tasks to extinguish STM maintenance, counterbalancing measures were used to ensure any potential benefits resulting from active rehearsal could be accounted for. All participants were quasi-randomly allocated to one of the two following condition order groups prior to the commencement of the experiment:

(a) FU, UU, UF, FF

(b) UF, UU, FU, FF

The two counterbalanced condition orders were formed to ensure that surprise delayed free-recall would be experienced across half of the sample during the FU and UF conditions. The expectance of further testing may have led participants to engage in conscious subvocal rehearsal, whereby information is actively maintained in STM. By comparing surprise vs expected delayed free-recall across the FU and UF conditions, the effectiveness of distractor tasks in extinguishing STM maintenance could be assessed.

As previously mentioned, surprise delayed free-recall was expected to extend to the second condition (i.e., the UU condition). Whilst delayed free-recall was consistently expected during the FF condition, it was assumed that conscious subvocal rehearsal would not be an issue during this condition. Participants were not expected to successfully engage in active rehearsal during the post-study delay interval of the FF condition since this interval was filled with a 9-minute Spot-the-Difference task (in addition to a 1-minute task which preceded delayed free-recall). It was deemed likely that any attempts to actively rehearse during this condition would be disrupted by engagement in the Spot-the-Difference task. If engagement in the Spot-the-Difference task was abandoned in place of active rehearsal, a trade-off between memory performance and post-study task performance would be evident via significant correlations.

2.2.2.7 Statistical Analysis

All statistical analyses were conducted using JASP (JASP Team, 2018). Independent samples t-tests were conducted as a means of comparing mean immediate free recall between each group across all conditions. Additionally, possible within-group differences in immediate free-recall performance across conditions were assessed via paired-samples t-tests. Repeated-measures analysis of variance (ANOVA) with within-subjects factor condition (UU vs FU vs UF vs FF), and between-subjects factor group (healthy younger adult group vs healthy older adult group) were also used. Paired-samples t-tests comparing uncapped proportion retention (delayed free-recall/immediate free-recall) within each group across all conditions (UU vs FU vs UF vs FF) were conducted. Additional analyses were conducted to see whether there were potential order effects or differences in performance based on self-reported conscious subvocal rehearsal or expectance of delayed free recall. The alpha level was set to .05 for all analyses other than the paired-samples t-tests, where it was set to .0083 following Bonferroni corrections.

2.2.3 Results

2.2.3.1 Memory Performance

2.2.3.1.1 *Immediate free-recall*

Tables 2.2a and 2.2b highlight the mean immediate free-recall performances of the healthy younger adult group (n = 24) and the healthy older adult group (n = 24) respectively across all conditions (UU vs FU vs UF vs FF).

Table 2.2a. Mean immediate free-recall performance of healthy younger adults (n = 24) across all experimental conditions.

Condition	Mean	SD	SEM
UU	.404	.164	.034
FU	.325	.122	.025
UF	.356	.125	.025
FF	.393	.120	.025

Note. Immediate free-recall performance = number of prose ideas recalled/total number of prose ideas presented. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Table 2.2b. Mean immediate free-recall performance of healthy older adults (n = 24) across all experimental conditions.

Condition	Mean	SD	SEM
UU	.437	.147	.030
FU	.375	.112	.023
UF	.369	.121	.025
FF	.393	.111	.023

Note. Immediate free-recall performance = number of prose ideas recalled/total number of prose ideas presented. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Independent samples t-tests demonstrated no significant differences in immediate free recall performance between the healthy younger and older adult groups across all conditions ($p > .05$). However, paired-samples t-tests did indicate significant within-group differences. Immediate free-recall performance within the healthy younger adult group appeared to be significantly poorer within the FU condition in comparison to both the UU and FF conditions, UU vs FU: t(23) = 2.565, p = .017, d = .524; FF vs FU: t(23) = 2.888, p = .008, d = .589. When looking at the healthy older adult group, immediate free-recall performance appeared to be significantly better within the UU condition in comparison to both the UF and FU conditions, UU vs FU: t(23) = 2.534, p = .019, d = .517; UU vs UF: t(23) = 2.747, p = .011, d = .561.

By no indication does it appear that pre-encoding engagement in an effortful task results in reduced immediate free-recall performance. The within-group differences in mean immediate free-recall between conditions are mitigated through the calculation of uncapped proportion retention (i.e., delayed free-recall/immediate free-recall) which takes into account discrepancies in the initial learning of material.

2.2.3.1.2 *Uncapped proportion retention*

Figure 2.2 illustrates the mean uncapped proportion retention of prose material between both groups across all conditions.

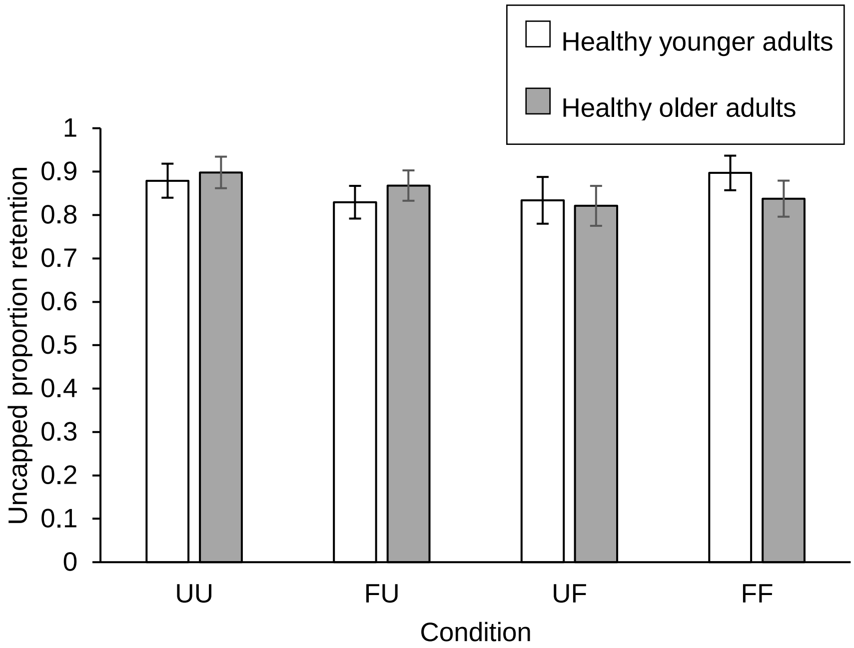

Figure 2.2. Mean uncapped proportion retention of prose material between groups across all experimental conditions. Uncapped proportion retention = delayed free-recall/immediate free-recall. Error bars represent SEM. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Additionally, Tables 2.3a and 2.3b provide a numerical overview of the mean uncapped proportion retention of prose material between the healthy younger and older adults across all of the experimental conditions respectively.

Table 2.3a. Mean uncapped proportion retention of prose material among healthy younger adults (n = 24) across all conditions.

Condition	Mean	SD	SEM
UU	.879	.192	.039
FU	.829	.185	.038
UF	.834	.264	.054
FF	.897	.195	.040

Note. Uncapped proportion retention = delayed free-recall/immediate free-recall. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Table 2.3b. Mean uncapped proportion retention of prose material among healthy older adults (n = 24) across all conditions.

Condition	Mean	SD	SEM
UU	.898	.178	.036
FU	.868	.171	.035
UF	.821	.225	.046
FF	.838	.204	.042

Note. Uncapped proportion retention = delayed free-recall/immediate free-recall. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

A repeated-measures analysis of variance (ANOVA), with between-subjects factor group (healthy younger adult vs healthy older adult) and within-subjects factor condition (UU vs FU vs UF vs FF), was conducted. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, therefore a Huynh-Feldt correction to degrees of freedom was made (ε = 0.901). Regardless of corrections, there was no main effects of condition, F(2.704, 46) = .916, p = .427, n^2_p = .020, or group, F(1, 46) = .011, p = .917, n^2_p = .000. Additionally, there was also no interaction between group and condition, F(2.704, 46) = .612, p = .592, n^2_p = .013.

Independent samples t-tests further supported the notion that there were no significant differences in uncapped proportion retention between the groups across all conditions (p > .05). Likewise, paired samples t-tests highlighted the lack of significant differences in uncapped proportion retention within each group across all conditions, irrespective of Bonferroni corrections ($p > .05$).

Given no significant age-related differences in uncapped proportion retention, subsequent analyses was conducted on both the individual groups as well as a combined group consisting of all participants (n = 48). This increased statistical power, and allowed for the more reliable exploration of the possible effects of rehearsal and order on memory performance.

Returning to the possible effect of condition on uncapped proportion retention, another ANOVA was conducted. Again, no significant effect of condition on uncapped proportion retention was found among the combined group, $F(3, 188) = .797$, $p = .497$, $n^2_p = .013$.

2.2.3.2 Possible Effects of Order and Active Rehearsal

Independent-samples t-tests showed no significant differences in uncapped proportion retention across all conditions – including the FU and UF condition - based on condition order ($p > .05$). This was seen across each group individually, as well as within the combined group. This was further supported by independent samples t-tests which highlighted that uncapped proportion retention did not vary significantly across both groups on both the UU and FU conditions depending on whether participants expected delayed free recall during the first testing session ($p > .05$).

While the expectation of delayed free-recall does not significantly impact uncapped proportion retention, active engagement in covert subvocal rehearsal does. When looking at the combined group, an independent samples t-test showed that uncapped proportion retention in the UU condition was significantly better for those who reported to have attempted intentional rehearsal (n = 5) vs those who did not (n = 43), $t(46) = 2.204$, $p = .033$, $d = 1.042$. However, when looking at the individual groups, only the healthy younger adult group demonstrated a significant benefit of rehearsal, $t(22) = 2.475$, $p = .022$. It should be noted that within the healthy younger adult group, only one participant reported to have rehearsed during the UU condition. Given this, the significance of the analysis on the combined group stems solely from an outlying performance within the healthy younger adult group. Concerning the FU condition, only six participants (all belonging to the healthy older adult group) reported to have engaged in conscious subvocal rehearsal. An independent samples t-test showed that uncapped proportion retention was not significantly better as a result of intentional rehearsal within this condition.

From these analyses, it can be somewhat reliably concluded that the distractor task was sufficient in extinguishing STM and preventing superior memory retention via conscious subvocal rehearsal. In turn, the measures of uncapped proportion retention following the post-study delay interval were a credible assessment of retention of items from long-term memory.

2.2.3.2 Spot-the-Difference Task Performance

Tables 2.4a and 2.4b highlight mean performance across the Spot-the-Difference task trials for the healthy younger adult group and the healthy older adult group respectively. Spot-the-Differences task trials 1 and 2 were completed during the FU and UF conditions, whereas trials 3 and 4 were completed during the pre- and post-encoding delay intervals of the FF condition respectively.

Table 2.4a. Mean spot-the-difference task performance of healthy younger adults (n = 24) across all four trials.

Trial	Mean	SD	SEM
1	.671	.122	.025
2	.700	.080	.016
3	.692	.063	.013
4	.718	.080	.016

Note. Spot-the-difference task performance = number of correctly identified differences/36. SD = Standard deviation, SEM = Standard error of the mean.

Table 2.4b. Mean spot-the-difference task performance of healthy older adults (n = 24) across all four trials.

Trial	Mean	SD	SEM
1	.514	.088	.018
2	.572	.068	.014
3	.552	.088	.018
4	.602	.099	.020

Note. Spot-the-difference task performance = number of correctly identified differences/36. SD = Standard deviation, SEM = Standard error of the mean.

Independent samples t-tests showed that the healthy younger adult group performed significantly better on all Spot-the-Differences task trials when compared to the healthy older adult group, $t(46) = 5.123$, $p < .001$, $d = 1.479$, $t(46) = 5.984$, $p < .001$, $d = 1.727$, $t(46) = 6.346$, $p < .001$, $d = 1.832$, $t(46) = 4.465$, $p < .001$, $d = 1.289$, for trials 1-4 respectively. In addition, healthy younger adults performed significant better on the distractor tasks following the first condition of each testing session (i.e., the first and third condition of the experiment, FU and UF conditions) in comparison to healthy older adults, t(46) = 2.356, *p* = .023, d = .680, t(46) = 2.750, *p* = .008, d = .794, for the first and third distractor task respectively.

For the healthy older adult group, performance was worse during the first Spot-the-Difference task trial in comparison to the others, t(23) = 3.109, *p* = .005, d = .635, t(23) = 1.785, *p* = .087, d = .364, t(23) = 5.047, *p* < .001, d = 1.030, for Trial 1 vs 2, Trial 1 vs 3, and Trial 1 vs 4, respectively. Overall, performance was best during the final Spot-the-Difference task, t(23) = 1.877, *p* = .073, d = .383, t(23) = 3.054, *p* = .006, d = .623, for Trial 4 vs 2, Trial 4 vs 3, respectively.

For the healthy younger adult group, only a near-significant difference in Spot-the-Difference task performance was present between the final trial and the first trial, t(23) = 1.881, *p* = .073, d = .384. In general, the pattern of performance seen across the Spot-the-Difference tasks indicate a possible practice effect. No significant correlations where seen between Spot-the-Difference task performance and uncapped proportion retention across both groups, signalling no possible trade-offs.

2.2.4 Discussion

Both healthy younger and older adults were able to maintain substantial amounts of prose material, regardless of whether the periods preceding and/or following prose presentation consisted of engagement in effortful tasks or wakeful rest. Given the apparent absence of an interfering effect across relevant conditions, it is difficult to derive an evaluation of the accountability of the theories (i.e., consolidation theory and temporal distinctiveness theory) with respects to the specific predictions each account makes (see Table 1 on Page 50). While the overall findings are a notable deviation from previous studies (Dewar et al., 2012b; Alber et al., 2014), the absence of any improvements in the retention of prose material following a brief period of post-encoding wakeful rest is not uncommon among healthy samples. Similar observations have been made in which the presence or absence of post-encoding wakeful rest had no discernible impact on prose retention (Dewar et al., 2010; Martini, Riedlsperger, Maran, & Sachse, 2017). Other studies have found small - albeit significant – benefits to prose retention in adults when RI was minimised (Cowan et al., 2004; Della Sala et al., 2005, Brokaw et al., 2016; Sacripante et al., 2019).

In addition to being unaffected by pre- and post-encoding encoding conditions, retention was consistently high irrespective of whether or not participants anticipated later recall across conditions or participated in conscious subvocal rehearsal. Given this, the necessity of the deception component within the current experiment can be questioned. It appears that the absence of enhanced delayed recall following intentional rehearsal was achieved via the inclusion of short distractor tasks prior to delayed free-recall tests. Based on the findings, it is reasonable to conclude that the use of such a task prior to each instance of delayed free-recall was sufficient at extinguishing any information being maintained in STM through rehearsal. However, without the use of a deception measure, it would be difficult to statistically explore whether anticipated recall may result in enhanced retention across specific conditions within the current paradigm.

One detail which has not been touched upon concerns the observation of ceiling effects across both groups, irrespective of the pre- and post-encoding conditions. The presence of ceiling effects impedes efforts to reliably discern differences in uncapped proportion retention among conditions. However, there does not appear to be a great number of possible reasons as to why this effect was present in the current experiment. It should be noted that whilst uncapped proportion retention of both healthy younger and older adults was substantially high (ranging between .82 - .89), this is not necessarily an indication that the to-be-retained material was intuitively easy for participants to retain. When reflecting upon the amount of information that was initially recalled following the presentation of the prose passages, it can be seen that participants on average reported no more than half of the total idea units from each prose passage. Given the lack of ceiling effects across tests of immediate free-recall, it seems the initial learning of the material was not effortless. However, it seems that the task of retaining whatever amount of information had been initially acquired during encoding was substantially less challenging for healthy subjects.

With respects to the participants who took part in the current experiment, the vast majority were well-educated and/or highly experienced in taking part in psychological experiments. All participants from the younger adult group were undergraduate Psychology students, while all participants from the older adult group were individuals with similar educational backgrounds who frequently took part in assessments of memory within the university. Given this, there remains a possibility that participants were not vulnerable to the effects of either RI or PI due to their prior educational background (i.e., experience in acquiring and retaining episodic information in an environment that would be expected to elicit interference). Perhaps ceiling effects would be avoided, and subsequent differences in uncapped proportion retention could be observed, if a sample of participants with less years of education had been assessed. This was explored further in Experiment 2.

2.3 Experiment 2

2.3.1 Aims

The current experiment aimed to assess whether the findings from Experiment 1 could be replicated when the same paradigm was used in a mixed sample of healthy, native-Italian speaking younger and older adults (n = 12) who had less educational experience. This sample was initially assessed as a means of forming a control group for the amnesic patient experiment discussed in Chapter 4 (i.e., Experiment 5). However, the data from this sample may be informative in indicating whether prior educational experience determines the degree of vulnerability to RI/PI. If so, testing such a sample may enable us to more appropriately evaluate the accuracy of the predictions outlined by the consolidation theory and temporal distinctiveness theory (see Table 1 on Page 50).

2.3.2 Methods

2.3.2.1 Participants

Twelve adults (7m/5f, mean age = 53.75 years, age range = 22 - 82 years) were tested. Like Experiment 1, all participants were healthy, with normal motor skills and normal or corrected eyesight and hearing. In addition, no participants reported pre-existing cognitive impairments or any history of brain damage. However, the average years of education within the current sample (mean education = 11.83 years, education range = 5 - 16 years) was substantially lower than in Experiment 1 (mean education = 15.36 years, education range = 11 - 21 years). All participants were native-Italian speakers, and were subsequently tested in Italian. The participants were tested at the Dipartimento di Riabilitazione, Ospedale Somma Lombardo in Italy. The participants were initially recruited as matched controls for a sample of amnesic patients (see Experiment 5), having volunteered in past research involving these patients.

2.3.2.2 Procedure

The procedure of Experiment 1 was utilised in the current experiment (see Figure 2.1).

2.3.2.3 To-Be-Retained Material

Again, all participants were presented with a prose passage after the 9-minute pre-encoding delay interval within each condition, totalling four prose passages throughout the course of the experiment.

The four prose passages used in the current experiment were taken from the Italian variant of the Rivermead Behavioural Memory Test (RBMT-3; Beschin, Urbano, & Treccani, 2013) (see Appendix C). Similar to the prose passages from the original version of the RBMT, each prose passage consisted of 21 story “ideas”. Scoring procedures used in Experiment 1 were adopted for this study. Inter-rater reliability (IRR) was again computed using a two-way random, consistency, average-measures ICC. Table 2.6 highlights the ICC between scores of immediate and delayed free-recall across all conditions. Mean ICC across immediate and delayed free recall scores was in the excellent range (ICC = .902 for immediate, ICC = .887 for delayed; Cicchetti, 1994), indicating that raters had a high degree of agreement. Once again, the original scores were used in the subsequent analyses. Reported findings did not vary significantly depending on which set of scores was used.

Table 2.6. Intra-class correlations coefficient (ICCs) of mean immediate (Imm) and delayed (Del) free-recall scores between two raters across all experimental conditions.

Condition	ICC	
	Imm	Del
UU	.879	.861
FU	.948	.962
UF	.927	.955
FF	.852	.768

Note. Imm = immediate free-recall, Del = delayed free-recall; UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

2.3.2.4 Delay Intervals

Identical to Experiment 1, the 9-minute pre-encoding and post-encoding delay intervals immediately preceding and following prose presentation and immediate free-recall assessment were either filled or unfilled.

2.3.2.4.1 *Filled delay intervals*

Filled delay intervals consisted of the same task used in Experiment 1 (i.e., Spot-the-Difference task). Like Experiment 1, participants were first introduced to the Spot-the-Difference task via a practice trial consisting of 2 picture pairs as a means of familiarising participants with the demands of the task. The Spot-the-Difference task was again used as a distractor task within the current experiment to ensure that any conscious subvocal rehearsal occuring during post-encoding wakeful rest would be interrupted, extinguishing rehearsed information being maintained within STM.

2.2.2.4.1 *Unfilled delay intervals*

Unfilled delay intervals consisted of wakeful rest which mirrored Experiment 1 (i.e., rest in quiet, darkened room).

2.3.2.5 Post-Session Debriefing

At the end of each session, participants were asked to complete a short questionnaire. Matching the questionnaire used in Experiment 1, the main purpose of the questionnaire was to again gain a more accurate account of whether or not conscious subvocal rehearsal occurred during the experiment and under which circumstances.

2.3.2.6 Counterbalancing

Due to the lack of identifiable issues with the counterbalancing measures used in Experiment 1, these were subsequently adopted for the current experiment.

2.3.2.7 Statistical Analysis

All statistical analyses were conducted using JASP. All comparative analysis and supplementary analysis conducted in Experiment 1 were ran with the current sample.

2.3.3 Results

2.3.3.1 Memory Performance

2.3.3.1.1 *Immediate free-recall*

Table 2.7 highlights the mean immediate free-recall performances (n = 12) across all conditions (UU vs FU vs UF vs FF).

Table 2.7. Mean immediate free-recall performance across all experimental conditions.

Condition	Mean	SD	SEM
UU	.448	.147	.042
FU	.375	.162	.047
UF	.442	.139	.040
FF	.411	.120	.035

Note. Immediate free-recall = number of prose ideas recalled/total number of prose ideas presented. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Immediate free-recall performance appeared to be significantly poorer within the FU condition in comparison to the UU condition, t(11) = 2.923, p = .014, d = .844. No other significant differences occurred among the other conditions. The current results appear to be more reflective of outlying performances from select participants skewing the mean within a small sample. Again, the calculation of uncapped proportion retention mitigates differences in immediate free-recall.

2.3.3.1.2 *Uncapped proportion retention*

Figure 2.3 illustrates mean uncapped proportion retention of prose material across all conditions.

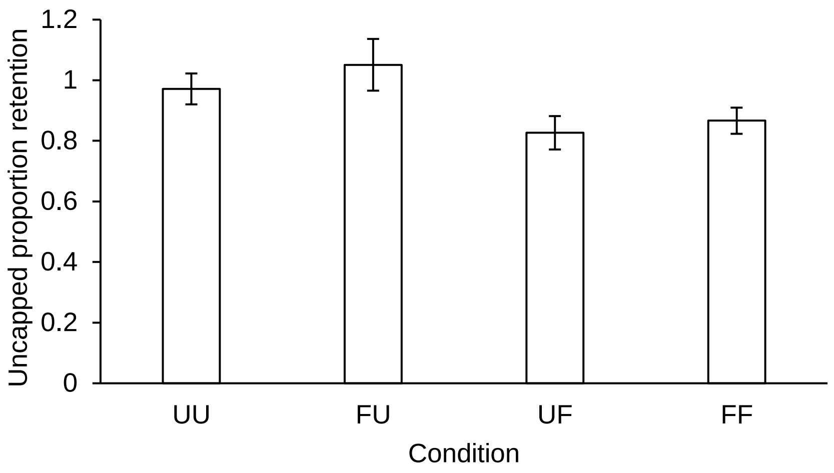

Figure 2.3. Mean uncapped proportion retention across all experimental conditions. Uncapped proportion retention = delayed free-recall/immediate free recall. Error bars represent SEM. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Additionally, Table 2.8 provides a numerical overview of the mean uncapped proportion retention across all of the experimental conditions.

Table 2.8. Mean uncapped proportion retention across all conditions.

Condition	Mean	SD	SEM
UU	.971	.177	.051
FU	1.051	.296	.085
UF	.827	.191	.055
FF	.866	.150	.043

Note. Uncapped proportion retention = delayed free-recall/immediate free-recall. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

A one-way ANOVA found a near-significant main effect of condition on uncapped proportion retention, F(3, 44) = 2.802, p = .051, n^2_p = .160. Subsequent paired samples t-tests found that uncapped proportion retention was significantly poorer within the UF condition when compared to both the UU and FU condition, t(11) = 2.474, p = .031, d = .714, t(11) = 2.460, p = .032, d = .710, for UU vs UF and FU vs UF respectively. However, following Bonferroni corrections, these differences were no longer significant (p > .0083).

Given the variability of performances across conditions within this notably small sample, and that the use of Bonferroni corrections have and continue to be considered a conservative measure that can increase the likelihood of false positives (Perneger, 1998), additional analysis was conducted to supplement the present findings. Bayesian paired-samples t-tests were conducted to compare uncapped proportion retention between conditions. Bayesian analysis yields the probability that the data came from a null hypothesis as opposed to a reasonable collection of possible non-nulls. Bayes Factors of 3 or above are taken as evidence favouring the non-null, with Factors below 3 favouring the null (Jeffreys, 1961; Raftery, 1995; Wetzels et al., 2011; see Jarosz & Wiley, 2014). In Bayesian statistics, adjusting the alpha level is not necessary (see Dienes, 2011; Kruschke, 2010). In avoiding alpha adjustments (i.e., Bonferroni corrections), issues regarding the further reduction of statistical power within a small sample can be averted (Courgeau, 2012).

Table 3. Results from Bayesian and conventional paired samples t-tests of uncapped proportion retention for healthy adults with less educational experience.

Comparison	t	df	*p*	d	BF_{10}
UU vs FF	1.301	11	.220	.376	.572
UU vs UF	2.474	11	.031	.714	2.405
UU vs FU	-1.038	11	.322	-.300	.450
FU vs FF	1.834	11	.094	.530	1.036
FU vs UF	2.460	11	.032	.710	2.359
UF vs FF	-.035	11	.603	-.154	.325

Note. Uncapped proportion retention = delayed free-recall/immediate free-recall.

As seen in Table 3, the Bayesian paired-samples t-tests all demonstrated weak evidence supporting notable differences between the conditions ($BF_{10} < 3$). Given this, the Bayesian analyses is in line with the non-significant differences observed between the UU/FU conditions and the FU condition following Bonferroni corrections to the conventional analysis.

2.3.3.2 Possible Effects of Order and Active Rehearsal

Similar to Experiment 1, independent-samples t-tests found no significant differences in uncapped proportion retention across all conditions – including the FU and UF condition - based on condition order ($p > .05$). Again, these findings were further supported by independent samples t-tests which showed that uncapped proportion retention did not vary significantly across the UU and FU conditions depending on whether participants expected delayed free recall during the first testing session ($p > .05$).

Additionally, an independent samples t-test showed that uncapped proportion retention across both the UU condition and the FU condition was not significantly better for those who reported to have attempted intentional rehearsal (n = 7 for UU, n = 4 for FU) vs those who did not (n = 5 for UU, n = 8 for FU) ($p > .05$).

From these analyses, it can be reliably assumed that the distractor task suitably extinguished STM and prevented an improvement in memory retention resulting from conscious subvocal rehearsal. In turn, the assessment of uncapped proportion retention following the post-encoding delay interval was a reliable measure of retention of items from LTM.

2.3.3.3 Spot-the-Difference Task Performance

Table 2.9 highlights mean performance across the Spot-the-Difference task trials.

Table 2.9. Mean spot-the-difference task performance across all four trials.

Trial	Mean	SD	SEM
1	.505	.143	.041
2	.560	.158	.046
3	.539	.146	.042
4	.583	.115	.033

Note. Spot-the-difference task performance = number of correctly identified differences/36. SD = Standard deviation, SEM = Standard error of the mean.

A paired samples t-test found that participants performed significantly better during the final Spot-the-Difference task trial when compared to the first, t(11) = 3.517, *p* = .005, d = 1.015. In addition, there were near-significant differences in Spot-the-Difference task performance between the first and second trial, as well as the third and final trial, with superior performance in the later trials, t(11) = 1.970, *p* = .074, d = .569, t(11) = 1.998, *p* = .071, d = .577, for Trial 2 vs 1 and Trial 4 vs 3 respectively.

The pattern of performance seen across the Spot-the-Difference tasks echoes the results previously observed in Experiment 1.

No significant correlations were established between Spot-the-Difference task performance and uncapped proportion retention. As a result, it is reliably concluded that no trade-offs occurred between interfering task engagement and memory retention.

2.3.4 Discussion

Mirroring the results of Experiment 1, healthy younger and older adults (within a mixed group) continue to retain a notable amount of recently acquired prose information, despite the presence of an effortful task that would theoretically elicit interference when encountered both before and after encoding. This is observed even when the tested sample of healthy adults do not have extensive educational experience.

This finding does not align with either the consolidation theory or the temporal distinctiveness theory. According to consolidation theory, performance across the conditions consisting of post-encoding wakeful rest would be expected to be notably better in comparison to those that consist of post-encoding engagement in an effortful task (i.e., UU = FU > UF = FF). This is based on the notion that RI has been minimised across such conditions (via post-encoding wakeful rest), allowing for the consolidation of prose material to remain uninterrupted. On the other hand, temporal distinctiveness theory would expect to see an enhanced benefit of rest within the UU condition when contrasted with the FU condition (i.e., UU > FU = UF > FF). This is due to the prose material within the UU condition being temporal isolated on both sides of the temporal dimension (i.e., before and after encoding). However, this does not appear to be the case from a numerical perspective.

2.4 General Discussion

Overall, it appears that both healthy younger and older adults – regardless of prior education experience - show little to no significant decreases in retention of prose material when learning is preceded and/or followed by an interpolated task. Additionally, wakeful rest prior to or after learning does not appear to enhance retention. This greatly limits our ability to systematically assess the accountability of the consolidation theory and the temporal distinctiveness theory, as it appears that the filled delay intervals did not result in any interference among the tested samples. Considerations need to be made towards the possible reasons as to why the interference of retained prose material was not observed across these experiments.

While an absence of an age-related difference in RI susceptibility is in contrast with past research (see Martini et al., 2018), it is not an uncommon finding (Craig et al., 2016b). Upon closer review of past research specifically investigating the benefits of post-encoding wakeful rest to prose retention, notable inconsistencies become apparent (see Table 2.5).

Table 2.5. Review of past studies investigating the benefits of post-encoding wakeful rest vs various post-encoding tasks to prose retention over differing retention interval lengths.

Author(s)	Retention interval(s)	Post-encoding task(s)	Sample(s)	Result
Cowan et al. (2004)	1 hr	Psychometric tests	Healthy mixed age (n = 6)	Small benefit
Della Sala et al. (2005)	1 hr	Psychometric tests	Healthy older adults (n = 10)	Small benefit
Dewar et al. (2010)	10 mins	Tone detection task	Healthy mixed age (n = 10)	No benefit
Dewar et al. (2012)	15-30 mins, 7 days	Spot-the-difference task	Healthy older adults (n = 14, 19)	Notable benefit
Alber et al. (2014)	15-30 mins, 7 days	Spot-the-difference task	Healthy older adults (n = 15)	Notable benefit
Brokaw et al. (2016)	15 mins	Visuospatial task (Snood)	Healthy younger adults (n = 22)	Small benefit
Martini et al. (2017)	7 days	Spot-the-difference task, reading newspaper	Healthy younger adults (n = 28, 36)	No benefit
Sacripante et al. (2019)	10 mins	Spot-the-difference task	Healthy younger and older adults (n = 45, 43)	Small benefit

Note. Results compared across healthy adult samples varying in age.

Given the limited number of studies which have assessed the retention of prose material following a brief period of wakeful rest or post-encoding task engagement, caution should be exercised when forming assumptions. However, based on the relevant literature over the last two decades, there are some key considerations which should be undertaken to further understand the lack of an empirical consensus surrounding interference effects on prose retention.

The possibility must be considered that the cognitive demand of a task following prose acquisition may influence the degree to which the target material is interfered. Task demand itself may be modulated by age. Healthy aging is known to entail declines in performance on tasks assessing different cognitive abilities, including processing speed, reasoning and working memory (Grady et al., 1998; Stebbins et al., 2002; Persson et al., 2006). Such declines have been linked both to the age-related atrophy of grey and white matter from specific brain regions and increasingly inefficient and sporadic brain activation in task-relevant and extraneous brain locations during task performance (Grady et al., 1994).

With these age-related declines in cognitive ability, it can be presumed that older adults may experience a higher degree of difficulty when engaging with many interpolated tasks. This may have several implications. Older adult participants may require a significant portion of finite cognitive resources to complete interpolated tasks – leading to potential declines in resources available for consolidative processes. Additionally, consolidation-related brain regions may be used to facilitate performance in interpolated tasks, resulting in further interference (Gray et al., 1994). As a by-product of this pronounced interference effect, post-encoding wakeful rest benefits are more likely to be observed across such populations. This notion is supported by the observation of small yet significant interference effects (< 10% decline) following post-encoding engagement in psychometric tests

(Cowan et al., 2004; Della Sala et al., 2005). While such post-encoding engagement resulted in substantial interference effects among patients with AA, such effects were less pronounced among control groups. This may have occurred since psychometric testing poses a reduced cognitive demand on neurologically-intact older adults. However, age-related declines outlined earlier may have still led to observations of minor interference effects.

This concept is further supported by the findings from a study by Dewar and colleagues (2010). In this study, a control sample - consisting predominantly of healthy older adults - retained more prose material following a 10-minute post-encoding tone detection task when compared to a condition in which participants rested wakefully for 10 minutes following prose acquisition. The tone detection task is believed to be a low mental-effort activity involving the repeated encoding of similar stimuli void of meaning. As such, its ability to elicit forgetting is questionable, with some studies showing no increases in forgetting (Lewandowsky, Geiger, & Oberauer, 2008; Ecker et al., 2015b).

The interfering properties of a visual spot-the-difference task, which has been implemented in numerous studies (Dewar et al., 2007, 2012; Alber et al., 2014; Martini et al., 2017; Sacripante et al., 2019) can also be brought into question. Studies have demonstrated benefits of a brief period of post-encoding wakeful rest which persist over long retention intervals in comparison to post-encoding period consisting of a spot-the-difference task (Dewar et al., 2012b; Alber et al., 2014). However, the magnitude and persistence of these benefits have been brought into question by more recent studies (Martini et al., 2017; Sacripante et al., 2019). It is important to note that while the study by Sacripante and colleagues (2019) demonstrated that post-encoding engagement in a spot-the-difference task can result in significant reductions in gist and peripheral details of short stories in both younger and older adults, the observed decrements were small (< 10%).

Returning to the findings from the current study, both younger and older adult groups performed equally well regardless of encountering a spot-the-difference task before and/or after prose presentation. However, the older adult group performed significantly poorer on all spot-the-difference task trials in comparison to the younger adult group. This is unsurprising based upon the previous discussions regarding age-related declines in cognitive ability. However, what is surprising is that this decrease in interpolated task performance – indicative of an increased task demand within this group – led to no marked declines in memory performance. From this, different assertions could be made. Namely, engagement in a spot-the-difference task – which is dissimilar semantically and in terms of modality to the prose material – may not result in a significant division in limited cognitive resources crucial for the maintenance of consolidative processes. Alternatively, the finite cognitive resources available to healthy older adults may be directed towards the consolidation of the prose material, resulting in the inability for participants to complete further tasks to a high level. On top of this, active brain regions responsible for the consolidation of prose material during the post-acquisition stage may not be available to facilitate subsequent performance on other tasks.

Reflecting more generally, these pattern of findings may be an indication that some to-be-retained material, specifically prose material from the RBMT, are less receptive to interference within neurologically intact populations. Explanations vary as to why the retention of prose material itself has been seen to be unaffected by RI in healthy populations. One explanation posits that the processing of prose material can be “elaborated” (Martini et al., 2017), whereby certain conditions can determine the manner in which prose information is processed (Craik, 2002, Craik & Lockhart, 1972).

One possible factor concerns the implementation of no time constraints during immediate and delayed free-recall. In Experiment 1, participants were given as long as they needed to recall as much of the prose material as they could remember within each condition. With no time constraints, participants may have been better able to establish memory “pegs” (Paivio, 1971, 1986). Memory “pegs” act as cues that may be derived from salient story ideas. The saliency of story ideas within the prose material may be closely tied to its relatedness to the overall story theme or to pre-existing knowledge from LTM (Ericsson & Kintsch 1995; see Goetz & Armbruster, 1980 for review). Such “pegs” may facilitate preserved retrieval by allowing for less salient portions of the prose passages to be recalled via association or “hanging” (Paivio, 1971, 1986, McDaniel & Pressley, 1987). The later use of such cues – which may be more resilient to interference via post-encoding task engagement (Robertson, 2012) – may have led to minimal forgetting across all the experimental conditions.

Additionally, the maintenance of memory “pegs” may have been further facilitated by very brief periods of disengagement during the post-encoding interfering tasks in Experiment 1 and 2. The Spot-the-Difference tasks within Experiment 1 and 2 were formed of picture pairs consisting of only two subtle differences. In instances where participants identified these differences before the required time, they may have been able to mentally return to the “pegs” as a means of aiding later retrieval of the prose material. It is therefore possible that the continuity of engagement in post-encoding tasks, as well as the cognitive demand of the task itself, modulates the degree to which minimal RI benefits can be observed in healthy older adults.

Another possibility may involve the level of engagement during the interfering task. Whilst mean Spot-the-Difference task performance across conditions was reasonable, this may not be an informative reflection of engagement during the task. During the Spot-the-Difference task trials, participants would regularly identify both differences between the picture pairs. Upon identifying all the differences in a pair, participants may have had brief opportunities to reflect upon details of the prose passages. These brief periods of reflection may have enabled participants to adequately maintain key story cues during task engagement. Such an ability to both maintain and later use invaluable retrieval cues may have allowed for participants to negate any potential interference that occurred as a product of engaging with the Spot-the-Difference task material. It is also reasonable to assume that both the level of engagement in the interfering tasks and the nature of the to-be-retained material were together relevant factors contributing to the nullification of potential interference effects. This reduced the likelihood of observing any benefits from minimising such interference.

Another consideration that needs to be discussed is the absence of a pronounced benefit to retention when wakeful rest is encountered before and/or after encoding of episodic content. While there remains a possibility that the interpolated task elicited little to no interference within Experiments 1 and 2, it is also possible that wakeful rest may have not necessarily promoted the optimal conditions for consolidation or facilitated temporal distinctiveness within these cognitively intact samples. Recent research has suggested that a high propensity for mindwandering during wakeful rest intervals – specifically, a frequent tendency to reflect on task-irrelevant thoughts – may work to disrupt consolidative processes in healthy younger and older adults (see Varma, Takashima, Fu, & Kessels, 2019). Indeed, engaging in autobiographical thinking following new learning has been seen to reduce later memory performance (Craig et al., 2014). While it can be concluded that task-relevant thinking - such as intentional rehearsal of the to-be-retained material - did not significantly support retention, it cannot be known for certain whether any task-irrelevant thinking resulted specifically in poorer memory performance. Given that mean memory performance was at ceiling across all conditions, it seems more plausible that the absence of differences was more likely due to the minimal interfering effect of the Spot-the-Difference task used within Experiments 1 and 2.

Our results build on these findings by demonstrating an additional absence of benefits resulting from minimal proactive interference within the same paradigm.

From a temporal distinctiveness perspective, an alternative explanation for the lack of minimal interference benefits in Experiment 1 can be made. The immediate and delayed free-recall of prose material may be similar to the recall of items within a forward serial recall task, which have previously shown no benefits of temporal isolation effects (Lewandowsky, Brown, Wright, & Nimmo, 2006; Nimmo & Lewandowsky, 2005, 2006; Parmentier, King, & Dennis, 2006). Within Experiment 1, immediate and delayed free-recall of the prose passage was not constrained, meaning participants were free to recall the passages in any order. However, participants may have elected to recall the story “ideas” in chronological order for a number of reasons. The narrative structure of the prose passages may have promoted recall that was more serial in nature compared to free recall. Story ideas at the start of the prose passages may have logically cued recall of adjacent story ideas. This progressive cueing effect may have meant the ability to utilise a positional dimension over a temporal one may have favoured superior recall (Geiger & Lewandowsky, 2008). As a result, the temporal distinctiveness of the prose material was less important in the retrieval process.

Chapter 3:

Evaluating factors affecting magnitude of minimal interference benefit

3.1 Introduction

In Chapter 2, healthy younger and older adults demonstrated absent benefits of pre- and post-encoding wakeful rest to the retention of episodic material (prose material) over the course of 10 minutes. An evaluation of past studies specifically exploring the forgetting of prose stimuli following interpolated tasks led to the conclusion that certain interconnected factors may determine the degree to which forgetting is experienced for this type of material across healthy populations.

To summarise, prose material in particular may be resilient to further interference if the following interpolated tasks enable the maintenance of facilitatory processes supporting retrieval. Most prose passages used in memory studies are semantically structured (Isaac & Mayes, 1999), meaning individual story ideas are interlaced and organised with respects to the overarching context of the story. As such, the story context is inherently used in the guidance of encoding and later recollection of ideas as a means of preserving a coherent narrative that fits the original memorandum. This guidance may entail the subsumption of satellite details into more salient story ideas that are imperative to the story context. During the encoding/consolidation process, story ideas may be hierarchically compressed so that salient items are prioritised – reducing costs to cognitive resources. This reduced demand circumvents interference from interpolated tasks since the maintenance of the compressed information does not command a significant proportion of limited resources to be maintained. However, this may come at a potential loss of less important story details that may not be recovered during the retrieval or "decompression" stage. However, the maintenance of key story ideas – which both maintains and is maintained by memory for the story context - allows for the recovery of some supplementary details during later recall. This process may be less likely to occur successfully if interpolated tasks following prose acquisition demand an excessive portion of cognitive resources or undivided attention which may not allow for the maintenance of the story context.

