Semantic, Phonological and Episodic Representations in Verbal Immediate Serial Recall

Submitted by

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Statement of Sources

This thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma.

No parts of this thesis have been submitted towards the award of any other degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgement in the main text of the thesis.

All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committees (where required).

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"*Sometimes you will never know the value of a moment until it becomes a memory*"
- Dr. Seuss

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AMT	activation/monitoring theory
ANOVA	analysis of variance
BAS	backward associative strength
DAT	dementia of the Alzheimer's type
DRM	Deese-Roediger-McDermott
***f*MRI**	functional magnetic resonance imaging
FTT	fuzzy trace theory
ISI	inter-stimulus interval
MTL	medial temporal lobe
NAM	neighbourhood activation model
OSCAR	oscillator-based associative recall
PFC	prefrontal cortex
PHG	parahippocampal gyrus
PPC	posterior parietal cortex
RSVP	rapid serial visual presentation
SIMPLE	scale-invariant memory, perception and learning
VLPFC	ventrolateral prefrontal cortex

Abstract

Psycholinguistic frameworks provide contemporary accounts of immediate serial recall (e.g., N. Martin & Saffran, 1997; R. C. Martin, Lesch, & Bartha, 1999). These models emphasise the inclusion of semantic/associative and phonological representations in verbal short-term memory but have difficulty explaining how serial order is represented and maintained. Conversely, computational models of immediate serial recall (e.g., Brown, Preece, & Hulme, 2000; Henson, 1998b; Lewandowsky & Farrell, 2008b; Page & Norris, 1998) have typically concentrated on the role of temporary episodic representations on short-term recall but have trouble accounting for the influence of multiple representations on performance. The aim of this research was to combine these two lines of research to form a more integrative approach to immediate serial recall. The intention was to contribute to current understandings of verbal short-term memory by exploring how the binding of semantic/associative, phonological and episodic representations would influence immediate serial recall.

The Deese-Roediger-McDermott (DRM) false memory paradigm was used as a framework to investigate the role of pre-existing phonological and semantic/associative knowledge on short-term memory. In line with the DRM framework and the embedded components model of working memory (Oberauer, 2002), the underlying assumption of this project was that long-term knowledge was arranged within pre-existing interconnected semantic and phonological networks that could communicate via spreading activation (Collins & Loftus, 1975). In Experiments 1 - 4, 80 adults aged between 18 - 53 years (*M* = 28.83, *SD* = 8.94) completed two computer-based immediate serial recall tasks during individual face-to-face testing sessions. Each task was comprised of 40 six-word trials. To study phonological and associate/semantic binding, the type of items within each list were manipulated such that

lists were phonologically similar or dissimilar and associatively related or unrelated to a never-presented critical lure. “Pure” lists contained items that were *either* phonologically similar (e.g., *rum*) or semantically associated (e.g., *jog*) to the critical lure (e.g., *run*) interleaved between unrelated and dissimilar words. In contrast, “hybrid” trials comprised *both* items that were phonologically similar and items that were associatively related to the critical item. Unrelated lists contained items that were not connected to a common critical lure or to each other. To examine episodic binding, lists were presented at either a standard rate (i.e., one word per 1,000 milliseconds) or a rapid rate (i.e., one word per 250 milliseconds). Episodic binding was also manipulated by having participants repeat the same recall task or by giving participants two similar recall tasks to complete. The time between the two tasks was also varied such that participants completed the tasks in immediate succession, or after a 15-minute or 60-minute delay. In Experiments 5 and 6, healthy ageing was examined as a way to further examine episodic binding. Forty older adults aged between 67 - 92 years (M = 75.85, SD = 6.17) with no reported cognitive impairments completed a similar procedure to that of the younger participants. In all experiments of this project, responses were scored for serial recall and false recall and a series of factorial ANOVAs were run to analyse the results.

Across all six experiments, the false memory effect was observed and false errors were reported to be significantly more likely during hybrid lists ($p < .001$) compared to other list types. Lures were also typically recalled towards the end of the list, under conditions in which episodic information was presumably at its weakest. False recall was not consistently impacted by age, presentation rate, or task repetition but these variables did influence true memory. Serial recall improved significantly with repetition ($p < .01$) across both age groups and younger adults tended to recall more items in position than older adults ($p < .05$). In addition, serial recall was significantly greater during standard as opposed to rapid presentation rate ($p < .05$) for younger individuals.

Together, these results support the notion that semantic/associative and phonological information is organised in pre-existing long-term networks and that the binding of this information can impact verbal short-term memory. These long-term activations appear to impact memory immediately after list presentation and persist for some time after the list has been recalled. The findings of this project also suggest that short-term recall is impacted by the strength and distinctiveness of temporary episodic content-context associations. Seemingly, episodic information can assist in maintaining order within the short-term system and also help one to ignore irrelevant activated representations in memory. In addition, how these temporary episodic bindings interact with long-term semantic and phonological networks also appears to be important to serial recall performance.

The outcomes of this thesis highlight the role of semantic/associative, phonemic and temporary episodic binding in verbal short-term memory, and have implications for contemporary accounts of immediate serial recall. Some of these findings can be explained using the embedded components model (Oberauer, 2002) whilst others are more consistent with either psycholinguistic (e.g., R. C. Martin et al., 1999) or computational frameworks (e.g., Brown et al., 2000, 2007; Burgess & Hitch, 2006; Page & Norris, 2009). However, no current models of immediate serial recall are able to accommodate for all of the results of this project, providing support for the need for an integrative approach to short-term recall.

Chapter One: Chapter Overviews

The overarching aim of this project was to examine the influence of associative/semantic, phonological, and episodic information on verbal short-term memory. The intention was to contribute to current understandings of immediate serial recall and contemporary frameworks of short-term memory. In particular, the purpose was to present an integrative model that could accommodate for the effects of both semantic and episodic memory on short-term recall. With this goal in mind, Chapter Two outlines the verbal short-term memory system and provides an introduction to contemporary models of immediate serial recall. This includes a discussion of frameworks that have focused on the role of phonological and/or semantic information in short-term memory tasks as well as those that have emphasised the impact of episodic information on performance. The aim of this chapter was to develop the rationale that short-term memory research would benefit from a more comprehensive account of immediate serial recall than what is currently available in the literature. That is, an integrative model that is able to describe the role of semantic, phonological and episodic information in verbal short-term memory.