Based on the discussion above, prose material may be easier to remember when compared to other conventional memoranda used in memory studies (i.e., lists of unrelated words, word-pairs, etc.). Retrieval is poorer for older adults when encoding strategies need to be formed independently by the participant (Craik, 1986; Craik & Rabinowitz, 1985). This may pose a minimal problem when participants are required to encode short stories. However, the same may not apply to the retention of lists of unrelated words.

Unlike stories, lists of unrelated word items do not possess an overarching context which participants can use to guide encoding/retrieval. Consequently, individuals have to derive their own strategies upon presentation in order to encode the material effectively. While many may attempt to utilise similar processes (i.e., maintenance of salient cues), this is likely less efficient due to an absence of pre-existing associations among the items. This absence requires participants to form their own associations, derived from their own knowledge and personal experiences. The formation and maintenance of these unique associations likely come at an increased cost of resources – resources which may not be available if participants are faced with interpolated tasks preceding and/or following new learning. Given this, the retention of a newly learnt list of unrelated words may be vulnerable to interference from tasks preceding and/or following it.

3.2 Experiment 3

3.2.1 Aims

The aim of Experiment 3 was to assess the effects of interference before and after new learning using material that would not readily allow for participants to use facilitatory processes to counter possible interfering effects. This was achieved by adopting the same methodology as Experiment 1 and 2, but using four sets of 15-item wordlists consisting of unrelated common nouns in place of prose material. Memory span for unrelated word items is typically lower when compared to prose span (Baddeley, Valar, & Wilson, 1987). Using wordlists in place of prose material may reduce the likelihood of at-ceiling performances that were encountered across Experiments 1 and 2 that assessed retention of prose.

Additionally, the number of subtle differences between each picture pair was increased within all Spot-the-Difference task trials. This was done as a means of ensuring continuous engagement in the task during the delay interval. Through increasing the demand of the interfering task, there was a reduced likelihood that participants could capitalise on brief windows of rest to utilise any possible maintenance strategies. This was all done in as a means of more reliably testing the differential predictions of the consolidation theory and temporal distinctiveness theory (see Table 1 on Page 50) that had not been successfully achieved across Experiments 1 and 2.

3.2.2 Methods

3.2.2.1 Participants

Twenty-four new healthy older adults (8m/16f, mean age = 68.500 years, age range = 63 – 74 years; mean education = 15.625 years, education range = 11 – 20 years) took part in the current experiment. Once again, all participants had normal or corrected hearing and eyesight. Mirroring Experiment 1, all participants were native-English speakers and testing was subsequently conducted in English. All participants were recruited from the Volunteer Panel via telephone and later tested in the neuropsychology lab within the Psychology Department at the University of Edinburgh.

3.2.2.2 Procedure

The experimental procedure for Experiment 3 was identical to Experiment 1 and 2.

3.2.2.3 To-Be-Retained Material

The to-be-retained material consisted of four wordlists (see Appendix D). Each wordlist was composed of 15 unrelated common nouns that were selected from the MRC Psycholinguistic Database. Items within each wordlist were standardised based on number of letters, number of syllables, familiarity, imaginability, and concreteness. Wordlists have been commonly used within past experiments investigating minimal RI benefits (Cowan et al., 2004; Dewar et al., 2007; 2009; 2012a; Craig, Della Sala, & Dewar, 2014). Participants were visually presented with each word on-screen for 5s each, with a 1s interval between each word. This occurred after each 9-minute pre-encoding delay interval. Participants were required to recall as many words as they could remember immediately after presentation and after a 1-minute distractor task which came after each 9-minute post-encoding delay interval. Both immediate and delayed free-recall were measured.

Proportion retention for each wordlist was calculated by dividing the number of wordlist items recalled correctly after delayed free-recall by the number of wordlist items recalled correctly at immediate free-recall. Proportion retention remained uncapped (see Chapter 2 for justification).

3.2.2.4 Delay Intervals

Following from Experiment 1 and 2, the 9-minute pre-encoding and post-encoding delay intervals immediately preceding and following wordlist presentation and immediate free-recall assessment were either filled or unfilled.

3.2.2.4.1 *Filled delay intervals*

An altered version of the Spot-the-Difference task used in Experiment 1 and 2 was adopted as the interference task during filled delay intervals. The number of subtle differences between each picture pair was increased from two to four for the altered version of the task used in the current experiment. This was done to increase the difficulty of the task and to ensure that all participants were continuously engaged in the task. By making this change, it decreased the probability that participants could potentially benefit from very brief periods of inactivity during the task in the event that they had identified all differences. The same alteration was made to the one-minute Spot-the-Difference tasks that were used as a distractor task within the current experiment to interrupt efforts of participants to maintain information in STM via conscious subvocal rehearsal.

The experimenter scored the overall performance of participants within each trial based on the total number of correctly identified differences divided by the total number of differences (72 differences within each condition trial, 8 differences within each distractor trial). The experimenter scored the individual performance of the participant on each picture pair within each trial using the Spot-the-Difference scoring sheet, marking 0 to 4, depending on how many differences were spotted during the allotted 25s.

3.2.2.4.2 *Unfilled delay intervals*

Unfilled delay intervals consisted of wakeful rest which mirrored Experiment 1 and 2 (i.e., rest in a quiet, darkened room).

3.2.2.5 Post-Session Debriefing

A short questionnaire, similar to the questionnaire used in Experiment 1 and 2, was used at the end of each session to explore potential rehearsal behaviours of participants during the experiment.

3.2.2.6 Counterbalancing

Due to the lack of identifiable issues with the counterbalancing measures used in both Experiment 1 and 2, these were subsequently adopted for the current experiment.

3.2.2.7 Statistical Analysis

All statistical analyses, which matched the analyses which was computed in Experiments 1 and 2 (with the absence of Bayesian analyses due to having a healthier sample size), were conducted using JASP (JASP Team, 2018).

3.2.3 Results

3.2.3.1 Memory Performance

3.2.3.1.1 *Immediate free-recall*

Table 3.1 highlights the mean immediate free-recall scores of participants across each condition.

Table 3.1. Mean immediate free-recall across all conditions

Condition	Mean	SD	SEM
UU	.667	.169	.035
FU	.628	.167	.034
UF	.606	.180	.037
FF	.553	.186	.038

Note. Immediate free-recall = number of wordlist items recalled/total number of wordlist items. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Paired-samples t-tests demonstrated a significant difference in immediate free-recall scores between the UU and FF conditions, with participants performing better within the UU condition, t(23) = 2.421 , *p* = .024 , d = .494. The difference between these conditions equates to less than two words (<12% of total wordlist items presented within the condition). This should not be a cause for concern when considering that the measure of uncapped proportion retention accounts for discrepancies in immediate free recall within the calculation. Additionally, the following results remained the same when outliers were removed (n = 2) from analyses. There were no other notable differences in immediate free-recall performance between all other conditions.

3.2.3.1.2 *Uncapped proportion retention*

Figure 3.1 demonstrates mean uncapped proportion retention of wordlist material across all conditions in the within-subjects study.

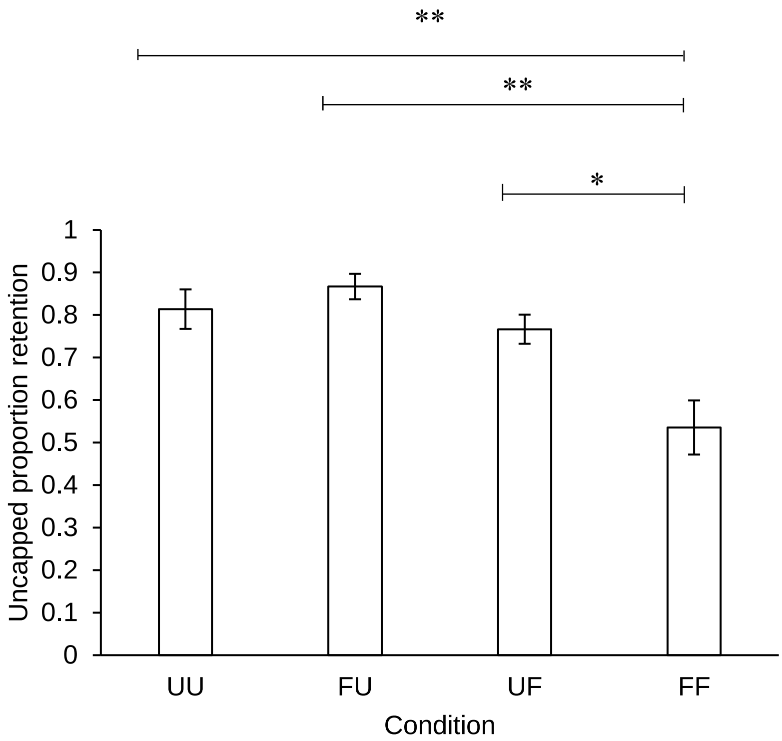

Figure 3.1. Mean uncapped proportion retention of wordlist material among healthy older adults (n = 24) across all experimental conditions in the within-subjects study. Uncapped proportion retention = delayed free-recall/immediate free-recall. Error bars represent SEM. * = p = 0.001, ** = p < 0.01. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Additionally, Table 3.2 provides a numerical overview of the uncapped proportion retention for the wordlist material across all of the experimental conditions.

Table 3.2. Mean uncapped proportion retention of wordlist material for healthy older adults (n = 24) across all conditions.

Condition	Mean	SD	SEM
UU	.814	.228	.047
FU	.867	.146	.030
UF	.767	.168	.034
FF	.536	.312	.064

Note. Uncapped proportion retention = delayed free-recall/immediate free recall. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

A one-way ANOVA found a significant effect of condition on uncapped proportion retention, F(3, 92) = 10.29, $p < .001$, $n^2_p = .251$. Paired-samples t-tests demonstrated that uncapped proportion retention in the FF condition was significantly poorer than all other conditions, t(23) = 4.158, $p < .001$, d = .849, t(23) = 4.606, $p < .001$, d = .940, t(23) = 3.694, $p = .001$, d = .754, for UU vs FF, FU vs FF, and UF vs FF, respectively. Additionally, participants performed significantly better within the FU condition compared to the UF condition, t(23) = 2.583, $p = .017$, d = .527. However, following Bonferroni corrections, this difference was no longer significant ($p > .0083$).

3.2.3.2 Possible Effects of Order and Active Rehearsal

Independent-samples t-tests indicated that there were no significant differences in mean uncapped proportion retention on the FU and UF conditions based on whether it was the first or third condition to be completed by the participants, t(22) = -

.775, *p* = .447, d = -.316, t(22) = .500, *p* = .622, d = .204, for FU and UF respectively. In addition, mean uncapped proportion retention did not vary significantly on the FU and UU conditions depending on whether participants expected delayed free-recall during these conditions, t(22) = .404, *p* = .426, d = .352, t(22) = 1.828, *p* = .081, d = .749, for FU and UU conditions respectively.

FU condition uncapped proportion retention did not significantly differ depending on whether participants engaged in conscious subvocal rehearsal, t(22) = .350, *p* = .730, d = .143. There was, however, a near-significant difference within the UU condition between those who reported engagement in conscious subvocal rehearsal and those who did not. Participants who reported to have engaged in conscious subvocal rehearsal during the wakeful rest period following immediate free-recall within the UU condition (n = 7, M = .953) recalled more items than those who did not (n = 17, M = .757), t(22) = 2.047, *p* = .053, d = .919.

From this, it can be concluded that the distractor task prior to delayed free-recall had some observed success in extinguishing STM maintenance. However, there are notable – yet non-significant - benefits of engaging in conscious subvocal rehearsal that are observed only within the UU condition. Subsequent explanations may account for this possible difference.

3.2.3.3 Spot-the-Difference Task Performance

Paired-samples t-tests established a learning effect whereby participants performed significantly better on the final Spot-the-Difference task of the final condition (occuring after the learning of the wordlist within the FF condition) compared to the Spot-the-Difference tasks that were performed during the first and third conditions (i.e., the FU and UF conditions), $t(23) = 2.816$, $p = .010$, $d = .575$, $t(23) = 2.110$, $p = .046$, $d = .431$, respectively. This was also seen in performances on the 1-minute Spot-the-Difference tasks prior to delayed free-recall in each condition, where participants scored better on the last condition compared to all other conditions. This may be indicative of growing familiarity with the demands of the task.

3.2.4 Discussion

Unlike the previous experiments (see Experiments 1 and 2), it appears that healthy older adults retain significantly less episodic content (wordlist items) when encoding is both preceded and followed by a more challenging effortful task (i.e., Spot-the-Difference task with four, rather than two, differences per picture pair). However, retention of this content is notably improved when participants are allowed to rest wakefully for a period of 9 minutes before and/or after encoding.

This general finding can be represented in the following manner: UU = FU = UF > FF. On the surface, this pattern of results more closely mirrors the predictions outlined by the temporal distinctiveness theory (UU > FU = UF > FF; see Table 1 on Page 50). Given that UU = UF and FU = UF, it seems that post-encoding engagement in an effortful task does not consistently elicit a high degree of interference comparable to that seen in the FF condition. This is in contrast with the consolidation theory, which would expect a comparable degree of interference between both the UF and FF conditions on the basis that an effortful task is encountered during the post-encoding delay interval in these conditions. However, it appears that the partial temporal isolation of the wordlist material following an instance of pre-encoding wakeful rest can sufficiently improve the distinctiveness and thus the retrieval of this content to a similar level seen across conditions consisting of post-encoding wakeful rest (i.e., the UU and FU conditions).

However, further evaluation of the results leads to the consideration of alternative explanations. One possible explanation for the observed poor mean uncapped proportion retention within the FF condition in Experiment 3 could involve cross-list PI between conditions. By the final condition (i.e., the FF condition), participants would have been exposed to three separate 15-item wordlists across the previous conditions. Residual memories for previous wordlist material may have begun to cumulate as participants progressed through the four conditions of the experiment. LTM for some of these items may have been more robust and resilient to further interference as a result of the post-learning environment supporting uninterrupted consolidation (i.e., minimal RI via post-encoding wakeful rest). This idea is supported by research which shows improved retention for prose material over longer delays consisting of further interference (i.e., up to seven days; Dewar et al., 2012b; Alber et al., 2014). Such benefits were persistent over extended periods of interference (i.e., everyday life), as long as new learning was immediately followed by a brief period of minimal RI.

Additionally, delayed-free recall of these earlier items during their respective conditions could theoretically lead to further strengthening via reconsolidation (Inda, Muravieva, & Alberini, 2011; explored later in Chapter 6). These processes could contribute to the unsolicited recall and further consolidation of prior items in later conditions, resulting in reduced consolidation of the target items due to a possible division in consolidative resources (Wixted, 2004). However, studies would suggest that the testing of previous items could result in improved uncapped proportion retention on subsequent trials (Szpunar, McDermott, & Roediger, 2008; Weinstein, McDermott, & Szpunar, 2011; Bäuml & Kliegl, 2013). Tests of delayed-free recall are believed to facilitate the formation of contextual cues that can be used to support list differentiation and reduce cumulative PI (Szpunar et al., 2008; Postman & Keppel, 1977). Such studies did not involve the introduction of interference both before and after wordlist presentation. Additional intra-condition interference elicited from engagement in alternative tasks (i.e., Spot-the-Difference task) may have disrupted the reduction of cumulative PI seen through testing.

As a result of this unhindered cumulative PI effect, the ability to remember items within the final condition may have been limited beyond the intended effects of the experimental manipulation. Since the wordlists consisted of items which were not distinctly related, it follows that the possible PI effects between conditions did not occur as a process of retrieval competition due to shared semantic similarity of the items.

Table 3.4a and 3.4b highlight the number of participants who reported items from earlier conditions in subsequent conditions, and the mean number of intrusive items recalled in each condition.

Table 3.4a. Percentage of participants who recalled intrusions during tests of immediate free-recall within the second, third and fourth conditions of Experiment 3.

Condition	Participants who recalled intrusions (%)	Mean number of intrusions recalled		
		Mean	SD	SEM
Second	4.167	.042	.204	.042
Third	25.000	.333	.702	.143
Fourth	29.167	.583	1.213	.248

Note. Mean number of intrusions recalled across conditions is also displayed. SD = Standard deviation, SEM = Standard error of the mean.

Table 3.4b. Percentage of participants who recalled intrusions during tests of delayed free-recall within the second, third and fourth conditions of Experiment 3.

Condition	Participants who recalled intrusions (%)	Mean number of intrusions recalled		
		Mean	SD	SEM
Second	25.000	.542	1.318	.269
Third	29.167	.417	.776	.158
Fourth	37.500	1.375	2.392	.488

Note. Mean number of intrusions recalled across conditions is also displayed. SD = Standard deviation, SEM = Standard error of the mean.

There were significantly more intrusions during immediate free-recall within the final condition (i.e., the FF condition) in comparison to the second condition (i.e., the UU condition), t(23) = 2.184, *p* = .039, d = .446. The difference in intrusions between these conditions may explain the observed significant difference in mean immediate free-recall performance between the respective conditions in Experiment

3. Participants also recalled more items from previous conditions during the test of immediate free-recall within the final condition in comparison to the third condition. However, this was only near-significant, t(23) = 1.904, p = .070, d = .389.

When considering intrusions occuring during delayed free-recall, there was only one near-significant difference, whereby more intrusions occurred during delayed free-recall of the final condition in comparison to the third condition, t(23) = .845, p = .078, d = .377. This finding may suggest that this possible cumulative PI effect may specifically impact immediate free-recall. It may be that the build-up of prior items in LTM limits new items from being initially encoded, or results in a division of limited consolidative resources between prior items and target items. Based on unsolicited reports during and after the experiment had concluded, a number of participants who recalled previous items in later conditions were aware that they had done so. This, however, does not indicate that a clear list differentiation had been adequately achieved.

An important detail that should be reiterated concerns counterbalancing and the use of two testing sessions. Participants completed four conditions across two testing sessions that occurred on separate days. As a result, intrusions occuring on the third condition were from items that were initially encoded anywhere from one day to one week previously. Since the third condition of the experiment could have been one of two conditions depending on assigned order group (i.e., the UF or FU condition), only half of the sample experienced the cumulative PI effect on these specific conditions during the third condition. Conversely, the UU condition and the FF condition always occurred during the second and fourth condition respectively. As a result, the build-up of previously encoded items was the same for all participants across these conditions based on their fixed position within the condition orders.

3.3 Experiment 4

3.3.1 Aims

The aim of Experiment 4 was to investigate the effects of interference before and after new learning in the absence of any cumulative cross-list PI effects. This was achieved by using the same methodology as Experiment 3, but with the adoption of a between-subjects study. With each participant only completing one out of the four conditions (UU, FU, UF, or FF), a more accurate observation of uncapped proportion retention could be made in the absence of PI effects which do not directly occur as a result of manipulations made within the specific condition. As an additional measure, recognition of the images seen during the Spot-the-Difference tasks was assessed at the end of the testing session (only across groups that completed the task; FU, UF and FF condition groups) to see whether the materials had been engaged with attentively.

In the absence of this cumulative PI effect, notable differences were expected. Most notably, performance on the FF condition should be substantially better in comparison to Experiment 3. As a result of this improvement due to the lack of an additional cross-list PI effect, the independent benefit of PI seen between the UF and FF condition may no longer be present. Regardless, performance on this condition should still remain significantly lower compared to conditions in which minimal RI is encountered (i.e., the UU and FU condition).

Since RI is encountered during the FF condition, significant decreases in memory retention should still occur.

Additionally, subtle overall improvements in uncapped proportion retention across all conditions should be seen. After the FF condition, this improvement may be best seen within the UU condition. This is due to the UU condition having a fixed position (i.e., second condition) in the condition orders within Experiment 3. As a result, all participants were susceptible to intrusions from the first condition. Only half of the participants in Experiment 3 were susceptible to PI from the previous two conditions during both UF and FU conditions. The other half of the sample either engaged in the UF or FU condition as the first condition of the first session, meaning no prior lists were encountered to pose as possible intrusions.

By introducing these changes, the predictions of each account (seen in Table 1 on Page 50) can be more reliably tested in the absence of possible retrieval interference following cross-list intrusions.

3.3.2 Methods

3.3.2.1 Participants

64 healthy older adults (17m/47f, mean age = 68.266 years, age range = 60 – 74 years; mean education = 16.531 years, education range =10 - 31 years) entered the experiment. A number of participants (n = 17) recruited for Experiment 4 had previously took part in Experiment 3. Based on the results from Experiment 3, it was decided that the use of prior participants was not an issue. This was assumed based on Experiment 3 analysis which determined that there were no significant

benefits depending on whether participants expected delayed free-recall of the wordlist material or not. In addition, the continued inclusion of distractor tasks prior to delayed free-recall would extinguish any information being maintained in STM. This is supported by the findings that were no significant differences observed between participants who reported to have engaged in conscious subvocal rehearsal and those who did not within conditions which consisted of minimal RI (i.e., UU and FU conditions).

Like the previous experiment, all participants had normal or corrected eyesight and hearing capabilities alongside no reported cognitive impairments. The experiment took place within the neuropsychology lab in the Psychology Department at the University of Edinburgh. Like previous experiments (i.e., Experiments 1, 3), participants were recruited from the Volunteer Panel. Testing was conducted in English.

3.3.2.2 Procedure

The procedure for Experiment 4 mirrored that of Experiment 3; however, there were two key differences. Within Experiment 4, participants were only asked to complete one of the four conditions (UU, FU, UF, or FF). Additionally, participants were asked to complete one or two recognition tests consisting of the materials within the Spot-the-Difference task(s) if encountered during the experiment (across the FU, UF and FF conditions).

Each participant was randomly allocated to one of these four condition groups prior to the commencement of the study. Additionally, participants were given questionnaires at the end of the experiment which corresponded to the condition they took part in. For participants who took part in conditions which consisted of minimal RI (i.e., UU and FU conditions), they were asked about whether they had engaged in conscious subvocal rehearsal during the wakeful rest period following immediate free-recall of the wordlist material.

Participants completed one or two yes/no recognition tests were conducted at the end of the experiment depending on if they had encountered a Spot-the-Difference task during the experiment. For those who encountered a single 9-minute Spot-the-Difference task either before or after wordlist encoding (i.e., during the FU or UF condition respectively), only one recognition test was administered. Two recognition tests were administered among participants who had encountered two separate Spot-the-Difference tasks during the experiment (i.e., participants within the FF condition group).

Within each recognition test, participants were presented with 36 images; 18 images were target images that the participant had encountered, the other 18 images were foils that the participant had not encountered during the experiment. Following the presentation of each image, participants were asked to report whether they had seen the image during the experiment, which was followed by a yes or no response.

Hit rates were computed by dividing the number of target items correctly recognised by the total number of targets (/18). Similarly, false alarm rates were computed by dividing the number of foils incorrectly recognised as targets by the total number of foils (/18). Recognition accuracy (d-prime, or d'), was calculated via the following equation: d'=z(hit rate) – z(false alarm rate). Many participants had a hit rate of 1, requiring a correction to be made (score was reduced by one half of a hit: 17.5/18). Similarly, many participants had a false alarm rate of

0, thus requiring a similar correction for the calculation of d' (score increased by one half of a false alarm: .5/18). On top of this, the correct response rate was calculated by adding the number of targets correctly recognised as targets (hits) and the number of foils correctly recognised as foils (correct rejections) and subsequently dividing this number by the total number of targets and foils (/36).

3.3.3 Results

3.3.3.1 Memory Performance

3.3.3.1.1 *Immediate free-recall*

Table 3.5 shows immediate free-recall scores of participants across each condition.

Table 3.5. Mean immediate free-recall for healthy older adults across all conditions.

Condition	Mean	SD	SEM
UU	.613	.173	.431
FU	.542	.175	.438
UF	.625	.156	.389
FF	.683	.143	.358

Note. Mean immediate free-recall = total items immediately recalled/total items presented. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Independent-samples t-tests demonstrated a significant difference in immediate free-recall scores between the FU and FF condition groups, with those within the FF condition group performing better, t(30) = 2.505 , *p* = .018 , d = .886 . The difference between these conditions equates to around two words (around 14% of total wordlist items presented within the condition). There were no significant differences between these two groups based on age or years of education which could account for the group differences on immediate free-recall. No outliers were identified which may be reducing the overall performance within the FU condition group.

Whilst a difference in immediate free-recall between groups is not ideal, the calculation of uncapped proportion retention again takes these discrepancies into account. No other significant differences in immediate free-recall were observed amongst the other condition groups.

3.3.3.1.2 *Uncapped proportion retention*

Figure 3.2 illustrates the mean uncapped proportion retention across all conditions for the between-subjects study.

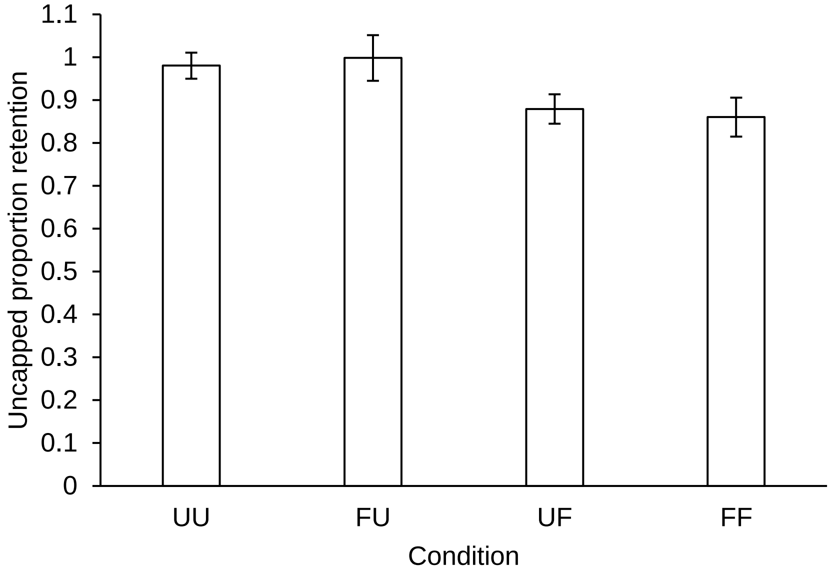

Figure 3.2. Mean uncapped proportion retention of healthy older adults (n = 64) across all experimental conditions in the between-subjects study. Uncapped proportion retention = delayed free-recall/immediate free-recall. Error bars represent SEM. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Table 3.6 provides a numerical overview of the mean uncapped proportion retention for the wordlist material across all of the experimental conditions.

Table 3.6. Mean uncapped proportion retention of wordlist material for healthy older adults across all conditions.

Condition	Mean	SD	SEM
UU	.980	.122	.030
FU	.998	.213	.053
UF	.879	.137	.034
FF	.860	.182	.045

Note. Uncapped proportion retention = delayed free recall/immediate free recall). SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

A one-way ANOVA found a significant effect of condition on uncapped proportion retention, $F(3, 60) = 2.784$, $p = .049$, $n^2_p = .122$. However, while independent-samples t-tests demonstrated that the UU condition group retained more words compared to both the FF condition group and the UF condition group, $t(30) = 2.195$, $p = .036$, d = .776, $t(30) = 2.202$, $p = .036$, d = .778, for UU vs FF, and UU vs UF, respectively, these findings were non-significant following Bonferroni corrections ($p > .0083$).

More independent-samples t-tests assessed differences in proportion retention, specifically between the FU condition group and the UF and FF condition groups. While the FU condition group retained more wordlist items compared to both the FF condition group and the UF condition group, $t(30) = 1.971$, $p = .058$, d = .697, $t(30) = 1.878$, $p = .070$, d = .664, for FU vs FF, and FU vs UF respectively, these differences were again non-significant.

3.3.3.2 Possible Effects of Active Rehearsal

Independent-samples t-tests indicated that there were no significant differences within both the FU and UU condition groups depending on whether participants engaged in conscious subvocal rehearsal or not. However, those who did report rehearsal did outperform those who did not numerically. Regardless, this finding provides further evidence to suggest the distractor tasks were sufficient in neutralising STM maintenance through interrupting conscious subvocal rehearsal.

3.3.3.3 Spot-the-Difference Task Performance

Paired-samples t-tests established a learning effect whereby participants performed significantly better on the final spot-the-difference task of the final condition (occuring after the learning of the wordlist within the FF condition) compared to the Spot-the-Difference tasks that were performed during the first and third conditions (i.e., the FU and UF conditions), $t(23) = 2.816$, $p = .010$, $d = .575$, $t(23) = 2.110$, $p = .046$, $d = .431$, respectively. This was also seen in performance on the 1-minute Spot-the-Difference tasks prior to delayed free-recall in each condition, where participants scored better on the last condition compared to all other conditions. This may be indicative of growing familiarity with the demands of the task.

Table 3.7 demonstrates mean performances across the recognition tests. Irrespective of the conditions consisting of Spot-the-Difference tasks, d’ was consistently high (alongside hit rates and correct response rates more generally). This indicates that participants were engaged with the material within the Spot-the-Difference task across all conditions.

Table 3.7. Mean recognition task measures across Recognition Test A and Recognition Test B.

	Recognition Test A			Recognition Test B		
	Mean	SD	SEM	Mean	SD	SEM
d'	3.497	.442	.078	3.488	.313	.056
Correct response rate	.971	.038	.007	.971	.026	.005
Hit rate	.984	.032	.006	.983	.033	.006
False alarm rate	.042	.058	.010	.040	.038	.007

Note. SD = Standard deviation, SEM = Standard error of the mean.

3.3.4 Discussion

With the removal of cross-list interference (seen in Experiment 3) through the use of a between-subjects design, healthy older adults were once again seen to retain considerable amounts of episodic content irrespective of whether or not an effortful task was encountered before and/or after new learning. This result is in line with the findings from Experiments 1 and 2, whereby the presence of an interpolated task during both pre- and post-encoding intervals had no discernible impact on the retention of prose material over a period of 10 minutes.

Again, the results of this experiment make it difficult to establish which theory (i.e., the consolidation theory and the temporal distinctiveness theory) provides a more representative explanation of forgetting in healthy populations, given that little forgetting occurred across all conditions. Both theories expect improved memory performance across a condition in which wakeful rest is encountered before and after new learning when compared to a condition in which an effortful task is instead engaged with during these intervals. However, this was not seen. These results call for the continued evaluation of the capacity of the Spot-the-Difference task to elicit interference of recently acquired episodic content (both for prose passages, and lists of unrelated words). This will be considered in the general discussion.

3.4 General Discussion

The findings from Experiments 3 and 4 further exemplify the difficulties of establishing interference effects – and consequently, benefits of wakeful rest – among healthy populations. The transition in episodic content from the use of prose passages to lists of unrelated words was motivated by the idea that wordlists may be more receptive to interference. Since the wordlist items used were unrelated and shared minimal semantic relatedness, memory strategies believed to support the high retention of prose passages across Experiments 1 and 2 (i.e., use of memory cues supported by story narrative) would not be in operation. This was reinforced by the use of a more engaging Spot-the-Difference task within Experiments 3 and 4 to ensure that any possible memory strategies could not be utilised during interfering tasks. However, both old and new problems arose.

In Experiment 3, cross-list PI following intrusions from prior conditions resulted in the misleading observation of a pattern of findings (i.e., UU = FU = UF > FF) that provided evidence in support of the temporal distinctiveness theory. It appears that these intrusions elicited a form of retrieval interference that neither the consolidation theory nor the temporal distinctiveness theory can directly explain. Given that the wordlist items were unrelated, it was likely that participants found it difficult to discern which item belonged to which list.

Following this, participants proceeded to retrieve previously recalled items in subsequent tests. This issue was not a factor within Experiments 1 and 2 since the story items were grouped together by a unique narrative that could not be easily confused.

In Experiment 4, it was reliably confirmed that the findings of Experiment 3 were predominantly the product of cross-list PI and not the result of a more engaging interpolated task that could elicit increased levels of interference compared to a previously used version (see Experiments 1 and 2). Using a between-subjects design, it was established that healthy older adults retained a substantial amount of wordlist items across all groups, despite some groups encountering more challenging Spot-the-Difference tasks before and/or after encoding. It cannot be claimed that participants may have disengaged with the task as a means of avoiding the interference of the wordlist material, given that recognition performance of the Spot-the-Difference material was notably high.

This brings us to question whether further measures would be required in order to adequately increase the degree of engagement in the interpolated task. Based on prior research, Spot-the-Difference tasks have been seen to elicit notable RI in healthy populations (Dewar et al., 2007, 2012; Alber et al., 2014; Sacripante et al., 2019). The Spot-the-Difference task used in Experiments 3 and 4 is objectively more challenging when compared to the similar task used in these studies, primarily due to the increased number of differences. However, a possibility remains that it is not the *degree* of engagement that determines the level of interference, but the *type* of engagement.

The Spot-the-Difference task was selected as the interpolated task on the basis that it elicited non-specific interference (see Page 71 for discussion). However, given that the material within the Spot-the-Difference task, and the task demands themselves, were unrelated to the to-be-retained material, it is possible that interfering the distinctiveness of the to-be-retained material with such a task could never be achieved. The semantic and modular distinctiveness of the episodic content may have supported its temporal distinctiveness at later retrieval. This idea is supported by the findings of Experiment 3, which saw reduced retention when the modular distinctiveness was not maintained due to intrusions from similar items (i.e., previously encoded words). Semantic distinctiveness of the to-be-retained material could also not be established within this experiment, given that no items belonged to the same semantic category. Such factors together may have contributed to the reduced retention of encoded wordlist content within the FF condition, given that this condition was subject to the full accumulation of previously encoded wordlist items from prior conditions. While this explanation may be regarded as purely speculative, it does open up a dialogue about how different forms of distinctiveness may interact to counter potentially interfering pre- and post-encoding activity. However, given that we are ultimately left with null results, it is difficult to say whether distinctiveness is a relevant topic of discussion in the conversation of forgetting in healthy populations.

Chapter 4:

Accountability of interference-based theories of forgetting among patients with anterograde amnesia

4.1 Introduction

Across Chapters 2 and 3, a number of investigations exploring PI and RI effects among neurologically intact populations were discussed. In Experiments 1 and 2, it was determined that the introduction of interpolated activity (i.e., a Spot-the-Difference task) immediately before or after the acquisition of episodic content (i.e., prose passages) had no significant effect on retention over a period of 10 minutes. This was seen irrespective of differences in educational experience which may have been associated with an increased resilience to interference. A number of explanations were subsequently outlined.

One proposed explanation was that prose retention may be greatly facilitated by the maintenance of interference-resistant retrieval cues in healthy populations. The interlinked nature of salient cues to the story context allows for them to be more easily maintained and resilient to further interference. As a result of this, subsumed items of lesser importance to the overall story can be adequately retrieved later via the preserved cues. Maintenance of these cues may be additionally aided by very brief instances of rest during post-study tasks that do not demand continuous engagement.

However, across Experiments 3 and 4 in Chapter 3, it was ultimately concluded that the retention of lists of unrelated word items were also unaffected by pre- and post-study task engagement, even when these tasks were objectively more challenging (i.e. Spot-the-Difference task consisting of twice as many differences).

While it appears that there is a pronounced difficulty in establishing interference effects in healthy populations (and thus, evaluating the accountability of interference-based theories of forgetting), this cannot be automatically assumed to apply to those with compromised memory systems. As previously discussed, patients presenting with AA have not only shown compelling improvements to LTM retention when RI was minimised via post-encoding wakeful rest (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2009; 2010; 2012a; Alber et al., 2014), but have also shown improvements following minimal PI (Moscovitch, 1982; Freedman & Cermak, 1986; Janowsky et al., 1989; Shimamura, 1995; Kopelman, 2002; Baldo & Shimamura, 2002).

With respect to the previously used paradigm across Experiments 1-4 (see Chapter 2 and 3), it remains a possibility that patients with AA could additionally benefit from pre-encoding wakeful rest that is not readily seen in healthy adults. Given that no study has attempted to simultaneously assess the benefits of both pre- and post-encoding wakeful rest to LTM retention in amnesic patients, it remains unknown whether both benefits will be experienced. If so, it may suggest that alternative theories of forgetting.

4.2 <u>Experiment 5</u>

4.2.1 Aims

The aims of the current experiment were to assess whether there were possible benefits of individually and simultaneously minimising *both* pre- *and* post-study task engagement to LTM retention of prose material in patients with AA. Given that previous experiments (i.e., Experiment 1, 2 and 4) demonstrated a lack of interference effects and wakeful rest benefits in healthy adults, this experiment intends to see whether this will continue to be seen when the retention of episodic content (prose material) is assessed among a sample of amnesic patients. This marks the first experimental attempt to concurrently assess PI and RI effects in amnesic patients as a means of evaluating the accountability of the consolidation theory and the temporal distinctiveness theory. Again, this evaluation was conducted by comparing memory performances across conditions where pre- and post-encoding activity had been manipulated in order to establish which set of predictions from each theory (seen in Table 1 on Page 50) accurately reflects the pattern of forgetting overall within this paradigm.

4.2.2 Methods

4.2.2.1 Participants

Twelve patients with a diagnosis of AA (7m/5f, mean age = 53.75 years, age range = 22 – 82 years; mean education = 11.58 years, education range = 5 – 17 years) entered the experiment (see Table 4.1a and Table 4.1b for demographic and anatomical measures of patients 1-6 and 7-12 respectively).

Table 4.1a. Selected demographic and anatomical measures for each amnesic patient (P1-P6).

Measure	Amnesic patients (P1-P6)					
	P1	P2	P3	P4	P5	P6
Age	82	54	22	52	55	57
Education (years)	10	13	11	8	17	13
Gender	m	m	f	f	m	M
Aetiology	CPCI	HYP	TBI	ISCH	OH	A
Known lesion sites	LRF	LRF	DAI, LFT	RTP	BA	LRF, RMT
Days since damage	170	95	1145	100	1330	900

Note. Aetiology: A = aneurysm, CPCI = chronic progressive cognitive impairment, HYP = hypoxia, ISCH = ischemia, OH = obstructive hydrocephalus, TBI = traumatic brain injury. Lesion site: L = left; R = right; F = frontal; P = parietal; T = temporal, M = medial, DAI = diffuse axonal injury, BA = territory of the basilar artery, according to CT or MRI.

Table 4.1b. Selected demographic and anatomical measures for each amnesic patient (P71-P12).

Measure	Amnesic patients (P7-P12)					
	P7	P8	P9	P10	P11	P12
Age	58	32	72	42	52	67
Education (years)	8	13	5	13	13	15
Gender	f	m	m	m	f	F
Aetiology	A	TBI	S	TBI	PI	H
Known lesion sites	DAI, LRF	LRF, LT	CR	RF	PR	BA
Days since damage	1275	950	105	1095	190	2190

Note. Aetiology: A = aneurysm, H = haemorrhage, PI = pontine ischemia, S = stroke, TBI = traumatic brain injury. Lesion site: L = left; R = right; F = frontal; T = temporal, DAI = diffuse axonal injury, BA = territory of the basilar artery, PR = pons region, CR = corona radiate, according to CT or MRI.

All participants were recruited and tested at the Dipartimento di Riabilitazione, Ospedale Somma Lombardo, Italy. All participants were native-Italian outpatients with no known pre-morbid psychiatric or neurological histories. All participants were assessed with numerous neuropsychological tests (see Table 4.1c and Table 4.1d for neuropsychological measures of patient 1-6 and 7-12 respectively).

Table 4.1c. Selected neuropsychological measures for each amnesic patient (P1-P6).

Measure	Amnesic patients (P1-P6)						Criteria
	P1	P2	P3	P4	P5	P6	
PRMQ Patient[a]	37	42	27	28	25	34	> 0
PRMQ Caregiver[a]	47	69	38	36	63	62	> 0
RBMT-3 classification[b]	Sig	Sig	Sig	Bor*	Sig	Sig	Sig impair
Rey's 15 words – immediate[c]	18*	39	28*	41	22*	25*	> 28.5
Rey's 15 words - delayed[c]	2	0	1	3	4	1	< 4.6
Rey figure copy[d]	31	33	34	30	36	36	> 28.87
Rey figure delayed[d]	1	5	10.5*	13*	5.5	7.5	< 9.46
Digit span[e]	4	5	5	7	5	4*	> 3.5
Corsi blocks[e]	4	4	4	4	4	4	> 3.25
Token test[f]	29	34	32	34	36	32	> 26.2
AAT[g]	NA	NA	NA	NA	NA	NA	NA
Phonological fluency[h]	20	34	35	18	32	17*	> 17.35
Verbal reasoning[i]	47	39	52	46	47	54	> 32
Raven progressive matrices[j]	18	23	35	17*	36	31	> 18
Cognitive estimation[k] accuracy	19*	19*	17	16	15	17	< 18
Cognitive estimation[k] bizarre	6*	3	2	5*	2	3	< 4
Wisconsin card sorting test[l]	118*	68	34	88	88	98*	< 90.59
MMSE[m]	24	26	26	28	30	24	> 24

Notes. [a] Smith, Della Sala, Logie, & Maylor, 2000, [b] Wilson et al., 2008, [c] Carlesimo et al., 1996, [d] Caffarra et al., 2002, [e] Orsini et al., 1987, [f] De Renzi & Faglioni, 1978, [g] De Blesser et al, 1986, [h] Novelli et al., 1986, [i] Spinnler & Tognoni, 1987, [j] Basso et al., 1987, [k] Della Sala et al., 2003, [l] Laiacona et al., 2000, [m] Measso et al., 1993. NA = no aphasia, * Instance where a performance does not match inclusion criteria.