The three subsequent chapters then discuss the manipulation of semantic, phonological and episodic information. These chapters are separated into the ways in which (1) semantic and phonological information and (2) episodic material are operationalised in this project. In order to manipulate semantic and phonological information in the immediate serial recall task, this project employed the Deese-Roediger-McDermott (DRM) false memory paradigm (Deese, 1959; Roediger & McDermott, 1995). Hence, Chapter Three provides a description of this procedure and its application within both the short- and long-term domain. To vary episodic information in the current project, healthy ageing was investigated. Therefore, Chapter Four summarises the influence of the normal ageing process on memory performance and outlines the key theoretical perspectives of age-related declines in cognition. The purpose in discussing memory and ageing at this point of the thesis was to provide a foundation for the inclusion of an ageing sample as a way to further manipulate episodic information in the immediate serial recall task. The inclusion of an ageing sample was also intended to assist in investigating and extending the possibility of an integrative model of verbal short-term memory. As an additional means to manipulate episodic information, this thesis manipulated presentation rate and repetition of the immediate serial recall task. Chapter Five details the ways in which these variables have been utilised in other short-term memory studies and their employment in false memory research.

After the relevant literature has been reviewed, Chapter Six delivers a general rationale and overview to the research, summarising the key points raised in the earlier chapters. The general aims and theoretical assumptions and predictions underpinning this thesis are included in this section to provide a basis for the experiments of the project. The six experiments of this thesis are detailed in Chapter Seven, Chapter Eight and Chapter Nine. The overall aim of these experiments was to investigate the binding of semantic/associative, phonological and episodic information, and the ways in which this information would influence true and false immediate serial recall. All experiments involved two immediate serial recall tasks using the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) and varying speeds of presentation. A general discussion of the results of these experiments are provided in Chapter Ten and implications for these findings in relation to an integrative model of immediate serial recall are considered in Chapter Eleven. In addition, the contributions that this project makes to verbal short-term memory research, false memory understandings, and theories on cognitive ageing are discussed. The chapter concludes with an outline of the project’s limitations and the consideration for future directions.

Chapter Two: An Introduction to Verbal Short-Term Memory

2.1 Chapter Outline

The aim of this chapter was to provide a preliminary understanding of the study of verbal short-term memory. The chapter begins with an introduction into the structure, its function and key theoretical bases of the memory system. A focus is then drawn more specifically to the exploration of verbal short-term memory using the immediate serial recall task. The predominant frameworks used to explain the effects of immediate serial recall are discussed and gaps in the current literature are acknowledged. The chapter concludes with a consideration of the potential areas for future research thereby outlining the direction for the current project.

2.2 The Memory System

Memory is critical to nearly every aspect of development across the lifespan. It is comprised of ones' ability to encode, store, manipulate, and retrieve information. Traditional models of the human memory system have typically differentiated between short- and long-term memory (e.g., Atkinson & Shiffrin, 1968; Baddeley & Warrington, 1970; Broadbent, 1957; Craik & Lockhart, 1972; James, 1890; Scoville & Milner, 1957; Shallice & Warrington, 1970; Vallar & Papagno, 2002; Waugh & Norman, 1965). Those in favour of multiple memory systems often emphasise the differences in the duration and capacity of those systems. Long-term memory is usually defined as a system of long-term storage, able to capture large amounts of information over extended periods of time. It is often described as an archive of information varying in both detail and accessibility. The conscious, declarative, explicit form of long-term memory is typically divided into semantic and episodic components. Semantic memory is defined as a system for storing general knowledge and world facts generally considered to persist across the lifespan while episodic memory is presumably where autobiographical information is retained and typically declines in older age (Craik & Rose, 2012; Gardiner, 2001; Squire, 1992; Tulving, 1972, 1983, 2002; Wheeler, Stuss, & Tulving, 1997).

In contrast, short-term memory is frequently referred to as a structure of temporary storage, posited to hold a limited amount of information, for a restricted duration of time (e.g., Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Cowan, 2008; Miller, 1956; Peterson & Peterson, 1959; Neath & Surprenant, 2003). Information in short-term memory is considered the focus of attention, which is highly accessible, albeit greatly susceptible to forgetting. Some presume this vulnerability to forgetting over the short-term is the result of decay (e.g., Baddeley, 1986, 2000; Brown, 1958; Burgess & Hitch, 1999; Cowan, 1999; Page & Norris, 1998; Peterson & Peterson, 1959) although others highlight the role of interference (e.g., Brown & Hulme, 1995; Keppel & Underwood, 1962; Nairne, 1990a; Waugh & Norman, 1965). The cause of short-term forgetting continues to be a source of ongoing debate in the literature. Nonetheless, there is general agreement that there are limits to the storage of information in the short-term system.

Short-term memory is notably described in Baddeley's multicomponent model of working memory (Baddeley, 1986; Baddeley & Hitch, 1974). In this model, working memory is defined as a temporary information storage system, limited both in capacity and duration, in which information decays over time without rehearsal (Baddeley, 1986; Baddeley & Hitch, 1974). This framework depicts working memory as the summation of three major components, namely the visuospatial sketchpad responsible for retaining visual information, the phonological loop required for holding verbal information, and the central executive for maintaining attentional control. The phonological loop is further divided into the phonological store, whereby information over the short-term is encoded and held, and the articulatory rehearsal in which information is maintained via rehearsal (Baddeley, 1986, 2000).

Whilst Baddeley's (1986) tripartite model was based on the notion of separate short- and long-term systems, in a later revision the contribution of long-term memory to working memory was also acknowledged with the inclusion of a fourth component (Baddeley, 2000). This additional constituent, referred to as the episodic buffer, was incorporated into the model in order to explain the transfer in information and influence between the different structures of memory (Baddeley, 2000). Although working memory is not always considered analogous to short-term memory, the two terms are often used interchangeably and some suggest at least partial overlap between the two concepts (e.g., Cowan, 2008; Engle, 2002). Irrespective of which term (or both) is adopted, most current memory frameworks that focus on a temporary storage system dictate that without rehearsal or transferral to long-term memory, information over the short-term will be lost (Nairne, 2002). The depiction of memory as a multi-store arrangement has been supported by neuropsychological case studies describing double dissociations between short- and long-term memory (e.g., Milner, Corkin, & Teuber, 1968; Warrington & Shallice, 1969), and brain imaging techniques that note different neural regions are activated when various memory tasks are employed (e.g., Talmi, Grady, Goshen-Gottstein, & Moscovitch, 2005).

It is important to note however that there is growing consensus in modern memory literature regarding the similarities between short- and long-term memory (e.g., Brown, Preece, & Hulme, 2000; Cabeza, Dolcos, Graham, & Nyberg, 2002; Cowan, 1988, 1995; Crowder, 1993; Crowder & Neath, 1991; Jonides et al., 2005; Melton, 1963; Nairne, 1991;

Neath & Crowder, 1990, 1996; Ranganath, Johnson, & D'Esposito, 2003; Surprenant & Neath, 2009). Several studies have promoted the idea that short- and long-term memory may actually exist on a continuum (Keppel & Underwood, 1962; Melton, 1963; Postman, 1964) and some neuropsychological investigations have questioned the notion of a double dissociation between the two memory stores (e.g., Jonides et al., 2008; Ranganath & Blumenfeld, 2005).

In addition, a number of frameworks have been developed based on the presumption of a more unitary memory system. Some of these models define short-term memory (or at least a considerable part of short-term memory) as activated long-term memory (Anderson, et al., 2004; Cowan, 1988, 1995, 2000; McElree, 2001; Oberauer, 2002; Verhaeghen, Cerella, & Basak, 2004). Cowan (1995, 1999, 2000), for example, posits an embedded components model in which short-term memory is defined as representations of long-term memory with high activation. This model highlights three areas of memory including short-term memory, long-term memory, and the focus of attention. According to this framework, information in focus has a high level of activation, but this activation begins to decline if attention is shifted to something else. At this stage, however, the information representations would still be available via short-term memory. Once activation levels have returned to original magnitudes, the representations would only be accessible through long-term memory. In short, the degree of activation depends on the recency and frequency of representations and whether such representations were currently being attended to (Cowan, 1995, 1999, 2000). Irrespective of the unitary versus multi-system debate or how the constituents of memory are classified, the idea that the memory system is responsible for different roles appears to be a prevailing concept in memory research. Moreover, the focus of most contemporary studies continues to be on the relationship between long- and short-term stores. Research into the connection between the long- and short-term memory systems has often focused on the contribution of long-term knowledge to verbal (speech-based) short-term memory and these investigations have typically been undertaken by studying immediate serial recall.

2.3 Verbal Immediate Serial Recall

2.3.1 The influence of phonological knowledge.

It is widely agreed that immediate serial recall is based on phonological, lexical or speech-based codes (Baddeley, 1986). Moreover, long-term phonological information is thought to play a role during the immediate serial recall task. The immediate serial recall task involves the visual or auditory presentation of items and requires immediate (verbal) recall following list presentation. Performance is measured using strict serial (correct-in-position) scoring, whereby items are scored correct when recalled in the exact order of presentation. The redintegration hypothesis has been a prominent theory of immediate serial recall over recent decades and has highlighted the influence of long-term memory on short-term recall (Hulme, Maughan, & Brown, 1991; Schweickert, 1993). This model presumes that performance on the immediate serial recall task requires the formation of phonological representations of the to-be-recalled items in memory. Over time though, these representations are thought to be lost if they are not continually rehearsed or transferred into long-term memory. Under these circumstances it is expected that the memory trace will degrade and be unable to be directly recalled as a response. However, the redintegration hypothesis also proposes a secondary process that can be undertaken in order to retrieve the to-be-recalled information (Hulme et al., 1991; Schweickert, 1993). The model presumes that long-term lexical information can be accessed using the degraded phonological representations as prompts to search the more permanent memory store and retrieve a reconstruction of the degraded short-term trace (Hulme et al., 1991; Schweickert, 1993). Schweickert (1993) was the first to conceptualise the redintegration process within a conceptual framework and it has been subsequently supported in other investigations (e.g., Brown & Hulme, 1995; Buchner & Erdfelder, 2005; Gathercole, Pickering, Hall, & Peaker, 2001; Hulme et al., 1991; Hulme et al., 1997; Lewandowsky & Farrell, 2000; Li, Schweickert, & Gandour, 2000; Saint-Aubin & Poirier, 2005; Schweickert, Chen, & Poirier, 1999).

The redintegration model demonstrates the importance of phonological knowledge in recalling information over the short-term. This proposition has been reinforced by the observation that such codes can be disrupted through irrelevant background speech (Salamé & Baddeley, 1982) or via concurrent articulation (articulatory suppression) in which rehearsal is inhibited through the repetition of a sound (e.g., *the, the, the*) during item presentation and/or recall (Baddeley, Lewis, & Vallar, 1984; Murray, 1968). Proactive interference effects have also been demonstrated in the short-term domain and posited as an indication of phonemic codes in the short-term system (Tehan & Humphreys, 1995). Indeed, phonological coding has been deemed an important contributor to immediate serial recall, over and above the effects of rehearsal and speed of articulation (Tehan, Fogarty, & Ryan, 2004)**.**

The influence of phonology on immediate serial recall is also readily apparent when observing the phonological similarity effect, which refers to the routine observation that immediate recall is better for dissimilar lists compared to similar sounding (rhyming) lists (Baddeley, 1966a, 1966b; Conrad, 1964; Conrad & Hull, 1964). Although some studies have found different results when using different scoring measures (e.g., Fallon, Groves, & Tehan, 1999; Poirier & Saint-Aubin, 1996), with strict serial recall the phonological similarity effect is readily apparent in short-term memory and has formed the basis for the phonological loop in Baddeley's working memory model (Baddeley, 1986; Conrad, 1964; Conrad & Hille, 1968). Furthermore, the effect has been demonstrated across different age groups (e.g., Henry, 1991; Morris, 1984) and for a wide range of stimuli including lists of letters (Conrad, 1964; Drewnowski, 1980; Wickelgren, 1965), words (Baddeley, 1966b), digits (Hintzman, 1965), and pictures (Schiano & Watkins, 1981), as well as with repeated lists (Coltheart, 1993) and with lists of interleaving similar and dissimilar items (Baddeley, 1968, Experiment 5; Farrell & Lewandowsky, 2003; Lewandowsky & Farrell, 2007).