Table 4.1d. Selected neuropsychological measures for each amnesic patient (P7-P12).

Measure	Amnesic patients (P7-P12)						Criteria
	P7	P8	P9	P10	P11	P12	
PRMQ Patient[a]	33	21	30	47	51	39	> 0
PRMQ Caregiver[a]	57	35	39	38	67	47	> 0
RBMT-3 classification[b]	Sig	Sig	Av*	Sig	Sig	Sig	Sig impair
Rey's 15 words – immediate[c]	13*	39	28	29*	26*	24*	> 28.5
Rey's 15 words – delayed[c]	1	3	2	4	3	3	< 4.6
Rey figure copy[d]	36	31	7.5*	36	18.5*	33	> 28.87
Rey figure delayed[d]	6	15*	4.5	10*	7	6	< 9.46
Digit span[e]	5	5	4	6	6	5	> 3.5
Corsi blocks[e]	4	3*	5	7	5	6	> 3.25
Token test[f]	33	33	29	34	34	33	> 26.2
AAT[g]	NA	NA	NA	NA	NA	NA	NA
Phonological fluency[h]	16*	34	23	42	30	15*	> 17.35
Verbal reasoning[i]	47	44	33	53	38	45	> 32
Raven progressive matrices[j]	22	34	18	36	32	35	> 18
Cognitive estimation[k] accuracy	23*	32*	17	8	17	18*	< 18
Cognitive estimation[k] Bizarre	4	14*	3	3	5*	2	< 4
Wisconsin card sorting test[l]	108*	98*	108*	19	128*	118*	< 90.59
MMSE[m]	25	21*	24	29	25	28	> 24

Notes. [a] Smith, Della Sala, Logie, & Maylor, 2000, [b] Wilson et al., 2008, [c] Carlesimo et al., 1996, [d] Caffarra et al., 2002, [e] Orsini et al., 1987, [f] De Renzi & Faglioni, 1978, [g] De Blesser et al, 1986, [h] Novelli et al., 1986, [i] Spinnler & Tognoni, 1987, [j] Basso et al., 1987, [k] Della Sala et al., 2003, [l] Laiacona et al., 2000, [m] Measso et al., 1993. NA = no aphasia, * Instance where performance does not match inclusion criteria.

Performances across these tests were used in conjunction with inclusion criteria to identify participants who were appropriate for the current experiment. The inclusion criteria, which closely matched that used in similar past research (Cowan et al., 2004; Dewar et al., 2010), consisted of the following: (a) reports from family of an abrupt onset of memory problems as the main symptom; (b) memory problems supported by self-reports on the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie, & Maylor, 2000); (c) classification as amnesic based on the Rivermead Behavioral Memory Test (RBMT-3; Wilson et al., 2008); (d) performance below cut-off for normality in verbal delayed recall (Rey's 15 words; Carlesimo et al., 1996) and nonverbal delayed recall (Rey Figure Copy; Caffarra, Vezzadini, Deici, Zonato, & Venneri, 2002); (e) normal performance in verbal and nonverbal short term memory tasks (digit span and Corsi blocks; Orsini et al., 1987); (f) score within the normal range on test of verbal comprehension (Token Test; De Renzi & Faglioni, 1978); (g) score within the normal range on an aphasia test battery including comprehension (Aachen Aphasie Test; De Bleser et al., 1986); (h) score within the normal range on test of verbal fluency (Novelli et al., 1986); (i) scores within the normal range in verbal reasoning (Verbal Judgement Test; Spinnler & Tognoni, 1987); (j) scores within the normal range in nonverbal reasoning (Raven's Progressive Matrices; Basso, Capitani, & Laiacona, 1987); (k) scores within the normal range on test of cognitive estimation (Cognitive Estimation Test; Della Sala, MacPherson, Phillips, Sacco & Spinnler, 2003); (l) scores within the normal range on the Wisconsin Card Sorting Test (WCST; Laiacona, Inzaghi, De Tanti, & Capitani, 2000); (m) scores within the normal range on the Mini Mental State Examination (MMSE; Measso et al., 1993). Participants were recruited on the basis that they met the majority of the inclusion criteria listed above.

4.2.2.2 Procedure

The current experiment adopted the procedure used across Experiments 1-3 (see Figure 2.1 in Chapter 2).

4.2.2.3 To-Be-Retained Material

Again, all participants were presented with a prose passage after the 9-minute pre-study delay interval within each condition, totalling four prose passages throughout the course of the experiment.

The four prose passages used in the current experiment matched those used in Experiment 2. Scoring procedures from Experiment 2 were used. Inter-rater reliability (IRR) was again computed. Table 4.2 highlights the ICCs between scores of immediate and delayed free-recall across all conditions. Mean ICCs across immediate and delayed free recall scores was in the excellent range (ICCs = .764 for immediate, ICCs = .798 for delayed; Cicchetti, 1994), indicating that raters had a high degree of agreement. Once again, the original scores were used in the subsequent analyses. Reported findings did not vary significantly depending on which set of scores was used.

Table 4.2. Intra-class correlation coefficients (ICC) of immediate and delayed free-recall scores between two raters across all experimental conditions.

Condition	ICC	
	Imm	Del
UU	.790	.816
FU	.713	.796
UF	.818	.690
FF	.734	.890

Note. Imm = mean immediate free-recall, Del = mean delayed free-recall. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Delayed free-recall of each prose passage was also assessed. Deception procedures used in the previous studies (i.e. Experiments 1-3) were adopted for the current experiment as a means of analysing surprise vs expected delayed free-recall in targeted conditions.

Proportion retention within each condition was calculated by dividing the number of story ideas recalled correctly after delayed free-recall by the number of story ideas recalled correctly at immediate free-recall. Proportion retention was capped at 1. There were only three instances in which proportion retention exceeded 1 (in which a participant recalls more items during delayed free-recall in comparison to immediate free-recall). Due to the inconsistency of superior delayed free-recall, it appeared more likely that these cases were a result of incomplete recall during immediate testing, rather than a systematic recovery of items during the post-study delay. The overall results remained the same when performance was uncapped; however, the variance within certain conditions was markedly higher. Given this, the decision was made to keep proportion retention capped.

4.2.2.4 Delay Intervals

Identical to Experiments 1-4, 9-minute pre-study and post-study delay intervals immediately preceding and following prose presentation and immediate free-recall assessment were either filled or unfilled.

4.2.2.4.1 *Filled delay intervals*

Filled delay intervals consisted of the same task used in both Experiment 1 and 2 (i.e., Spot-the-Difference task). The version of the Spot-the-Difference task used in the studies of Chapter 2 was adopted due to its reduced difficulty (i.e. two differences per pair, as opposed to four in later versions). Based on the varying degrees of cognitive impairment seen across the patient sample, it was determined that the use of a less demanding interpolated task would avoid excessive overload, potential fatigue and at-floor performances in most participants. However, it was still assumed that interference effects should still be observed using such a task based on the heightened sensitivity of patients with anterograde amnesia to interference.

Like all previous studies which employ the Spot-the-Difference task (i.e. Experiment 1-4, also Experiment 6), participants were first introduced to the Spot-the-Difference task via a practice trial consisting of 2 picture pairs as a means of familiarizing participants with the demands of the task.

The Spot-the-Difference task was again used as a distractor task within the current experiment to ensure that any conscious subvocal rehearsal occuring during post-study wakeful rest would be interrupted, extinguishing rehearsed information being maintained within STM.

4.2.2.4.2 *Unfilled delay intervals*

Unfilled delay intervals consisted of wakeful rest which mirrored all previous experiments (i.e. rest in quiet, darkened room).

4.2.2.5 Post-Session Debriefing

At the end of each session, participants were asked to complete a short questionnaire. Matching the questionnaire used in Experiment 2, the main purpose of the questionnaire was to again gain a more accurate account of whether or not conscious subvocal rehearsal occurred during the experiment and under which circumstances.

4.2.2.6 Counterbalancing

The counterbalancing measures used in Experiments 1 and 2 were adopted for the current study. It is important to note that while these counterbalancing measures are appropriate to ensure surprised delayed free-recall in key conditions, some order effects could be experienced. In Experiment 3, it was seen that an accumulation of intrusions across conditions could result in poorer performances in later conditions beyond the manipulations of the condition itself. However, this issue appeared to be absent across the experiments which utilised prose passages. It appears that items within prose passages are more distinguishable from one another, while items from lists of unrelated words are less so. Given this, it was concluded that the use of two counterbalanced groups within the current experiment was justified.

4.2.2.7 Statistical Analysis

All statistical analyses were conducted using JASP, allowing for the conduction of Bayesian analyses alongside conventional analyses. Immediate free recall across conditions was assessed via Bayesian paired-samples t-tests. Bayesian paired-samples t-tests of proportion retention across all conditions (UU vs FU vs UF vs FF) were also conducted. Additional Bayesian analyses were conducted to see whether there were potential order effects or differences in performance based on self-reported conscious subvocal rehearsal or expectance of delayed free recall. Alike previous experiments, the alpha level was set at .05 for all analyses excluding conventional paired-samples t-tests, where the alpha level was set at .0083.

Similar to Experiment 2, the use of Bayesian analyses within the current experiment was justified based on the small sample size. The use of Bayesian statistics allows for the conduction of analyses that does not require alpha adjustments (see Dienes, 2011; Kruschke, 2010) that further contribute to lowering statistical power within a small sample (Courgeau, 2012).

4.2.3 Results

4.2.3.1 Memory Performance

4.2.3.1.1 *Immediate free-recall*

Table 4.3a shows mean immediate free recall scores of amnesic patients (n = 12) across all conditions. Bayesian paired-samples t-tests demonstrated no strong evidence (BF < 3.00) that amnesic patients scored differently on tests of immediate free-recall across all conditions. It is, however, important to highlight that immediate free-recall was poor overall across the conditions. Evidently, some patients within the sample did not exhibit preserved immediate free-recall which is usually seen in those with AA. This is supported by pathological performances from multiple patients across key neuropsychological tests (i.e. Rey's 15 words – immediate recall; Rey Figure Copy, digit span, etc.).

Table 4.3a. Mean immediate free-recall of amnesic patients across all experimental conditions.

Condition	Mean	SD	SEM
UU	.264	.095	.028
FU	.194	.094	.027
UF	.200	.096	.028
FF	.230	.089	.026

Note. Immediate free-recall = number of prose ideas recalled/total number of prose ideas presented. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

4.2.3.1.2 *Proportion retention*

Figure 4.2 demonstrate the group mean proportion retention of the prose material for the amnesic patients across all conditions.

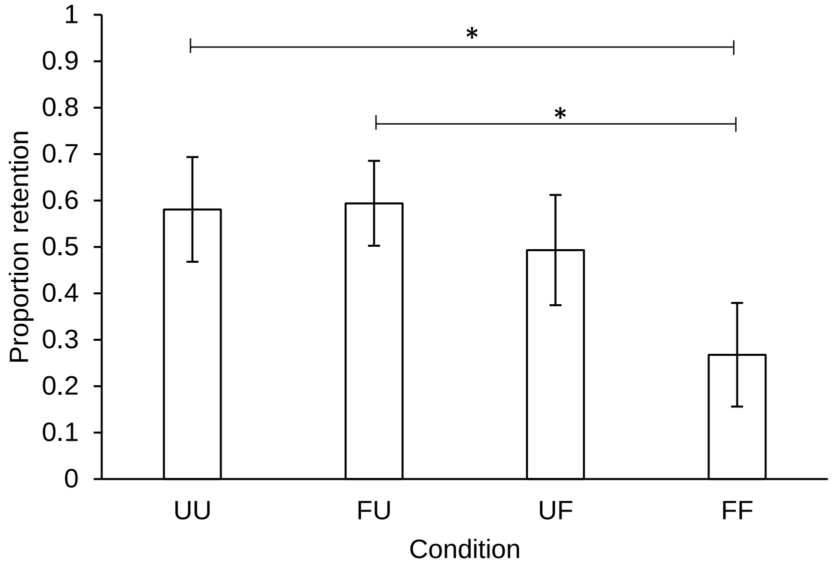

Figure 4.2. Mean proportion retention of amnesic patients across all experimental conditions. Proportion retention = delayed free-recall/immediate free-recall. Error bars represent SEM. * = BF_{10} > 3.00. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Table 4.3b provides a numerical overview of the mean proportion retention of the prose material for amnesic patients across all of the experimental conditions.

Table 4.3b. Mean proportion retention of prose material for amnesic patients across all conditions.

Condition	Mean	SD	SEM
UU	.581	.391	.113
FU	.594	.317	.091
UF	.493	.411	.119
FF	.268	.387	.112

Note. Proportion retention = delayed free recall/immediate free recall. SD = Standard deviation, SEM = Standard error of the mean. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

Conventional and Bayesian paired-samples t-tests were conducted to analyse whether there were notable differences in proportion retention performance between each condition. Table 4.3c highlights the results of the t-tests. One of the t-tests was performed with the adoption of a one-tailed hypothesis (i.e. UU vs FF). This was done with respect to the shared predictions of the two accounts which would expect to see superior performance within the UU condition.

Table 4.3c. Results from Bayesian and conventional paired samples t-tests of proportion retention for amnesic patients.

Comparison	t	df	*p*	d	BF_{10}
UU vs FF*	2.239	11	.023	.646	3.380
UU vs UF	.575	11	.577	.166	.463
UU vs FU	-.097	11	.925	-.028	.289
FU vs FF	3.060	11	.011	.883	5.539
FU vs UF	.788	11	.447	.227	.569
UF vs FF	1.789	11	.101	.517	.980

Note. Proportion retention = delayed free-recall/immediate free-recall. * = one-tailed hypothesis. UU = unfilled pre-encoding delay interval – unfilled post-encoding delay interval; FU = filled pre-encoding delay interval – unfilled post-encoding delay interval; UF = unfilled pre-encoding delay interval – filled post-encoding delay interval; FF = filled pre-encoding delay interval – filled post-encoding delay interval.

There was strong evidence for differences between the UU and FF conditions, as well as the FU and FF conditions (BF > 3). However, when reflecting upon the conventional paired-samples t-tests, there was no significant differences in retention between these conditions when Bonferroni corrections were implemented.

4.2.3.2 Possible Effects of Order and Active Rehearsal

Bayesian independent-samples t-tests indicated no strong evidence supporting differences on the FU and UF condition based on condition order, whether participants expected delayed free recall during the first condition or not, and whether participants reported to have attempted intentional rehearsal (see Table 4.3d and Table 4.3e for FU and UF respectively).

Table 4.3d. Results from Bayesian and conventional paired samples t-tests of proportion retention (delayed free recall/immediate free recall) across the FU condition in amnesic patients comparing performance based on condition order (FU first vs UF first), whether delayed recall was expected or not (No vs Yes), and whether participants reported to have rehearsed during the condition (No vs Yes).

	FU				
Comparisons	t	df	p	d	BF_{10}
Condition Order	.088	10	.932	.051	.468
Expected Recall	1.385	10	.196	.811	.838
Rehearsed	1.386	10	.196	.800	.835

Table 4.3e. Results from Bayesian and conventional paired samples t-tests of proportion retention (delayed free recall/immediate free recall) across the UF condition in amnesic patients comparing performance based on condition order (FU first vs UF first), whether delayed recall was expected or not (No vs Yes), and whether participants reported to have rehearsed during the condition (No vs Yes).

	UF				
Comparisons	t	df	*p*	d	BF_{10}
Condition Order	.349	10	.734	.201	.486
Expected Recall	.201	10	.845	.118	.477
Rehearsed	.891	10	.394	.515	.600

From this, it was concluded that the distractor task was sufficient in extinguishing STM and preventing superior memory retention via conscious subvocal rehearsal.

4.2.3.4 Spot-the-Difference Task Performance

Bayesian paired-samples t-tests established a learning effect whereby amnesic patients scored better on the Spot-the-Difference tasks occuring before or after new learning in the final condition (FF condition) compared to the first condition (either the FU or UF condition), before new learning: BF_{10} = 4.096, conventional $t(1, 11) = 2.851$, $d = .823$; after new learning: BF_{10} = 9.359, conventional $t(1, 11) = 3.422$, $d = .988$. This was also seen in performance on the 1-minute Spot-the-Difference tasks prior to delayed free recall in each condition, where amnesic patients scored better on the last condition compared to the first two conditions. This may be indicative of growing familiarity with the demands of the task.

4.2.4 Discussion

Amnesic patients were better able to retain substantial portions of newly encoded prose material after a delay of 10 minutes when an unfilled period consisting of wakeful rest immediately followed prose learning (i.e., during the UU and FU condition). This generally supports the notion that patients with AA maintain a poor but nevertheless functional ability to commit new episodic memories to LTM; an ability that is profoundly promoted by minimal RI via post-encoding wakeful rest (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2009; 2010; 2012a; Alber et al., 2014).

Prose retention was improved in amnesic patients within the current experiment as a result of post-encoding wakeful rest, regardless of whether the pre-encoding delay interval was filled or unfilled (i.e., during the FU and UU conditions respectively). Additionally, prose retention was consistently poorer as a result of filled post-encoding delay intervals consisting of a Spot-the-Difference task (i.e., during the UF and FF conditions).

Overall, it appears that RI encountered following post-encoding engagement with an effortful task has a consistent detrimental impact on retained episodic information in amnesic patients. The immediate introduction of wakeful rest after encoding allows for these negative effects to be circumvented via reduced exposure to further sensory stimulation. This benefit does not appear to be a product of uninterrupted STM maintenance in the present experiment since short distractor tasks preceding delayed free-recall adequately extinguished any information maintained in STM in those who engaged in conscious subvocal rehearsal during post-encoding wakeful rest.

While the effects of post-encoding activity were consistently observed, the effects of pre-encoding activity on prose retention in amnesics were not. There was no apparent benefit resulting from the individual introduction of pre-encoding wakeful rest in a condition where a filled delay interval followed encoding (i.e., during the UF condition). Greater improvements to prose retention were not observed in conditions consisting of post-encoding wakeful rest when pre-encoding wakeful rest had additionally been introduced (i.e., during the UU condition). However, while pre-encoding activity may appear largely irrelevant to the successful retention and retrieval of episodic information in anterograde amnesia, this is potentially deceptive.

A superadditive decline in mean memory performance on the FF condition was observed following the concurrent presence of both pre- and post-encoding activity. The combined effect of both RI and PI within a single condition reasonably outweighs the individual interference effects seen due to the sole introduction of RI or PI in other conditions (i.e., UF and FU conditions). Given this unique effect, it appears that while RI vastly impairs the LTM retention of episodic information in amnesic patients, PI may play a secondary, interactive role alongside RI to produce more acute degrees of forgetting in amnesics.

These findings favour consolidation theory based on the greater importance of post-encoding activity as a determinant of successful retention and retrieval. When post-encoding interference is encountered (i.e., during the UF and FF conditions), the consolidation of the prose material is believed to be interrupted via the processing of additional material within the spot-the-difference task. This is directly in line with previous research which has demonstrated improvements to LTM retention following minimal RI (Cowan et al, 2004; Della Sala et al., 2005; Dewar et al., 2009, 2012a; Alber et al., 2014). Additionally, it supports the notion that forgetting can be elicited via the post-encoding introduction of stimuli which is modally and semantically unrelated to the to-be-retained material (Dewar et al., 2010).

Such findings have been partially attributed to resource competition (Wixted, 2004; Dewar et al., 2009). It is assumed that all cognitive processes - including the encoding and consolidation of episodic information (Varma et al., 2017) – require an amount of resources drawn from a finite “energy budget” in order to be performed (Raichle & Gusnard, 2002; Wixted, 2004). This limited cognitive resource, which is distributed among many cognitive processes (Raichle & Gusnard, 2002) is believed to be substantially constrained in those with AA (Wixted, 2004; Dewar et al., 2009), although this is yet to be fully understood. Given this assumption, the reallocation of resources following the processing of post-encoding stimuli (i.e., during the spot-the-difference task) may have resulted in the depletion of resources available for the consolidation of previously acquired episodic information (i.e., prose material). As a result, synaptic consolidation is believed to be greatly hindered and episodic memory traces remain in a weakened state that leaves them prone to forgetting. Conversely, under conditions of minimal post-encoding sensory stimulation (i.e., during the UU and FU conditions), the consolidation of previously learned episodic memories can remain uninterrupted in amnesic patients as the significant division of residual resources is avoided.

While the sole benefit of post-encoding wakeful rest could also be seen as supportive evidence for temporal distinctiveness theory, the lack of similar benefits following pre-encoding wakeful rest – in which uni-directional temporal isolation is also attained - weakens this position. As such, marked benefits from uni-directional temporal isolation were only observed in amnesic patients when it occurred after encoding, but not before. This stands in contrast to studies conducted on healthy samples which saw benefits following both pre- and post-encoding rest benefits over shorter intervals (Ecker et al., 2015b).

Reflecting on limitations, the poor immediate free-recall performance of the amnesic patients may be problematic. The amount of material initially encoded was substantially small, which may have contributed to an increased difficulty in establishing more notable differences between certain key conditions – mainly, between the FU and UF conditions. However, poor immediate free-recall for prose material (Cowan et al., 2004; Dewar et al., 2010; Alber et al., 2014), as well as for word lists (Dewar et al., 2012b), is a common observation in amnesic patients. A LTM component is likely present within the assessment of immediate free-recall, leading to likely observations of poorer performances as a result of the limited LTM capacities of this group. Poor immediate free-recall performance within the current sample, alongside impaired performance on key neuropsychological tests conducted prior to the experiment, may be indicative of a patient sample that is severely impaired. This can also be considered in conjunction with the variability of performances seen across the patients, with some patients performing at floor regardless of whether unfilled intervals of wakeful rest preceded or followed prose presentation. While it was not evident from the sample that floor performances corresponded to specific aetiologies, future research adopting the current paradigm could investigate this further; assessing and comparing performance across a larger number of patients who vary based on lesion loci (i.e., frontal vs temporal patients).

Irrespective of this, it appears that AA patients are predominantly susceptible to interference resulting from post-encoding engagement with further sensory stimulation. Reducing post-encoding activity via wakeful rest appears to facilitate the successful retention of newly encoded episodic information in amnesics that would have otherwise been forgotten over a period of 10 minutes. Given that pre-encoding activity does not appear to have a substantial effect on the retention of episodic memory in amnesics over this time period, accounts expecting notable effects remain unsupported by the current findings. Rather, explanations which emphasise the importance of post-encoding effects – such as the consolidation interference account – seem to better fit the pattern of forgetting seen among amnesics within the current study. However, the novel observation of a superadditive effect following the simultaneous presence of PI and RI alludes to a smaller role of PI.

Chapter 5:

Minimal interference and prospective memory

5.1 Introduction

Throughout the thesis so far, it has been both discussed and demonstrated that a reduction of RI - by means of post-encoding wakeful rest – can facilitate LTM retention of episodic information in healthy adults (Müller & Pilzecker, 1900; Dewar et al., 2007; 2009; 2012b; Alber et al., 2014; Craig et al., 2014; see Chapter 3). However, this benefit is not always consistent (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2010; Martini et al., 2017; 2018; Varma et al., 2017; see Chapter 2).

Across Experiments 1 and 2, instances were seen in which healthy younger and older adults showed little to no observable benefits from both pre- and post-encoding wakeful rest. However, in Chapter 3, findings from Experiments 3 and 4 allude to a number of possible factors mediating the magnitude of the observable benefits of minimal interference. This includes the nature of the to-be-retained material. Reflecting on the findings from Experiments 1 and 2, it appears that certain information – such as verbally presented prose passages - may benefit substantially from retrieval strategies which circumvent interference from non-specific interference tasks. These strategies may be facilitated by brief respites during less engaging post-encoding tasks, although the extent to which this affects memory performance remains unknown.

From Experiment 3, it can be seen that cumulative inter-condition interference may inadvertently inflate pre-encoding wakeful rest benefits seen with other information – more specifically, visually presented word lists. As a result of this, the benefits of post-encoding wakeful rest appear less prominent, albeit present. Experiment 4 demonstrates that the benefits of post-encoding wakeful rest remain in the absence of inter-condition interference, whilst previous observations of pre-encoding wakeful rest benefits dissipate. With this in mind, it appears that RI – and its minimisation – is the more influential factor in dictating the degree of retention and forgetting in healthy adults.

While there is a growing literature supporting the idea that minimal RI via post-encoding wakeful rest facilitates the retention of information in episodic LTM, it has yet to be established whether this specific wakeful rest benefit extends to prospective memory (PM).

PM is defined as the ability to remember to carry out planned activities in the future (Brandimonte, Einstein, & McDaniel, 1996; Kliegel, McDaniel, & Einstein, 2008). We rely on PM to perform a variety of tasks in our everyday lives; ranging from remembering to send an email to a colleague before the end of the week to taking important medication before going to sleep. Recent studies have reported that sleep following the administration of PM task instructions significantly improves performance on the subsequent PM test, even after 12 (Scullin & McDaniel, 2010) to 48 hours (Diekelmann, Wilhelm, Wagner, & Born, 2013a; 2013b) following instruction presentation. The enhancement of both retrospective (to recall that something has to be performed) and prospective components (to recall what has to be performed) of PM tasks following post-instruction sleep has been interpreted in terms of facilitated consolidation (Diekelmann & Born, 2010). During post-instruction sleep, participants are no longer exposed to further sensory stimulation that may retroactively interfere with the consolidation of recently learned PM instructions. This interpretation mirrors explanations proposed to account for the benefits of post-encoding wakeful rest to episodic LTM retention (Müller & Pilzecker, 1900; Wixted, 2004; Scullin & McDaniel, 2010).

Given the similarities, it follows that wakeful rest after PM instruction may result in comparable improvements in performance when compared to a post-instruction delay filled with an effortful task.

5.2 <u>Experiment 6</u>

5.2.1 Aims

The current experiment aimed to assess PM under conditions previously seen to benefit or hinder LTM retention; namely, a brief period of wakeful rest or interference via an effortful task following new learning respectively. To investigate this, performance on an event-based PM task was assessed when PM task instruction was followed by: (a) an unfilled post-encoding delay interval consisting of wakeful rest; or (b) a filled post-encoding delay interval consisting of a non-specific interfering task (i.e., Spot-the-Difference task). Based on the past findings from minimal RI research into episodic memory, and the observed benefits of post-instruction sleep on PM, performance on a test of PM was predicted to be significantly better if instructions were immediately followed by a brief instance on wakeful rest. Conversely, it was predicted that a marked decrease in PM performance would be observed if PM task instruction was followed by further demanding tasks.

5.2.2 Method

5.2.2.1 Participants

Thirty-two healthy younger adults (6m/26f, mean age = 18.81 years, age range = 17 - 25 years; mean education = 14.06 years, education range = 13 - 18 years) entered the experiment. All participants were native-English speakers with no known cognitive impairments. All had healthy or corrected hearing and eyesight. Participants were formed of undergraduate Psychology students from the University of Edinburgh who were volunteering as a means of earning course credit. Participants were subsequently recruited via email and later tested in the neuropsychology lab within the University of Edinburgh Psychology department.

5.2.2.2 Procedure

Figure 5.1 illustrates the experimental procedure of the current experiment.

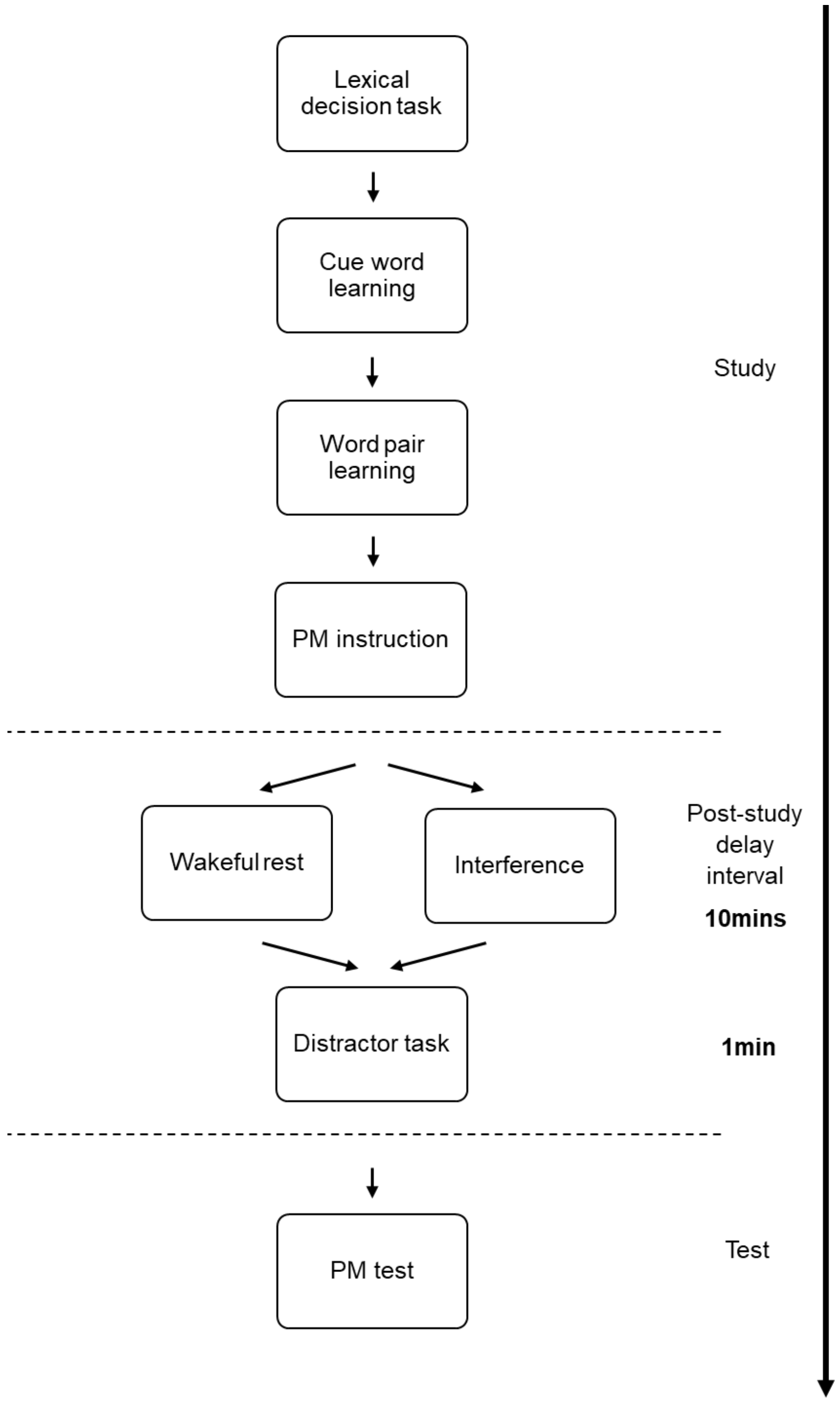

Figure 5.1. The experimental procedure of Experiment 6. Interference and distractor task consisted of a spot-the-difference task. PM = prospective memory.

Prior to the commencement of the experiment, participants were randomly assigned to one of the two condition groups (i.e., unfilled vs filled post-encoding delay interval). Those assigned to the unfilled post-encoding delay interval experienced a 10-minute period of wakeful rest following PM task instruction. Conversely, those who were assigned to the filled post-encoding delay interval experienced a 10-minute period following PM task instruction which involved an effortful task (i.e., Spot-the-Difference task).

Participants first took part in the study phase of the experiment. During the study phase, participants completed a short lexical decision task consisting of 100 items. After this, participants then completed the cue word learning task and cue-associate word pair learning task. During these tasks, participants learned the to-be-retained material (i.e., cue-associate word pairs) which would be assessed in a later PM task.

Upon successful completion of these tasks, participants were then given the instructions for the PM task. Participants were instructed that they would take part in a longer lexical decision task after 11 minutes. Participants were informed that they would be randomly presented with previously learnt cue words alongside real words and non-words during this task. They were instructed to input the associate word upon the detection of a cue word in place of the typical response as part of the lexical decision task. After the presentation of the PM task instructions had concluded, participants were faced with either an unfilled or filled delay interval lasting 10 minutes. This was followed by a 1-minute Spot-the-Difference task which acted as a distractor in order to extinguish any rehearsed information maintained within STM. After this, participants took part in the PM task. At the end of the study, participants were briefly asked about their behaviours during the experiment (i.e., whether they had rehearsed, briefly thought about the to-be-retained material or task instructions, and whether this occurred during any of the Spot-the-Difference tasks) before being fully debriefed.

5.2.2.3 Study Phase

5.2.2.3.1 *Lexical decision task*

Participants first completed a practice trial of the lexical decision task at the beginning of the study phase of the experiment. Within this task, participants had to quickly and accurately identify whether or not presented items were real words or non-words. Each item was presented individually in the centre of the screen. Upon presentation of an item, participants had to press a key which corresponded to their judgement. Participants were instructed to press the “R” key if they believed the item was a real word, or the “N” key if they believed the item was a non-word. Participants were directly instructed to perform this task as quickly as they could, while ensuring that they made no judgement errors during the task. Upon pressing a key, there was a delay of 500 milliseconds before the next item was displayed.

The real word items within the lexical decision tasks consisted of unrelated, common nouns. Non-word items were also derived from unrelated common nouns – however, one consonant was substituted. The word items were chosen from the MRC Psycholinguistic database and were matched for number of letters (i.e., 5-6 letters), syllables (i.e., 2 syllables), familiarity, concreteness, and imaginability (> 400 for the latter three variables). During the practice trial, participants were presented with 100 items (50 real word, 50 non-word). During the later PM test, which would occur during the test phase of the experiment, participants were presented with 270 items (185 real word, 185 non-word).

Accuracy and reaction time measurements were obtained via PsychoPy2 (Peirce, 2009; Peirce & MacAskill, 2018) during both the study phase lexical decision task and the test phase lexical decision task that was completed concurrently with the PM task. Within the study phase task, accuracy was measured as a proportion of correctly identified items divided by the total number of presented items (/100 for the study phase trial). For the test phase task, performance on the four items following each cue word were omitted. This was done in order to exclude observations of slowing in reaction time and decreased accuracy that may occur as a product of response processes associated with performing the concurrent PM task. This is in line with past experiments which have made similar adjustments (Smith & Bayen, 2004). Consequently, mean accuracy and reaction times were assessed over 214 items within the test phase task. Reaction time was measured in seconds, from the moment of presentation to key input (i.e., “R” or “N” key).

5.2.2.3.2 *To-be-retained material*

Participants were tasked with retaining 15 cue-associate word pairs (see Appendix F) which were to be learned across two tasks encountered during the study phase of the experiment. These word pairs were later assessed in an adapted version of a laboratory event-based PM task used in a previous study (Diekelmann et al., 2013a). This PM task occurred during the test phase of the experiment. The 15 cue-associate word pairs consisted of 30 unrelated, common nouns (e.g. report, driver, battle). The selection process for the cue-associate word pair items matched that used to select word items for the lexical decision task. The total number of cue-associate word pairs used were matched with previous work investigating the benefits of minimal RI to LTM as opposed to the sleep studies involving PM as a means of maintaining consistency with the wakeful rest literature.

5.2.2.3.2.1 *Cue word learning task*

Participants were first required to independently learn the 15 cue words during the study phase of the experiment. A cue word learning task was conducted in which participants were visually presented with a list of 15 cue words. Similar to the lexical decision task items, each cue word was presenting individually in the centre of the screen. However, each cue word was presented on screen for 5 seconds before progressing to the next item. Following presentation, participants were asked to freely recall as many of the cue words as they could remember in no particular order.

Participants were required to verbally recall 12 or more cue words (80%) during a test of immediate free-recall in order to proceed onto the next task. The 80% criterion for the learning of cue words was chosen based on pilot investigations indicating that this level of performance enabled highly accurate recognition of the words in a later test. Performances below the 80% criterion resulted in the repetition of the same task until the criterion was met. It was fundamental to the assessment of later PM performance that initial encoding of the cue words had been achieved and established experimentally. If cue words were poorly recognised during the PM task, then overall PM performance would be difficult to measure since an assessment of associate word retention could not be reliably made.

5.2.2.3.2.2 *Cue-associate word pair learning task*

Participants subsequently completed the cue-associate word pair learning task. During this task, participants were visually presented with each word pair individually. These word pairs consisted of a previously learned cue word and a second, associate word. The word pairs were presented in the centre of the screen for 5 seconds each. Participants then took part in a test of cued recall, where they would type in the associate word upon the visual presentation of the corresponding cue word in the centre of the screen. This involved each participant first pressing the “Space” key, before inputting the relevant word item. Participants would then press the “Enter” key to confirm their response. These key inputs matched those required within the later test of PM, ensuring participants were familiar with the PM task procedure prior to the presentation of instructions.

Participants were required to recall 9 or more associate second words (60%) during a test of cued recall given immediately after the presentation of the 15 cue-associate word pairs in order to proceed with the experiment. The 60% criterion was adopted from previous studies (Drosopoulos, Schulze, Fischer, & Born, 2007; Diekelmann et al., 2013a) based on the observed maximal effects of sleep on consolidation of word pair memories at this level. Again, if the criterion was not met by participants they would be required to repeat the task until the desired performance was achieved.

5.2.2.4 Test Phase

5.2.2.4.1 *Prospective memory task*

In the PM task, participants were required to identify previously learned cues (i.e., recognise cue words learned during study phase) and perform associated actions (i.e., recall corresponding associate words) during a concurrent task (i.e., longer lexical decision task). The PM task used in the current experiment was adapted from a version used in a previous study investigating the benefits of sleep to PM (Diekelmann et al., 2013a). At the end of the study phase of the experiment, participants were given the instructions for the PM task. Participants were informed that they would be assessed on their recognition of the cue words and their ability to subsequently recall the corresponding associate words during a longer version of the lexical decision task completed earlier. This lexical decision task would occur after a 1-minute Spot-the-Difference task that would follow the 10-minute delay interval (unfilled or filled).

Participants were told to be aware of previously learned cue words appearing during the later lexical decision task in which participants were presented with a series of real words and non-words. Participants were informed that upon recognising a cue word during the lexical decision task, they were not to respond to the item in line with the instructions of the lexical decision task (i.e., pressing the “R” key to confirm their real word judgement). Instead, participants were instructed to press an alternative button to signal that the cue word had been recognised by them (i.e., press the “Space” key), before inputting the associate word into the computer (confirming their inputted word with the “Enter” key).

Participants were clearly informed that the PM task instructions were only going to be presented once, with no future reminders. All participants had to confirm that they fully understood the instructions before progressing onto the delay interval.

Within the PM task, cue words were presented every 16th to 20th word (mean: 18th) during the concurrent lexical decision task. Whilst the order of cue word presentation was randomised, the spacing of cue words was relatively consistent across participants. Similar spacing practices have been adopted in other PM studies (Marsh, Hancock, & Hicks, 2002; Maylor, Smith, Sala, & Logie, 2002; McGann, Ellis, & Milne, 2002; Reese & Cherry, 2002; Smith, 2003; Smith & Bayen, 2004).

The number of correctly recognised cue words within the concurrent lexical decision task was measured, as well as the number of correctly recalled associate words. The proportion of correctly recalled associate words was also measured (i.e., number of associate words recalled during the PM test / number of associate words recalled during the study phase of the experiment). This was calculated to observe the overall rate of forgetting across the delay interval. This was not calculated for the cue words since cue words were assessed differently across the experiment (i.e., recall during study phase, recognition during test phase).

5.2.2.5 Delay Interval

We manipulated whether the 10-minute period immediately following PM task instruction presentation would be filled or unfilled.

5.2.2.5.1 *Filled delay interval*

Filled delay intervals consisted of the longer version of the Spot-the-Difference task used in both Experiment 1 and Experiment 2. Within this version, participants were exposed to 20 picture pairs over the course of 10 minutes. During this time, participants were asked to identify two subtle differences between each picture pair presented.

As in Experiment 1 and 2, participants were first introduced to the Spot-the-Difference task via a practice trial consisting of 2 picture pairs as a means of familiarising participants with the demands of the task. This was during the study phase of the experiment, prior to the lexical decision task.

The Spot-the-Difference task was again used as a distractor task within the current experiment to ensure that any conscious subvocal rehearsal occuring during post-encoding wakeful rest would be interrupted, extinguishing rehearsed information being maintained within STM. This 1-minute task – consisting of 2 picture pairs – was presented immediately after the filled/unfilled delay interval. The use of a non-specific interfering task post-PM task instructions would allow us to specifically assess the effects of interfering with the consolidation process and not similarity-based interference resulting from retrieval competition (Dewar et al., 2007).

5.2.2.5.2 *Unfilled delay interval*

Unfilled delay intervals consisted of wakeful rest which mirrored the experiments from Chapters 2-4 (i.e., rest in quiet, darkened room).