Verbal (phonological) short-term memory has also been presumed to be essential for a variety of linguistic abilities. For instance, Baddeley and colleagues (e.g., Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1990; Gathercole, Willis, Emslie, & Baddeley, 1992; Vallar & Baddeley, 1987) have conducted extensive research into the role of the short-term system in language acquisition within the context of the working memory model (for a review see Baddeley, 2003). Based on this research, working memory (specifically the phonological loop) is thought to impact a number of language processes including those involved in learning new words (e.g., Baddeley, Papagno, & Vallar, 1988) and second languages (e.g., Atkins & Baddeley, 1998; Gathercole, Service, Hitch, Adams, & Martin, 1999; Papagno, Valentine, & Baddeley, 1991; Papagno & Vallar, 1992; Service, 1992). In addition, this research has suggested that impairments in (phonological) short-term memory underwrite many language disorders (e.g., Gathercole & Baddeley, 1989; Gathercole & Baddeley, 1990). Other studies have also highlighted the link between phonological short-term memory and learning (e.g., Gupta & Tisdale, 2009a, 2009b; for a review see Gathercole, 2006).

2.3.2 The contribution of semantic/associative information.

While the importance of phonological codes in verbal short-term memory is well-established, more recent investigations have also demonstrated the involvement of semantic/associative codes within the short-term system and the role of pre-existing semantic/associative information on immediate serial recall performance. For example, evidence for semantic knowledge contributing to verbal short-term recall comes from discoveries such as the better recall for words versus non-words (i.e., the lexicality effect; Gathercole et al., 2001; Jefferies, Frankish, & Noble, 2009; Saint-Aubin & Poirier, 2000), pseudohomophones compared to control non-words (Besner & Davelaar, 1982), high-frequency versus low-frequency words (Hulme et al., 1997; Roodenrys & Quinlan, 2000; Saint-Aubin, & LeBlanc, 2005; Watkins & Watkins, 1977), concrete rather than abstract words (Acheson, Postle, & MacDonald, 2010; Allen & Hulme, 2006; Bourassa & Besner, 1994; Romani, McAlpine, & R. C. Martin, 2008; Tse & Altarriba, 2009; Walker & Hulme, 1999), content words over function words (Caza & Belleville, 1999) and pleasant as opposed to neutral words (Monnier & Syssau, 2008) under short-term recall conditions. The semantic similarity effect refers to the observation that during strict serial recall, words that are semantically (categorically) similar are better recalled than words that are semantically dissimilar, providing additional support for the influence of semantic knowledge in the short-term domain (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1999b; Tse, 2009; Tse, Li, & Altarriba, 2011).

It is important to note, however, that short-term memory research has traditionally investigated semantic memory with regard to similarity as opposed to associations. This is noteworthy because some studies have attempted to differentiate between semantic and associative relationships. For instance, Thompson-Schill, Kurtz, and Gabrieli (1998) defined associations as the "probability that one word will call to mind a second word" (p. 440) (e.g., Nelson, McEvoy, & Schreiber, 1998) and semantic relatedness as the "similarity in meaning or the overlap in featural descriptions of two words" (p. 440). These researchers acknowledged that words could be highly associated and semantically dissimilar (e.g., fruit-fly), or weakly associated and semantically similar (e.g., radish-beets) or both highly associated and semantically similar (e.g., crown-king). Others propose that semantic association and semantic similarity share a graded relationship (Crutch & Warrington, 2010). McRae, Khalkhali, and Hare (2012) argued against dividing semantic memory up into associative versus semantic relatedness/similarity and instead suggested that associations between words were actually determined by semantic relationships. Moreover, studies that have explored associative relatedness and serial recall have reported mixed findings. For example, some have found that associations can negatively impact memory performance (Underwood & Goad, 1951) while others show no effect (Crowder, 1979, Experiment 2) or even an advantage (Tse, 2009). Nevertheless, both semantic and associative relatedness are assumed to impact order memory in the short-term domain (Acheson, MacDonald, & Postle, 2011) and aid immediate serial recall (e.g., Stuart & Hulme, 2000; Tse, 2009; Tse, Li, & Altarriba, 2011).

Tse (2009) for example investigated the influence of categorical and associative similarity on immediate serial recall. Categorical similarity was manipulated by including word lists derived from the same (e.g., *apple, banana, grape*) or different categories. Associative similarity was measured by the inclusion of lists that were either associatively related (e.g., *honey, sugar, sour*) or unrelated to each other. Importantly, similarity was found to aid immediate serial recall for both list types. That is, serial recall was greater for associatively related versus associatively unrelated lists and for categorically similar versus categorically dissimilar lists. Tse, Li, and Altarriba (2011) provided further strength for this proposition. These researchers also compared associative lists (e.g., *climb, mountain, peak, steep, summit, valley*) and categorical lists (e.g., *cat, deer, dog, horse, lion, tiger*). Consistent with the observations of Tse (2009), an advantage for similar as opposed to dissimilar lists was established across both list types (i.e., associatively related lists and categorically similar lists).

Irrespective of this debate, a criticism of the redintegration model has been its focus on phonological/lexical representations, as opposed to semantic/lexical (or associative) representations in verbal short-term memory (Romani et al., 2008; Thorn, Frankish, & Gathercole, 2009; Thorn, Gathercole, & Frankish, 2005). Although the framework has been updated to allow for the contribution of semantic/lexical knowledge during the reconstructive stage of the recall process (Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1999a, 1999b, 2000), some investigations have proposed that semantic factors impact performance much earlier on (e.g., Romani et al., 2008). That is, while the redintegration model suggests that semantic/lexical representations impact immediate serial recall during retrieval/output processes, other investigations have proposed that semantic factors have the potential to effect short-term recall from the moment of list presentation (e.g., Jefferies, Frankish, & Lambon Ralph, 2006; Knott, Patterson, & Hodges, 1997; N. Martin & Saffran, 1992, 1997; R. C. Martin, Lesch, & Bartha, 1999; R. C. Martin & Romani, 1994, 1995; Romani et al., 2008; Romani & R. C. Martin, 1999). In response to some of these redintegration model criticisms, another category of verbal short-term memory models under the heading of psycholinguistic frameworks has become increasingly prevalent (e.g., Hartley & Houghton, 1996; N. Martin & Saffran, 1997; R. C., Martin, 2005; R. C. Martin et al., 1999).

2.3.3 Psycholinguistic models of immediate serial recall.

Psycholinguistic models highlight the role of linguistic processes in understanding memory performance and propose a link between the underlying mechanisms of language and short-term memory tasks, including immediate serial recall tasks. Many of these accounts tend to propose that long-term memory has a greater influence on short-term memory than what is described in the traditional redintegration framework and presume verbal short-term memory extends beyond Baddeley's (1986, 2000) phonological loop (Acheson & MacDonald, 2009; Cowan, 1999; Cowan & Chen, 2009; Gupta, 2003, 2009; N. Majerus, 2009; N. Martin & Gupta, 2004; R. C. Martin, 2006; Romani et al., 2008).

Psycholingusitic research has examined samples of both healthy, younger adults as well as older participants and those suffering from cognitive impairments. For example some support for these models has been established by studying patients with brain damage, typically those exhibiting dissociations between semantic and phonological short-term memory performance (Freedman & R. C. Martin, 2001; Hanten & R. C. Martin, 2000; Hoffman, Jefferies, Ehsan, Hooper, & Lambon Ralph, 2009; N. Martin & Saffran, 1997; R.C. Martin & He, 2004; R. C. Martin, Shelton, & Yaffee, 1994; Reilly et al., 2012; Wong & Law, 2008). These patients usually display problems in remembering semantic (or phonological) information in short-term memory but retain the capacity to remember phonological (or semantic) material over the short-term. For example, patients with impairments in phonological short-term memory may retain the typical effect of lexicality but display a reduction in the effects of phonological similarity (R. C. Martin et al., 1994). Conversely, patients with semantic short-term memory deficits may show attenuation of lexicality effects on recall tasks but still exhibit the phonological similarity effect (e.g., Jefferies, Hoffman, Jones, & Lambon Ralph, 2008). These investigations highlight the importance in considering the role of both phonological and semantic short-term memory on episodic recall.

Neurological studies also point to an influence of semantics on episodic memory performance (e.g., Menon, Boyett-Anderson, Schatzberg, & Reiss, 2002) and verbal working memory over and above the influence of phonological factors (Caza, Belleville, & Gilbert, 2002; R. C. Martin & Romani, 1994). Moreover, some neuroimaging studies have suggested that holding semantic information versus phonological information involves the activation of different neural regions (Delvin, Matthews, & Rushworth, 2003; Fiez, 1997; R. C. Martin, Wu, Freedman, Jackson, & Lesch, 2003; McDermott, Petersen, Watson, & Ojemann, 2003; Poldrack et al., 1999; Shivde & Thompson-Schill, 2004). Inferior parietal lobe damage is associated with phonological short-term memory impairments (Vallar & Papagno, 1995), whilst semantic short-term memory problems have been attributed to damage in the left frontal lobe (Hanten & R. C. Martin, 2000; R. C. Martin & He, 2004; R. C. Martin et al., 1999), specifically, the left inferior and middle frontal gyri (Hamilton, R. C. Martin, & Burton, 2010). In addition, verbal short-term memory has been presumed to be important for various (semantic and phonologically based) linguistic skills, including those pertaining to language comprehension and production, vocabulary acquisition, and long-term learning (Caplan & Waters, 1999; Gathercole, 2006; Gathercole, Hitch, Service, & Martin, 1997; Gupta & MacWhinney, 1997; Gupta & Tisdale, 2009b; Kempler, Teng, Dick, Taussig, & Davis, 1998; R. C. Martin & He, 2004; Miller, Finney, Meador, & Loring, 2010; Monetta & Pell, 2007; Reilly et al., 2012; Saito, Yoshimura, Itakura, & Lambon Ralph, 2003).

R. C. Martin and colleagues (e.g., R. C. Martin & Freedman, 2001; R. C. Martin et al., 1999) have advocated extensively for the distinction between semantic and phonological components/stores (or buffers) in short-term memory, and propose that short-term phonological memory is involved in learning new phonemic information whilst short-term semantic memory is essential for the creation of new lexical-semantic material. These researchers have formalised these ideas within a multiple buffer model of short-term memory (R. C. Martin et al., 1999), which has been supported in various forms by other investigations (e.g., Hanten & R. C., Martin, 2000; R. C. Martin & Freedman, 2001; R. C. Martin & He, 2004).

According to this multiple-component model (illustrated in Figure 1), the short-term store is comprised of a network of semantic, phonological and lexical buffers of activation responsible for retaining temporary representations in memory. There is a semantic buffer critical for holding semantic-lexical material, an input-phonological buffer responsible for remembering phonological information for language perception, and an output-phonological buffer to retain phonological representations for speech production (R. C. Martin et al., 1999). Representations within each of these temporary components are presumed to parallel representations activated in more permanent storage components (or long-term “knowledge structures”) (R. C. Martin et al., 1999).