5.2.2.6 Post-Session Debriefing

At the end of the experiment, participants were asked to complete a short questionnaire. In line with the questionnaires used in the experiments explored in Chapters 2 and 3, the main purpose of the questionnaire was to obtain a more accurate account of whether or not conscious subvocal rehearsal occurred during the experiment and under which circumstances. More specifically, the questionnaires intended to establish whether participants had consciously thought about the to-be-retained material, or the PM task instructions, prior to the commencement of the final assessment.

5.2.2.7 Statistical Analysis

All statistical analyses were conducted using JASP (JASP Team, 2018). Comparisons of mean performance across the study phase learning tasks (i.e., cue word learning task, cue-associate word pair learning task) were conducted between condition groups (i.e., unfilled vs filled post-encoding delay interval) via independent samples t-tests. This was done to ensure groups did not significantly differ in memory performance prior to PM testing. Further independent samples t-tests were conducted to compare PM task performance (i.e., cue words recognised, proportion of associate words recalled) between condition groups. A combination of paired and independent samples t-tests were used to investigate possible differences in lexical decision task accuracy and reaction times between the study and test phase tasks, with comparisons between condition groups. Additionally, possible trade-offs between PM task performance and interfering task performance (i.e., Spot-the-Difference task) were investigated via various correlations. Supplementary analysis was conducted using a combination of t-tests and correlations aimed at looking for possible differences in PM task performance based on multiple factors (i.e., gender, years of education).

5.2.3 Results

5.2.3.1 Performance across Study Phase Tasks

Tables 5.1 highlights mean task performance across conditions on the cue word learning and cue-associate word pair learning tasks completed during the study phase of the experiment. Mean number of attempts for participants to achieve the minimum required performance level across both tasks are also shown.

Table 5.1. Mean performance on study phase learning tasks and mean attempts to complete task between the condition groups.

	Condition	Mean	SD	SEM
Recall on cue word learning task	Unfilled	13.188	1.047	.262
	Filled	13.125	1.204	.301
Cue word learning task attempts	Unfilled	2.000	.730	.183
	Filled	2.375	1.204	.301
Recall on cue-associate word pair learning task	Unfilled	11.875	1.586	.397
	Filled	12.375	1.928	.482
Cue-associate word pair learning task attempts	Unfilled	1.188	.403	.101
	Filled	1.063	.250	.063

Note. Study phase tasks = cue word learning task and cue-associate word pair learning task. SD = standard deviation, SEM = standard error of the mean.

Tables 5.2 highlights the results of independent-samples t-tests comparing performances on study phase tasks between the condition groups

Table 5.2. Independent-samples t-tests comparing mean study phase task performance between condition groups (unfilled post-encoding delay interval, filled post-encoding delay interval).

	t	df	*p*	d
Recall on cue word learning task	.157	30.000	.877	.055
Cue word learning task attempts	-1.065^{w}	24.72^{w}	.297^{w}	-.377^{w}
Recall on cue-associate word pair learning task	-.801	30.000	.429	.283
Cue-associate word pair learning task attempts	1.054^{w}	25.05^{w}	.302^{w}	.373^{w}

Note. ^{w} = Welch t-test, conducted due to significant Levene's test representing unequal variance.

Independent samples t-tests showed no significant differences in performance across the study phase learning tasks (both cue word learning task and cue-associate word pair learning task) between condition groups (p < .05). Additionally, no significant differences were seen in the number of trials required to achieve a sufficient performance across the tasks between condition groups. These findings indicate that the condition groups are matched in their baseline memory performances, meaning any future observations of significant differences can be more reliably attributed to the experimental manipulations.

5.2.3.2 Performance on Prospective Memory Task

Figures 5.2 illustrates the mean proportion of cue words detected during the PM task (number of cue words detected during PM task / total number of cue words presented during PM task) across both condition groups (i.e., unfilled post-encoding delay interval vs filled post-encoding delay interval).

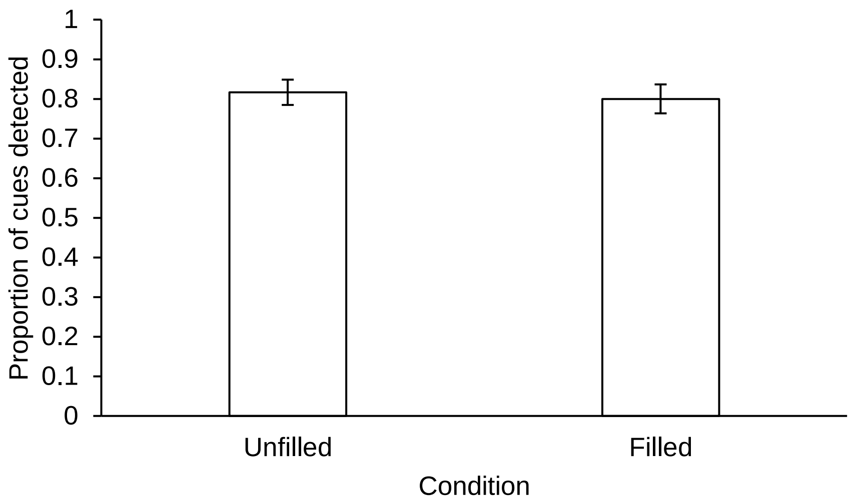

Figure 5.2. Mean proportion of cue words detected during the PM test (number of cues detected during PM test / total number of cues presented during PM test) across both condition groups (unfilled post-encoding delay interval, filled post-encoding delay interval). Error bars represent standard error of the mean.

Independent samples t-tests found no significant differences in the number of cue words successfully detected during the PM task based on condition (i.e., unfilled post-encoding delay interval vs filled post-encoding delay interval) ($p > .05$).

Figures 5.3 highlights the mean proportion retention of associate words recalled during the PM test (number of associate words recalled during PM task / number of associate words recalled during cue-associate word pair learning task) across the condition groups.

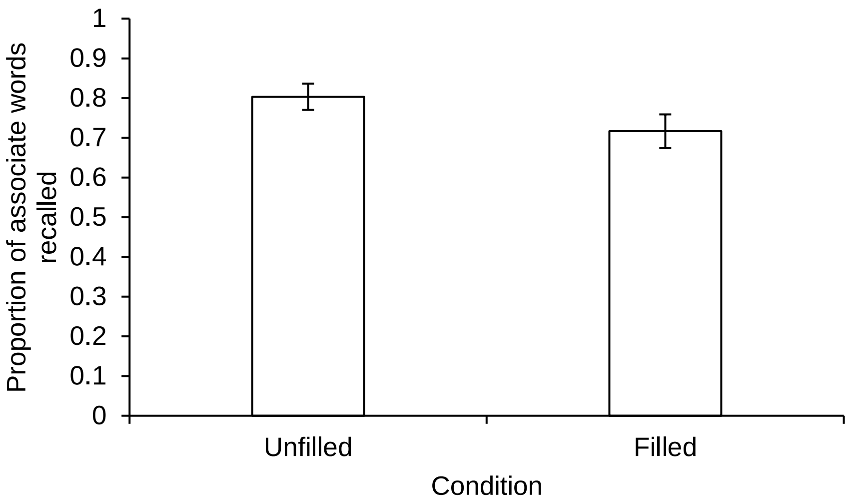

Figure 5.3. Mean proportion retention of associate words recalled during the PM task (number of associate words recalled during PM task / number of associate words recalled during word pair learning task) across both condition groups (unfilled post-encoding delay interval, filled post-encoding delay interval). Error bars represent standard error of the mean.

Similar to cue word recognition, independent samples t-tests found no significant differences in the proportion retention of associate words recalled depending on whether the post-encoding delay interval following PM task instruction was filled or unfilled.

5.2.3.3 Lexical Decision Task Performance

Tables 5.3 demonstrates the mean accuracy and reaction times across the study phase lexical decision task (LDT-S) and the test phase lexical decision task (LDT-T) between condition groups (unfilled post-encoding delay interval vs filled post-encoding delay interval). One participant was identified as having an outlying mean reaction time across both tasks. The following analysis was conducted with this participant excluded. It is important to note that the findings were consistent irrespective of their exclusion.

Table 5.3. Mean accuracy and reaction times across the study phase lexical decision task (LDT-S) and the test phase lexical decision task (LDT-T) between condition groups (unfilled post-encoding delay interval, filled post-encoding delay interval).

	Condition	Mean	SD	SEM
LDT-S accuracy	Unfilled	.963	.025	.007
	Filled	.963	.028	.007
LDT-S reaction time	Unfilled	.706	.091	.024
	Filled	.731	.107	.027
LDT-T accuracy	Unfilled	.941	.030	.008
	Filled	.944	.026	.006
LDT-T reaction time	Unfilled	.832	.090	.023
	Filled	.837	.132	.033

Note. SD = standard deviation, SEM = standard error of mean. N = 15 for unfilled group, n = 16 for filled group.

Tables 5.4 shows the results of independent-samples t-tests comparing mean accuracy and reaction times across the study phase lexical decision task (LDT-S) and the test phase lexical decision task (LDT-T) between condition groups.

Table 5.4. Independent-samples t-tests comparing mean accuracy and reaction times across the study phase lexical decision task (LDT-S) and the test phase lexical decision task (LDT-T) between condition groups (unfilled post-encoding delay interval vs filled post-encoding delay interval)

	t	df	*p*	d
LDT-S accuracy	-.472	30.000	.641	-.167
LDT-S reaction time	.602	30.000	.552	.213
LDT-T accuracy	-.184	30.000	.855	-.065
LDT-T reaction time	.112	30.000	.911	.040

Independent-samples t-tests found no significant differences in mean reaction time or accuracy across the lexical decision tasks between the condition groups (i.e., unfilled vs filled post-encoding delay interval).

However, comparisons of lexical decision task performance between the study and test phase tasks of the experiment differed. Paired-samples t-tests demonstrated a significant slowing of reaction time within the test phase lexical decision task in comparison to the study phase lexical decision task, $t(30) = 7.620$, $p < .001$, $d = 1.369$. There was also a significant decline in accuracy during the test phase lexical decision task (M = .963) when compared to the study phase task (M = .943), $t(30) = 3.543$, $p = .001$, $d = .636$.

While significant, the observed 2% decline in accuracy is an unlikely indication of a potential trade-off between lexical decision task accuracy and improved PM task performance. This is supported by non-significant correlations between test phase lexical decision task performance (both reaction time and accuracy) and PM task performance (both cue word recognition and associate word recall).

5.2.3.4 Possible Effects of Active Rehearsal

Multiple independent samples t-tests were conducted to establish whether active rehearsal of the to-be-retained material (i.e., cue-associate word pairs) or the PM task instructions impacted PM task performance. Table 5.5details the instances of self-reported engagement in active rehearsal. Additionally, this table documents instances in which participants merely thought about the experimental material or instructions during other periods of the experiment.

Table 5.5. Number of self-reported cases of participants thinking about or actively rehearsing the to-be-retained material (cue-associate word pairs) and PM task instructions across conditions (unfilled post-encoding delay interval, filled post-encoding delay interval).

		Unfilled (n = 16)		Filled (n = 16)	
		Yes	No	Yes	No
Cue-associate word pairs	Thought	12	4	10	6
	Rehearse	8	8	7	9
	Rehearse during STD task	0	16	3	13
PM task instructions	Thought	11	5	11	5
	Rehearse	6	10	5	11
	Rehearse during STD task	3	13	6	10

Independent samples t-tests were conducted. There were no significant differences in the number of cue words detected or associate words recalled during the PM task depending on whether participants thought about the to-be-retained material or the PM task instructions. This remained consistent when looking at the condition groups individually.

These findings indicate that the distractor task was sufficient at extinguishing any maintenance of items from STM.

5.2.3.5 Possible Differences Based on Gender and Education

A large portion of the sample (n = 32) were females (n = 26). An independent samples t-test found that male participants (n = 6) identified significantly more cue words during the PM task in comparison to female participants, t(21.352) = 3.617, *p* = .002, d = .991. This, however, did not lead to the observation of significant differences in associate word recall during the PM task between genders.

Additional independent samples t-tests conducted on the older adult sample found that male participants (n = 4) again identified significantly more cue words during the PM task when compared to female participants (n = 6), t(6.271) = 3.566, *p* = .011, d = 1.572. In addition to this, male participants recalled significantly more associate words in comparison to male participants during the PM task, t(6.814) = 2.865, *p* = .025, d = 1.289. It is important to note that the latter observation would be expected since participants are unable to recall associate words without first recognising the cue word initially. Additionally, it should be highlighted that in all instances of significant differences, Welch's unequal variances t-tests were conducted due to significant Levene's test.

Pearson's r-correlations found no significant correlations between the number of years of education and PM task performance (i.e., number of cue words detected, proportion of associate words recalled).

5.2.3.6 Spot-the-Difference Task Performance

No significant correlations were found between Spot-the-Difference task performance and the number of cues recognised or the proportion of associate words recalled within the PM study. This indicates that there were no possible trade-offs between the interfering task (i.e., Spot-the-Difference task) and PM task performance.

5.2.4 Discussion

In the current experiment, the aim was to see whether the benefits of post-encoding wakeful rest, seen to significantly improve LTM retention in healthy adults, would extend to PM. Given that PM is facilitated by post-encoding sleep, it follows that post-encoding wakeful rest could result in similar improvements - if a shared mechanism (i.e., reduction of post-encoding sensory stimulation and uninterrupted consolidation) is solely responsible for the benefit. However, participants performed equally well on the tests of PM regardless of whether PM task instruction was proceeded by a brief period of wakeful rest or further engagement in effortful tasks.

In the current experiment, a significant slowing of reaction time was seen during the test phase lexical decision task when compared to the study phase lexical decision task. Such slowing of response time during a task which is completed concurrently with a PM task has been observed in previous studies (Burgess, Quayle, & Frith, 2001; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, 2003). The slowing of reaction time on a concurrent task is proposed to be a result of nonautomatic preparatory attentional processes being employed to detect cues in the environment that correspond to the PM task itself. According to the preparatory attentional processes and memory processes (PAM) theory of prospective memory (Smith, 2003), this process has been proposed to be capacity-consuming. If the prospective component of PM tasks relies upon our limited resources, then the presumption follows that effortful tasks engaged during the post-encoding period may deplete these resources and result in a heightened difficulty in utilising preparatory attentional processes. Since a significant decline in PM performance was not observed as a result of task engagement following PM task instruction, several possibilities remain.

Processes involved in the completion of the PM task and the interfering task (i.e., Spot-the-Difference task) may utilise distinct cognitive resources. This means that engagement in a post-instructional task does not deplete resources required for memorandum consolidation. Additionally, post-instructional task engagement does not proactively deplete resources required for successful cue detection during PM testing.

A key caveat of the current experiment concerns the general nature of investigations into PM. In order for PM to be suitably assessed, as with any assessment of memory, participants are required to first adequately encode the to-be-retained material prior to testing. However, within PM studies, this typically involves repeated learning trials (as seen in the current study) until a participant attains a desired performance level. Repeated exposure to the target material, coupled with the repeated tests, may contribute to the formation of more resilient memory traces for the to-be-retained material. Given this, it may be very difficult to observe any negative effects of post-encoding task engagement. It could be proposed that repeated testing could facilitate multiple instances of consolidation and reconsolidation, which enable the memory trace to strengthen to a degree that makes it immeasurably impervious to interference. In equal measure, it would be difficult to assess the extent to which post-encoding wakeful rest has contributed to improved PM task performance if repeated trials has resulted in near-maximum consolidation.

There are some findings that can be reflected upon which bring such ideas into question. Namely, the notion that the proportion of associate words recalled during the PM task does not appear to be near-. If repeated learning trials had led to the development of resilient memory traces, then at-ceiling performances should be a commonality. While this is a notable point, it is important to highlight that participants only had to recall 60% of the associate words during the cue-associate word pair learning task in order to complete the study phase of the experiment.

Correlations between the number of trials needed to complete a learning task and later PM performance could also be looked at. If repeated trials resulted in more resilient memory traces, then presumably it would be expected that PM task performance would correlate positively with the number of attempts and PM task performance. However, this was not observed. The absence of this observation does not necessarily lead to the rejection of this idea. It is conceivable that highly functioning participants, who require a small number of trials to achieve a satisfactory performance, are generally predisposed to performing well in tests of PM regardless of post-encoding activity.

More generally, the benefits of post-encoding sleep on PM can be reflected upon. Such studies have also involved the inclusion of repeated learning trials. Even with the possibility of reconsolidation across condition groups, post-encoding sleep has been seen to substantially improve PM performance. This may lead us to consider beneficial properties of sleep which differentiate it from wakeful rest, which have been broadly detailed (see Sejnowski & Destexhe, 2000). However, further attention should be drawn to key procedural deviations between PM studies involving sleep and wakeful rest. Most importantly, PM assessment is conducted at wildly different time intervals. In the current experiment, PM is assessed after 11 minutes. Whereas in typical sleep studies, PM is assessed over days. It is possible that the incomparable length of the filled interval within sleep studies allows for the benefits of repeated learning trials to wear off. If participants are exposed to a plethora of further information over a sustained period of time, this may allow for the reinstatement of the negative effects of post-encoding interference. Conversely, participants who engage in a long period of post-encoding sleep allow for the preservation of the testing effects, meaning an observation of improved PM is far more likely.

It should be noted that efforts were undertaken to explore whether healthy older adults would perform similarly to younger adults when tested using the current paradigm. However, many older participants experienced great difficulty in achieving the necessary performances during the learning trials, and were later challenged by the demands of the PM test. Given this, testing of this sample was curtailed.

While post-encoding wakeful rest has been seen to result in improvements in the retention of information of episodic memory, this benefit does not extend to PM. This is surprising, given that sleep following PM instruction has been seen to facilitate later performance across tests of PM. Both post-encoding sleep and wakeful rest have been suggested to promote uninterrupted consolidation via the reduction of further sensory stimulation after learning. However, with the findings that post-encoding wakeful rest does not lead to improvements in PM performance, it seems that post-encoding sleep may have additionally facilitatory properties.

Chapter 6:

Understanding interference and drug-induced amnesics

6.1 Introduction

Administering an acute dose of benzodiazepines (BZs) to cognitively-intact healthy adults often results in a temporary memory impairment that is reminiscent of AA (marked impairment of delayed-free recall of episodic information encoded following the administration of BZs, intact immediate free-recall). A selective inability to retain episodic information is commonly seen following the ingestion of typical BZs, while STM (e.g., digit span, Hennessy, Kirkby, & Montgomery, 1991; Rusted, Eaton-Williams, & Warburton, 1991; Curran, Gardiner, Java, & Allen, 1993), semantic memory (Nogueira, Pompéia, Galduróz, & Bueno, 2006) and implicit LTM (Pompéia, Gorenstein, & Curran, 1996) are often spared. These effects mirror cognitive changes observed among many patients with organic non-material specific amnesias, particularly those who display AA for episodic information in the absence of other impaired cognitive abilities (e.g., general intelligence, immediate free-recall of episodic content and other types of LTM and STM) (Aggleton & Brown, 1999; Parkin & Leng, 2014; see also Kopelman, 2002).

Parallels between cognitive impairments following the ingestion of BZs and those seen among some patients with amnesia have prompted researchers to consider the possible utilisation of BZs as a pharmacological model of organic amnesia (Brown, Lewis, Brown, Horn, & Bowes, 1982; Lister, 1985; Thomas-Antérion, Koenig, Navez, & Laurent, 1999). Such a prospect is of great utility, given that the administration of BZs leads to an impermanent, reversible amnesic effect that is ultimately safe (Madhusoodanan & Bogunovic, 2004). However, it has yet to be established which type of amnesia BZs models best. In addition to this, it is not yet known whether the temporary AA elicited via the administration of BZs may be alleviated by post-encoding wakeful rest, as seen in some amnesic patients (see Experiment 5).

The goal of the current experiment was to compare the acute oral effects of BZs in healthy young adults with the published cognitive profile of patients with different forms of amnesia according to Parkin and Leng's (2014) classification. Their classification covers the following cognitive characteristics: (a) working memory capacity (WMC); (b) susceptibility to retroactive interference (RI) that occurs immediately after encoding (i.e., during synaptic consolidation); and (c) accelerated forgetting, which takes place over longer periods of time and may signal changes across later consolidative processes (i.e., systems consolidation). Table 6.3 (in the Results section) summarises the cognitive constructs under investigation and whether they are affected in each type of amnesia. It is important to highlight that the classification outlined by Parkin and Leng was originally proposed in 1993 and is subject to scrutiny based on more current understandings. However, there is a continued relevance of their classification with respects to characterising different forms of amnesia based on behavioural findings (see Dickerson & Eichenbaum, 2010).

WMC is a construct that measures the capacity for individuals to engage attention in a controlled manner, allowing relevant selection and maintenance of goal-relevant information in mind (Cowan, 2008). Consequently, it is implicated in the encoding (Wang & Morris, 2010) and later retrieval of information from LTM, having an influential effect upon both immediate and delayed free-recall of episodic memories as a result of this (Unsworth, 2016; Unsworth & Engle, 2007). While theoretically defining working memory (WM) itself is a contentious topic in its own right, the Embedded Processes Theory proposed by Cowan (1999, 2005) provides us with a relevant understanding of WM that incorporates LTM (see Cowan, 2008 for discussion). Within this functional model, WM is believed to be “activated LTM”, with only a subset of activated information being within the focus of attention.

WMC is often not impaired in patients with amnesia resulting from various aetiologies (see Baddeley & Wilson, 2002; Allen, Vargha-Khadem, & Baddeley, 2014), including medial temporal lobe damage (Leng & Parkin, 1989; Kopelman & Stanhope, 1997) and Global Transient Amnesia when immediate recall is intact (Quinette et al., 2003; Quinette et al., 2006). However, WMC has been seen to be limited in amnesic Korsakoff patients who present diencephalic damage (Parkinson, 1980). Thus, in order to establish which type of amnesia BZs mirror, WMC needs to be assessed under its effects. This enables us to dismiss the possibility that memory impairments following drug administration are not due to difficulties with encoding and/or retrieval.

It appears that only one study has previously assessed acute WMC BZ effects to date (Reder et al., 2006), demonstrating no effect. However, WMC performance is closely associated to executive functioning (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010), which is inconsistently impaired by BZs (Buffett-Jerrott & Stewart, 2002). This impairment has been associated with BZ-induced sedation, or "low arousal" (see Buffett-Jerrott & Stewart, 2002). While reductions in arousal have been linked to subtle decreases in immediate free-recall (Ghoneim, Mewaldt, Berie, & Hinrichs, 1981), sedation alone does not provide a reliable account for the acute AA effects of BZs (see Buffett-Jerrott & Stewart, 2002; Mintzer & Griffiths, 2007).

Apart from possible effects during encoding and retrieval, it is hypothesised that the impairments associated with the administration of BZs is predominantly caused by the interference of post-treatment consolidative processes that stabilise recently acquired episodic memories into LTM (see Curran, 1986; Zhu et al., 2018). A study by Brown and colleagues (1982) found that when BZs were injected 10 minutes after encoding of to-be-remembered episodic information, delayed recall of this material was unaffected when tested minutes to hours later. Furthermore, BZs have been seen to have no significant effect on the recall of information that was learned prior to drug ingestion (no retrograde amnesia or RA; Curran & Birch, 1991; Ghoneim, Hinrichs, & Mewaldt, 1984). Given this, it appears that BZs may specifically impair early consolidative processes that occur immediately after encoding (i.e., synaptic consolidation: see Dudai, 2004; Wang & Morris, 2010). As previously discussed, newly formed memory traces are susceptible to interference during this time (Squire, 2009b; Tano, Molina, Maldonado, & Pedreira, 2009).

However, it has yet to be established whether BZs anterogradely disrupt later consolidation processes (i.e., systems consolidation: Squire, 2009b; Tano et al., 2009; Wang & Morris, 2010). It is important to determine which of these processes is affected following the administration of BZs, given that they are often differentially affected across various amnesias. As will be discussed later, some types of amnesic patients are notably vulnerable to the interference of early consolidative processes, while others demonstrate possible impairment in later consolidative processes. This can be assessed experimentally by (a) manipulating post-encoding activity that occurs in the immediate 10 minutes following memory acquisition; and (b) examining the proportion of target items retained at different time intervals after these 10 minutes have elapsed. These experimental manipulations will be discussed next.

As previously discussed, there is a strong body of data which demonstrates improved delayed free-recall of episodic information in amnesic patients if encoding is subsequently followed by a brief interval of minimal RI (MinRI; Cowan et al., 2004; Dewar et al., 2010; see Experiment 5). It has been shown that even a brief 6-minute respite from further sensory stimulation following learning can vastly improve later recall in amnesic patients (Dewar et al., 2009). This memory benefit of MinRI has been observed in patients presenting with various unspecific amnesia types resulting from brain injury (e.g., anoxia, head injury) (Cowan et al., 2004; Dewar et al., 2009; 2010) and neurodegeneration (Mild Cognitive Impairment - MCI) and initial stages of Alzheimer's Disease (AD) (Della Sala et al., 2005; Dewar et al., 2012a). These effects are also found in some (Craig, Della Sala, & Dewar, 2014; Dewar et al., 2012b), but not all studies in healthy adults (Martini, Riedlsperger, Maran, & Sachse, 2017; Martini, Zamarian, Sachse, Martini, & Delazer, 2018; Varma et al., 2018; Varma, Daselaar, Kessels, & Takashima, 2017) and elderly controls (Dewar et al., 2010).

It should be noted that some amnesic patients have shown no improvements to delayed free-recall from MinRI

(Cowan et al., 2004). In addition to this, MCI and AD patients displaying more severe conditions show a reduced benefit from MinRI (Dewar et al., 2012a). The variance among these patients with regards to the benefit of MinRI remains unknown. Given this, a comparison of the effects of BZ under the conditions of both RI and MinRI can further clarify what type of organic AA these drugs best model in this respect.

To determine whether the ingestion of BZs results in changes to later consolidative processes, reductions in the proportion of episodic items retained across various delayed tests can be compared between groups who have been treated with BZs (i.e., diazepam) or a placebo. Accelerated forgetting over periods longer than 24 hours is not seen in patients with AA resulting from medial temporal lobe and diencephalon damage (Geurts, van der Werf, & Kessels, 2015; McKee & Squire, 1992), but has been seen in Transient Epileptic Amnesia patients (Butler et al., 2009; Elliott, Isaac, & Muhlert, 2014). Additionally, some MCI patients have displayed accelerated forgetting one week after encoding (Walsh et al., 2014). However, this observation is not consistent (Alber et al., 2014, improved retention after one week following brief wakeful rest after encoding; Manes, Cecilia, Calcagno, Cardozo, & Hodges, 2008, no post-encoding manipulation of activity; see also Geurts et al., 2015). Therefore, determining if BZs accelerate forgetting can assist in the characterization of the clinical conditions that these drugs model. This is specifically relevant when long-acting BZs are administered, as is the case of the classic BZ compound diazepam and its metabolites, which have long elimination half-lives (see Mandelli, Tognoni, & Garattini, 1978; Riss, Cloyd, Gates, & Collins, 2008). It is thus reasonable to assume that BZs could continue to impair consolidation over days after memory encoding under the drug. This was assessed with delayed recall 7 days after encoding.

Another unexplored effect of BZs concerns its impact on previously consolidated episodic information when this information is subsequently brought back to mind following a test of delayed recall. It is believed that delayed free-recall may entail the process of “reconsolidation”, whereby memories that have been stabilised following consolidation become labile again and subjected to new consolidation during and after retrieval (Squire, 2009b; Tano et al., 2009; Wang & Morris, 2010). Some researchers posit that consolidation and reconsolidation operate under similar mechanisms (Dudai & Eisenberg, 2004; McKenzie & Eichenbaum, 2011). Hence, if BZs affect post-treatment consolidation, then it may also impact reconsolidation that occurs during the post-treatment period. To study how reconsolidation is affected by BZs, delayed recall of episodic information was assessed 7 days after: (a) an encoding session which occurred under the drug; or (b) pre-treatment encoding that was followed by a post-treatment test of delayed recall (reconsolidated) a couple of hours later. To date, this has not been studied in amnesic patients of any kind.

6.2 Experiment 7

6.2.1 Aims

The aim of the current experiment was to provide evidences of what type of organic, non-material specific amnesia acute administration of BZs best model. This was achieved by comparing the effects of 15 mg of diazepam – which elicits severe transient AA (Unrug-Neervoort, Van

Luijtelaar, & Coenen, 1992; Gorissen, Eling, Van Luijtelaar, & Coenen, 1995; Gorissen, Curran, & Eling 1998) – with symptoms reported in the literature of these clinical conditions.

Testing took place across two sessions (Day 1 session and Day 7 session). During the Day 1 session, there was a pre-treatment period, followed by the administration of either diazepam or placebo (double-blind, independent group design). Following a 60-minute delay, the post-treatment period commenced. A second session (i.e., the Day 7 session) followed a week later. This session was drug-free. Pre- (baseline) and post-treatment effects of diazepam (controlling for sedation) were assessed on a number of cognitive processes: (a) WMC; (b) immediate and delayed free- and cued-recall of episodic memory for prose; (c) susceptibility to RI (spot-the difference task) during the 10 min following immediate free-recall of prose, by measuring delayed recall of this content compared to that of episodic information followed by immediate MinRI (quiet rest in a darkened room for 10 min) (Alber et al., 2014); and (d) retention of episodic information consolidated under RI or MinRI and reconsolidated under the drug.

Based on the literature, 15 mg of diazepam was predicted to not impair WMC beyond its sedative action. However, specific and disproportional impairment of retention of episodic memories (i.e., prose passages) encoded post-treatment (controlling for immediate free-recall and sedation) was expected following drug administration when compared to other cognitive processes (i.e., immediate free-recall, WMC). Additionally, it was hypothesised that early consolidative processes (i.e., synaptic consolidation) and reconsolidation of episodic memories would be negatively affected following the administration of BZs. There were no expectations regarding the possible effects of BZs on susceptibility to RI and accelerated forgetting. In addition, there was no expectations concerning which specific type of clinical amnesia in Parkin and Leng's (2014) classification would be best reflected by effects seen following drug ingestion.

6.2.2 Methods

6.2.2.1 Participants

Twenty-six younger adults (16m/10f, mean age = 23.50, age range = 18-35 years, years of education > 12 years) took part in the study. All participants were native-Portuguese speaking students from the Universidade Federal de São Paulo who were recruited via email. All participants were tested in a lab within the Universidade Federal de São Paulo in Brazil, with testing being conducted in their native language.

All participants were physically- and mentally-healthy based on a number of measures: (a) all had a body mass index (kg/cm2) that ranged between 20 to 30; (b) all showed no significant signs of depression and anxiety (based on scores on the Hospital Anxiety and Depression Scale: Zigmond & Snaith, 1983; adapted for local use by Marcolino et al., 2007; (c) all reported no history of learning difficulties (i.e., Attention Deficit Hyperactive Disorder, dyslexia, etc.), nor neuropsychiatric or clinical conditions that would preclude the administration of BZs (psychosis, drug abuse, glaucoma, allergy to benzodiazepines, pregnancy, lactation, liver, kidney or respiratory problems, hypoalbuminemia, brain damage); (d) all reported a low weekly consumption of alcohol (less than 5 units) and a lack of regular use of recreational drugs (i.e., tobacco, cannabis, cocaine etc.); and (e) all reported to no prescription or consumption of psychoactive medication (excluding hormonal contraceptives with monthly pauses). Female participants were only tested during menses to standardise their hormonal status, in addition to avoiding effects of the active phase of oral contraceptives, which can affect episodic memory (e.g., Mordecai, Rubin, & Maki, 2008).

6.2.2.2 Test Battery

6.2.2.2.1 *Visual Analogue Mood Scale (VAMS)*

The mood of participants was measured via 16 100-mm horizontal ungraded visual-analogue scales. Each scale included opposite mood states at the extremities, such as alert/drowsy (Bond & Lader, 1974; Portuguese translation: Guimarães, 1998). Participants were required to make a vertical mark along the lines to indicate how they were feeling at the time of testing. The scores of different scales (number of cm from the extreme left of each line to the vertical mark) were then combined, creating numerous mood scores. These scores included “anxiety”, “physical sedation”, “mental sedation” and “other symptoms” (Guimarães, 1998). This scale was completed at the beginning of the pre-treatment period and at the beginning and end of the post-treatment period (see 6.2.2.5 for Procedure).

6.2.2.2.2 *Selective Counting Span (WMC task)*

In this self-paced, selective counting span task (based on the task used by Engle, Tuholski, Laughlin, & Conway, 1999), participants were presented with sequences of screens.

On each screen, participants were presented with an arrangement of scattered light blue circles, dark blue circles, and dark blue squares. Participants were instructed to verbally count the number of dark blue circles that were on each screen (thus requiring conjunctive search: Treisman & Gelade, 1980). Each screen consisted of 3-9 dark blue circles. At the end of the count, participants were required to repeat the total number of dark blue circles counted (e.g., if the screen contained four dark blue circles, participants would say “one-two-three-four-four”). Participants would then immediately progress to the next screen by pressing a key on the keyboard. The procedure was repeated until participants were prompted to recall the total number of dark blue circles counted on each of the previous screens, respecting serial position. Participants completed three practice trials prior to the commencement of the test. The test itself had three trials each containing 2 to 6 screens. Scores were the 'all-or-nothing load score' (ANL; Conway et al., 2005), meaning responses were only scored as correct if they perfectly matched the serial order.

This task was used as a measure of WMC as it suitably prevented rehearsal and/or the grouping or chunking of information in adults (Conway et al., 2005). This enabled us to determine how much information could be passively stored in WM before and after drug ingestion.

6.2.2.2.3 *Running-memory span (WMC task)*

The running-memory task used in the current experiment was based on a variant used by Cowan and colleagues (2005; Variant 2). Participants were verbally presented with lists of 10 to 20 single digits (excluding 0) at a fast pace. Digits were pseudo-randomly ordered, with a digit only being repeated after a moving window of 7 consecutive different digits. This task was adapted to account for discrepancies between the English and Portuguese language. In the Portuguese language, digits consist of more syllables/phonemes in comparison to English. As such, digits in Portuguese require longer presentation durations in order for the digits to be audibly discernible. This was achieved by extending the presentation duration of each digit from 250 milliseconds (standard) to 350 milliseconds (based on pilot studies). This allowed for stimuli to be distinguishable (excluding the digit “one”, which remained at 250 ms since it the number of phonemes do not differ from English). Participants completed a single practice trial for each list length, totalling 10 practice trials. This was followed by two test trials for each list length, totally 20 test trials. Participants were required to wait until list presentation concluded before recalling as many digits as possible. Participants were instructed to recall the lists in forward order and in the same serial position as presented. Participants were asked to report if they had forgotten any digit within the recalled sequence. If any digit had been forgotten, participants were required to point out in which specific positions. One point was awarded for each recalled digit in the correct serial position. Scores were the mean number of points in all trials.

6.2.2.3 To-Be-Retained Material

Six standardised prose passages were used to assess immediate and delayed episodic memory in the current experiment. These passages were Portuguese variants of the stories used in the Logical Memory Test (Wechsler, 1987 Bolognani et al., 2015; Martins, Bolognani, Pompéia, Bueno, & Miranda, 2015) (see Appendix G). Each prose passage consisted of 25 story idea units (unlike the prose passages used across Experiments 1(a), 1(b), and 3, which only consisted of 21 units). Audio recordings of the prose passages were presented to participants. Once presentation had concluded, participants were required to freely recall the prose passage as accurately as possible immediately after presentation.

Presentation and immediate free-recall of prose passages occurred across a number of learning phases. There were three learning phases across the Day 1 session: (a) a pre-treatment learning phase, (b) a beginning post-treatment learning phase, and (c) an end post-treatment learning phase. Within each learning phase, a pair of prose passages would be individually presented. Individual tests of immediate free-recall would follow the presentation of each passage, which was directly succeeded by one of two post-encoding conditions (see Section 6.2.2.4 and Figure 6.1b for more).

Delayed recall was assessed for the first two prose pairs during the post-treatment period on Day 1, and again for all prose pairs during the Day 7 session (see Procedure). In a similar practice to previous experiments in the thesis (i.e., Experiment 1(a), 1(b), and 3), all tests of recall were audio recorded for later scoring by the experimenter and a second rater who was blind to the treatment conditions. Scoring was conducted in line with the rubric of the Logical Memory Test (Wechsler, 1987). Full marks were awarded for items that were recalled verbatim, or if specific synonyms or approximations were recalled instead. Acceptable approximations were pre-selected by a panel of judges (Bolognani et al., 2015). Points were not deducted if items were recalled in the wrong order. Statistical analyses were carried out separately for data of both raters; showing no significant differences across the results ($p >$

.05). Given this, the scores of the original scorer were subsequently used in later analyses.

In the event that participants were unable to freely recall at least one item of each prose passage during delayed tests of free-recall, subsequent cues were provided. However, a cue was only provided if participants continued to recall no items following further encouragement from the experimenter. This was done as a means of dissociating impaired storage/consolidation (in which case, cues would not aid recall) from impaired retrieval, which might be affected by low arousal following BZ ingestion. In this case, cues would assist in the retrieval of consolidated information. The first cue concerned the occupation of the central character. As the language of Portuguese contains a noun class grammatical gender system, the cue of character occupation also provided additional information regarding the character’s sex. The second cue was an item that corresponded to the main problem in the prose passage (e.g., “a story related to a robbery”, as is the case for the Anna Thompson prose passage of the Logical Memory test; see Wechsler, 1987). If participants remained unable to recall any story items following the second cue, no further cues were provided and the test was concluded. If cues were provided, subsequent recalled items were only scored as correct if the items were not directly linked to the cues that were given.

Retention was calculated by dividing delayed (free- or cued-) recall by immediate free-recall. These scores will be detailed in the Results section.

6.2.2.4 Post-Encoding Conditions

During each learning phase, and directly after immediate free-recall of each prose passage, participants were faced with one of two post-encoding conditions that were adapted from Alber et al (2014):

6.2.2.4.1 *Immediate retroactive interference condition (RI)*

During this post-encoding condition, participants engaged in a spot-the-difference task for 15 minutes. The spot-the-difference task closely resembled the version used within Experiments 1-2 and Experiment 5-6, with two alterations: (a) the duration of picture pair presentation was reduced from 30 seconds each to 28 seconds. Presentation duration was reduced overall to allow for more picture pairs to be presented within each task; and (b) an additional difference was added to one of the images. This enabled us to instruct participants to find “up to three differences” throughout the tasks. This new instruction ensured continual engagement with the on-screen picture pairs, even following the successful identification of all possible differences - without directly increasing the demand of the task (i.e., via the inclusion of more differences, as done across Experiments 3 and 4 in Chapter 3). Performance on the spot-the-difference task was measured by the total number of differences identified.

6.2.2.4.2 *Minimal retroactive interference (MinRI)*

During this post-encoding condition, participants were instructed to remain seated and to rest wakefully for 10 minutes in a quiet, darkened room. Over the course of this interval, participants were supervised from an adjacent room to ensure participants did not sleep or use mobile phones during the unfilled delay. This was followed by a 5-minute period in which participants took part in a spot-the-difference task.

6.2.2.5 Procedure

The current study was approved by the Universidade Federal de São Paulo Ethics Committee. Informed consent was provided by all participants prior to the commencement of the experiment which occurred over two sessions (Day 1 session and Day 7 session).

At recruitment, participants were not explicitly informed about the activities that would be conducted during the second session (i.e., the Day 7 session, occuring 7 days after the first session).

Participants were advised to abstain from alcohol and other drugs for 24 hours before and after each session. The experiment followed a parallel-group, double-blind design. Participants were randomly allocated to one of two oral treatments formulated in identical capsules: placebo (talcum) or 15 mg of diazepam. All randomisations in this experiment were carried out using www.randomizer.org.

The Day 1 session (see Figures 6.1a and 6.1b for Day 1 session experimental procedure and learning phase procedure respectively) included a pre- and a post-treatment period, both of which occurred in the morning following a light, caffeine-free breakfast.

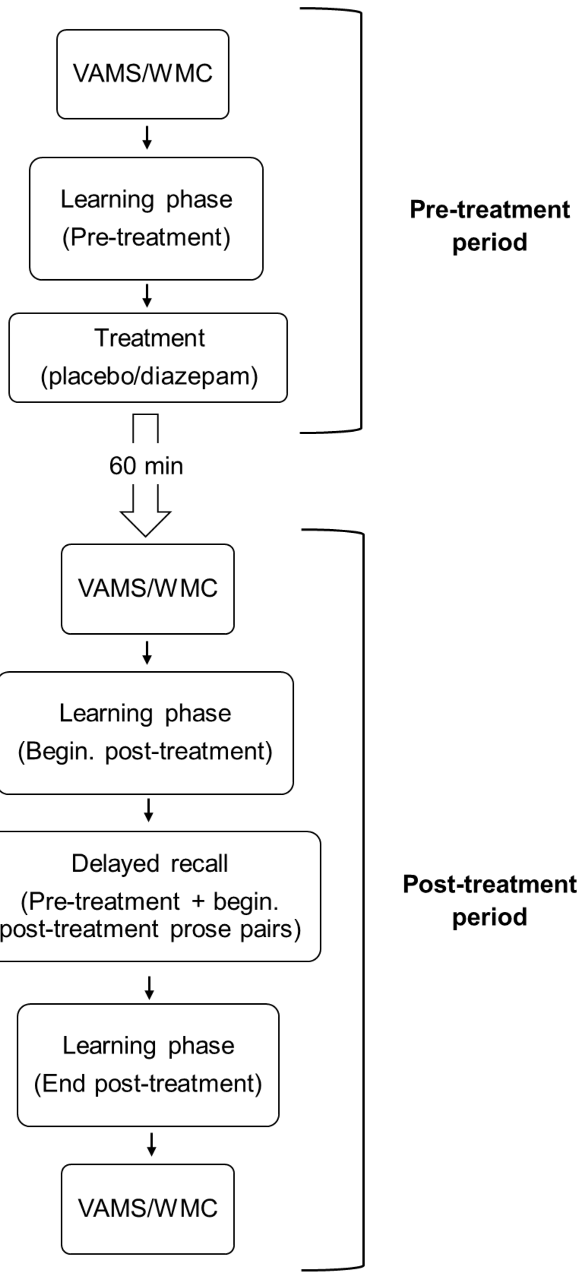

Figure 6.1a. Experimental procedure for Day 1 session. VAMS = Visual Analogue Mood Scale, WMC = Working Memory Capacity. Details regarding the Learning phase can be found on Figure 6.1b

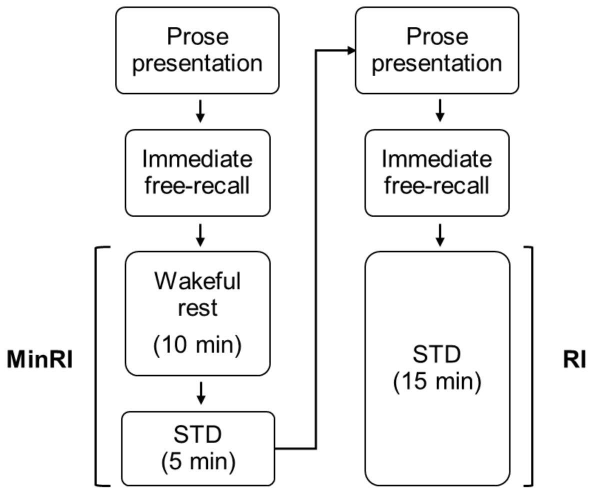

Figure 6.1b. Procedure of the learning phase. Three learning phases were employed throughout the Day 1 Session: (a) A pre-treatment learning phase (two prose passages); (b) a beginning post-treatment learning phase (following the first post-treatment VAMS/WMC tasks, two prose passages); and (c) an end post-treatment learning phase (following tests of delayed recall of previous two prose pairs, two prose passages) (see Figure 6.1a). Immediate free-recall was followed by one of two post-encoding conditions: (a) minimal retroactive interference condition (MinRI); or (b) retroactive interference condition (RI). Order of prose passages and post-encoding condition was randomised. STD = spot-the-difference task.

Upon arrival, participants were asked to report baseline mood/sedation using a Visual Analogue Mood Scales (VAMS). WMC was subsequently determined using two tasks in random order (Counting Span and Running Memory Span; see details in the Test Battery section). The presentation of two prose passages followed, each proceeded by immediate free-recall. Immediate free-recall of each story was succeeded by one of two interference conditions (details in Test battery section). At the end of this session, participants received the oral treatment (diazepam or placebo).

It was not possible to fully counterbalance all factors. As an alternative to complete counterbalancing, 15 random orders of tasks were constructed. Each order was used once for a diazepam participant and once for a placebo participant. To construct these 15 orders, counting and running spans were put in random order at each phase. Each time a participant was presented with a pair of prose passages, the gender of the character within the story was randomised (each pair consisted of one male and one female character, order was randomised). The order of RI and MinRI retention intervals was also randomised at each juncture.

The post-treatment period on Day 1 started 60 minutes after drug ingestion. The 60 minute delay prior to further testing was chosen to allow for the diazepam to reach theoretical peak-plasma concentration (Mandelli et al., 1978). Between treatment administration and the start of the post-treatment phase, participants either interacted with the experimenter or accessed messages on their mobile phones.

The post-treatment phase began with the VAMS to control for BZ-induced sedation and/or mood changes. This was followed by the WMC tasks. After these tasks, participants were faced with another learning phase (beginning post-treatment), following the same procedure as before (see Figure 6.1b). After the end of the post-encoding condition that followed the second prose passage within this phase (i.e., after 15 minutes), participants were given a surprise test of delayed free-recall of all presented prose passages. This included a test for the pre-treatment prose passages and the post-treatment prose passages (totalling four). Participants were asked to recall these prose passages in as much detail as they could remember. They were free to recall the prose passages in any order they preferred. Recall was not time-restricted.

The protocol of both presentation and delayed recall matched that used by Alber and colleagues (2014), except that we: (a) presented two pairs of stories totalling four, as opposed to a single pair totalling two stories; (b) provided up to two cues following complete recall failure, as a means of disassociating possible sedation-induced retrieval failures from potential consolidation interference (see Tulving, 1974; Buschke, 1984; Ivanoiu et al., 2005); and (c) presented a final, third pair of prose passages at the end of the post-treatment phase, which was only tested immediately after presentation (the reason for this is outlined later).

At the end of post-treatment period, participants completed a final VAMS to establish whether diazepam-induced subjective mood/sedation remained present. Following this, participants were informed that there would be a follow-up session 7 days later in which they would be required to complete a test of their intelligence quotient (IQ), to ensure that the treatment groups were matched. Participants were not explicitly informed that an assessment of delayed recall of all six presented prose passages would occur during this later session. Participants were then safely transported home, with explicit instructions not to drive or operate machinery over the next 24 hours.

The Day 7 session, occuring one week later, was free of any treatment (diazepam or placebo) (see Figure 6.1c).

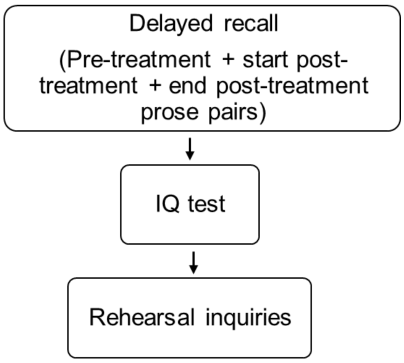

Figure 6.1c. Experimental procedure for Day 7 session.

Participants carried out a surprise test of delayed free-recall (7-day delay) of all stories presented on Day 1, in addition to an IQ test (Raven, Court, & Raven, 1985, adapted by Arthur, Tubre, Paul, & Sanchez-Ku, 1999). Participants were then asked to report whether or not they had rehearsed or thought about any of the prose passages over the last seven days. It should be noted that of the six prose passages presented during the Day 1 session, only the last two were not assessed after a delay during the post-treatment phase. The last two stories were not subjected to a delayed test during the Day 1 session as a means of: (a) determining the persistence of a possible immediate MinRI effect 7 days later in the absence of elicited reconsolidation (via delayed test during Day 1 session); and (b) assessing the effect of diazepam on consolidation and reconsolidation of information that occurred post-treatment over the period that extended until the drug was no longer active (see Mandelli et al., 1978; Riss et al., 2008).

6.2.2.6 Statistical Analysis

Chi-square was used to compare the proportion of men and women in each experimental group. A number of repeated-measures analysis of variance (ANOVA) were conducted (alongside Bonferroni post-hoc tests where appropriate) to analyse the remaining data. Factors and levels are described in the Results section. When factors interacted, only higher order effects are described. Statistical results that were not cited next did not reach significant or near-significant effects ($p > .08$).

6.2.3 Results

6.2.3.1 Baseline Comparison Between Groups

There were equivalent proportions of men and women in both treatment groups, $X^2(1, N = 26) = 1.22$; $p = .27$: 8m/5f in the placebo and diazepam groups, respectively. Independent samples t-tests were conducted to see whether there were differences in age, IQ and pre-treatment performance in the test battery across both treatment groups (placebo vs. diazepam). The treatment groups did not differ in age (M = 23.50, SD = 4.17; $M_{Diazepam}$ = 23.87, SD = 4.40; $M_{Placebo}$ = 23.10, SD = 4.05), IQ, nor mood ratings pre-treatment ($p > .05$). Lack of pre-treatment differences between groups with respect to WMC and immediate delayed-recall performance can be found, respectively, in analyses described in Section 6.2.3.3 and 6.2.3.4 respectively. Thus, similarity between groups was ensured by random allocation into diazepam and placebo treatment.

6.2.3.2 Effects on Mood

Changes in mood from baseline (change scores = rating at the beginning and end of the post-treatment period - pre-treatment rating) were analysed using a repeated-measures ANOVA with within-subject factor post-treatment assessment moment (change scores at start of post-treatment vs. change scores at end of post-treatment) and between-subject factor treatment (placebo vs. diazepam). Diazepam increased physical sedation, $F(1, 28) = 42.09$, $p < .001$, $\eta_p^2 = .6$, mental sedation $F(1, 28) = 24.49$, $p < .001$, $\eta_p^2 = .47$, and "other symptoms", $F(1, 28) = 8.57$, $p < .01$, $\eta_p^2 = .24$. However, there were no effects of post-treatment assessment moment nor an interaction of this factor with treatment, indicating that the subjective effects elicited by the drug were maintained throughout the course of the post-treatment period. This was expected given the long half-life of this drug and its metabolites. Data on mood changes can be found in Appendix H. BZ-induced changes in mood were controlled across all analyses; given that the pattern of effects remain unchanged following its control, the original analyses were subsequently reported.

Table 6.1. Summary of the observed changes in memory following the acute administration of diazepam.

	Memory effects of diazepam	Interpretation*	Relevant Tables/ Figures
Expected effects of BZs	Subtle decline in immediate free-recall following diazepam ingestion (Day 1)	Possible slight impairment in association between items at encoding	Figure 6.3 Appendix I
	Reduced retention of episodic information encoded post-diazepam that were recalled after both short (Day1) and long delays (Day7)	AA	Figure 6.4a Figure 6.4b Figure 6.5a Figure 6.5b Appendix I
	Higher retention of pre-treatment prose passages at delayed test of recall (Day 1)	Lack of RA / Retrograde facilitation	Figure 6.4a Figure 6.4b Appendix I
Previously unknown effects of BZs	Preserved performance on running span memory and counting span tasks post-diazepam (Day 1)	Preserved WMC	Figure 6.2a Figure 6.2b
	Absence of differences between minimal retroactive interference (MinRI) and retroactive interference (RI) on Day 1 and Day 7 for diazepam-treated participants	No improvement in recall following MinRI	Figure 6.4a Figure 6.4b Figure 6.5a Figure 6.5b Appendix I
	No significant reductions in proportion retention between Day 1 to Day 7 for episodic content encoded post-treatment	No accelerated forgetting	Figure 6.6 Appendix I
	Dissipation of retrograde facilitation post-diazepam on Day 1 after a long delay (Day 7)	Impaired reconsolidation	Figure 6.5a Figure 6.5b Appendix I

Note. Day 1 included two periods, pre- and post-treatment, in both of which stories were presented followed by MinRI and RI with immediate subsequent immediate recall, although delayed recall was carried out only post-treatment (see Figure 6.1); Day 7 involved a drug-free session with delayed recall of all stories.

6.2.3.3 Effects on Working Memory Capacity

The repeated-measures ANOVAs used to analyse the Counting Span (Figure 6.2a) and Running Memory Span scores (Figure 6.2b) included the within-subjects factor session (pre-treatment vs. post-treatment) and between-subjects factor treatment (placebo vs. diazepam). No effect of treatment, session, nor an interaction ($p > .05$) was found for the Counting Span task, demonstrating that diazepam did not impact performance. Additionally, there was no effect of treatment nor an interaction of treatment and session in the Running Memory Span task ($p > .05$). However, there was an effect of session, $F(1, 28) = 4.30$, $p = .047$, $\eta_p^2 = .13$, with performance declined slightly on the post-treatment session. Visual scrutiny of the graph alludes to a drop in performance within the diazepam group, but an exploratory post hoc analysis for the insignificant interaction ($p = .08$) failed to show significant contrasts. Table 6.1 summarises the investigated memory effects of BZs, the general findings and the relevant Tables and Figures in which results can be observed.

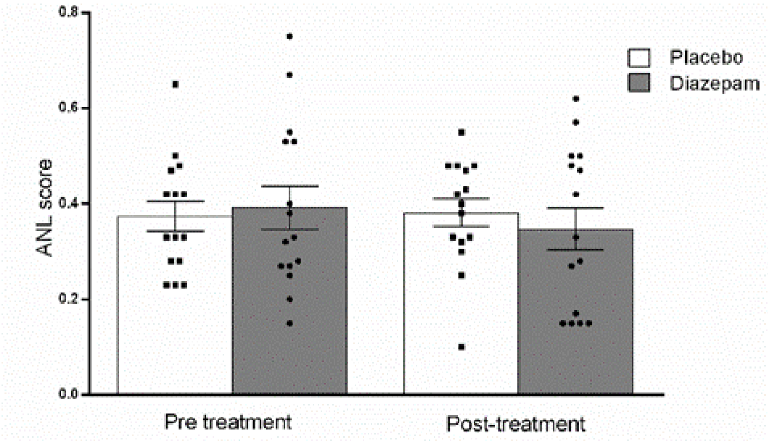

Figure 6.2a. Scores on Counting Span task. Individualised (dots and squares) and mean (± SE) scores (histograms with error bars) on the Counting Span task (all or nothing load scores: ANL) per treatment group (placebo or diazepam) and period on Day 1 session (pre- or post-treatment).

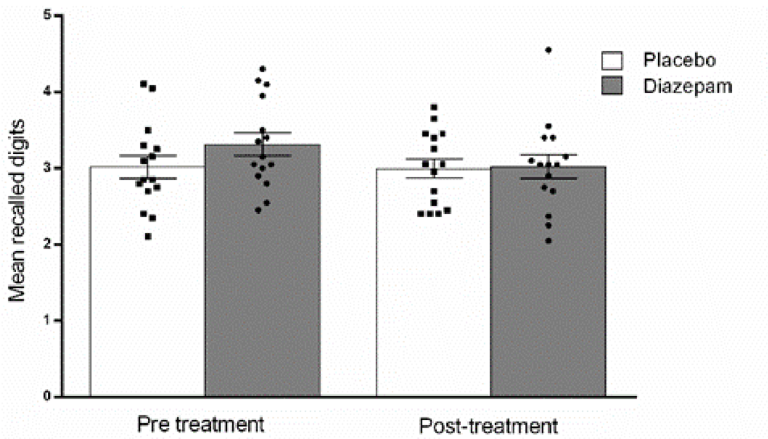

Figure 6.2b. Scores on Running Memory Span task. Individualised (dots and squares) and mean (± SE) scores (histograms with error bars) on the Running Memory Span task (mean number of recalled digits in the correct serial order), per treatment group (placebo or diazepam) and period on Day 1 session (pre- or post-treatment).

6.2.3.4 Effects on Immediate Free-Recall

A repeated-measures ANOVA with within-subjects factors encoding moment (prose pair presented pre-treatment vs. prose pair presented at start of post-treatment vs. prose pair presented at end of post-treatment) and post-encoding condition (RI vs. MinRI) and between subjects factor treatment (placebo vs. diazepam) was used to analyse immediate free-recall of the prose passages. The within-subjects factor of post-encoding condition was employed to establish whether immediate recall of the different versions of the stories were comparable and randomised appropriately. Data of one participant in the diazepam group for the final two prose passages (presented at the end of the post-treatment period) were excluded from the analysis due to equipment failure.

There was a significant interaction between treatment and session, $F(2, 54) = 7.49$, $p = .001$, $\eta_p^2 = .22$ (see Figure 6.3; means ± SD in Appendix I). The post hoc analysis showed no differences between groups at baseline, but the diazepam group performed poorer on tests of immediate recall for the pair of prose passages presented at the beginning of the post-treatment period compared to immediate recall of the other prose pairs (i.e., pre-treatment and end of post-treatment prose pairs) ($p < .05$). Additionally, this was significantly poorer than immediate recall performances of the placebo group across all immediate recall tests ($p < .05$). Immediate free-recall of the last prose pair (presented at end of post-treatment period) was only marginally lower in the diazepam group when contrasted with the placebo group ($p = .07$). There was no effect of interference, nor did this factor interact with the others ($p > .63$). However, an effect of interference was expected because this manipulation only occurred after immediate recall.

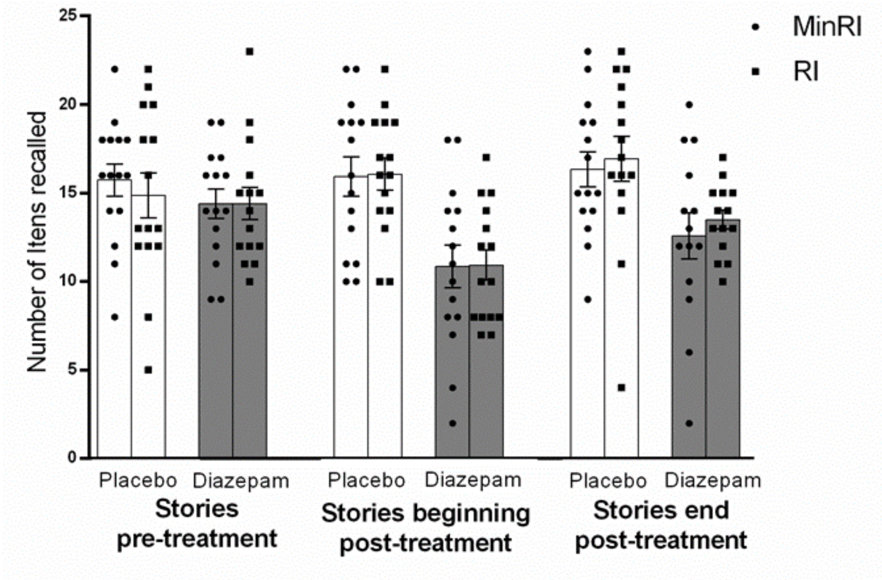

Figure 6.3. Immediate free-recall. Individualised (dots and squares) and mean (± SE) story idea units (histograms with error bars) recalled during immediate free-recall of prose passages presented at different test moments (pre-treatment; beginning of the post-treatment period, end of the post-treatment period) per treatment group (placebo or diazepam) and type of interference (MinRI = Minimal Retroactive Interference and RI = Retroactive Interference).

Main effects of post-encoding condition (RI vs. MinRI) and interactions of post-encoding condition with other factors were not observed in any of the analyses within this experiment. However, Figures throughout this chapter illustrate the results of recall following these conditions so that they can be appropriately visualised.

6.2.3.5 Effects on Delayed Recall

6.2.3.5.1 *Analysis of the anterograde and retrograde effects of diazepam measured at the post-treatment period (Day 1)*

There were only three instances in which a single item from a previously presented prose passage (i.e., during pre-treatment) intruded in a test of recall for post-treatment stories (two participants from diazepam group, one participant from placebo group). Given this, it is unlikely that PI accounted substantially for the current findings. A repeated-measures ANOVA with within-subjects factors encoding moment (encoding at pre-treatment vs. encoding at the start of post-treatment) and post-encoding condition (RI vs. MinRI) and between-subjects factor treatment (placebo vs. diazepam) was conducted to assess differences in proportion retention (delayed free-recall divided by immediate free-recall) of the first two pairs of presented prose passages. The results showed an interaction of treatment and encoding moment, $F(1, 28) = 103.37$, $p < .001$, $\eta_p^2 = .79$, with the diazepam group demonstrating reduced retention of prose passages encoded post-treatment when compared to both their retention of pre-treatment prose passages, as well as the retention of post-treatment prose passages by the placebo group ($p < .001$).

This demonstrates clear AA for material encoded under the effects of BZs, but an absence of RA for material that was encoded prior to drug administration (Figure 6.4a). Retention of prose passages presented at the start of the post-treatment period was significantly better when compared to the prose passages that were learned during the pre-treatment period ($p < .01$). Conversely, retention of the pre-treatment prose passages was significantly better in the diazepam group, when compared to the proportion retention of pre-treatment prose passages in the placebo group ($p < .001$). This is representative of a retroactive facilitation effect, which is common across studies of BZs (see the Discussion section). The effects of post-encoding condition (i.e., RI, MinRI) were not significant and did not interact with the other factors ($p > 0.21$).

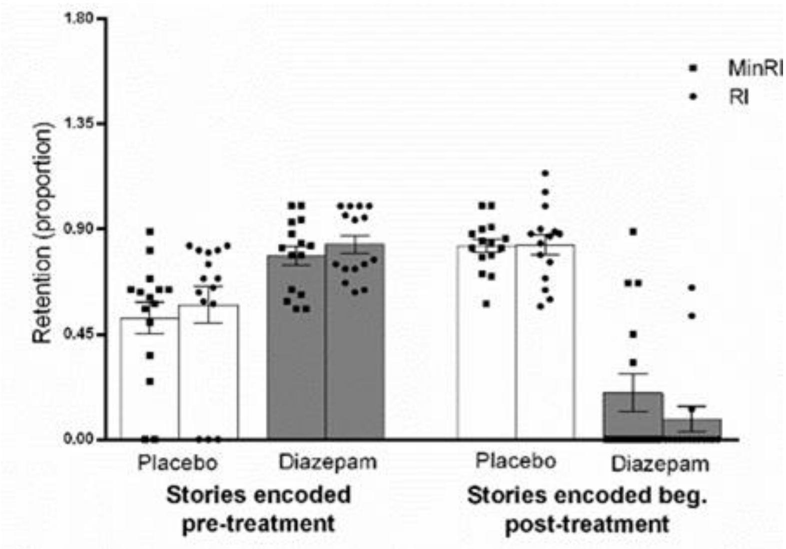

Figure 6.4a. Retention at delayed recall (Day 1; no cues). Individualised (dots and squares) and mean (± SE) retention scores (histograms with error bars) assessed in delayed post-treatment free-recall of stories presented pre-treatment and at the beginning of the post-treatment period, by treatment group (placebo or diazepam) and type of interference (MinRI = Minimal Retroactive Interference and RI = Retroactive Interference).

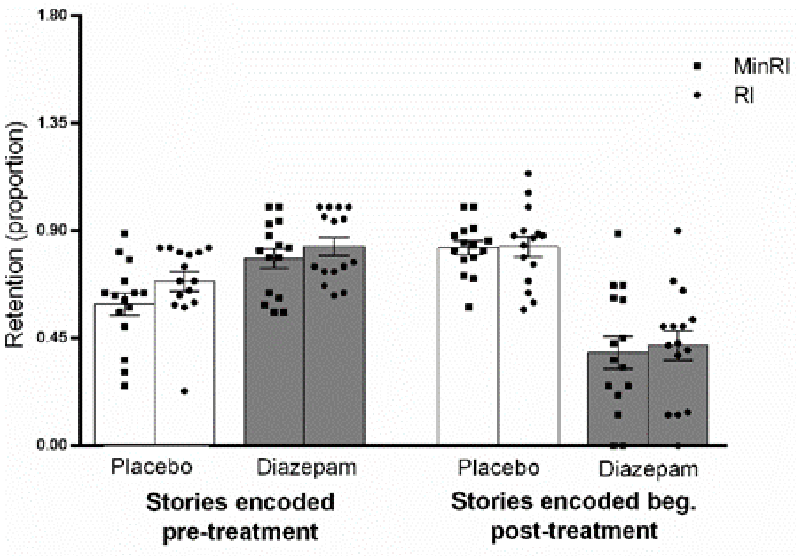

Figure 6.4b. Retention at delayed recall (Day 1; after cues). Individualised (dots and squares) and mean (± SE) retention scores (histograms with error bars) assessed in delayed post-treatment after providing cues of stories presented pre-treatment and at the beginning of the post-treatment period, by treatment group (placebo or diazepam) and type of interference (MinRI = Minimal Retroactive Interference and RI = Retroactive Interference).

A similar repeated-measures ANOVA was conducted, comparing proportion retention when cues were provided at delayed recall (see Figure 6.4b and Table 6.2).

Table 6.2. Number of participants who scored zero (did not recall any story idea units from the prose passages: total anterograde amnesia) during delayed tests of recall on Day 1 and Day 7 sessions (0 cues, free-recall), after one and 2 cues (cued-recall) according to moment in which stories were encoded and interference conditions (MinRI: minimal retroactive interference; RI: retroactive interference).

Encoding period	Recall	Cues	Placebo		Diazepam	
			MinRI	RI	MinRI	RI
Pre-treatment period	Post-treatment period (Day 1)	0	2	3	0	0
		1	1	1	0	0
		2	0	0	0	0
	7-day delay (Day 7)	0	1	1	1	1
		1	1	0	1	0
		2	0	0	0	0
Beginning of the post-treatment period (subjected to delayed recall on Day 1)	Post-treatment period (Day 1)	0	0	0	10	12
		1	0	0	5	4
		2	0	0	2	1
	7-day delay (Day 7)	0	2	2	13	9
		1	1	1	11	7
		2	0	0	6	6
End of the post-treatment period (not subjected to delayed recall on Day 1)	7-day delay (Day 7)	0	9	7	13	12
		1	1	1	12	12
		2	0	1	8	9

Note: There were no zero scores for immediate free-recall.

Proportion retention was determined by subtracting the cue items from the total number of prose passage items that were subsequently recalled in the delayed test, then dividing this by the total number of items recalled during the immediate test. Scores were summed for one and two cues because almost all diazepam-treated individuals needed two cues in order to retrieve extra story information (see Table 6.2). The results mirrored those seen for free-recall, with a significant interaction of treatment vs. session: $F(1, 28) = 56.56$, $p < .001$, $\eta_p^2 = .67$. Post hoc tests showed similar significant contrasts, demonstrating that the effects of BZs did not merely result from difficulty in retrieving information, but vastly hindered storage/consolidation that could not be successfully retrieved even with reminders. Again, there was no significant effect of post-encoding condition (RI vs. MinRI), or significant interactions with encoding moment and treatment ($p > .09$).

6.2.3.5.2 *Effects on reconsolidation*

A low number of participants reported that they expected a test of delayed recall of the prose passages during on Day 7 session (three in the placebo group and two in the diazepam group). Additionally, only three participants in the placebo group and five participants in the diazepam reported remembering some prose passage material between Day 1 and Day 7 sessions. As there was no group differences, this was not taken into account in the analyses.

To assess the effects of treatment (placebo vs. diazepam) on the reconsolidation of episodic memories, three metrics were employed. These metrics involved differential calculations of proportion retention, utilising scores from delayed tests of recall that were either free or cued. The focus was on the two pairs of prose passages that were either presented during the pre-treatment period or at the beginning of the post-treatment period. Scores from delayed tests conducted during the post-treatment period on Day 1, as well as the delayed test during the Day 7 session, were considered in these calculations.

Proportion retention within the first metric was calculated by dividing the total number of story idea units freely-recalled during the Day 7 test of delayed recall (no cues) by the total number of story idea units freely-recalled during the post-treatment test of delayed recall during the Day 1 session (no cues). However, a large portion of the participants in the diazepam group did not freely recall any items from the prose passages presented at the start of the post-treatment period on Day 1 (10 participants in the MinRI condition and 12 in the RI condition: see Table 6.2). Given this, proportion retention could not be computed for these participants and thus analysis was not carried out.

However, this metric was useful in comparing recall on Day 7 for pre-treatment prose passages that had been subsequently recalled during the post-treatment test on Day 1. A repeated-measures ANOVA with within-subjects factor post-encoding condition (RI vs. MinRI) and between-subjects factor treatment (placebo vs. diazepam) was conducted. Most notably, there was no effect of treatment ($p = .29$). Given this, it is apparent that the retrograde facilitation of pre-treatment prose passages experienced by diazepam-treated participants (seen in delayed tests of recall during the Day 1 session) no longer had an effect at Day 7. From this, it can be assumed that the recalling of pre-treatment prose passages under the effects of the drug seemed to have hindered its reconsolidation. Again, the post-encoding condition (i.e., RI, MinRI) had no effects and did not interact with treatment.

The second metric was calculated by dividing the total number of story idea units freely-recalled on Day 7 (no cues) by the total number of story idea units recalled during the post-treatment delayed test on Day 1 (after cues) (Figure 6.5a). Another repeated-measures ANOVA, with within-subjects factors encoding moment (pre- treatment vs. start of the post-treatment period) and post-encoding condition (RI vs. MinRI) and between-subjects factor treatment (placebo vs. diazepam), was conducted. Three participants from the diazepam group were excluded; two performed at floor on Day 1 test of delayed recall (even following cues), and one was identified as an outlier (SD over 3 above mean). This analysis showed an effect of treatment on proportion retention, $F(1, 25) = 4.82$, $p = .04$, $\eta_p^2 = .16$, with diazepam-treated participants demonstrating poorer retention when compared to the placebo group. Additionally, this analysis also revealed poorer retention, regardless of treatment, when encoding took place post-treatment than pre-treatment, effect of encoding moment: $F(1, 25) = 11.94$, $p = .002$, $\eta_p^2 = .32$. There was no interaction of these factors.

This further solidifies that while the administration of BZs facilitates the retention of episodic material encoded pre-treatment when compared to placebo on Day 1, bringing this information back to mind post-treatment hinders its reconsolidation. This interference is comparable to the interference effects seen when both encoding and retrieval are conducted post-treatment. Once again, the post-encoding condition (RI vs. MinRI) had no effect and did not interact with other factors.

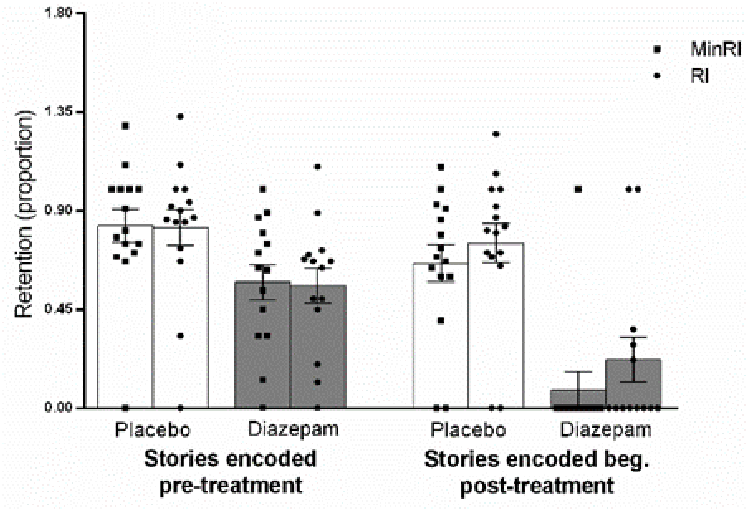

Figure 6.5a. Retention on Day 7 (before cues). Individualised (dots and squares) and mean (± SE) retention scores (histograms with error bars) of stories on Day 7 free-recall, in relation to the delayed cued-recall in the post-treatment period of stories encoded pre-treatment and at the beginning of the post-treatment period on Day 1, per treatment group (placebo or diazepam) and type of interference (MinRI = Minimal Retroactive Interference and RI = Retroactive Interference).

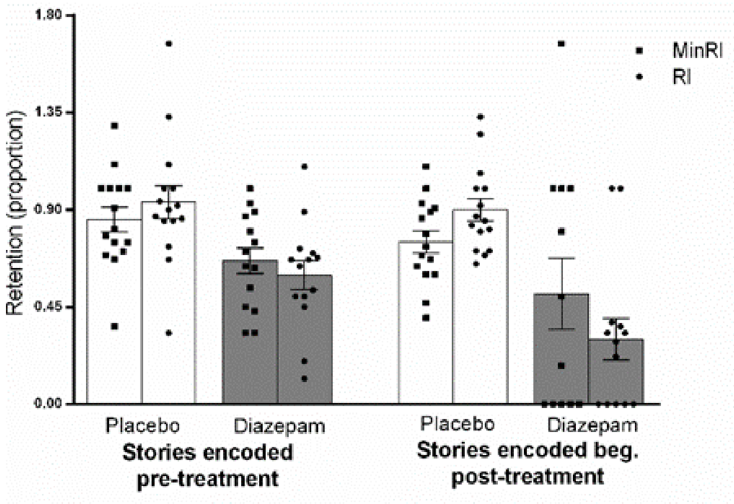

Figure 6.5b. Retention on Day 7 (after cues). Individualised (dots and squares) and mean (± SE) retention scores (histograms with error bars) of stories on Day 7 cued-recall, in relation to the delayed cued-recall in the post-treatment period of stories encoded pre-treatment and at the beginning of the post-treatment period on Day 1, per treatment group (placebo or diazepam) and type of interference (MinRI = Minimal Retroactive Interference and RI = Retroactive Interference).

The third metric (Figure 6.5b) was calculated by dividing the total number of story idea units recalled on Day 7 (after cues) by the total number of story idea units recalled in the post-treatment period on Day 1 (after cues). The three participants outlined above were again removed from the analysis due to their at-floor or outlying performances. Utilising the same repeated-measures ANOVA as before, the analysis demonstrated similar effects, treatment: $F(1, 25) = 25.99$, $p < .001$, $\eta_p^2 = .51$; encoding moment: $F(1, 25) = 5.29$, $p = .03$, $\eta_p^2 = .17$; interaction: $F(1, 25) = 5.26$, $p = .03$, $\eta_p^2 = .17$. Additionally, there were no significant post hoc contrast ($p > .08$), which leads us to suggest that the diazepam-induced effects were not due to difficulties at retrieval.

6.2.3.5.3 *Effects of diazepam on consolidation over a short and long delay*

To determine the extent to which diazepam impacts both synaptic consolidation (occuring within the immediate minutes following encoding) and systems consolidation (occurring over the course of a week following encoding), a repeated-measures ANOVA with within-subjects factors duration of delay (proportion retention of prose passages presented and recalled during Day 1 session vs. proportion retention of prose passages presented and recalled during Day 7 session) and post-encoding condition (RI vs. MinRI), and between-subjects factor treatment (placebo vs. diazepam) was conducted.

The use of delayed recall of the final two prose passages presented at the end of the post-treatment period (Day 1) allowed us to assess the retention of material that had not been possibly subjected to reconsolidation (the first two prose pairs had been subjected to reconsolidation during the Day 1 session prior to the Day 7 delayed recall test). In this analysis, proportion retention of the prose passages presented and recalled during the post-treatment period (calculated by dividing delayed cued-recall of stories presented at the beginning of the post-treatment period by immediate free-recall of these stories at the same session) was compared against the proportion retention of the last pair of prose passages that were later assessed in the Day 7 session (calculated by dividing the delayed cued-recall of the final prose passage pair assessed at Day 7 by the immediate free-recall in the post-treatment period on Day 1) (see Figure 6.6). This analysis showed an effect of treatment, $F(1, 26) = 70.57$, $p < .001$, $\eta_p^2 = .73$, with diazepam-treated participants performing poorer in comparison to the placebo group. Additionally, regardless of treatment, the proportion of story idea items retained declined more after 7 days than during the time span between immediate and delayed recall in the post-treatment period, $F(1, 26) = 75.85$, $p < .001$, $\eta_p^2 = .74$. Importantly, treatment did not interact with duration of delay, displaying that the disruptive effects of diazepam are restricted to consolidation that occurs immediately following encoding, but not over extended periods where the drug was still active. Given this, diazepam did not accelerate forgetting at a differential rate from placebo. The post-encoding condition (i.e., RI, MinRI), again, had no effects and did not interact with the other factors.

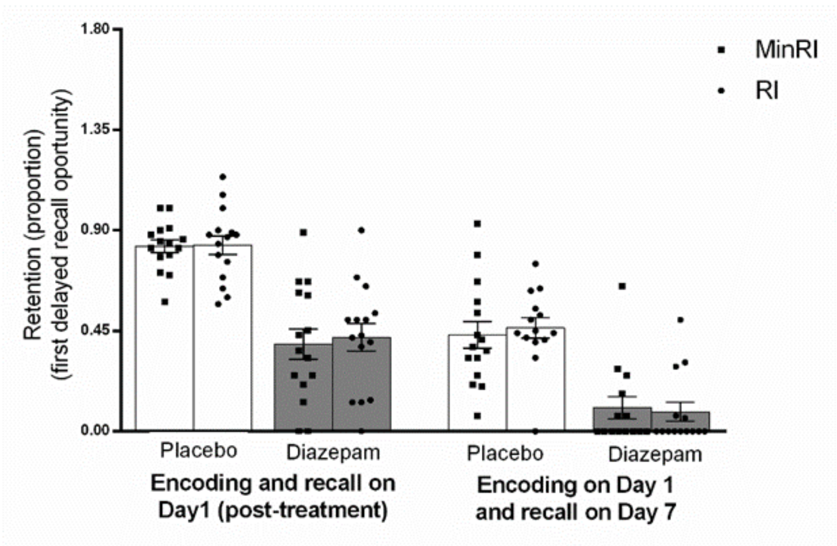

Figure 6.6. Retention of story items over a short delay (encoding and retrieval post-treatment on Day 1) and a long delay (encoding post-treatment on Day 1 and recall on Day 7). Individualised (dots and squares) and mean (± SE) retention scores (histograms with error bars) post cues in the first delayed recall opportunity of stories encoded post-treatment, per treatment group (placebo or diazepam) and type of interference (MinRI = Minimal Retroactive Interference and RI = Retroactive Interference).

Table 6.3. Summary of characteristics of different types of patients with organic non-material-specific anterograde amnesia and effects of acute diazepam (15 mg) oral administration on the differential diagnostic criteria based on the cognitive constructs under investigation.

	Working memory capacity	Benefit from minimal retroactive interference (MinRI)	Episodic memory decay
Korsakoff's Syndrome	Impaired[1]	-	Typical[2]
Medial temporal lobe insult	Spared[3]	Yes (general lesion)[4;5] No (probable hippocampal lesion)[5]	Typical[6;7]
Alzheimer's disease (AD)	Impaired[8;9]	Yes (but decreases in more severe AD)[10]	Typical[11;12]
Mild cognitive impairment	Spared[13]	Yes (low benefit in AD probable converters)[10]	Accelerated[14] Typical[15;11]
Transient epileptic amnesia	Spared[16]	-	Accelerated[2;17]
Transient global amnesia	Spared[18]	-	Typical[19]
Acute oral diazepam (15 mg)	Spared[20]	No[20]	Typical[20]

Note. [1]Parkinson (1980); [2]Elliot et al. (2014); [3]Baddeley et al. (2011); [4]Dewar et al. (2010); [5]Cowan et al. (2004); [6]Geurts et al. (2015); [7]McKee & Squire (1992); [8]Hamdan & Bueno (2005); [9]Kensinger et al. (2003); [10]Dewar et al. (2012b); [11]Alber et al. (2014); [12]Hart et al. (1987); [13]Hamdan & Bueno (2005); [14]Walsh et al. (2014); [15]Manes et al. (2008); [16]Tudesco et al. (2010); [17]Lah et al. (2014); [18]Quinette et al. (2003); [19]Hodges & Warlow (1990), [20]Present study.

Table 6.3 summarises the results found regarding diazepam effects and the comparison to amnesic conditions according to the classification of Parkin and Leng (2014).

6.2.4 Discussion

In the current experiment, the acute oral administration of 15 mg of diazepam elicited cognitive effects that were in line with predictions that typical BZs induce profound AA for episodic content in healthy adults, with reasonably spared immediate free-recall (Curran, 1991) and WMC (Reder et al., 2006). More specifically, it was observed that this dose equally hinders initial consolidation/reconsolidation processes. Interestingly, episodic material that was encoded prior to drug administration remain unaffected (no obstruction of consolidation/retrieval for pre-treatment stories, absence of RA). Additionally, this dose did not heighten susceptibility to immediate RI (see Dewar et al., 2009) nor accelerate forgetting over a seven-day period (see Geurts et al., 2015; Kopelman & Stanhope, 1997). Similar to previous findings (Curran, 1991; Buffett-Jerrott & Stewart, 2002; Mintzer & Griffiths, 2007), these effects could not be explained by the predicted diazepam-induced increase in physical and mental sedation (Curran & Birch, 1991; Sarasin, Ghoneim, & Block, 1996).

Collectively, these results appear to indicate that BZs are not a suitable model of “generic” non-material specific organic amnesias (e.g., Lister, 1985; Curran, 1991; Thomas-Antérion et al., 1999), but instead are consistent with the notion that the effect of BZs mimic organic AA seen in patients with medial temporal lobe damage and MCI patients who subsequently develop AD.

With respect to the immediate free-recall of memory for prose material, the findings matched the pattern of effects seen in different types of clinical amnesia (Baddeley & Wilson, 2002; Dewar et al., 2010). A decline in immediate free-recall scores was observed across the post-treatment period following the administration of diazepam, but the effect was substantially smaller in comparison to the observed effect on delayed free-recall (Ghoneim et al., 1981; Curran, 1986, 1991; Curran & Birch, 1991). This subtle impediment did not result from sedation; instead, it may have originated from the impeded ability to utilise episodic LTM (impaired by BZs) that can aid performance in this type of task (Verfaellie & Keane, 2017). This provides us with a possible explanation as to why amnesics display lower immediate recall scores when memory load is high or the retention interval is extended beyond the constraints of working memory (Jeneson & Squire, 2012), seen in instance of immediate memory for prose material.