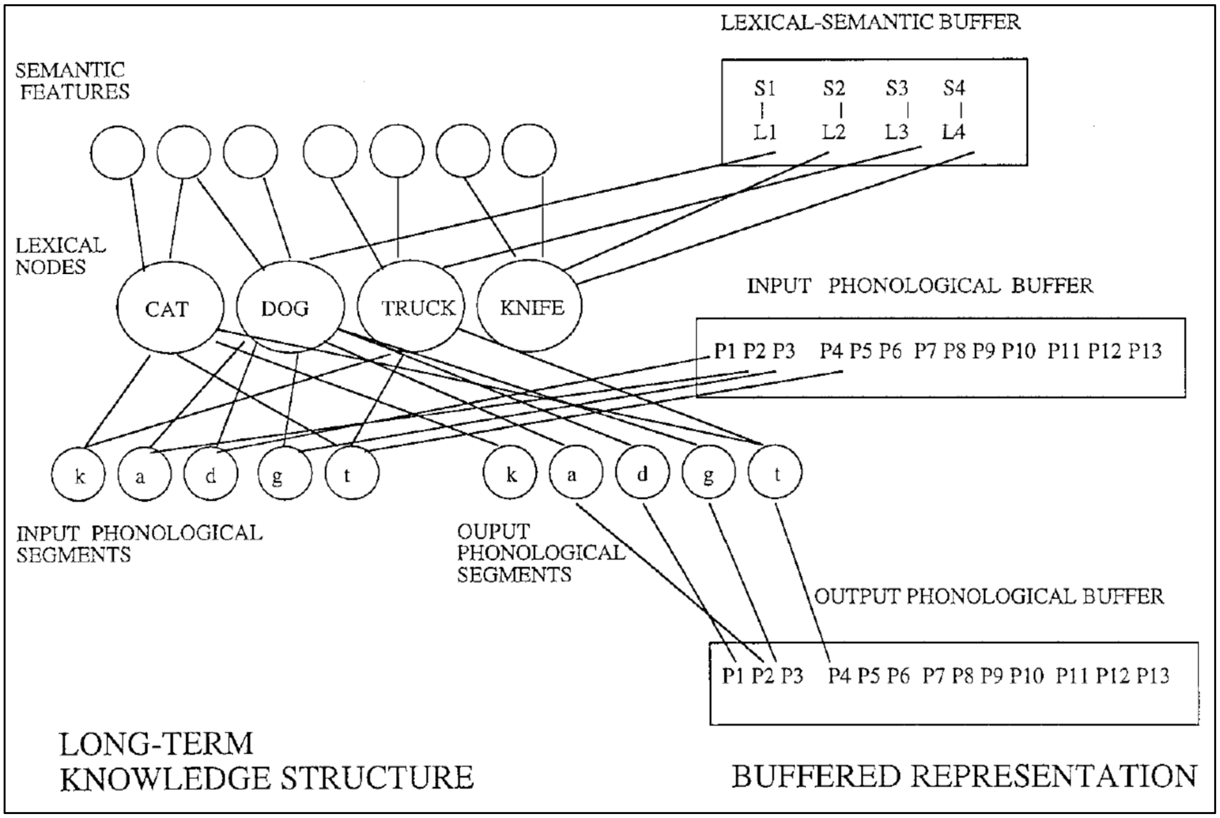

Figure 1. Multiple buffer model of short-term memory. From "Independence of Input and Output Phonology in Word Processing and Short-Term Memory," by R. C. Martin, M. F. Lesch, and M. C. Bartha, 1999, *Journal of Memory and Language, 41,* p. 8.

Another prominent short-term memory psycholinguistic framework has been emphasised by N. Martin and colleagues (e.g., N. Martin, Ayala, & Saffran, 2002; N. Martin & Gupta, 2004; N. Martin & Saffran, 1992, 1997; N. Martin, Saffran, & Dell, 1996; Saffran & N. Martin, 1990). These researchers have described a word processing account of language and serial position based on an interactive activation model of word production (Dell & O'Seagha, 1992; see also Dell, N. Martin, & Schwartz, 2007; Dell, Schwartz, N. Martin, Saffran, & Gagnon, 1997; Foygel & Dell, 2000; Schwartz, Dell, N. Martin, Gahl, & Sobel, 2006). According to this activation framework (depicted in Figure 2), short-term memory is comprised of three types of processing levels (i.e., lexical, semantic and phonological) and during a memory task, temporary activation spreads back and forth between these levels (N. Martin & Gupta, 2004). This activation is thought to occur within nodes located in each processing level and is presumed to assist in preserving item representations in memory until output (N. Martin & Saffran, 1997). The nature of spreading activation means that as additional representations are activated, they are able to feedback (and "refresh") representations that have been previously activated (N. Martin, 2009). Without this spreading activation process, however, representations seemingly decay as soon as they are activated.

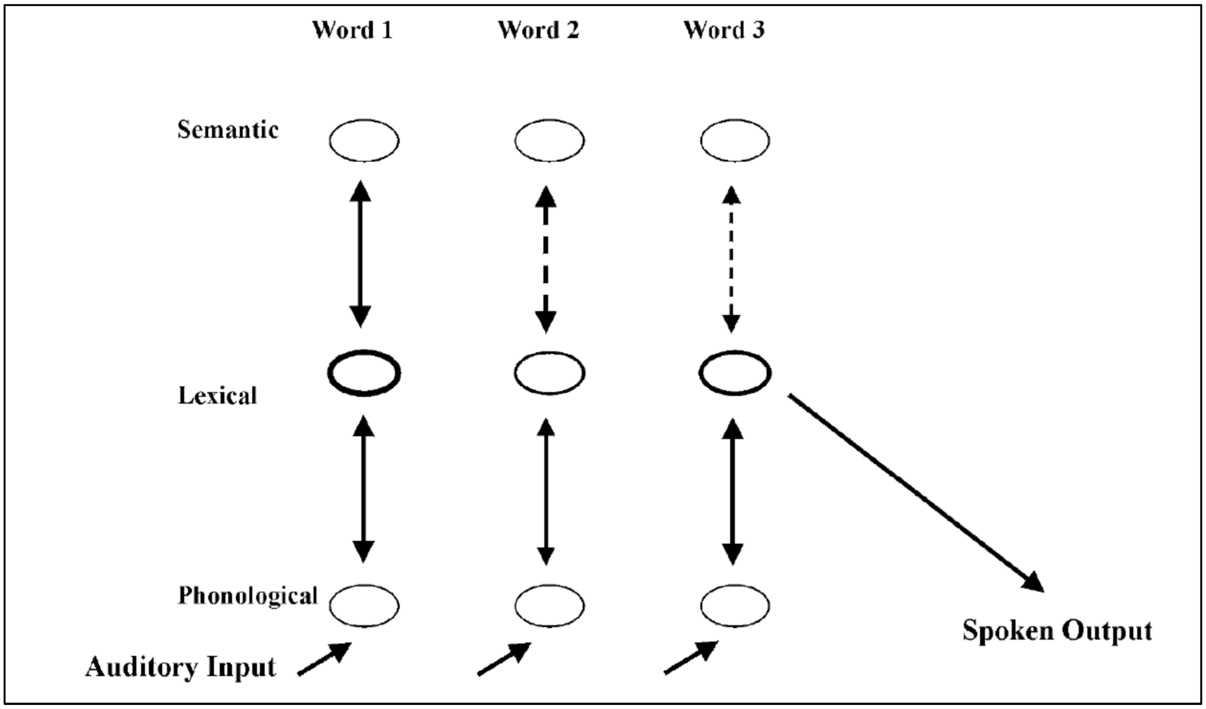

Figure 2. Activation model. From "Exploring the Relationship between Word Processing and Verbal Short-term Memory: Evidence from Associations and Dissociations," by N. Martin and P. Gupta, 2004, *Cognitive Neuropsychology, 21,* p. 221.

Based on this approach, order information is also retained via the activation process. That is, each node (relating to each word in a list) becomes primed during list presentation and this priming in turn leads to the activation of semantic and phonological representations, which help to maintain the item in memory until retrieval (N. Martin & Saffran, 1997). Spreading activation is prescribed to go from phonological to lexical to semantic representations within the network and can accumulate over time through the feedback/feedforward process (N. Martin, 2009). As a result, words presented earlier in the list are activated earlier and thus have a better chance of gaining assistance from these representations (N. Martin & Saffran, 1997). More specifically, words at the beginning of the list have more opportunity for semantic representations to be activated (and strengthened) at recall (N. Martin, 2009). In contrast, words at the end of the list have minimal representations activated at the semantic level but, due to their position in presentation, will have received the most recent activations of phonological representations (N. Martin, 2009). Thus the type and strength of representations associated with an item is dependent on the item's position within the list. In this way, the activated representations are seen to assist in the maintenance of serial order. Multiple levels of representations then serve to support serial recall. Even if one level in the system is damaged, recall can be supported by representations at the other levels (N. Martin & Gupta, 2004).