Although a significant decrease in immediate free-recall was seen at peak-plasma concentration of the drug, immediate free-recall was only marginally worse by the end of the post-treatment period (p = .07) when compared to placebo-treated participants. The progressive dissipation of the subtle deficit in immediate free-recall was observed, despite the sedative effects of diazepam remaining constant until the experiment concluded on Day 1. It is possible that diazepam-treated participants are able to overcome lesser symptoms by making specific adjustments (see Cittadini & Lader, 1991; Ellinwood, Linnoila, Easler, & Molter, 1983).

It should also be acknowledged that diazepam-treated participants may have been aware that they had ingested the drug as opposed to a placebo. It is not entirely clear whether this awareness may have had an impact of the mood measures; however, given that effects remained the same when this measure was accounted for, the awareness of drug ingestion specifically may have not played a significant role in post-treatment performance.

As seen in many forms of amnesia (e.g., Parkinson, 1980; Leng & Parkin, 1989; Kopelman & Stanhope, 1997; Baddeley & Wilson, 2002; Quinette et al., 2003, 2006; Allen et al., 2014), healthy participants under the effects of diazepam did not demonstrate impaired WMC. This allows us to refute the likelihood that complications in active search and retrieval of recently activated LTM (Unsworth, 2016; Unsworth & Engle, 2007) were responsible for reductions in immediate free-recall. Automatic linguistic processes - which operate during immediate prose-recall (Jefferies, Lambon Ralph, & Baddeley, 2004) – were unlikely to be impacted by diazepam ingestion, given that BZs do not typically impede verbal short-term nor implicit memory processes (Curran, 1991; with lorazepam being the only exception; see Giersch, Boucart, Elliott, & Vidailhet, 2010).

With this in mind, it appears that diazepam decreases immediate recall of prose passages through an alternative mechanism. This mechanism may be linked with shifts in the functioning of the hippocampus, which is implemented in the formation of associations at encoding (conjunction working memory: Olson, Page, Moore, Chatterjee, & Verfaellie, 2006; see also Hannula, Tranel, & Cohen, 2006) that is not assessed in the WMC tasks that were used. An absence of WMC deficits following the administration of diazepam also indicates that BZs do not mirror amnesia in Korsakoff patients, who often demonstrate reduced WMC (Parkinson, 1980). However, this assertion demands further investigation, given the scarcity of studies that have explored this construct in patients with different forms of amnesia.

The small improvement to delayed recall following cues could additionally implicate possible hippocampal-dependent changes at encoding under BZs. This may indicate that memory traces may not be adequately integrated with their respective episodes at encoding if encoding occurs under the effects of BZs. If so, this may result in later retrieval difficulties in the absence of cues (cue-dependent forgetting: Tulving, 1974). However, this seems unlikely to provide us with a robust explanation for BZ-induced AA, given that delayed recall was still substantially lower following drug administration, even with the inclusion of cues. This appears to support the notion that BZs predominantly impact the consolidation of episodic content that is encoded under the effects of the drug (Curran, 1986, 1991; Gorissen et al., 1998; trace-dependent forgetting: Tulving, 1974; see also Shimmerlik, 1978).). This is in line with the effects observed across different amnesic patients (see Hirst, Johnson, Kim, Risse, & Phelps, 1986; Aggleton & Brown, 1999; Baddeley & Wilson, 2002; Tulving, 2002; Quinette et al., 2006; Alber et al., 2014).

The increased retention of the prose passages presented at the start of the post-treatment period by the placebo group, in contrast with the prose passages that were learned during the pre-treatment period, could be explained in a number of ways. According to the temporal distinctiveness theory, the shorter temporal distance between the learning of the post-treatment prose passages and delayed recall could have resulted in this material being more distinct at retrieval when compared to the pre-treatment prose passages (Brown et al., 2007). A recency effect (Baddeley & Hitch, 1993) could also provide another means of interpreting these findings. In contrast, the diazepam-treated participants displayed higher retention of the prose passages presented pre-treatment than the placebo-treated participants, demonstrating a retroactive facilitation effect. This opposes the idea that BZs impede retrieval, supporting past findings (Curran, Schiwy, & Lader, 1987; Coenen & van Luijtelaar, 1997; Delgado, Izquierdo, & Chaves, 2005). This result elucidates a number of queries revolving around the possible effects of BZ – specifically, state-dependent learning, time course of effects on consolidation and susceptibility to interference.

State-dependent effects can be excluded on the basis that retrograde facilitation was observed following diazepam administration (see Lister, 1985). Retrograde facilitation may be observed across the diazepam-treated participants due to the drug-induced disruption of post-treatment material consolidation, a process that may retroactively interfere with the continued consolidation of pre-treatment prose passages (RI that may have been observed across the placebo group) (see Ghoneim et al., 1984; Curran, 1991). Given this, it seems that the effects of BZs are limited to the impairment of early consolidative processes (Wang & Morris, 2010) that take place immediately after encoding (Fiebig & Lansner, 2014). Ongoing consolidative mechanisms that commenced prior to drug ingestion appear unaffected (Brown et al., 1982; Fiebig & Lansner, 2014), if not supported by BZs due its ability to inhibit interference from subsequent consolidative episodes. The form of RI seen across the placebo group varies from the RI that was intended to be elicited experimentally via the post-encoding inclusion of an effortful task (i.e. spot-the-difference task).

While it has been demonstrated that some amnesic patients benefit from MinRI (Dewar et al., 2009, 2010; see Experiment 5), this was not established following the administration of diazepam; even though the degree of AA elicited following drug ingestion mirrored that seen across amnesic patients. Given this, BZs may impede consolidation in a similar manner to what has been seen in some amnesic patients who are unable to benefit from periods of post-encoding wakeful rest. The reasons for the lack of a post-encoding wakeful rest benefit in these patients is still not fully understood, but may be linked with more severe hippocampal damage (Cowan et al., 2004; Dewar et al., 2012a). One possibility is that in these specific clinical conditions and in the drug-induced amnesia following diazepam administration, hippocampal function that is essential for initial consolidation (Dudai, 2004; Mednick et al., 2011; Wang & Morris, 2010) may be so disrupted that they cannot benefit from MinRI, which acts by protecting memory from overloading (see Dewar et al., 2012a). In other words, BZs seem not to spare "residual retention" abilities (Dewar et al., 2012a) that can benefit from MinRI. However, this hypothesis is yet to be investigated.

A lack of a MinRI benefit to retention within the placebo-treated controls is unsurprising, given the inconsistency of this benefit among studies assessing healthy younger (Martini et al., 2017, 2018; Varma et al., 2017) and older (Dewar et al., 2010) adults who are high functioning and cognitively-intact (see Chapter 2). Among these samples, consolidation is likely highly efficient, with no differences following the post-encoding encountering of interpolated tasks unless extremely taxing, or if the to-be-retained material is more complex (see Varma et al., 2018; see Chapter 2 and 3). Alternatively, wakeful rest within this sample may entail autobiographical thinking which can act as RI in itself (Craig et al., 2014; Varma et al., 2018), making it difficult to establish differences following experimental manipulations given that rest is not a passive state for healthy individuals (Andreasen et al., 1995).

It should be highlighted that the AA elicited by BZs specifically is not dependent on the post-encoding activity. Such a prospect had not been previously considered or addressed in previous studies of BZs. However, post-encoding engagement with further sensory stimulation immediately following presentation of episodic content has been seen to reduce delayed recall in amnesic patients whose clinical conditions (resulted from brain injury due to anoxia, head injury, stroke, AD and MCI) were shown to be (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2009, 2010, 2012a) specifically vulnerable to RI.

Another effect that had not been explored in past research of BZs until now was the possible effects of the drug on reconsolidation. Retention after seven days was significantly lower for diazepam-treated participants, even for episodic content that had been adequately consolidated prior to treatment but subjected to reconsolidation under the effects of diazepam during a delayed test of recall in the Day 1 session. These findings support the notion that early consolidative processes and reconsolidation initial processes are potentially mediated by similar physiological mechanisms (Dudai & Eisenberg, 2004; McKenzie & Eichenbaum, 2011). Conversely, consolidation processes that take place over longer periods of time (i.e., systems consolidation: Tano et al., 2009; Wang & Morris, 2010; Fiebig & Lansner, 2014) do not appear to be affected by the administration of BZs, due to no observations of accelerated forgetting across diazepam-treated participants (cf. Geurts et al., 2015). It should be noted that, among the diazepam group, floor performances across Day 7 tests of delayed recall may have obstructed the ability to reliably observe accelerated forgetting. If an absence of accelerated forgetting following the administration of BZs could have been adequately confirmed across the experiment, it would have enabled us to reliably reject the notion that BZs model amnesias such as Transient Epileptic Amnesia (Elliott et al., 2014; Lah, Mohamed, Thayer, Miller, & Diamond, 2014), in which accelerated forgetting is a notable feature.

With all the findings collectively in mind, it has been established that acute oral administration of BZs (diazepam) hinders earlier consolidative processes (i.e., synaptic consolidation). Additionally, this profound, diazepam-induced AA cannot be adequately accounted for by sedation effects alone. It was determined that the treatment of diazepam does not accelerate forgetting, nor impair WMC. However, subtle declines in immediate free-recall were observed following drug administration. Diazepam-treated participants were also seen to not exhibit benefits from post-encoding wakeful rest, as typically seen in many patients with AA (see Experiment 5). From this, it can be concluded that acute doses of BZs adequately model amnesias resulting from medial temporal lobe damage and effects observed in most MCI patients.

The current experiment is the first to obtain all relevant findings from a single investigation, rather than contrasting similarities between cognitive changes following the administration of BZs and those seen in amnesic patients with the compilation of data from a number of separate investigations (Lister, 1985; Thomas-Antérion et al., 1999). Using BZs to model this form of amnesia can be of great utility as a means of: (a) exploring mechanisms of memory; and (b) facilitating large-sampled testing of manipulations that may improve episodic memory retention in individuals with memory impairments.

Chapter 7:

General Conclusions

7.1. <u>Brief Summary of the Aims of the Thesis</u>

This thesis intended to evaluate the accountability of prominent interference-based theories of forgetting (i.e., consolidation theory, temporal distinctiveness theory) in explaining patterns of episodic memory loss across different populations (i.e., healthy younger and older adults, patients with AA). Efforts to evaluate these accounts are necessary, given that both perspectives provide fundamentally different - yet equally credible - interpretations of known forgetting effects (more specifically, RI). The key problem in determining which theory better explains forgetting overall is that much of the current behavioural data that demonstrates effects of interference – and benefits following its minimisation via wakeful rest – can be concurrently explained by both accounts.

According to the consolidation theory (i.e., Müller & Pilzecker, 1900; Wixted, 2004; Dudai, 2004), the loss of episodic information from LTM occurs due to the disruption of the consolidation process. Early consolidative processes in particular, which entail the initial stabilisation of memory traces immediately after encoding (i.e., synaptic consolidation; see Dudai, 2004; Dudai et al., 2015), are presumed to be highly vulnerable to interruption following engagement in further sensory stimulation (Müller & Pilzecker, 1900; Dewar et al., 2009; see Sosic-Vasic et al., 2018). Neuroscientific explanations have outlined a number of possible causes for this interference effect. Such explanations propose that the maintenance of LTP for previously encoded memories, or the “offline replay” of episodic representations during wakefulness (Peigneux et al., 2004; Foster & Wilson, 2006; Tambini et al., 2010; Carr et al., 2011; Lewis & Durrant, 2011; see Craig et al., 2015), can be disrupted by the subsequent induction of LTP that is elicited via post-encoding task engagement (i.e., during a Spot-the-Difference task) (Xu et al., 1998; Izquierdo et al., 1999; Mednick et al., 2011).

With respect to this account, the minimisation of RI via post-encoding wakeful rest avoids this disruption by reducing further sensory stimulation. This in turn is believed to facilitate the early period of stabilisation that contributes to the formation of stronger memory traces that are less fragile to future interference (Müller and Pilzecker, 1900). Many studies have demonstrated notable benefits to episodic memory retention following brief instances of post-encoding wakeful rest; across both healthy adults (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2007; 2009; 2012b; Alber et al., 2014; Craig, Della Sala, & Dewar, 2014; Brokaw et al., 2016) and patients presenting with AA following brain injury (e.g., anoxia, head injury) (Cowan et al., 2004; Dewar et al., 2009; 2010), neurodegeneration (e.g., Mild Cognitive Impairment - MCI) and initial stages of Alzheimer’s Disease (AD) (Della Sala et al., 2005; Dewar et al., 2012a).

However, the benefits following the minimisation of RI can also be accounted for by alternative interference-based theories of memory and forgetting. Temporal distinctiveness theory (Brown et al., 2007) interprets these post-encoding wakeful rest benefits as evidence of improved retrieval following partial temporal isolation. According to this account, the benefit of minimal RI is associated within the eliminiation of post-encoding memories which decrease the distinctiveness of the target memory at retrieval if both are adjacently encoded in time. However, under this account, the elimination of neighbouring memories that precede the encoding of a target memory can also result in increased distinctiveness and thus improved recall. Given this, the temporal distinctiveness account both implicates RI and PI effects in forgetting, and can explain observed benefits following their reduction via rest (Ecker et al., 2015a; 2015b).

7.2. Establishing Theoretical Accountability across Studies of Minimal RI and PI

As a means of establishing data that may selectively favour a single account, numerous investigations into the possible effects of both RI and PI on the retention of various episodic material (i.e., prose, see Experiments 1-2, 5; lists of words, see Experiments 3-4) were carried out. The simultaneous assessment of both the interference effects, and possible gains following their reduction, provided a means of identifying which effect plays a more significant role in forgetting within a single paradigm. Variations in retention were assessed over a critical interval of time where interference is posited to be at its most effective (i.e., 10 minutes; Müller & Pilzecker, 1900; Cowan et al., 2004).

Across Experiments 1 and 2, it was found that both healthy younger and older adults can retain a substantial portion of previously learned prose material over 10 minutes, irrespective of whether prose acquisition and immediate free-recall was preceded and/or followed by an interpolated task (i.e., Spot-the-Difference task). The absence of interference effects – and benefits following pre- and post-encoding wakeful rest – was consistent across groups varying in age and prior educational experience. While the overall findings from these experiments make it difficult to evaluate theories of forgetting, the results promoted further considerations that could have implications for these accounts.

Firstly, a lack of any observed interference effects within Experiments 1 and 2 was possibly due to the choice of interpolated task. Past research has shown that post-encoding engagement in a visual Spot-the-Difference task can elicit notable RI effects (Dewar et al., 2012; Alber et al., 2014); however, this effect is not always consistent among healthy adults (Martini et al., 2017; Sacripante et al., 2019). It is possible that the amount of mental effort required to complete the task may vary across different versions. The proposal that the degree of effort demanded from an interpolated task mediates interference effects goes against the idea that *any* mental exertion – regardless of factors such as task difficulty or demand - can lead to increased forgetting (originally outlined by Müller & Pilzecker, 1900; Dewar et al., 2007). However, this phenomena may explain why RI effects have been difficult to observe across healthy populations in the past (see Dewar et al., 2010; Martini et al., 2017). But how may a less engaging interpolated task facilitate the circumvention of interference effects across Experiments 1 and 2? Very brief periods of inactivity during a post-encoding interpolated task may have allowed for certain strategies to be undertaken that benefit the retention of prose material specifically. The maintenance of cues (Paivio, 1971, 1986) – derived from interference-resistant salient story idea units that are closely linked to the prose context (Robertson, 2012; Ericsson & Kintsch 1995; see Goetz & Armbruster, 1980 for review) – may have been easier to achieve during such a task. These cues may have subsequently aided the retrieval of less salient portions of the prose passages that were grouped with certain context-based cues (McDaniel & Pressley, 1987).

Experiments 3 and 4 were conducted in order to see whether interference effects would remain absent across the same paradigm when the retention of unrelated words was assessed in place of the prose material. In addition to this change, the interpolated activity was adapted so that continual engagement during the task would be maintained throughout.

The results of Experiments 3 and 4 demonstrated that, similar to prose material, retention of wordlist material across a sample of healthy older adults was largely unhindered by the pre- and post-encoding encountering of an interpolated task. Observations of reduced retention across certain conditions within Experiment 3 was found to be a result of cumulative cross-list PI from prior wordlists. This was established following the elimination of this cross-list PI effect via the use of a between-subjects design in Experiment 4 that revealed no significant differences in retention afterwards.

While there were difficulties in assessing the effects of RI and PI (and benefits following their minimisation) across healthy samples in Experiments 1-4, it was unknown whether these same challenges would be encountered when testing the current paradigm on patients with AA. Given that patients have previously shown benefits following the independent minimisation of both RI (Cowan et al., 2004; Della Sala et al., 2005; Dewar et al., 2009; 2010; 2012a; Alber et al., 2014) and PI (Moscovitch, 1982; Freedman & Cermak, 1986; Janowsky et al., 1989; Shimamura, 1995; Kopelman, 2002; Baldo & Shimamura, 2002), there remained a possibility that an alternative pattern of findings would be established if the previous paradigm was utilised among a sample of amnesic patients. Experiment 5 subsequently investigated this as a means of establishing whether the consolidation theory could more widely explain patterns of forgetting across this paradigm when the subjects had impaired episodic LTM.

Similar to the observed pattern of forgetting seen among healthy older adults within Experiment 4, many of the amnesic patients that were tested retained a substantially reduced portion of newly learned episodic content when learning was followed by an effortful task. However, retention was also seen to improve considerably in some patients if given the opportunity to rest wakefully following new learning. Once again, it appears that the consolidation theory provides an explanation which better fits the data obtained from this paradigm. This is mostly due to the pronounced role of RI in determining the degree of forgetting seen among patients with AA. As mentioned on numerous occasions throughout the thesis, similar improvements to retention following minimal RI have been routinely established across a number of patient studies exploring post-encoding wakeful rest benefits (Cowan et al, 2004; Della Sala et al., 2005; Dewar et al., 2009, 2012a; Alber et al., 2014).

However, the role of PI cannot be overwhelmingly neglected based on the findings from Experiment 5. Mirroring Experiment 3, a superadditive decline in mean proportion retention was observed among patients when prose learning was both preceded and followed by a Spot-the-Difference task. However, unlike Experiment 3, this finding cannot be attributed to cross-condition PI based on the lack of intrusions across different tests of immediate and delayed free-recall. Given this unique effect, it is possible that PI does play a role in forgetting among amnesic patients (as previously observed; see Kopelman, 2002). However, it appears that the effects of PI that are elicited via a pre-encoding task are only notable when coupled with RI.

It should be highlighted that amnesic patients demonstrated these interference effects and wakeful rest gains when tasked with retaining prose material. Given that healthy younger and older adults did not show the same interference effects for prose across Experiments 1 and 2, the results from Experiment 5 illustrate a key divergence between these groups. These findings support the idea that patients with AA possess a heightened susceptibility to RI when compared to healthy adults (see Dewar et al., 2010). This has been linked specifically to hippocampal damage (Cowan et al., 2004; Dewar et al., 2009; 2010; 2012a). It is believed that this specific cerebral insult can impair the ability of amnesics to handle resource competition (Wixted, 2004; Dewar et al., 2009), due to brain-damaged induced constraints on cognitive resources required to perform tasks (Wixted, 2004; Dewar et al., 2009). Upon engaging with post-encoding stimuli, resources may be redirected from the LTP of the prose material towards the LTP for the interpolated task material (see Mednick et al., 2011; Craig et al., 2015), resulting in increased forgetting.

7.3. Investigation of Minimal Interference Benefits across Alternative Paradigms

While it may be concluded that RI greatly contributes to the forgetting of episodic information among many healthy older adults (as seen in Experiment 3 and 4) and amnesic patients (as seen in Experiment 5), this effect – and its reduction via post-encoding wakeful rest – does not appear to hugely influence memory performance across alternative forms of memory (i.e., PM; Experiment 6) or across samples of drug-induced amnesics (Experiment 7). It has already been discussed that RI is not readily seen to disrupt the consolidation and retrieval of prose material within healthy populations (as seen across Experiments 1 and 2). In addition to this, the presence or absence of a post-encoding interpolated task does not appear to affect later performance on a test of PM. This finding does not align with sleep research which has attributed improvements to PM task performance to the post-instruction minimisation of further sensory stimulation that is achieved via sleep (Diekelmann & Born, 2010; Scullin & McDaniel, 2010). These findings may exemplify a methodological difficulty in exploring the benefits of uninterrupted consolidation via wakeful rest across a paradigm that requires the use of multiple learning trials. Among healthy adults, the possibility remains that information learned over numerous trials may result in the formation of interference-resilient memory traces prior to the experimental manipulation of the post-encoding delay interval. However, the results could more interesting indicate an important distinction between the benefits of sleep and wakeful rest. While both of these states result in the minimisation of further incoming information that may elicit RI, sleep may also involve additional processes which work to enhance the consolidation of information (see Sejnowski & Destexhe, 2000). This does not rule out the applicability of the consolidation theory in explaining forgetting with regards to performing a planned action in the future. However, it does suggest that PM may be more robust to short intervals of interference, or less receptive to benefits following a very brief instance of wakeful rest.

The inability to benefit from the introduction of post-encoding wakeful rest was also observed across a sample of healthy adults who, following the administration of diazepam, displayed an impaired ability to retain prose material that was encoded after drug ingestion. As discussed in Chapter 2, the absent or small benefit of minimal RI via wakeful rest among healthy younger adults is not uncommon when it concerns the retention of prose material (Cowan et al., 2004; Della Sala et al., 2005l Dewar et al., 2010; Martini et al., 2017). However, given that the diazepam-treated participants displayed post-treatment performances that mirrored amnesic patients with AA, the absence of this benefit is notable. However, it is important to note that the ingestion of diazepam may have temporally disrupted hippocampal functioning, impairing the initial consolidation of any prose encountered post-treatment to a level that did not allow for post-encoding wakeful rest to be beneficial. This has also been seen among some amnesic patients with medial temporal lobe damage (Cowan et al., 2004). Based on this, it appears that the administration of BZs to healthy younger adults results in the brief incapacity of residual retention abilities (Dewar et al., 2012a) that can be fairly intact in certain amnesic patients (as evidenced in Experiment 5).

7.4. <u>Future Directions</u>

Further investigations could explore why the retention of information from episodic LTM in healthy adults may be selectively susceptible to RI based on the material encoded (i.e., prose, list of words). Adopting the same paradigm as used in Experiments 1-5, research could assess the retention of nonsensical prose passages that do not fit a common narrative this is familiar to the participant. Given that the use of cues derived from salient story ideas may facilitate the later retrieval of prose (irrespective of interpolated tasks), the absence of a comprehendible context may not enable healthy adults to engage in this strategy. This may subsequently lead to the observation of post-encoding wakeful rest benefits, as seen when the retention of wordlist material is assessed (Experiment 3 and 4).

On top of this investigation, research could further explore the differential interfering effects of interpolated tasks based on the mental effort that the task demands. While Experiment 3 demonstrated reduced retention following the post-encoding encountering of a more challenging Spot-the-Difference task (four differences, instead of two), it is not necessarily clear whether this is a sole result of the change in episodic content or if it is an additional product of a more tasking post-encoding activity. Additionally, Experiment 4 could be replicated, with another alteration to the interpolated task. While the experiments within this thesis all utilised various versions of a Spot-the-Difference task, the effects of RI and PI were not assessed when the pre- and post-encoding interpolated tasks consisted of information that was similar semantically or in terms of modality to the to-be-retained material. Given that the previous research supporting the temporal distinctiveness theory (i.e., Ecker et al., 2015a; 2015b) manipulated the temporal distance of a target memory from other similar memories (i.e., lists of words), it is possible that a clear effect of PI may only be observable when the pre-encoding task actively elicits interference at the point of retrieval. While forgetting in such a study (elicited by similarity PI) may not be representative of everyday forgetting (unlike diversion RI; Wixted, 2004), it may provide an indication as to why the temporal distinctiveness theory has received support across previous research.

Regarding the role of PI, further exploration of the superadditive effect seen following both RI and PI on prose retention in amnesic patients could be undertaken to further understand this effect. While a similar effect was observed across healthy older adults in Experiment 3, it was concluded following the findings of Experiment 4 that this result was likely an artefact of cross-condition PI. This form of PI was believed not to be present within Experiment 5, given that the prose passages were distinct and less likely to be confused with one another in comparison to lists of unrelated words. However, the absence of intrusions across assessments of recall in amnesics may not necessarily indicate that this form of PI was not in play. Future research could utilise a between-subjects study, akin to Experiment 4, to see whether this effect may similarly dissipate following the elimination of previous conditions.

A replication of Experiments 3 and 4 could also be conducted across a sample of healthy younger adults to discern whether age-related differences in interference effects can be seen when the retention of words is assessed using the main paradigm of this thesis.

7.5. <u>Closing Remarks</u>

Almost 120 years ago, Georg Elias Müller and Alfons Pilzecker made the claim that the exertion of mental effort can retroactively inhibit the consolidation of a recently acquired memory. While not the first to observe this, they prominently demonstrated that a brief period of rest following learning could promote consolidation and improved retention of information from episodic memory through the sole minimisation of RI. While this thesis was able to establish the primary role of RI alone in eliciting the forgetting of episodic information among select individuals with AA, this was not clearly apparent among cognitively intact populations. Given the absence of clear PI effects in amnesic patients which may implicate alternative explanations of forgetting (i.e., the temporal distinctiveness theory), it appears that the consolidation theory provides a more reliable explanation that can be adopted to better understand forgetting across individuals with impaired long-term memory. While the evaluation of the accountability of the consolidation theory and the temporal distinctiveness theory appears to be more challenging to achieve among healthy populations, there are many exciting avenues of research that remain to be explored following the findings discussed in this thesis.

References

Aggleton, J. P., & Brown, M. W. (1999). Episodic memory, amnesia, and the hippocampal-anterior thalamic axis. *Behavioral and Brain Sciences*, *22*(3), 425-489. https://doi.org/10.1017/S0140525X99002034

Agranoff, B.W., David, R. E., & Brink, J. J. (1966). Chemical studies on memory fixation in goldfish. *Brain Research*, *1*(3), 303-309. https://doi.org/10.1016/0006-8993(66)90095-3

Alber, J., Della Sala, S., & Dewar, M. (2014). Minimizing interference with early consolidation boosts 7-day retention in amnesic patients. *Neuropsychology*, *28*(5), 667-675. https://doi.org/10.1037/neu0000091

Allen, R. J., Vargha-Khadem, F., & Baddeley, A. D. (2014). Item-location binding in working memory: Is it hippocampus-dependent? *Neuropsychologia*, *59*(1), 74-84. https://doi.org/10.1016/j.neuropsychologia.2014.04.013

Andreasen, N. C., O'Leary, D. S., Cizadlo, T., Arndt, S., Rezai, K., Watkins, G. L., Boles Ponto, L. L., & Hichwa, R. D. (1995). Remembering the past: Two facets of episodic memory explored with positron emission tomography. *American Journal of Psychiatry*, *152*(11), 1576-1585. https://doi.org/10.1176/ajp.152.11.1576

Arthur, W. J., Tubre, C. T., Paul, S. D., & Sanchez-Ku, M. L. (1999). College-sample psychometric and normative data on a short form of the Raven Advanced Progressive Matrices Test. *Journal of Psychoeducational Assessment*, *17*(4), 354-361. https://doi.org/10.1177/073428299901700405

Baddeley, A. D. (1976). The psychology of memory. New York, NY: Basic Books.

Baddeley, A. D., & Hitch, G. (1993). The recency effect: Implicit learning with explicit retrieval? *Memory and Cognition*, *21*(2), 146-155. https://doi.org/10.3758/BF03202726

Baddeley, A. D., & Warrington, E. K. (1970). Amnesia and the distinction between long- and short-term memory. *Journal of Verbal Learning & Verbal Behavior, 9*(2), 176-189. https://doi.org/10.1016/S0022-5371(70)80048-2

Baddeley, A. D., & Wilson, B. A. (2002). Prose recall and amnesia : Implications for the structure of working memory. *Neuropsychologia*, *40*(10), 1737-1743. https://doi.org/10.1016/S0028-3932(01)00146-4

Baddeley, A. D., Jarrold, C., & Vargha-Khadem, F. (2011). Working memory and the hippocampus. *Journal of Cognitive Neuroscience*, *23*(12), 3855-3861. https://doi.org/10.1162/jocn_a_00066

Baddeley, A.D., Vallar, G., & Wilson, B. A. (1987). Sentence comprehension and phonological memory: Some neuropsychological evidence. In: Coltheart, M. (Ed.) *Attention and performance XII: the psychology of reading* (pp. 509-529). London: Lawrence Erlbaum Associates.

Bahrick, H. P. (1984). Semantic memory content in permastore: Fifty years of memory for Spanish learned in school. *Journal of Experimental Psychology: General*, *113*(1), 1-27. https://doi.org/10.1037/0096-3445.113.1.1

Baldo, J. V., & Shimamura, A. P. (2002). Frontal lobes and memory. In A. D. Baddeley, M. D. Kopelman, & B. A Wilson (Eds.), *The handbook of memory disorders* (2nd ed., pp. 363-379). Chichester, UK: John Wiley.

Ballard, P. (1913). *Obliviscence and reminiscence* (British Journal of Psychology. Monograph supplement; I, 2). Cambridge: University press.

Bartko, S. J., Cowell, R. A., Winters, B. D., Bussey, T. J., & Saksida, L. M. (2010). Heightened susceptibility to interference in an animal model of amnesia: Impairment in encoding, storage, retrieval--or all three? *Neuropsychologia*, *48*(10), 2987-2997. https://doi.org/10.1016/j.neuropsychologia.2010.06.007

Basso, A., Capitani, E., & Laiacona, M. (1987). Raven's Coloured Progressive Matrices: Normative values on 305 adult normal controls. *Functional Neurology*, *2*(2), 189-194.

Bäuml, K. H. T., & Kliegl, O. (2013). The critical role of retrieval processes in release from proactive interference. *Journal of Memory and Language*, *68*(1), 39-53. https://doi.org/10.1016/j.jml.2012.07.006

Beschin, N., Urbano, T., & Treccani, B. (2013). *Rivermead Behavioural Memory Test-3*. Firenze: Giunti OS.

Bigham, J. (1894). Memory. Studies from the Harvard psychological laboratory (II). *Psychological Review, 1*(5), 453-461.

Bjork, R. A., & Whitten, W. B. (1974). Recency-sensitive retrieval processes in long-term free recall. *Cognitive Psychology*, *6*(2), 173-189. https://doi.org/10.1016/0010-0285(74)90009-7

Bliss, T. V. P., & Lomo, T. (1973). Long-lasting potentiation of synaptic transmission in the dentate area of the anaesthetized rabbit following stimulation of the perforant path. *Journal of Physiology*, *232*(2), 331-356. https://doi.org/10.1113/jphysiol.1973.sp010273

Bolognani, S. A. P., Miranda, M. C., Martins, M. R., Rzezak, P., Bueno, O. F. A., Camargo, C. H. P. de, & Pompeia, S. (2015). Development of alternative versions of the Logical Memory subtest of the WMS-R for use in Brazil. *Dementia and Neuropsychologia*, *9*(2), 136-148. https://doi.org/10.1590/1980-57642015DN92000008

Bond, A., & Lader, M. (1974). The use of analogue scales in rating subjective feelings. *British Journal of Medical Psychology*, *47*(3), 211-218. https://doi.org/10.1111/j.2044-8341.1974.tb02285.x

Brandimonte, M., Einstein, G. O., & McDaniel, M. A. (Eds.). (1996). *Prospective memory: Theory and applications.* Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Briggs, S. E. (1954). Acquisition, extinction, and recovery functions in retroactive inhibition. *Journal of Experimental Psychology*, *47*(5), 285-293. https://doi.org/10.1037/h0060251

Britt, S. H. (1935). Retroactive inhibition: A review of the literature. *Psychological Bulletin*, *32*(6), 381-440. https://doi.org/10.1037/h0061316

Brokaw, K., Tishler, W., Manceor, S., Hamilton, K., Gaulden, A., Parr, E., & Wamsley, E. J. (2016). Resting state EEG correlates of memory consolidation. *Neurobiology of Learning and Memory*, *130*, 17-25. https://doi.org/10.1016/j.nlm.2016.01.008

Brown, G. D. A., & Chater, N. (2001). The chronological organisation of memory: Common psychological foundations for remembering and timing. In C. Hoerl & T. McCormack (Eds.), *Time and memory: Issues in philosophy and psychology* (pp. 77-110). Oxford, England: Oxford University Press.

Brown, G. D. A., Morin, C., & Lewandowsky, S. (2006). Evidence for time-based models of free recall. *Psychonomic Bulletin & Review*, *13*(4), 717-723. https://doi.org/10.3758/BF03193986

Brown, G. D. A., Neath, I., & Chater, N. (2007). A temporal ratio model of memory. *Psychological Review*, *114*(3), 539-576. https://doi.org/10.1037/0033-295X.114.3.539

Brown, J. (1958). Some tests of the decay theory of immediate memory. *Quarterly Journal of Experimental Psychology, 10*(1)*,* 12-21. https://doi.org/10.1080/17470215808416249

Brown, J., Lewis, V., Brown, M., Horn, G., & Bowes, J. B. (1982). A comparison between transient amnesias induced by two drugs (diazepam or lorazepam) and amnesia of organic origin. *Neuropsychologia*, *20*(1), 55-70. https://doi.org/10.1016/0028-3932(82)90087-2

Buffett-Jerrott, S. E., & Stewart, S. H. (2002). Cognitive and sedative effects of benzodiazepine use. *Current Pharmaceutical Design*, *8*(1), 45-58. https://doi.org/10.2174/1381612023396654

Burgess, P. W., Quayle, A., & Frith, C. D. (2001). Brain regions involved in prospective memory as determined by positron emission tomography. *Neuropsychologia*, *39*(6), 545-555. https://doi.org/10.1016/s0028-3932(00)00149-4

Burnham, W. H. (1903). Retroactive amnesia: Illustrative cases and a tentative explanation. *American Journal of Psychology*, *14*(3-4), 382-396. https://doi.org/10.2307/1412310

Buschke, H. (1984). Cued Recall in Amnesia. *Journal of Clinical Neuropsychology*, *6*(4), 433-440. https://doi.org/10.1080/01688638408401233

Butler, C. R., Bhaduri, A., Acosta-Cabronero, J., Nestor, P., Kapur, N., & Graham, K. (2009). Transient epileptic amnesia: Regional brain atrophy and its relationship to memory deficits. *Brain*, *132*(2), 357-368. https://doi.org/10.1093/brain/awn336

Caffarra, P., Vezzadini, G., Dieci, F., Zonato, F., & Venneri, A. (2002). Rey-Osterrieth complex figure: Normative values in an Italian population sample. *Neurological Sciences*, *22*(6), 443-447. https://doi.org/10.1007/s100720200003

Carlesimo, G. A., Caltagirone, C., Gainotti, G. U. I. D., Fadda, L., Gallassi, R., Lorusso, S., ... & Parnetti, L. (1996). The mental deterioration battery: normative data, diagnostic reliability and qualitative analyses of cognitive impairment. *European Neurology*, *36*(6), 378-384. https://doi.org/10.1159/000117297

Carr, M. F., Jadhav, S. P., & Frank, L. M. (2011). Hippocampal replay in the awake state: A potential substrate for memory consolidation and retrieval. *Nature Neuroscience*, *14*(2), 147-153. https://doi.org/10.1038/nn.2732

Carr, M. F., Jadhav, S. P., & Frank, L. M. (2011). Hippocampal replay in the awake state: A potential substrate for memory consolidation and retrieval. *Nature Neuroscience*, *14*(2), 147-153. https://doi.org/10.1038/nn.2732

Cheng, N. Y. (1929). Retroactive effect and degree of similarity. *Journal of Experimental Psychology*, *12*(5), 444-458. https://doi.org/10.1037/h0071397

Cicchetti, D.V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological Assessment*, *6*(4), 284-290. https://doi.org/10.1037/1040-3590.6.4.284

Cittadini, A., & Lader, M. (1991). Lack of effect of a small dose of flumazenil in reversing short-term tolerance to benzodiazepines in normal subjects. *Journal of Psychopharmacology*, *5*(3), 220-227. https://doi.org/10.1177/026988119100500307

Clopath, C. (2012). Synaptic consolidation: An approach to long-term learning. *Cognitive Neurodynamics*, *6*(3), 251-257. https://doi.org/10.1007/s11571-011-9177-6

Coenen, A. M., & van Luijtelaar, E. L. (1997). Effects of benzodiazepines, sleep and sleep deprivation on vigilance and memory. *Acta Neurologica Belgica*, *97*(2), 123-129.

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, Z. D., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks : A methodological review and user's guide. *Psychonomic Bulletin and Review*, *12*(5), 769-786. https://doi.org/10.3758/BF03196772

Courgeau, D. (2012). *Probability and social science methodological relationships between the two approaches* (Methodos series; v.10). Dordrecht; New York: Springer. https://doi.org/10.1007/978-94-007-2879-0

Cowan, N. (1999). An embedded-processes model of working memory. In A. Miyake & P. Shah (Eds.), *Models of working memory* (pp. 62-101). Cambridge, UK: Cambridge University Press.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, *24*(1), 87-185. https://doi.org/10.1017/S0140525X01003922

Cowan, N. (2005). *Working memory capacity*. Hove, UK: Psychology Press.

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Progress in Brain Research*, *169*, 323-338. https://doi.org/10.1016/S0079-6123(07)00020-9

Cowan, N., Beschin, N., & Della Sala, S. (2004). Verbal recall in amnesiacs under conditions of diminished retroactive interference. *Brain*, *127*(4), 825-834. https://doi.org/10.1093/brain/awh107

Cowan, N., Elliott, E. M., Saults, S. J., Morey, C. C., Mattox, S., Hismjatullina, A., & Conway, A. R. A. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology*, *51*(1), 42-100. https://doi.org/10.1016/j.cogpsych.2004.12.001

Craig, M., Della Sala, S., & Dewar, M. T. (2014). Autobiographical thinking interferes with episodic memory consolidation. *PLoS One*, *9*(4), e93915. https://doi.org/10.1371/journal.pone.0093915

Craig, M., Dewar, M. T., & Della Sala, S. (2015). Retroactive Interference. In J. D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences* (2nd ed., Vol. 20, pp. 613-620). Elsevier Ltd. https://doi.org/10.1016/B978-0-08-097086-8:51042-3

Craig, M., Dewar, M. T., Della Sala, S., & Wolbers, T. (2015). Rest boosts the long-term retention of spatial associative and temporal order information. *Hippocampus*, *25*(9), 1017-1027. https://doi.org/10.1002/hipo.22424

Craig, M., Dewar, M. T., Harris, M. A., Della Sala, S., & Wolbers, T. (2016a). Wakeful rest promotes the integration of spatial memories into accurate cognitive maps. *Hippocampus*, *26*(2), 185-193. https://doi.org/10.1002/hipo.22502

Craig, M., Wolbers, T., Harris, M. A., Hauff, P., Della Sala, S., & Dewar, M. T. (2016b). Comparable rest-related promotion of spatial memory consolidation in younger and older adults. *Neurobiology of Aging*, *48*, 143-152. https://doi.org/10.1016/j.neurobiolaging.2016.08.007

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive capabilities, mechanisms, and performances* (pp. 409-422). Amsterdam: Elsevier.

Craik, F. I. M. (2002). Levels of processing: Past, present... and future? *Memory*, *10*(5-6), 305-318. https://doi.org/10.1080/09658210244000135

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*(6), 671-684. https://doi.org/10.1016/S0022-5371(72)80001-X

Craik, F. I. M., & Rabinowitz, J. C. (1985). The effects of presentation rate and encoding task on age-related memory deficits. *Journal of Gerontology*, *40*(3), 309-315. https://doi.org/10.1093/geronj/40.3.309

Crowder, R. G. (1976). Principles of learning and memory. Hillsdale, NJ: Erlbaum.