Although the activation model (N. Martin & Saffran, 1997; N. Martin & Gupta, 2004) shares similarities to the multiple buffer model (R. C. Martin et al., 1999), Romani, McAlpine, and R. C. Martin (2008) highlighted an important distinct between the two approaches. These researchers noted that according to the multiple buffer framework, semantic information in short-term memory was retained in a specific structure (i.e., a semantic buffer). In contrast, based on the activation model (N. Martin & Saffran, 1997) short-term memory was not divided into separate components, rather it was conceptualised as activated representations in the language network. Romani et al. (2008) proposed a revision to the multiple buffer model, which was in line with some of the key assumptions held by the activation model (N. Martin & Saffran, 1997). The updated framework was referred to as a place holder model and the architecture of this model is outlined in Figure 3.

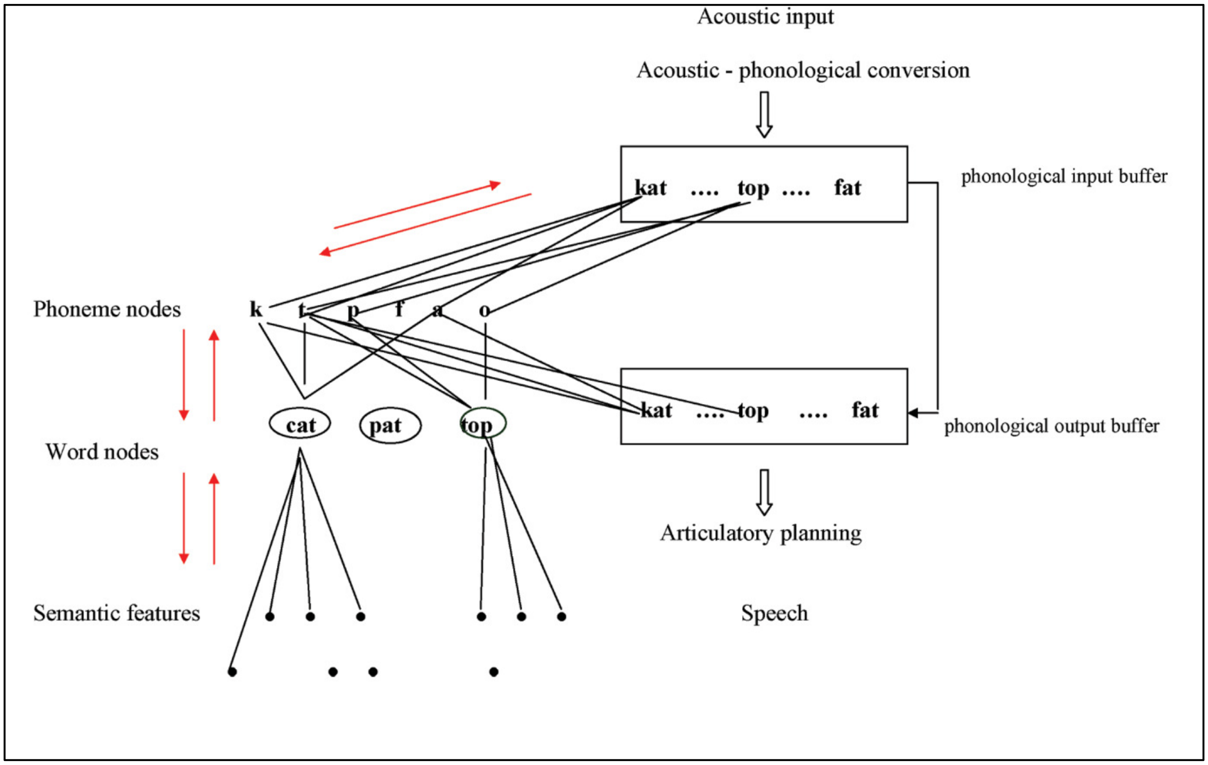

Figure 3. A place holder model of short-term memory. From “Concreteness effects in different tasks: Implications for models of short-term memory,” by C. Romani, S. McApline, and R. C. Martin, 2008, *The Quarterly Journal of Experimental Psychology, 61,* p. 315.

This short-term memory model depicted the semantic buffer not as a distinct structure but rather as temporarily activated representations in lexical-semantic memory. In this way the semantic layer was described as a “virtual” (as opposed to a “structural”) component (Romani et al., 2008). Another important change to the model proposed by Romani et al. (2008) involved the issue of how serial order was upheld by the short-term system. Romani et al. suggested that the representations within the phonological input and output buffers were essential in memory for order, referring to these buffers as “place holders.” It was speculated that these buffers were connected to (and interacted with) semantic and lexical representations. This interaction was depicted as bi-directional, in turn assisting in the maintenance of order (Romani et al., 2008). These propositions were not unlike the conclusions drawn by N. Martin and colleagues (e.g., N. Martin & Gupta, 2004; N. Martin & Saffran, 1997), thus highlighting the trends of psycholinguistic research in explaining serial order effects.

Although the psycholinguistic models presented in this section may differ slightly in their depiction of the memory system, it is clear that they all emphasise the communication between multiple representations in memory. Moreover, each framework stresses the importance in the interaction between these representations as a means to reinforce input and output of information over the short-term. In short, psycholinguistic research highlights the link between semantic, phonological and lexical information and the importance in considering this relationship during immediate serial recall.

2.3.4 The binding of semantic/associative and phonological representations.

The notion that semantic/associative and phonological representations are in some way connected has also been emphasised by another area of research. Like several psycholinguistic models, studies of semantic/associative and phonological binding have presumed that both phonological and semantic/associative representations play an integral role in correct serial recall of words (Knott et al., 1997; Patterson et al., 1994; see also Seidenberg & McClelland, 1989). Knott, Patterson, and Hodges (1997) for instance have described a semantic binding hypothesis in relation to the activation model (N. Martin & Saffran, 1990). This research has proposed that phonological and semantic representations are linked (or bound) together and that this connection serves to stabilise the phonological trace and aid correct serial recall (Knott et al., 1997; Patterson et al., 1994). Jefferies, Frankish, and Lambon Ralph (2006; Jefferies et al., 2008) have established support for the semantic binding hypothesis and have emphasised the role of the binding function in maintaining information in verbal short-term memory.