Curran, H. V. (1986). Tranquillising memories: A review of the effects of benzodiazepines on human memory. *Biological Psychology*, *23*(2), 179-213. https://doi.org/10.1016/0301-0511(86)90081-5

Curran, H. V. (1991). Benzodiazepines, memory and mood: A review. *Psychopharmacology*, *105*(1), 1-8. https://doi.org/10.1007/BF02316856

Curran, H. V., & Birch, B. (1991). Differentiating the sedative, psychomotor and amnesic effects of benzodiazepines: A study with midazolam and the benzodiazepine antagonist, flumazenil. *Psychopharmacology*, *103*(4), 519-523. https://doi.org/10.1007/BF02244252

Curran, H. V., Schiwy, W., & Lader, M. (1987). Differential amnesic properties of benzodiazepines: A dose-response comparison of two drugs with similar elimination half-lives. *Psychopharmacology*, *92*(3), 358-364. https://doi.org/10.1007/BF00210844

Curran, V. H., Gardiner, J. M., Java, R. I., & Allen, D. (1993). Effects of lorazepam upon recollective experience in recognition memory. *Psychopharmacology*, *110*(3), 374-378. https://doi.org/10.1007/BF02251297

De Bleser, R., Denes, F., Luzzatti, C., Mazzucchi, A., Poeck, K., Spinnler, H., & Willmes, K. (1986). L'Aachener Aphasie Test (AAT). Problemi e soluzioni per una versione italiana del test e per lo studio crosslinguistico dei disturbi afasici. *Archivio di Psicologia Neurologia Psichiatria*, *47*(2), 209-237.

De Renzi, E., & Faglioni, P. (1978). Normative data and screening power of a shortened version of the Token Test. *Cortex*, *14*(1), 41-49. https://doi.org/10.1016/S0010-9452(78)80006-9

DeCamp, J. E. (1915). A study of retroactive inhibition. *Psychological Monographs, 19*(4), i-69. https://doi.org/10.1037/h0093126

Delgado, V. B., Izquierdo, I., & Chaves, M. L. F. (2005). Differential effects of acute diazepam on emotional and neutral memory tasks in acutely hospitalized depressed patients. *Neuropsychiatric Diseases and Treatment*, *1*(3), 269-275.

Della Sala, S., Cowan, N., Beschin, N., & Perini, M. (2005). Just lying there, remembering: Improving recall of prose in amnesic patients with mild cognitive impairment by minimising interference. *Memory*, *13*(3-4), 435-440. https://doi.org/10.1080/09658210344000387

Della Sala, S., Cowan, N., Beschin, N., & Perini, M. (2005). Just lying there, remembering: Improving recall of prose in amnesic patients with mild cognitive impairment by minimising interference. *Memory*, *13*(3-4), 435-440. https://doi.org/10.1080/09658210344000387

Della Sala, S., MacPherson, S. E., Phillips, L. H., Sacco, L., & Spinnler, H. (2003). How many camels are there in Italy? Cognitive estimates standardised on the Italian population. *Neurological Sciences*, *24*(1), 10-15. https://doi.org/10.1007/s100720300015

Dennis, N. A., & Cabeza, R. (2008). Neuroimaging of healthy cognitive aging. In F. I. M Craik & T. A. Salthouse (Eds.), *Handbook of aging and cognition* (3rd ed., pp.1-54). Mahwah, NJ: Erlbaum.

Dewar, M. T., Alber, J., Butler, C., Cowan, N., & Della Sala, S. (2012b). Brief wakeful resting boosts new memories over the long term. *Psychological Science*, *23*(9), 955-960. https://doi.org/10.1177/0956797612441220

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. https://doi.org/10.1016/S0010-9452(08)70492-1

Dewar, M. T., Della Sala, S., Beschin, N., & Cowan, N. (2010). Profound retroactive interference in anterograde amnesia: What interferes? *Neuropsychology*, *24*(3), 357-367. https://doi.org/10.1037/a0018207

Dewar, M. T., Garcia, Y. F., Cowan, N., & Sala, S. D. (2009). Delaying interference enhances memory consolidation in amnesic patients. *Neuropsychology*, *23*(5), 627-634. https://doi.org/10.1037/a0015568

Dewar, M. T., Pesallaccia, M., Cowan, N., Provinciali, L., & Della Sala, S. (2012a). Insights into spared memory capacity in amnestic MCI and Alzheimer's disease via minimal interference. *Brain and Cognition*, *78*(3), 189-199. https://doi.org/10.1016/j.bandc.2011.12.005

Dey, M. K. (1969). Retroactive inhibition as a function of similarity of meaning in free-recall learning. *Psychologische Forschung*, *33*(1), 79-84. https://doi.org/10.1007/BF00424618

Dickerson, B., & Eichenbaum, H. (2010). The episodic memory system: Neurocircuitry and disorders. *Neuropsychopharmacology, 35*(1), 86-104. https://doi.org/10.1038/npp.2009.126

Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature Reviews Neuroscience*, *11*(2), 114-126. https://doi.org/10.1038/nrn2762

Diekelmann, S., Wilhelm, I., Wagner, U., & Born, J. (2013a). Sleep improves prospective remembering by facilitating spontaneous-associative retrieval processes. *PloS one*, *8*(10), e77621. https://doi.org/10.1371/journal.pone.0077621

Diekelmann, S., Wilhelm, I., Wagner, U., & Born, J. (2013b). Sleep to implement an intention. *Sleep*, *36*(1), 149-153. https://doi.org/10.5665/sleep.2322

Dienes, Z. (2011). Bayesian versus orthodox statistics: Which side are you on? *Perspectives on Psychological Science*, *6*(3), 274-290. https://doi.org/10.1177/1745691611406920

Drosopoulos, S., Schulze, C., Fischer, S., & Born, J. (2007) Sleep's function in the spontaneous recovery and consolidation of memories. *Journal of Experimental Psychology: General*, *136*(2), 169-183. https://doi.org/10.1037/0096-3445.136.2.169

Dudai, Y. (2004). The neurobiology of consolidations, or, how stable is the engram? *Annual Review of Psychology*, *55*(1), 51-86. https://doi.org/10.1146/annurev.psych.55.090902.142050

Dudai, Y., & Eisenberg, M. (2004). Rites of passage of the engram: Reconsolidation and the lingering consolidation hypothesis. *Neuron*, *44*(1), 93-100. https://doi.org/10.1016/j.neuron.2004.09.003

Dudai, Y., Karni, A., & Born, J. (2015). The consolidation and transformation of memory. *Neuron*, *88*(1), 20-32. https://doi.org/10.1016/j.neuron.2015.09.004

Ebbinghaus, H. (1964). *Memory: A contribution to experimental psychology*. Oxford, England: Dover. (Original work published 1885).

Ecker, U. K., Brown, G. D., & Lewandowsky, S. (2015a). Memory without consolidation: Temporal distinctiveness explains retroactive interference. *Cognitive Science*, *39*(7), 1570-1593. https://doi.org/10.1111/cogs.12214

Ecker, U. K., Tay, J. X., & Brown, G. D. (2015b). Effects of prestudy and poststudy rest on memory: Support for temporal interference accounts of forgetting. *Psychonomic Bulletin & Review*, *22*(3), 772-778. https://doi.org/10.3758/s13423-014-0737-8

Ellinwood, E. H., Linnoila, M., Easler, M. E., & Molter, D. W. (1983). Profile of acute tolerance to three sedative anxiolytics. *Psychopharmacology*, *79*(2-3), 137-141. https://doi.org/10.1007/BF00427800

Elliott, G., Isaac, C. L., & Muhlert, N. (2014). Measuring forgetting: A critical review of accelerated long-term forgetting studies. *Cortex*, *54*(1), 16-32. https://doi.org/10.1016/j.cortex.2014.02.001

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General*, *128*(3), 309-331. https://doi.org/10.1037/0096-3445.128.3.309

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review*, *102*(2), 211. https://doi.org/10.1037/0033-295X.102.2.211

Fiebig, F., & Lansner, A. (2014). Memory consolidation from seconds to weeks: A three-stage neural network model with autonomous reinstatement dynamics. *Frontiers in Computational Neuroscience*, *8*(64), 1-17. https://doi.org/10.3389/fncom.2014.00064

Foster, D. J., & Wilson, M. A. (2006). Reverse replay of behavioural sequences in hippocampal place cells during the awake state. *Nature*, *440*(7084), 680-683. https://doi.org/10.1038/nature04587

Freedman, M., & Cermak, L. S. (1986). Semantic encoding deficits in frontal lobe disease and amnesia. *Brain and Cognition, 5*(1), 108-114. https://doi.org/10.1016/0278-2626(86)90063-1

Gates, A. I. (Eds.) (1930). Psychology for students of education. New York, NY: Macmillan.

Geiger, S. M., & Lewandowsky, S. (2008). Temporal isolation does not facilitate forward serial recall—or does it? *Memory & Cognition*, *36*(5), 957-967. https://doi.org/10.3758/MC.36.5.957

Geurts, S., van der Werf, S. P., & Kessels, R. P. C. (2015). Accelerated forgetting? An evaluation on the use of long-term forgetting rates in patients with memory problems. *Frontiers in Psychology*, *6*(752), 1-9. https://doi.org/10.3389/fpsyg.2015.00752

Ghoneim, M. M., Hinrichs, J. V., & Mewaldt, S. (1984). Dose-response analysis of the behavioral effects of diazepam: I. Learning and memory. *Psychopharmacology*, *82*(4), 291-295. https://doi.org/10.1007/bf00427672

Ghoneim, M. M., Mewaldt, S. P., Berie, J. L., & Hinrichs, J. V. (1981). Memory and performance effects of single and 3-week administration of diazepam. *Psychopharmacology*, *73*(2), 147-151. https://doi.org/10.1007/BF00429206

Gibson, E. J., & Gibson, J. J. (1934). Retention and the interpolated task. *American Journal of Psychology, 46*(4), 603-610. https://doi.org/10.2307/1415499

Giersch, A., Boucart, M., Elliott, M., & Vidailhet, P. (2010). Atypical behavioural effects of lorazepam: Clues to the design of novel therapies? *Pharmacology and Therapeutics*, *126*(1), 94-108. https://doi.org/10.1016/j.pharmthera.2010.01.004

Goetz, E.T., & Armbruster, B.B. (1980). Psychological correlates of text structure. In R. J. Spiro, R. J., Bruce, B. C., & Brewer, W. F. (Eds.), *Theoretical issues in reading comprehension* (pp. 201-220). London, England: Routledge.

Gorissen, M. E. E., Curran, H. V., & Eling, P. A. T. M. (1998). Proactive interference and temporal context encoding after diazepam intake. *Psychopharmacology*, *138*(3-4), 334-343. https://doi.org/10.1007/s002130050679

Gorissen, M. E. E., Eling, P. A. T. M., Van Luijtelaar, G., & Coenen, A. (1995). Effects of diazepam on encoding processes. *Journal of Psychopharmacology*, *9*(2), 113-121. https://doi.org/10.1177/026988119500900205

Grady, C. L., Maisog, J. M., Horwitz, B., Ungerleider, L. G., Mentis, M. J., Salerno, J. A., ... & Haxby, J. V. (1994). Age-related changes in cortical blood flow activation during visual processing of faces and location. *Journal of Neuroscience*, *14*(3), 1450-1462. https://doi.org/10.1523/JNEUROSCI.14-03-01450.1994

Grady, C. L., McIntosh, A. R., Bookstein, F., Horwitz, B., Rapoport, S. I., & Haxby, J. V. (1998). Age-related changes in regional cerebral blood flow during working memory for faces. *Neuroimage*, *8*(4), 409-425. https://doi.org/10.1006/nimg.1998.0376

Greenberg, R., & Underwood, B. J. (1950). Retention as a function of stage of practice. *Journal of Experimental Psychology*, *40*(4), 452-457. https://doi.org/10.1037/h0062147

Guimarães, F.S. (1998). Escalas analógicas visuais na avaliação de estados subjetivos. *Revista de Psiquiatria Clínica*, *25*(5), 217-222.

Gurd, J. M., Kischka, U., & Marshall, J. C. (2010) (Eds.). *Handbook of clinical neuropsychology*. Oxford University Press, USA.

Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: an overview and tutorial. *Tutorials in Quantitative Methods for Psychology*, *8*(1), 23. https://doi.org/10.20982/tqmp.08.1.p023

Hamdan, A. C., & Bueno, O. F. A. (2005). Relações entre controle executivo e memória episódica verbal no comprometimento cognitivo leve e na demência tipo Alzheimer. *Estudos de Psicologia, 10*(1), 63-71. https://doi.org/10.1590/S1413-294X2005000100008

Hannula, D. E., Tranel, D., & Cohen, N. J. (2006). The long and the short of it: Relational memory impairments in amnesia, even at short lags. *Journal of Neuroscience*, *26*(32), 8352-8359. https://doi.org/10.1523/JNEUROSCI.5222-05.2006

Harden, L. M. (1929). A quantitative study of the similarity factor in retroactive inhibition. *Journal of General Psychology, 2*(4), 421-432. https://doi.org/10.1080/00221309.1929.9918081

Hart, R. P., Kwentus, J. A., Taylor, J. R., Harkins, S. W., & Commonwealth, V. (1987). Rate of forgetting in dementia and depression. *Journal of Consulting and Clinical Psychology*, *55*(1), 101-105. https://doi.org/10.1037/0022-006X.55.1.101

Heine, R. (1914). Über Wiedererkennen und rückwirkende Hemmung. *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, *68*, 161-236.

Heller. O., Mack, W., & Seitz, J. (1991). Replikation der Ebbinghaus'schen Vergessenskurve mit der Ersparnis-methode: "Das Behalten und Vergessen als Function der Zeit". *Zeitschrift für Psychologie mit Zeitschrift für angewandte Psychologie, 199*(1)*,* 3-18.

Hennessy, M. J., Kirkby, K. C., & Montgomery, I. M. (1991). Comparison of the amnesic effects of midazolam and diazepam. *Psychopharmacology*, *103*(4), 545-550. https://doi.org/10.1007/BF02244257

Herbart, J. F. (1816). *Lehrbuch zur Psychologie*. Königsberg, Germany: Unzer.

Herbart, J. F. (1825). *Psychologie als Wissenschaft neu gegründet auf Erfahrung, Metaphysik und Mathematik*. Zweiter, analytischer Teil. Königsberg, Germany: Unzer.

Hirst, W., Johnson, M. K., Kim, J. K., Risse, G., & Phelps, E. A. (1986). Recognition and recall in amnesics. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *12*(3), 445-451. https://doi.org/10.1037/0278-7393.12.3.445

Hodges, J. R., & Warlow, C. P. (1990). Syndromes of transient amnesia: Towards a classification. A study of 153 cases. *Journal of Neurology, Neurosurgery and Psychiatry*, *53*(10), 834-843. https://doi.org/10.1136/jnnp.53.10.834

House, B. J., Smith, M., & Zeaman, D. (1964). Verbal learning and retention as a function of number of lists in retardates. American Journal of Mental Deficiency, 69, 239-243.

Hovland, C. I. (1940). Experimental studies in rote-learning theory. VI. Comparison of retention following learning to same criterion by massed and distributed practice. *Journal of Experimental Psychology*, *26*(6), 568-587. https://doi.org/10.1037/h0055061

Inda, M. C., Muravieva, E. V., & Alberini, C. M. (2011). Memory retrieval and the passage of time: From reconsolidation and strengthening to extinction. *Journal of Neuroscience*, *31*(5), 1635-1643. https://doi.org/10.1523/JNEUROSCI.4736-10.2011

Isaac, C. L., & Mayes, A. R. (1999). Rate of forgetting in amnesia: II. Recall and recognition of word lists at different levels of organization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(4), 963-977. https://doi.org/10.1037/0278-7393.25.4.963

Ivanoiu, A., Adam, S., Van Der Linden, M., Salmon, E., Juillerat, A. C., Mulligan, R., & Seron, X. (2005). Memory evaluation with a new cued recall test in patients with mild cognitive impairment and Alzheimer's disease. *Journal of Neurology*, *252*(1), 47-55. https://doi.org/10.1007/s00415-005-0597-2

Izquierdo, I., Schröder, N., Netto, C.A., & Medina, J. H. (1999). Novelty causes time dependent retrograde amnesia for one-trial avoidance in rats through NMDA receptor- and CaMKII-dependent mechanisms in the hippocampus. *European Journal of Neuroscience*, *11*(9), 3323-3328. https://doi.org/10.1046/j.1460-9568.1999.00742.x

Janowsky, J. S., Shimamura, A. P., Kritchevsky, M., & Squire, L. R. (1989). Cognitive impairment following frontal lobe damage and its relevance to human amnesia. *Behavioral Neuroscience*, *103*(3), 548-560. https://doi.org/10.1037//0735-7044.103.3.548

Jarosz, A. F., & Wiley, J. (2014). What are the odds? A practical guide to computing and reporting Bayes factors. *The Journal of Problem Solving*, *7*(1), 2-9. https://doi.org/10.7771/1932-6246.1167

Jarrard, L. E. (1975). Role of interference in retention by rats with hippocampal lesions. *Journal of Comparative Physiology and Psychology*, *89*(5), 400-408. https://doi.org/10.1037/h0077049

JASP Team. (2018). JASP (Version 0.8.1.0)[Computer software].

Jefferies, E., Lambon Ralph, M. A., & Baddeley, A. D. (2004). Automatic and controlled processing in sentence recall: The role of long-term and working memory. *Journal of Memory and Language*, *51*(4), 623-643. https://doi.org/10.1016/j.jml.2004.07.005

Jeffreys, H. (1961). *Theory of probability* (3rd Ed.). Oxford, UK: Oxford University Press.

Jeneson, A., & Squire, L. R. (2012). Working memory, long-term memory, and medial temporal lobe function. *Learning and Memory*, *19*(1), 15-25. https://doi.org/10.1101/lm.024018.111

Jenkins, J. B., & Dallenbach, K. M. (1924). Oblivescence during sleep and waking. *American Journal of Psychology*, *35*(4), 605-612. https://doi.org/10.2307/1414040

Johnson, L. M. (1933). Similarity of meaning as a factor in retroactive inhibition. *Journal of General Psychology, 9*(2)*,* 377-389. https://doi.org/10.1080/00221309.1933.9920942

Kandel, E., Dudai, Y., & Mayford, M. (2014). The molecular and systems biology of memory. *Cell, 157*(1), 163-186. https://doi.org/10.1016/j.cell.2014.03.001

Kapur, N., & Brooks, D. J. (1999). Temporally-specific retrograde amnesia in two cases of discrete bilateral hippocampal pathology. *Hippocampus*, *9*(3), 247-254. https://doi.org/10.1002/(SICI)1098-1063(1999)9:3<247::AID-HIPO5>3.0.CO;2-W

Kensinger, E. A., Shearer, D. K., Locascio, J. J., Growdon, J. H., & Corkin, S. (2003). Working memory in mild Alzheimer's disease and early Parkinson's disease. *Neuropsychology*, *17*(2), 230-239. https://doi.org/10.1037/0894-4105.17.2.230

Keppel, G. (1968). Retroactive and proactive inhibition. In T. R. Dixon, & D. L. Horton (Ed.), *Verbal Behavior and General Behavior Theory* (pp. 172-213). Englewood Cliffs, NJ: Prentice-Hall.

Keppel, G., Postman, L., & Zavortink, B. (1968). Studies of learning to learn: VIII. The influence of massive amounts of training upon the learning and retention of paired-associate lists. *Journal of Verbal Learning and Verbal Behavior*, *7*(4), 790-796. https://doi.org/10.1016/S0022-5371(68)80143-4

Kliegel, M., McDaniel, M. A., & Einstein, G. O. (Eds.). (2008). *Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives*. New York, NY: Taylor & Francis Group/Lawrence Erlbaum Associates.

Kline, L. W. (1921). An experimental study of associative inhibition. *Journal of Experimental Psychology, 4*(4), 270-299. https://doi.org/10.1037/h0071479

Köhler, W. (1923). Zur theorie des sukzessivvergleichs und der zeitfehler. *Psychological Research*, *4*(1), 115-175. https://doi.org/10.1007/BF00410635

Kopelman, M. D. (2002). Disorders of memory. *Brain*, *125*(10), 2152-2190. https://doi.org/10.1093/brain/awf229

Kopelman, M. D., & Stanhope, N. (1997). Rates of forgetting in organic amnesia following temporal lobe, diencephalic, or frontal lobe lesions. *Neuropsychology*, *11*(3), 343-356. https://doi.org/10.1037/0894-4105.11.3.343

Kruschke, J. K. (2010). Bayesian data analysis. *Wiley Interdisciplinary Reviews: Cognitive Science*, *1*(5), 658-676. https://doi.org/10.1002/wcs.72

Lah, S., Mohamed, A., Thayer, Z., Miller, L., & Diamond, K. (2014). Accelerated long-term forgetting of verbal information in unilateral temporal lobe epilepsy: Is it related to structural hippocampal abnormalities and / or incomplete learning? *Journal of Clinical and Experimental Neuropsychology*, *36*(2), 158-169. https://doi.org/10.1080/13803395.2013.874405

Laiacona, M., Inzaghi, M. G., De Tanti, A., & Capitani, E. (2000). Wisconsin card sorting test: a new global score, with Italian norms, and its relationship with the Weigl sorting test. *Neurological Sciences*, *21*(5), 279-291. https://doi.org/10.1007/s100720070065

Lechner, H. A., Squire, L. R., & Byrne, J. H. (1999). 100 years of consolidation—remembering Müller and Pilzecker. *Learning and Memory*, *6*(2), 77-87. https://doi.org/10.1101/lm.6.2.77

Leng, N. R. C., & Parkin, A. J. (1989). Aetiological variation in the amnesic syndrome: Comparisons using the brown-peterson task. *Cortex*, *25*(2), 251-259. https://doi.org/10.1016/S0010-9452(89)80041-3

Lewandowsky, S., Brown, G. D., Wright, T., & Nimmo, L. M. (2006). Timeless memory: Evidence against temporal distinctiveness models of short-term memory for serial order. *Journal of Memory and Language*, *54*(1), 20-38. https://doi.org/10.1016/j.jml.2005.08.004

Lewandowsky, S., Geiger, S. M., & Oberauer, K. (2008). Interference-based forgetting in verbal short-term memory. *Journal of Memory and Language*, *59*(2), 200-222. https://doi.org/10.1016/j.jml.2008.04.004

Lewis, P. A., & Durrant, S. J. (2011). Overlapping memory replay during sleep builds cognitive schemata. *Trends in Cognitive Science*, *15*(8), 343-351. https://doi.org/10.1016/j.tics.2011.06.004

Lister, R. G. (1985). The amnesic actions of benzodiazepines in man. *Neuroscience and Biobehavior Reviews*, *9*(1), 87-94. https://doi.org/10.1016/0149-7634(85)90034-X

Logie, R. H., & D'Esposito, M. (2007) Working memory in the brain. *Cortex*, *43*(1), 1-4. https://doi.org/10.1016/s0010-9452(08)70441-6

Lund, F. H. (1926). The Criteria of Confidence. *American Journal of Psychology*, *37*(3), 372-381. https://doi.org/10.2307/1413623

Madhusoodanan, S., & Bogunovic, O. J. (2004). Safety of benzodiazepines in the geriatric population. *Expert Opinion on Drug Safety*, *3*(5), 485-493. https://doi.org/10.1517/14740338.3.5.485

Mandelli, M., Tognoni, G., & Garattini, S. (1978). Clinical pharmacokinetics of diazepam. *Clinical Pharmacokinetics*, *3*(1), 72-91. https://doi.org/10.2165/00003088-197803010-00005

Manes, F., Cecilia, S., Calcagno, M. L., Cardozo, J., & Hodges, J. (2008). Accelerated forgetting in subjects with memory complaints. *Journal of Neurology*, *255*(7), 1067-1070. https://doi.org/10.1007/s00415-008-0850-6

Manns, J. R., Hopkins, R. O., & Squire, L. R. (2003). Semantic memory and the human hippocampus. *Neuron*, *38*(1), 127-33. https://doi.org/10.1016/s0896-6273(03)00146-6

Marcolino, J. Á. M., Mathias, L. A. D. S. T., Piccinini Filho, L., Guaratini, Á. A., Suzuki, F. M., & Alli, L. A. C. (2007). Escala hospitalar de ansiedade e depressão: Estudo da validade de critério e da confiabilidade com pacientes no pré-operatório. *Revista Brasileira de Anestesiologia*, *57*(1), 52-62. https://doi.org/10.1590/S0034-70942007000100006

Marsh, R. L., Hancock, T. W., & Hicks, J. L. (2002). The demands of an ongoing activity influence the success of event-based prospective memory. *Psychonomic Bulletin and Review, 9*(3), 604-610. https://doi.org/10.3758/BF03196319

Marsh, R. L., Hicks, J. L., Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*(5), 861-870. https://doi.org/10.1037/0278-7393.29.5.861

Martin, S. J. & Morris, R. G. M. (2002). New life in an old idea: The synaptic plasticity and memory hypothesis revisited. *Hippocampus*, *12*(5), 609-636. https://doi.org/10.1002/hipo.10107

Martin, S. J., Grimwood, P. D. & Morris, R. G. M. (2000). Synaptic plasticity and memory: An evaluation of the hypothesis. *Annual Review of Neuroscience*, *23*(1), 649-711. https://doi.org/10.1146/annurev.neuro.23.1.649

Martini, M., Riedlsperger, B., Maran, T., & Sachse, P. (2017). The effect of post-learning wakeful rest on the retention of second language learning material over the long term. *Current Psychology*, 1-8. https://doi.org/10.1007/s12144-017-9760-z

Martini, M., Zamarian, L., Sachse, P., Martini, C., & Delazer, M. (2018). Wakeful resting and memory retention: A study with healthy older and younger adults. *Cognitive Processing*, *20*(1), 125-131. https://doi.org/10.1007/s10339-018-0891-4

Martins, M. R., Bolognani, S. A. P., Pompéia, S., Bueno, O. F. A., & Miranda, M. C. (2015). Versões alternativas do subteste memória lógica da wms-r: análise de desempenho de uma amostra saudável da cidade de são paulo. *Psicologia: Reflexão e Crítica*, *28*(3), 444-453. https://doi.org/10.1590/1678-7153.201528303

Maylor, E. A., Darby, R. J., Logie, R. H., Della Sala, S., & Smith, G. (2002). Prospective memory across the lifespan. In P. Graf & N. Ohta (Eds.), Lifespan development of human memory (pp. 235-256). Cambridge, MA: The MIT Press.

McCabe, D. P., Roediger, H. L., McDaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2010). The relationship between working memory capacity and executive functioning: Evidence for a common executive attention construct. *Neuropsychology*, *24*(2), 222-243. https://doi.org/10.1037/a0017619

McDaniel, M. A., & Pressley, M. (Eds.). (1987). *Imagery and related mnemonic processes: Theories, individual differences, and applications*. New York, NY: Springer-Verlag Publishing.

McGann, D., Ellis, J., & Milne, A. (2002). Conceptual and perceptual processing in prospective remembering: Differential influences of attentional resources. *Memory and Cognition*, *30*(7), 1021-1032. https://doi.org/10.3758/bf03194320

McGeoch, J. A. (1932). Forgetting and the law of disuse. *Psychological Review, 39*(4), 352-370. https://doi.org/10.1037/h0069819

McGeoch, J. A. (1942). The psychology of human learning. New York, NY: Longmans, Green.

McGeoch, J. A., & McDonald, W. T. (1931). Meaningful relation and retroactive inhibition. *American Journal of Psychology, 43*(4), 579-588. https://doi.org/10.2307/1415159

McGeoch, J. A., Nolen, M. E. (1933). Studies in retroactive inhibition. IV. Temporal point of interpolation and degree of retroactive inhibition. *Journal of Comparative Psychology*, *15*(3), 407-417. https://doi.org/10.1037/h0072751

McGraw, K. O., & Wong, S. P. (1996). Forming inferences about some intraclass correlation coefficients. *Psychological Methods, 1*(1), 30-46. https://doi.org/10.1037/1082-989X.1.1.30

McKee, R. D., & Squire, L. R. (1992). Equivalent forgetting rates in long-term memory for diencephalic and medial temporal lobe amnesia. *Journal of Neuroscience*, *12*(10), 3765-3772. https://doi.org/10.1523/JNEUROSCI.12-10-03765.1992

McKenzie, S., & Eichenbaum, H. (2011). Perspective consolidation and reconsolidation: Two lives of memories? *Neuron*, *71*(2), 224-233. https://doi.org/10.1016/j.neuron.2011.06.037

Measso, G., Cavarzeran, F., Zappalà, G., Lebowitz, B. D., Crook, T. H., Pirozzolo, F. J., Arnaducci, L. A., Massari, D., & Grigoletto, F. (1993). The mini-mental state examination: Normative study of an Italian random sample. *Developmental Neuropsychology*, *9*(2), 77-85. https://doi.org/10.1080/87565649109540545

Mednick, S. C., Cai, D. J., Shuman, T., Anagostaras, S., & Wixted, J. T. (2011). An opportunistic theory of cellular and systems consolidation. *Trends in Neuroscience*, *34*(10), 504-514. https://doi.org/10.1016/j.tins.2011.06.003

Melton, A., & Irwin, J. (1940). The influence of degree of interpolated learning on retroactive inhibition and the overt transfer of specific responses. *American Journal of Psychology, 53*(2), 173-203. https://doi.org/10.2307/1417415

Mintzer, M. Z., & Griffiths, R. R. (2007). A triazolam/amphetamine dose-effect interaction study: Dissociation of effects on memory versus arousal. *Psychopharmacology*, *192*(3), 425-440. https://doi.org/10.1007/s00213-007-0726-y

Mordecai, K. L., Rubin, L. H., & Maki, P. M. (2008). Effects of menstrual cycle phase and oral contraceptive use on verbal memory. *Hormones and Behavior*, *54*(2), 286-293. https://doi.org/10.1016/j.yhbeh.2008.03.006

Morin, C., Brown, G. D. A., & Lewandowsky, S. (2010). Temporal isolation effects in recognition and serial recall. *Memory and Cognition*, *38*(7), 849-859. https://doi.org/10.3758/MC.38.7.849

Moscovitch, M. (1982). Multiple dissociations of function in amnesia. In L. S. Cermak (Ed.) *Human memory and amnesia* (pp. 337-370). Hillsdale, NJ: Lawrence Erlbaum.

Müller, G. E., & Pilzecker, A. (1900). *Experimentelle beiträge zur lehre vom gedächtniss* (Vol. 1). Leipzig, Germany: JA Barth.

Müller, G. E., & Schumann, F. (1894). Experimentelle Beiträge zur Untersuchung des Gedächtnisses. *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, *6*, 6-190.

Munn, N. L. (1962). *Introduction to Psychology* (Abri. ed. of *Psychology: The fundamentals of human adjustment*, 4th ed.). Boston, MA: Houghton Mifflin.

Murdock, B. B., Jr. (1960). The distinctiveness of stimuli. *Psychological Review*, *67*(1), 16-31. https://doi.org/10.1037/h0042382

Murray, D. J. (1976). Research on human memory in the nineteenth century. *Canadian Journal of Psychology/Revue canadienne de psychologie*, *30*(4), 201-220. https://doi.org/10.1037/h0082062

Murre, J. M., & Dros, J. (2015). Replication and analysis of Ebbinghaus' forgetting curve. *PloS one*, *10*(7), e0120644. https://doi.org/10.1371/journal.pone.0120644

Nadel, L., & Moscovitch, M. (1997). Memory consolidation, retrograde amnesia and the hippocampal complex. *Current Opinion in Neurobiology*, *7*(2), 217-227. https://doi.org/10.1016/s0959-4388(97)80010-4

Neath, I., & Surprenant, A. M. (2015). Proactive interference. In J. D. Wright (Ed.) *International Encyclopedia of the Social & Behavioral Sciences* (2nd ed., Vol. 19, pp. 1-8). Elsevier Ltd. https://doi.org/1cra0.1016/B978-0-08-097086-8.51054-X

Nimmo, L. M., & Lewandowsky, S. (2005). From brief gaps to very long pauses: Temporal isolation does not benefit serial recall. *Psychonomic Bulletin and Review*, *12*(6), 999-1004.

Nimmo, L. M., & Lewandowsky, S. (2006). Distinctiveness revisited: Unpredictable temporal isolation does not benefit short-term serial recall of heard or seen events. *Memory & Cognition*, *34*(6), 1368-1375. https://doi.org/10.3758/BF03193278

Nogueira, A. M. L., Pompéia, S., Galduróz, J. C. F., & Bueno, O. F. A. (2006). Effects of a benzodiazepine on free recall of semantically related words. *Human Psychopharmacology: Clinical and Experimental*, *21*(5), 327-336. https://doi.org/10.1002/hup.775

Nørby, S. (2015). Why Forget? On the adaptive value of memory loss. Perspectives on Psychological Science, 10(5), 551-78. https://doi.org/10.1177/1745691615596787

Novelli, G., Papagno, C., Capitani, E., Laiacona, M., Vallar, G., & Cappa, S. F. (1986). Tre test clinici di ricerca e produzione lessicale. Taratura su soggetti normali. *Archivio di Psicologia, Neurologia e Psichiatria*, *47*(4), 477-506.

Olson, I. R., Page, K., Moore, K. S., Chatterjee, A., & Verfaellie, M. (2006). Working memory for conjunctions relies on the medial temporal lobe. *Journal of Neuroscience*, *26*(17), 4596-4601. https://doi.org/10.1523/JNEUROSCI.1923-05.2006

Orsini, A., Grossi, D., Capitani, E., Laiacona, M., Papagno, C., & Vallar, G. (1987). Verbal and spatial immediate memory span: Normative data from 1355 adults and 1112 children. *The Italian Journal of Neurological Sciences, 8*(6), 539-548. https://doi.org/10.1007/BF02333660

Paivio, A. (1971). *Imagery and verbal processes*. New York, NY: Holt, Rinehart, and Winston.

Paivio, A. (1986). *Mental representations: A dual coding approach*. New York, NY: Oxford University Press.

Parkin, A., & Leng, N. (2014). *Neuropsychology of the Amnesic Syndrome*. London: Psychology Press.

Parkinson, S. R. (1980). Aging and amnesia: A running span analysis. *Bulletin of the Psychonomic Society*, 15(*4*), 215-217. https://doi.org/10.3758/BF03334512

Parmentier, F. B., King, S., & Dennis, I. (2006). Local temporal distinctiveness does not benefit auditory verbal and spatial serial recall. *Psychonomic Bulletin & Review*, *13*(3), 458-465. https://doi.org/10.3758/BF03193870

Peigneux, P., Laureys, S., Fuchs, S., Collette, F., Perrin, F., Reggers, J., Phillips, C., Degueldre, C., Del Fiore, G., Aerts, J., Luxen, A., & Maquet, P. (2004). Are spatial memories strengthened in the human hippocampus during slow wave sleep? *Neuron*, *44*(3), 535-545. https://doi.org/10.1016/j.neuron.2004.10.007

Peirce J. W. (2009). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics, 2*(10), 1-8. https://doi.org/10.3389/neuro.11.010.2008

Peirce, J. W., & MacAskill, M. R. (2018). *Building Experiments in PsychoPy.* London: Sage.

Perneger, T. V. (1998). What's wrong with Bonferroni adjustments. *British Medical Journal, 316*(7139), 1236-1238. https://doi.org/10.1136/bmj.316.7139.1236

Persson, J., Nyberg, L., Lind, J., Larsson, A., Nilsson, L. G., Ingvar, M., & Buckner, R. L. (2005). Structure–function correlates of cognitive decline in aging. *Cerebral Cortex*, *16*(7), 907-915. https://doi.org/10.1093/cercor/bhj036

Pompéia, S., Gorenstein, C., & Curran, H. V. (1996). Benzodiazepine effects on memory tests: Dependence on retrieval cues? *International Clinical Psychopharmacology*, *11*(4), 229-236. https://doi.org/10.1097/00004850-199612000-00003

Postman, L. (1968). Hermann Ebbinghaus. *American Psychologist*, *23*(3), 149-157. https://doi.org/10.1037/h0025659

Postman, L., & Alper, T. (1946). Retroactive inhibition as a function of the time interpolation of the inhibitor between learning and recall. *American Journal of Psychology*, *59*(3), 439-449. https://doi.org/10.2307/1417613

Postman, L., & Keppel, G. (1977). Conditions of cumulative proactive inhibition. *Journal of Experimental Psychology: General*, *106*(4), 376-403. https://doi.org/10.1037/0096-3445.106.4.376

Pratt, C. C. (1936a). The law of disuse. *Psychological Review, 43*(1), 83-93. https://doi.org/10.1037/h0059321

Pratt, C. C. (1936b). Interaction across modalities: I. Successive stimulation. *Journal of Psychology*, *2*(2), 287-294. https://doi.org/10.1080/00223980.1936.9917460

Quinette, P., Guillery, B., Desgranges, B., De La Sayette, V., Viader, F., & Eustache, F. (2003). Working memory and executive functions in transient global amnesia. *Brain*, *126*(9), 1917-1934. https://doi.org/10.1093/brain/awg201

Quinette, P., Guillery-Girard, B., Noël, A., de la Sayette, V., Viader, F., Desgranges, B., & Eustache, F. (2006). The relationship between working memory and episodic memory disorders in transient global amnesia. *Neuropsychologia*, *44*(12), 2508-2519. https://doi.org/10.1016/j.neuropsychologia.2006.03.031

Raftery, A. E. (1995). Bayesian model selection in social research. In P. V. Marsden (Ed.), *Sociological methodology* (pp. 111-196). Cambridge, MA: Blackwell.

Raichle, M. E., & Gusnard, D. A. (2002). Appraising the brain's energy budget. *Proceedings of the National Academy of Sciences*, *99*(16), 10237-10239. https://doi.org/10.1073/pnas.172399499

Raven, J. C., Court, J., & Raven, J. (1985). *A manual for Raven's Progressive Matrices and vocabulary scales*. London: HK Lewis.

Reder, L. M., Proctor, I., Anderson, J. R., Gyulai, F., Quinlan, J. J., & Oates, J. M. (2006). Midazolam does not inhibit association formation, just its storage and strengthening. *Psychopharmacology*, *188*(4), 462-471. https://doi.org/10.1007/s00213-006-0436-x

Reed, J. M., & Squire, L. R. (1998). Retrograde amnesia for facts and events: Findings from four new cases. *Journal of Neuroscience*, *18*(10), 3943-3954. https://doi.org/10.1523/JNEUROSCI.18-10-03943.1998

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. https://doi.org/10.1076/anec.9.2.98.9546

Rempel-Clower, N., Zola, S. M., Squire, L. R., & Amaral, D. G. (1996). Three cases of enduring memory impairment following bilateral damage limited to the hippocampal formation. *Journal of Neuroscience*, *16*(16), 5233-5255. https://doi.org/10.1523/JNEUROSCI.16-16-05233.1996

Ribot, T. A. (1881) *Les Maladies de la Memoire* (English translation: Diseases of Memory). New York, NY: Appleton-Century-Crofts.

Ribot, T. A. (1977). *Diseases of Memory: An Essay in Positive Psychology* (W. H. Smith Trans.). University Publications of America. (Original work published 1882).

Ricker, T. J., Vergauwe, E., & Cowan, N. (2016). Decay theory of immediate memory: From Brown (1958) to today (2014). *Quarterly Journal of Experimental Psychology*, *69*(10), 1969-1995. https://doi.org/10.1080/17470218.2014.914546

Riss, J., Cloyd, J., Gates, J., & Collins, S. (2008). Benzodiazepines in epilepsy: Pharmacology and pharmacokinetics. *Acta Neurologica Scandinavica*, *118*(2), 69-86. https://doi.org/10.1111/j.1600-0404.2008.01004.x

Robertson, E. M. (2012). New insights in human memory interference and consolidation. *Current Biology*, *22*(2), R66-R71. https://doi.org/10.1016/j.cub.2011.11.051

Robinson, E. S. (1920). Some factors determining the degree of retroactive inhibition. *Psychological Monographs, 28*(6), i-57. https://doi.org/10.1037/h0093155

Rubin, D. C. (1989). Issues of regularity and control: Confessions of a regularity freak. In L. W. Poon, D. C. Rubin, & B. A. Wilson (Eds.), *Everyday cognition in adulthood and late life* (pp. 84-103). New York, NY: Cambridge University Press. https://hdl.handle.net/10161/19001

Rubin, D. C., & Wenzel, A. E. (1996). One hundred years of forgetting: A quantitative description of retention. *Psychological Review, 103*(4), 734-760. https://doi.org/10.1037/0033-295X.103.4.734

Rubin, D. C., Hinton, S., & Wenzel, A. (1999). The precise time course of retention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(5), 1161-1176. https://doi.org/10.1037/0278-7393.25.5.1161

Rusted, J. M., Eaton-Williams, P., & Warburton, D. M. (1991). A comparison of the effects of scopolamine and diazepam on working memory. *Psychopharmacology*, *105*(3), 442-445. https://doi.org/10.1007/BF02244443

Sacripante, R., McIntosh, R. D., & Della Sala, S. (2019). Benefit of wakeful resting on gist and peripheral memory retrieval in healthy younger and older adults. *Neuroscience Letters*, *705*, 27-32. https://doi.org/10.1016/j.neulet.2019.04.026

Sanders, H. I., & Warrington, D. K. (1971). Memory for remote events in amnesic patients. *Brain*, *94*(4), 661-668. https://doi.org/10.1093/brain/94.4.661

Sarasin, D. S., Ghoneim, M. M., & Block, R. I. (1996). Effects of sedation with midazolam or propofol on cognition and psychomotor functions. *Journal of Oral Maxillofacial Surgery*, *54*(10), 1187-1193. https://doi.org/10.1016/S0278-2391(96)90348-1

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology, Neurosurgery and Psychiatry*, *20*(1), 11-21. https://doi.org/10.1136/jnnp.20.1.11

Scullin, M. K., & McDaniel, M. A. (2010). Remembering to execute a goal: Sleep on it! *Psychological Science*, *21*(7), 1028-1035. https://doi.org/10.1177/0956797610373373

Sejnowski, T. J., & Destexhe, A. (2000). Why do we sleep? *Brain Research*, *886*(1-2), 208-223. https://doi.org/10.1016/s0006-8993(00)03007-9

Shimamura, A. (1995). Memory and frontal lobe function. In M. Gazzaniga (Ed.), *The Cognitive Neurosciences.* Cambridge, MA: MIT Press.

Shimamura, A. P., Jurica, P. J., Mangels, J. A., Gershberg, F. B., & Knight, R. T. (1995). Susceptibility to memory interference effects following frontal lobe damage: Findings from tests of paired-associate learning. *Journal of Cognitive Neuroscience, 7*(2), 144-152. https://doi.org/10.1162/jocn.1995.7.2.144

Shimmerlik, S. (1978). Organization theory and memory for prose: A review of the literature. *Review of Educational Research*, *48*(1), 103-120. https://doi.org/10.3102/00346543048001103

Sills, D. L., & Merton, R. K. (1968). *International encyclopedia of the social sciences*. New York, NY: Macmillan Free Press.

Skaggs, E. B. (1925). Further studies in retroactive inhibition. *Psychological Monographs*, *34*(8), 1-60.

Skaggs, E. B. (1933). A discussion on the temporal point of interpolation and degree of retroactive inhibition. *Journal of Comparative Psychology*, *16*(3), 411-414. https://doi.org/10.1037/h0074460

Slamecka, N. J., & McElree, B. (1983). Normal forgetting of verbal lists as a function of their degree of learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*(3), 384-397. https://doi.org/10.1037/0278-7393.9.3.384

Smith, G., Della Sala, S., Logie, R. H., & Maylor, E. A. (2000). Prospective and retrospective memory in normal aging and dementia: A questionnaire study. *Memory*, *8*(5), 311-321. https://doi.org/10.1080/09658210050117735

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), 347-361. https://doi.org/10.1037/0278-7393.29.3.347

Smith, R. E., & Bayen, U. J. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(4), 756. https://doi.org/10.1037/0278-7393.30.4.756

Sosic-Vasic, Z., Hille, K., Kröner, J., Spitzer, M., & Kornmeier, J. (2018). When learning disturbs memory – temporal profile of retroactive interference of learning on memory formation. *Frontiers in Psychology*, *9*(82), 1-9. https://doi.org/10.3389/fpsyg.2018.00082

Spinnler H., & Tognoni, G. (Eds.) (1987). Standardizzazione e taratura italiana di test neuropsicologici. *The Italian Journal of Neurological Sciences*, *Suppl 8 to No. 6*, 1-120.

Squire, L. R. (1975). A stable impairment in remote memory following electroconvulsive therapy. *Neuropsychologia*, *13*(1), 51-58. https://doi.org/10.1016/0028-3932(75)90047-0

Squire, L. R. (1987). *Memory and brain*. New York, NY: Oxford University Press.

Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review*, *99*(2), 195-231. https://doi.org/10.1037/0033-295x.99.2.195

Squire, L. R. (2004). Memory systems of the brain: A brief history and current perspective. *Neurobiology of Learning and Memory, 82*(3), 171-177. https://doi.org/10.1016/j.nlm.2004.06.005

Squire, L. R. (2009a). The legacy of patient H. M. for neuroscience. Neuron, 61(1), 6-9. https://doi.org/10.1016/j.neuron.2008.12.023

Squire, L. R. (2009b). Memory and Brain Systems: 1969-2009. *Journal of Neuroscience*, *29*(41), 12711-12716. https://doi.org/10.1523/JNEUROSCI.3575-09.2009

Squire, L. R., & Alvarez, P. (1995). Retrograde amnesia and memory consolidation: A neurobiological perspective. *Current Opinion in Neurobiology*, *5*(2), 169-177. https://doi.org/10.1016/0959-4388(95)80023-9

Squire, L. R., & Wixted, J. T. (2011). The cognitive neuroscience of memory since H.M. *Annual Review of Neuroscience*, *34*(1), 259-288. https://doi.org/10.1146/annurev-neuro-061010-113720

Squire, L. R., & Zola-Morgan, S. (1991). The medial temporal lobe memory system. *Science*, *253*(5026), 1380-1386. https://doi.org/10.1126/science.1896849

Squire, L. R., Clark, R. E., & Knowlton, B. J., (2001). Retrograde amnesia. *Hippocampus*, *11*(1), 50–55. https://doi.org/10.1002/1098-1063(2001)11:1<50::AID-HIPO1019>3.0.CO;2-G

Squire, L. R., Slater, P.C., & Chace, P. M. (1975). Retrograde amnesia: Temporal gradient in very long-term memory following electroconvulsive therapy. *Science*, *187*(4171), 77-79. https://doi.org/10.1126/science.1109228

Stebbins, G. T., Carrillo, M. C., Dorfman, J., Dirksen, C., Desmond, J. E., Turner, D. A., ... & Gabrieli, J. D. (2002). Aging effects on memory encoding in the frontal lobes. *Psychology and Aging*, *17*(1), 44. https://doi.org/10.1037/0882-7974.17.1.44

Stern, L. D. (1981). A review of theories of human amnesia. *Memory and Cognition*, *9*(3), 247-262. https://doi.org/10.3758/BF03196959

Strong, E. K. (1914). Two factors which influence economical learning. *Journal of Philosophy, Psychology and Scientific Methods*, *11*(5), 124-131. https://doi.org/10.2307/2012365

Szpunar, K. K., McDermott, K. B., & Roediger, H. L., III. (2008). Testing during study insulates against the buildup of proactive interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(6), 1392-1399. https://doi.org/10.1037/a0013082

Tait, W. D. (1913). The effect of psycho-physical attitudes on memory. *Journal of Abnormal Psychology, 8*(1), 10-37. https://doi.org/10.1037/h0072167

Tambini, A., Ketz, N., & Davachi, L. (2010). Enhanced brain correlations during rest are related to memory for recent experiences. *Neuron*, *65*(2), 280-290. https://doi.org/10.1016/j.neuron.2010.01.001

Tano, M. C., Molina, V. A., Maldonado, H., & Pedreira, M. E. (2009). Memory consolidation and reconsolidation in an invertebrate model: The role of the GABAergic system. *Neuroscience*, *158*(2), 387-401. https://doi.org/10.1016/j.neuroscience.2008.10.039

Thomas-Antérion, C., Koenig, O., Navez, M., & Laurent, B. (1999). Midazolam effects on implicit and explicit memory processes in healthy subjects. *Psychopharmacology*, *145*(2), 139-143. https://doi.org/10.1007/s002130051042

Thorndike, E. L. (1913). *Educational psychology: The psychology of learning*. New York, NY: Teachers College, Columbia University.

Tolman, E. C. (1918). Retroactive inhibition as affected by conditions of learning. *Psychological Monographs, 25*(1), i-50. https://doi.org/10.1037/h0093113

Treisman, A., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12*(1), 97-136. https://doi.org/10.1016/0010-0285(80)90005-5

Tudesco, I. D. S. S., Vaz, L. J., Araújo, M. M. S., Belzunces, E., Noffs, M. H., Caboclo, L. O. S. F., Yacubian, E. M. T., Sakamoto, A. C., & Bueno, O. F. A. (2010). Assessment of working memory in patients with mesial temporal lobe epilepsy associated with unilateral hippocampal sclerosis. *Epilepsy Behavior*, *18*(3), 223-228. https://doi.org/10.1016/j.yebeh.2010.04.021

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381-403). New York, NY: Academic Press.

Tulving, E. (1974). Cue-dependent forgetting. *American Scientist*, *62*(1), 74-82.

Tulving, E. (1985). How many memory systems are there? *American Psychologist*, *40*(4), 385-398. https://doi.org/10.1037/0003-066X.40.4.385

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology, 53*(1), 1-25. https://doi.org/10.1146/annurev.psych.53.100901.135114

Tulving, E., & Pearlstone, Z. (1966). Availability versus accessibility of information in memory for words. *Journal of Verbal Learning and Verbal Behavior, 5*(4), 381-391. http://doi.org/10.1016/S0022-5371(66)80048-8

Underwood, B. J. (1957). Interference and forgetting. *Psychological Review*, *64*(1), 49-60. https://doi.org/10.1037/h0044616

Underwood, B. J., & Postman, L. (1960). Extraexperimental sources of interference in forgetting. *Psychological Review*, *67*(2), 73-95. https://doi.org/10.1037/h0041865

Underwood, B. J., Ekstrand, B. R. (1967). Studies of distributed practice: XXIV. Differentiation and proactive inhibition. *Journal of Experimental Psychology*, *74*(4), 574-580. https://doi.org/10.1037/h0024779

Unrug-Neervoort, A., Van Luijtelaar, G., & Coenen, A. (1992). Cognition and vigilance: Differential effects of diazepam and buspirone on memory and psychomotor performance. *Neuropsychobiology*, *26*(3), 146-150. https://doi.org/10.1159/000118910

Unsworth, N. (2016). Working memory capacity and recall from long-term memory: Examining the influences of encoding strategies, study time allocation, search efficiency, and monitoring abilities. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *42*(1), 50-61. https://doi.org/10.1037/xlm0000148

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review*, *114*(1), 104-132. https://doi.org/10.1037/0033-295X.114.1.104

Varma, S., Daselaar, S. M., Kessels, R. P. C., & Takashima, A. (2018). Promotion and suppression of autobiographical thinking differentially affect episodic memory consolidation. *PLoS One*, *13*(8), e0201780. https://doi.org/10.1371/journal.pone.0201780

Varma, S., Takashima, A., Fu, L., & Kessels, R. (2019). Mindwandering propensity modulates episodic memory consolidation. *Aging Clinical and Experimental Research, 31*(11), 1601-1607. https://doi.org/10.1007/s40520-019-01251-1

Varma, S., Takashima, A., Krewinkel, S., Van Kooten, M., Fu, L., Medendorp, W. P., ... & Daselaar, S. M. (2017). Non-interfering effects of active post-encoding tasks on episodic memory consolidation in humans. *Frontiers in Behavioral Neuroscience*, *11*(54), 1-13. https://doi.org/10.3389/fnbeh.2017.00054

Verfaellie, M., & Keane, M. M. (2017). Neuropsychological investigations of human amnesia: Insights into the role of the medial temporal lobes in cognition. *Journal of the International Neuropsychological Society*, *23*(9-10), 732-740. https://doi.org/10.1017/S1355617717000649

Walsh, C. M., Wilkins, S., Bettcher, B. M., Butler, C. R., Miller, B. L., & Kramer, J. H. (2014). Memory consolidation in aging and mci after 1 week. *Neuropsychology*, *28*(2), 273-280. https://doi.org/10.1037/neu0000013

Wang, S. H., & Morris, R. G. M. (2010). Hippocampal-neocortical interactions in memory formation, consolidation, and reconsolidation. *Annual Review of Psychology*, *61*(1), 49-79. https://doi.org/10.1146/annurev.psych.093008.100523

Warrington, E. K., Weiskrantz, L. (1970). Amnesic syndrome: consolidation or retrieval. *Nature*, *228*(5272), 628-630. https://doi.org/10.1038/228628a0

Warrington, E. K., Weiskrantz, L. (1978). Further analysis of the prior learning effect in amnesic patients. *Neuropsychologia*, *16*(2), 169-177. https://doi.org/10.1016/0028-3932(78)90104-5

Warrington. E. K., Weiskrantz, L. (1974). The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia*, *12*(4), 419-428. https://doi.org/10.1016/0028-3932(74)90072-4

Watkins, M. J., & Watkins, O. C. (1976). Cue-overload theory and the method of interpolated attributes. *Bulletin of the Psychonomic Society*, *7*(3), 289-291. https://doi.org/10.3758/BF03337192

Watkins, O. C., & Watkins, M. J. (1975). Buildup of proactive inhibition as a cue-overload effect. *Journal of Experimental Psychology: Human Learning and Memory*, *1*(4), 442-452. https://doi.org/10.1037/0278-7393.1.4.442

Webb, L. W. (1917). Transfer of training and retroaction: A comparative study. *Psychological Monographs, 24*(3), i-90. https://doi.org/10.1037/h0093121

Wechsler, D. (1987). *Manual for the Wechsler Memory Scale – revised*. San Antonio, TX: The Psychological Corporation.

Weinstein, Y., McDermott, K. B., & Szpunar, K. K. (2011). Testing protects against proactive interference in face–name learning. *Psychonomic Bulletin and Review*, *18*(3), 518-523. https://doi.org/10.3758/s13423-011-0085-x

Weiss, W., & Margolius, G. (1954). The effect of context stimuli on learning and retention. *Journal of Experimental Psychology*, *48*(5), 318-322. https://doi.org/10.1037/h0060746

Wenger, E. L., & Shing, Y. (2016). Episodic memory. In *Cognitive Training: An Overview of Features and Applications* (pp. 69-80). Springer International Publishing.

Wetzels,, R., Matzke, D., Lee, M. D., Rouder, J. N., Iverson, G. J., & Wagenmakers, E. J. (2011). Statistical evidence in experimental psychology: An empirical comparison using 855 t tests. *Perspectives on Psychological Science*, *6*(3), 291-298. https://doi.org/10.1177/1745691611406923

Whitely, P. L. (1924). The Dependence of learning and recall upon prior mental and physical conditions. *Journal of Experimental Psychology, 7*(6), 420-428. https://doi.org/10.1037/h0071701

Whitely, P. L. (1927). The dependence of learning and recall upon prior intellectual activities. *Journal of Experimental Psychology, 10*(6), 489-508. https://doi.org/10.1037/h0075186

Williams, M. (1950). The effects of experimentally induced needs upon retention. *Journal of Experimental Psychology*, *40*(2), 139-151. https://doi.org/10.1037/h0057273

Williams, O. (1926). A study of the phenomenon of reminiscence. *Journal of Experimental Psychology, 9*(5), 368-387. https://doi.org/10.1037/h0069781

Wilson, B. A., Greenfield, E., Clare, Baddeley, A., Cockburn, J. Watson, P., … & Crawford, J. (2008). *The Rivermead Behavioural Memory Test – Third Edition (RBMT-3)*. London, UK: Pearson Assessment.

Wilson, B.A., Cockburn, J. & Baddeley, A. (1985) *Rivermead Behavioural Memory Test*. Thames Valley Test Company, London.

Winocur, G. & Weiskrantz, L. (1976). An investigation of paired-associate learning in amnesic patients. *Neuropsychologia*, *14*(1), 97-110. https://doi.org/10.1016/0028-3932(76)90011-7

Wipf, J. L., & Webb, W. B. (1962). Supplementary report: Proactive inhibition as a function of method of reproduction. *Journal of Experimental Psychology*, *64*(4), 421. https://doi.org/10.1037/h0040266

Wixted, J.T. (2004). The psychology and neuroscience of forgetting. *Annual Review of Psychology*, *55*, 235-269. https://doi.org/10.1146/annurev.psych.55.090902.141555

Woodworth, R. S. (1929). *Psychology* (2nd ed.). New York, NY: Holt.

Xu, L., Anwyl, R., & Rowan, M. J. (1998). Spatial exploration induces a persistent reversal of long-term potentiation in rat hippocampus. *Nature*, *394*(6697), 891-894. https://doi.org/10.1038/29783

Youtz, A. C. (1941). An experimental evaluation of Jost's laws. *Psychological Monographs, 53*(1), i-54. https://doi.org/10.1037/h0093486

Zhu, S., Noviello, C. M., Teng, J., Walsh, R. M., Kim, J. J., & Hibbs, R. E. (2018). Structure of a human synaptic GABAA receptor. *Nature*, *559*(7712), 67-72. https://doi.org/10.1038/s41586-018-0255-3

Zigmond, A. S., & Snaith, R. P. (1983). The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica*, *67*(6), 361-370. https://doi.org/10.1111/j.1600-0447.1983.tb09716.x

Appendices

Appendix A: Prose Passages – Experiment 1

Prose A:

Mr Brian / Kelly / a Security Express employee / was shot dead / on Monday / during a bank raid / in Brighton. / The four raiders / all wore masks / and one carried / a sawn-off / shotgun. / Police detectives / were sifting through / eye-witness accounts / last night. / A police spokesman said / 'He was a very brave man. / He went for / the armed raider / and put up a hell of a fight'.

Prose B:

Firemen / and volunteers / worked all day / yesterday / beating out / a moorland fire / six miles / south / of Keswick / in the Lake District. / Fire engines / were unable to reach the area / so fire-fighting equipment / was brought in by helicopter. / Livestock / was evacuated / from the neighbouring / Highlands Farm / as it was engulfed / in clouds / of dense white smoke.

Prose C:

Two hundred men / at a shipyard / on Tyneside / went on strike / this morning. / The men walked out / over a dispute / concerning fifty / redundancies. / The shop steward / Mr. Thomas / Lindsay / told reporters / 'It is outrageous! / The Company has full order-books / for the next two years'. / A management spokesperson said / 'We are hoping to begin / fresh negotiations / at head-office / tomorrow'.

Prose D:

A Dutch / oil tanker / sank / ten miles / off the Norfolk coast / last night. / The crew / were picked up / by a coast-guard patrol boat. / An oil slick / is already forming / and conservationists / are worried / about the effects / on wildlife. / Local enthusiasts / are mounting an operation / to save / any birds / found stranded / on the beaches.

Appendix B: Scoring Rubric for Experiment 1

Prose A:

Idea n°	Story idea	Full mark	Half mark
1	Mr Brian	Mr Brian OR Brian	NA
2	Kelly	Kelly	NA
3	a Security Express employee	a Security Express employee OR an employee of Security Express	indication of security employee, security guard without mentioning of company
4	was shot dead	was shot dead	indication of death, i.e. murdered, killed
5	on Monday	on Monday	NA
6	during a bank raid	during a bank raid	indication of robbery, i.e. bank robbery or heist
7	in Brighton	in Brighton	indication of England
8	The four raiders	The four raiders	indication of raiders, i.e. robbers
9	all wore masks	all wore masks	NA
10	and one carried	and one carried	indication of possession, i.e. one had
11	a sawn-off	a sawn-off	NA
12	shotgun	shotgun	indication of firearm, i.e. pistol, gun
13	Police detectives	Police detectives	indication of police or detectives
14	were sifting through	were sifting through	indication of looking, i.e. looking, analysing
15	eye-witness accounts	eye-witness accounts	NA
16	last night	last night	NA
17	A police spokesman said	A police spokesman said OR A police spokesperson said	indication of police representative
18	'He was a very brave man	He was a very brave man OR He was very brave	indication of bravery
19	He went for	He went for	indication of defence, i.e. he attacked
20	the armed raider	the armed raider	indication of criminal
21	and put up a hell of a fight'	and put up a hell of a fight	indication of fight

Prose B:

Idea n°	Story idea	Full mark	Half mark
1	Firemen	Firemen OR firefighters	NA
2	and volunteers	and volunteers	indication of assistance from others, i.e. helpers
3	worked all day	worked all day	indication of length of time
4	yesterday	yesterday	NA
5	beating out	beating out	indication of fighting fire, i.e. battling
6	a moorland fire	a moorland fire	indication of fire, i.e. blaze
7	six miles	six miles	indication of a number of miles
8	south	south	NA
9	of Keswick	of Keswick	NA
10	in the Lake District	in the Lake District	NA
11	Fire engines	Fire engines	indication of vehicles, i.e. trucks
12	were unable to reach the area	were unable to reach the area	indication of inaccessibility
13	so fire-fighting equipment	so fire-fighting equipment	indication of equipment
14	was brought in by helicopter	was brought in by helicopter	indication of aerial assistance, i.e. airlifted
15	Livestock	Livestock	indication of farm animals
16	was evacuated	was evacuated	indication of removal to safety
17	from the neighbouring	from the neighbouring	indication of nearby, i.e. nearby, close
18	Highlands Farm	Highlands Farm	indication of farm
19	as it was engulfed	as it was engulfed	indication of coverage, i.e. enveloped, immersed
20	in clouds	in clouds	NA
21	of dense white smoke	of dense white smoke	indication of smoke

Prose C:

Idea n°	Story idea	Full mark	Half mark
1	Two hundred men	Two hundred men OR Two hundred workers	indication of 100+ men/workers
2	at a shipyard	at a shipyard	NA
3	on Tyneside	on Tyneside	NA
4	went on strike	went on strike	indication of strike action
5	this morning	this morning	indication of morning, i.e. earlier today
6	The men walked out	The men walked out OR The workers walked out	
7	over a dispute	over a dispute	indication of argument, i.e. over a disagreement
8	concerning fifty	concerning fifty	NA
9	redundancies	redundancies	indication of redundancies, i.e. laid off
10	The shop steward	The shop steward	NA
11	Mr Thomas	Mr Thomas OR Thomas OR Tom	NA
12	Lindsay	Lindsay	NA
13	told reporters	told reporters	indication of informing news sources, i.e. told newspapers
14	'It is outrageous!	'It is outrageous!	indication of anger, disbelief
15	The Company has full order-books	The Company has full order-books OR The Company has full orders	NA
16	for the next two years'	for the next two years'	indication of several years
17	A management spokesperson said	A management spokesperson said	indication of Company representative
18	'We are hoping to begin	'We are hoping to begin	NA
19	fresh negotiations	fresh negotiations	indication of new discussions
20	at head-office	at head-office	indication of headquarters
21	tomorrow'	tomorrow'	NA

Prose D:

Idea n°	Story idea	Full mark	Half mark
1	A Dutch	A Dutch	NA
2	oil tanker	oil tanker	indication of ship
3	sank	sank	NA
4	ten miles	ten miles	indication of multiple miles
5	off the Norfolk coast	off the Norfolk coast	NA
6	last night	last night	NA
7	The crew	The crew	NA
8	were picked up	were picked up	indication of rescue, i.e. were rescued, were saved
9	by a coast-guard patrol boat	by a coast-guard patrol boat	indication of rescue boat
10	An oil slick	An oil slick	NA
11	is already forming	is already forming	indication of development, i.e. is already developing
12	and conservationists	and conservationists	indication of environmentalists
13	are worried	are worried	indication of concern, i.e. are concerned, are cautious
14	about the effects	about the effects	NA
15	on wildlife	on wildlife	NA
16	Local enthusiasts	Local enthusiasts OR enthusiasts	indication of volunteers
17	are mounting an operation	are mounting an operation	indication of action, i.e. are developing a plan
18	to save	to save	indication of rescue
19	any birds	any birds OR birds	NA
20	found stranded	found stranded	indication of stuck
21	on the beaches	on the beaches	NA

Appendix C: Prose Passages – Experiment 2 and 5

Prose A:

Il signor Alberto / Fossati, / una guardia giurata, / e stato ucciso / lunedi / durante una rapina in banca / a Perugia. / I quattro rapinatori / portavano tutti un maschera / e uno di loro aveva / anche una pistola / con silenziatore. / Ieri notte / la polizia / he raccolto / le testimonianze oculari. / Un signore presente ha detto: / 'E stato davvero molto coraggioso. / Ha rincorso / I rapinatori armati / ed ha iniziato una furibonda sparatoria'.

Prose B:

Vigili del fuoco / e volontari / hanno lavorato tutto il giorno / ieri / per domare / un tremendo incendio / in Toscana / 6 chilometri / a sud / di Siena. / La autopompe / non potevano arrivare sul posto / cosi le attrezzature per spegnere il fuoco / sono state portate in elicottero. / Il bestiame / e stato fatto evacuare / dalla vicina / fattoria del signore Mollica / che era avvolta / in una folta coltre / di fumo bianco.

Prose C:

Duecento dipendenti / di un cantiere navale / die Savona / sono scesi in sciopero / questa mattina. / La loro protesta reguarda / il licenziamento / di cinquanta / operai. / Il rappresentante sindacale / signor Giovanni / Ornaghi / he dichiarato ai giornalisti presenti. / “E vergognoso! / La compagnia ha richieste di furniture / per i prossimi due anni”. / Un dirigente della compagnia ha affermato: / “Speriamo di poter iniziare / domain / nuove trattative / con la sede centrale”.

Prose D:

Una petroliera, / olandese / e affondata / la notte scorsa / a 10 miglia / dalla costa di Livorno. / Gli uomini dell equipaggio / sono stati tratti in salvo / da un’unita di pattuglia della guardia costiera. / Si sta gia formando / un’enorme macchia d’olio, / e gli ecologisti / sono preoccupati / per I danni / all’ambiente. / Alcuni volontari della zona / si stanno organizzando / per salvare / gli ucelli / arenati / sulle spiagge.

Appendix D: Wordlist Material – Experiment 3

	Con	Fam	Imag	Let	Syl
List 1					
HELMET	602	528	620	6	2
KETTLE	602	551	594	6	2
PUDDLE	604	521	562	6	2
HAMMER	605	515	618	6	2
MIRROR	605	593	627	6	2
SAUCER	606	533	544	6	2
PICKLE	606	562	641	6	2
SPIDER	607	526	597	6	2
COTTON	608	521	562	6	2
NEEDLE	608	533	589	6	2
CANDY	602	559	601	5	2
TABLE	604	599	582	5	2
GRAVY	606	522	594	5	2
PENNY	606	613	609	5	2
CIGAR	580	536	619	5	2
Sum					

List 2					
FOREST	609	513	633	6	2
WINDOW	609	621	602	6	2
CHERRY	611	514	582	6	2
SHOWER	588	593	615	6	2
BUTTON	613	573	580	6	2
PILLOW	613	602	624	6	2
COFFEE	613	625	618	6	2
INFANT	579	513	600	6	2
PENCIL	617	598	607	6	2
BUTTER	618	615	603	6	2
LEMON	608	518	632	5	2
ANKLE	608	543	613	5	2
TIGER	611	513	606	5	2
HONEY	611	533	608	5	2
DAISY	613	519	573	5	2
Sum					

List 3	Con	Fam	Imag	Let	Syl
BOTTLE	591	591	619	6	2
JERSEY	621	559	572	6	2
COLLAR	622	509	582	6	2
CARROT	622	539	577	6	2
FATHER	594	591	646	6	2
RUBBER	596	547	599	6	2
WALRUS	629	506	590	6	2
CLOSET	599	540	525	6	2
TICKET	590	586	574	6	2
CARPET	581	508	538	6	2
PIANO	615	545	630	5	2
PAPER	599	635	590	5	2
WATER	616	641	632	5	2
HOTEL	591	565	597	5	2
APPLE	620	598	637	5	2
Sum					

List 4					
PIMPLE	579	557	617	6	2
LOCKER	586	538	569	6	2
GARLIC	636	509	565	6	2
CEREAL	637	543	576	6	2
BULLET	595	517	611	6	2
POSTER	592	545	600	6	2
DOCTOR	575	573	600	6	2
ROCKET	645	525	612	6	2
CEMENT	646	516	578	6	2
COFFIN	595	531	606	6	2
SUGAR	620	608	595	5	2
PUPPY	623	522	635	5	2
RIVER	585	565	633	5	2
MOVIE	590	523	571	5	2
PEDAL	602	512	556	5	2
Sum					

Con = concreteness, Fam = familiarity, Imag = imaginability, Let = number of letters, Syl = number of syllables, BNC Freq = British National Corpus (BNC) frequency measure.

Appendix E: Wordlist Material – Experiment 4

	Con	Fam	Imag	Let	Syl	BNC Freq
List 1						
LAWYER	569	520	557	6	2	2098
VIOLIN	626	468	606	6	3	558
MAGNET	550	526	543	6	2	314
ARTIST	554	547	600	6	2	3921
DAGGER	576	480	581	6	2	278
BEAVER	589	470	612	6	2	165
POWDER	513	521	524	6	2	1307
RUBBLE	493	407	482	6	2	365
HOCKEY	535	514	593	6	2	593
NAPKIN	585	495	582	6	2	181
SILVER	564	528	582	6	2	4841
WALNUT	642	538	590	6	2	347
CHISEL	597	469	567	6	2	172
OYSTER	573	453	521	6	2	211
TENNIS	574	528	634	6	2	2774
Sum						

Con = concreteness, Fam = familiarity, Imag = imaginability, Let = number of letters, Syl = number of syllables, BNC Freq = British National Corpus (BNC) frequency measure.

Appendix F: Cue-Associate Word Pairs – Experiment 6

Cue word	Associate word
VOTER	CHILD
BIBLE	WORLD
CANARY	QUEEN
NAVAL	BLACK
REPORT	CHAIR
AUTHOR	HOBBY
DOLLAR	TIMBER
CLOWN	SILVER
WINDOW	NURSE
RIVER	GINGER
TOILET	WRITE
BEETLE	ROBBER
COFFIN	BATTLE
BASKET	OXYGEN
DRIVER	FAIRY

Appendix G: Prose Material – Experiment 7

Prose 1 (Female):

Maria / da Conceição, / do sertão / do Ceará,/ trabalhava / de lavadeira / para o prefeito / da cidade. / Numa manhã, / encontrou / no bolso / de uma calça suja, / uma caixinha bonita / contendo um anel / de ouro / e uma nota fiscal / no valor de 2.000 Reais. / A joia / escapou de suas mãos / e caiu no ralo. / Ela pegou um galho / de árvore / para tentar fisgar o anel. / Depois de 30 minutos / finalmente conseguiu recuperá-lo.

Prose 2 (Female):

Suzana / Borges / da periferia / de Salvador, / estudante / de direito / na Universidade / Federal, / reclamou / no escritório / da diretoria / que tinha sumido, / de cima da sua mesa, / na tarde anterior, / os livros / que ela tinha comprado. / Ela disse que ia ter 3 / provas, / que ainda não tinha estudado, / e que os exames aconteceriam / dali a 2 dias. / A diretora / preocupada com a situação da menina / emprestou livros / para ela.

Prose 3 (Female):

Ana / Soares / do Sul / do Paraná, / empregada / como faxineira / em um prédio / de escritórios, / relatou, / na delegacia / de polícia / que tinha sido assaltada / na Rua do Estado / na noite anterior / e roubada / em 150 reais. / Ela disse que tinha 4 / Filhinhos, / o aluguel não tinha sido pago / e eles não comiam / há dois dias. / Os policiais / tocados pela história da mulher / fizeram uma coleta / para ela.

Prose 4 (Male):

Luis / Marques / adorava / escutar música / clássica. / Seu primeiro / filho / nasceu na maternidade / Santa Luzia, / e chorava muito. / Ele percebeu / que o silêncio acabara / e ele não poderia mais ouvir / seus CDs. / Quando a criança / completou 8 meses / ele estava desesperado, / pois o aparelho de som / somente tocava musiquinhas infantis. / Então, ele trocou o CD / e colocou uma sinfonia / de Beethoven. / Para sua surpresa / a criança se acalmou. / E a casa virou o Paraíso.

Prose 5 (Male):

José / Oliveira / jogava / futebol / de salão / todo domingo / na quadra / da cooperative / agrícola. / Estava treinando com o time / para um Campeonato / quando sua chuteira / desamarrou. / O jogador tropeçou / caindo de costas / fora do campo. / Ele tentou levantar, / mas sua perna / doía muito. / Foi carregado de maca / e levado para o vestiário. / O medico / o examinou / e viu que não tinha fratura. / Ele ficou feliz como uma criança.

Prose 6 (Male):

Roberto / Mota / estava dirigindo / um caminhão / Mercedes / numa rodovia / à noite / no vale / do Paraíba / levando ovos / para Taubaté / quando o eixo / quebrou. / O caminhão derrapou / caindo numa valeta / fora da estrada. / Ele foi jogado / contra o painel / e se assustou muito. / Não havia trânsito / e ele duvidou que pudesse ser socorrido. / Naquele instante, seu rádio Amador / tocou. / Ele respondeu imediatamente: / ”Aqui fala Tubarão”.

Appendix H: Mean (±SD) ratings of the Visual Analogue Mood Scale (VAMS) – Experiment 7

	Placebo		
	Pre-treatment	*Beginning Post-treatment*	*End Post-treatment*
Alert x drowsy (mm)	0.37 ± 0.21	0.42 ± 0.28	0.51 ± 0.27
Calm x excited (mm)	0.27 ± 0.15	0.35 ± 0.20	0.30 ± 0.19
Strong x feeble (mm)	0.40 ± 0.16	0.40 ± 0.17	0.42 ± 0.20
Clear headed x muzzy (mm)	0.20 ± 0.17	0.26 ± 0.26	0.32 ± 0.26
Well-coordinated x clumsy (mm)	0.41 ± 0.15	0.37 ± 0.21	0.44 ± 0.23
Energetic x lethargic (mm)	0.32 ± 0.17	0.32 ± 0.19	0.37 ± 0.19
Contented x discontented (mm)	0.29 ± 0.18	0.28 ± 0.20	0.30 ± 0.17
Tranquil x trouble (mm)	0.25 ± 0.22	0.26 ± 0.20	0.24 ± 0.19
Quick witted x mentally slow (mm)	0.35 ± 0.20	0.34 ± 0.22	0.36 ± 0.22
Relaxed x tense (mm)	0.31 ± 0.19	0.25 ± 0.17	0.28 ± 0.19
Attentive x dreamy (mm)	0.30 ± 0.19	0.35 ± 0.23	0.45 ± 0.27
Proficient x Incompetent (mm)	0.23 ± 0.16	0.25 ± 0.25	0.29 ± 0.23
Happy x sad (mm)	0.36 ± 0.18	0.29 ± 0.16	0.31 ± 0.21
Amicable x antagonistic (mm)	0.21 ± 0.12	0.23 ± 0.18	0.25 ± 0.17
Interested x bored (mm)	0.25 ± 0.17	0.24 ± 0.21	0.33 ± 0.25
Gregarious x withdrawn (mm)	0.25 ± 0.17	0.29 ± 0.18	0.33 ± 0.19

	Placebo		
	Pre-treatment	*Beginning Post-treatment*	*End Post-treatment*
MOOD FACTORS			
Anxiety (score)	0.28 ± 0.18	0.28 ± 0.15	0.27 ± 0.16
Physical sedation (score)	0.32 ± 0.14	0.32 ± 0.18	0.36 ± 0.19
Mental sedation (score)	0.33 ± 0.19	0.39 ± 0.24	0.48 ± 0.23
Other symptoms (score)	0.28 ± 0.14	0.26 ± 0.17	0.30 ± 0.17

	Diazepam		
	Pre-treatment	*Beginning Post-treatment*	*End Post-treatment*
Alert x drowsy (mm)	0.47 ± 0.18	0.80 ± 0.12	0.83 ± 0.14
Calm x excited (mm)	0.20 ± 0.16	0.12 ± 0.09	0.11 ± 0.09
Strong x feeble (mm)	0.35 ± 0.19	0.62 ± 0.15	0.66 ± 0.21
Clear headed x muzzy (mm)	0.16 ± 0.20	0.58 ± 0.26	0.52 ± 0.31
Well-coordinated x clumsy (mm)	0.35 ± 0.17	0.75 ± 0.15	0.71 ± 0.16
Energetic x lethargic (mm)	0.33 ± 0.16	0.54 ± 0.29	0.57 ± 0.22
Contented x discontented (mm)	0.17 ± 0.12	0.35 ± 0.19	0.30 ± 0.18
Tranquil x trouble (mm)	0.24 ± 0.21	0.38 ± 0.29	0.20 ± 0.16
Quick witted x mentally slow (mm)	0.26 ± 0.18	0.65 ± 0.19	0.66 ± 0.23
Relaxed x tense (mm)	0.26 ± 0.18	0.24 ± 0.14	0.18 ± 0.13
Attentive x dreamy (mm)	0.27 ± 0.16	0.65 ± 0.13	0.65 ± 0.20
Proficient x Incompetent (mm)	0.20 ± 0.13	0.57 ± 0.19	0.60 ± 0.22
Happy x sad (mm)	0.27 ± 0.17	0.32 ± 0.19	0.33 ± 0.18
Amicable x antagonistic (mm)	0.21 ± 0.20	0.23 ± 0.22	0.23 ± 0.17
Interested x bored (mm)	0.16 ± 0.14	0.31 ± 0.20	0.31 ± 0.18
Gregarious x withdrawn (mm)	0.25 ± 0.19	0.31 ± 0.21	0.34 ± 0.20

	Diazepam		
	Pre-treatment	*Beginning Post-treatment*	*End Post-treatment*
MOOD FACTORS			
Anxiety (score)	0.23 ± 0.13	0.25 ± 0.12	0.16 ± 0.10
Physical sedation (score)	0.27 ± 0.13	0.57 ± 0.12	0.58 ± 0.17
Mental sedation (score)	0.37 ± 0.13	0.72 ± 0.10	0.74 ± 0.14
Other symptoms (score)	0.20 ± 0.12	0.30 ± 0.14	0.29 ± 0.15

Appendix I. Mean (± SD) number of story idea units recalled at immediate free-recall, delayed (free- or cued-) recall in the post-treatment period Day 1 and at the Day 7 as well as retention (proportion) of the stories, per treatment group (placebo and diazepam) and type of interference.

		Free-recall				Cued-recall			
		Placebo		Diazepam		Placebo		Diazepam	
Encoding	Recall	MinRI	RI	MinRI	RI	MinRI	RI	MinRI	RI
pre-treatment	Immediate	15.7 ± 3.5	14.9 ± 4.9	14.4 ± 3.2	14.4 ± 3.5	-	-	-	-
	Delay post-treatment	8.2 ± 4.6	9.4 ± 5.9	11.3 ± 3.1	12.1 ± 4.1	9.5 ± 3.6	10.5 ± 4.6	11.3 ± 3.1	12.1 ± 4.1
	7-day delay	7.5 ± 3.3	8.9 ± 4.7	6.3 ± 3.7	6.7 ± 4.1	7.7 ± 2.8	9.2 ± 4.2	7.5 ± 3.0	7.3 ± 3.6
	Retention post-treatment delay/Immediate	0.5 ± 0.3	0.6 ± 0.3	0.8 ± 0.2	0.8 ± 0.1	0.6 ± 0.2	0.7 ± 0.2	0.8 ± 0.2	0.8 ± 0.1
	Retention 7-day delay/Immediate	0.5 ± 0.2	0.6 ± 0.2	0.5 ± 0.2	0.5 ± 0.2	0.5 ± 0.2	0.6 ± 0.2	0.5 ± 0.2	0.5 ± 0.2
	Ret 7day delay/post-treatment delay	0.83 ± 0.3[a]	0.8 ± 0.3[b]	0.6 ± 0.3	0.6 ± 0.3	0.8 ± 0.3	0.8 ± 0.3	0.7 ± 0.2	0.6 ± 0.2

		Free-recall				Cued-recall			
		Placebo		Diazepam		Placebo		Diazepam	
Encoding	Recall	MinRI	RI	MinRI	RI	MinRI	RI	MinRI	RI
Beginning post-treatment	Immediate	15.9 ± 4.3	16.1 ± 3.5	10.9 ± 4.7	10.9 ± 3.3	-	-	-	-
	Delay post-treatment	12.4 ± 4.6	13.4 ± 3.6	2.8 ± 4.9	1.3 ± 3.4	13.0 ± 3.2	13.4 ± 3.6	5.1 ± 4.7	5.0 ± 3.4
	7-day delay	8.6 ± 4.4	10.3 ± 4.7	0.5 ± 1.8	1.3 ± 2.0	9.6 ± 2.8	11.5 ± 2.4	1.9 ± 2.7	1.9 ± 2.0
	Retention post-treatment delay/Immediate	0.8 ± 0.2	0.8 ± 0.2	0.2 ± 0.3	0.1 ± 0.2	0.8 ± 0.1	0.8 ± 0.2	0.4 ± 0.3	0.4 ± 0.2
	Retention 7-day delay/Immediate	0.5 ± 0.3	0.6 ± 0.3	0.1 ± 0.1	0.1 ± 0.2	0.6 ± 0.1	0.7 ± 0.1	0.2 ± 0.2	0.2 ± 0.2
	Retention 7day delay/post-treatment delay	0.7 ± 0.3[c]	0.8 ± 0.3	0.0 ± 0.0[d]	0.5 ± 0.5[e]	0.8 ± 0.2	0.9 ± 0.2	0.5 ± 0.5[a]	0.6 ± 1.3[c]
End post-treatment	Immediate	16.3 ± 3.8	16.9 ± 4.9	12.6 ± 4.8[c]	13.5 ± 2.0[c]	-	-	-	-
	7-day delay	2.5 ± 4.0	5.0 ± 5.1	0.9 ± 3.5[a]	0.9 ± 2.3[a]	7.0 ± 3.8	8.0 ± 3.0	1.9 ± 3.57[c]	0.9 ± 2.3[c]
	Ret 7-day delay/Immediate	0.2 ± 0.2	0.4 ± 0.4	0.1 ± 0.2[c]	0.1 ± 0.1[c]	0.4 ± 0.2	0.53 ± 0.3	0.1 ± 0.2[c]	0.1 ± 0.2[c]