According to the semantic binding perspective, being able to recall a (known) word during an immediate serial recall task requires knowledge about how the phonemes (or phonological elements) within that word are organised (Patterson et al., 1994). Phonological representations themselves are deemed to be important to this process because speech production and comprehension presumably reinforce output of the correct phoneme combination (Patterson et al., 1994). However, semantic representations are also assumed to be vital to this process because long-term semantic/lexical knowledge is thought to support the arrangement of phonemes within a word (Patterson et al., 1994). While the binding of these different types of representations can assist in recall, the nature of this binding also means that if semantic memory/knowledge is degraded, impaired, or unable to be accessed, an important source of information needed for recalling the word is gone (Patterson et al., 1994).

Support for the semantic binding hypothesis has often arisen through studies of (typically older) patients with semantic dementia (e.g., Patterson et al., 1994; Jefferies et al., 2008). During immediate serial recall these patients stereotypically make phoneme migration errors by incorrectly combining the phonemes of different words together (e.g., *mint, rug* recombined as *rint, mug*) (e.g., Patterson et al., 1994). The source of these migration errors has been linked to impairments in long-term semantic memory, a characteristic of semantic dementia (Jefferies et al., 2004; Jefferies, Jones, Bateman & Lambon-Ralph, 2005; Knott et al., 1997, 2000; Patterson et al., 1994). In turn, deficits in semantic knowledge are thought to impact semantic-phonological binding (Jefferies et al., 2008). A similar pattern of results has also been observed in healthy participants through the employment of unpredictable mixed lists of words and nonwords (Jefferies et al., 2006).

These concepts have underlined an additional criticism of the redintegration approach. Traditionally the model has been described as an item-based account of immediate serial recall (Hulme et al., 1997; Schweickert, 1993). That is, it presumes that the effects of item frequency on recall only influence the relevant item and only occur at the time each individual item is recalled (Hulme, Stuart, Brown, & Morin, 2003). The importance of inter-item associations in short-term immediate serial recall tasks, however, has become increasingly apparent (e.g., Cowan, Baddeley, Elliott, & Norris, 2003; Hulme et al., 2003; Stuart & Hulme, 2000). Hence, the redintegration framework has been criticised for its failure to take into account the impact of whole list composition on performance (e.g., Jefferies et al., 2006; although see Hulme et al., 2003; Stuart & Hulme, 2000 for revisions to the model). Indeed semantic-binding further emphasises the idea that long-term representations are important to short-term memory much earlier than the redintegration hypothesis suggests, supplementing many of the underlying presumptions of current psycholinguistic accounts. The notion that semantic and phonological information are able to bind together to impact serial recall is another key assumption common to both psycholinguistic frameworks and the semantic-binding hypothesis.

2.3.5 The organisation of memory in long-term networks.

Many contemporary short-term memory models also highlight the importance of understanding how long-term memory is arranged in order to appreciate the impact that permanent knowledge can have on short-term recall. Indeed, many current memory frameworks conceptualise the organisation of knowledge within pre-existing, interconnected networks (e.g., Luce & Pisoni, 1998; Nelson, Kitto, Galea, McEvoy, & Bruza, 2013; Oberauer, 2002; Poirier, Dhir, Saint-Aubin, Tehan, & Hampton, 2011; Poirier, Saint-Aubin, Mair, Tehan, & Tolan, 2015; Vitevitch, 2008; Vitevitch, Chan, & Roodenrys, 2012). These accounts assume that the memory/language network is arranged in such a way that concepts that are related on some dimension have stronger associations. In turn, stronger associations between concepts imply that they are more strongly connected and thus more likely to be activated when the original concept is triggered through a process of spreading activation.

Importantly, spreading activation theory is not limited to short-term recall. It has also been discussed in relation to semantic priming (Collins & Loftus, 1975), speech production (Dell, 1986), letter processing (McClelland & Rumelhart, 1981), memory and problem solving (Anderson, 1976), and false memory (Roediger, Balota, & Watson, 2001). Typically, these accounts represent memory/language as a network of interconnected nodes (Collins & Loftus, 1975). According to this view, a node is activated in memory when one is exposed to a particular concept represented by that node. This activation is thought to move (or spread) within the semantic network via connections to other related concepts (Collins & Loftus, 1975) in what is presumed to be a rapid, uncontrollable, and automatic process (Posner &

Snyder, 1975). Other models provide similar accounts of the connection between related words in memory and the notion of shared (or spreading) activation between them (e.g., Coltheart, Curtis, Atkins, & Haller, 1993; Luce & Pisoni, 1998; Marslen-Wilson, 1987; Plaut, McClelland, Seidenberg, & Patterson, 1996).

Luce and Pisoni (1998) described in detail the arrangement of spoken words in memory when developing the neighbourhood activation model (NAM). According to this framework, when a word is presented the representations of other words with a similar acoustic-phonetic (i.e., sound) pattern are also activated in memory. In developing this model, Luce and Pisoni considered the number of words within a neighbourhood, the frequency of words in language, and the phonological similarity between words. Based on this account, speed and accuracy in recognising words were thought to be impacted by both the number and nature of words in a similarity neighbourhood. Several investigations support the notion that verbal short-term memory can be influenced by the size and frequency of the phonological neighbourhood (Roodenrys, 2009; Roodenrys & Hinton, 2002; Roodenrys, Hulme, Lethbridge, Hinton, & Nimmo, 2002). The phonological network is thought to be interconnected, with links demonstrating phonological similarity between words (Vitevitch, 2008; Vitevitch et al., 2012). In particular, any words that can be derived by deleting, adding, or substituting a phoneme from another word may be considered a phonological neighbour of that word (Coltheart, Davelaar, Jonasson, & Besner, 1977; Goldinger, Pisoni, & Logan, 1991; Luce & Pisoni, 1998; Vitevitch, 2008; Vitevitch et al., 2012). Words that share similar features are presumed to be located closer together within the network, increasing the potential for spreading activation to occur between them.

Recently, the arrangement of long-term networks in memory has also been extended to semantic knowledge. Generally, these studies have found that the organisation of semantic (and associative) relationships in memory makes an important contribution to short-term recall (Nelson et al., 2013; Poirier et al., 2011; Poirier et al., 2015). To illustrate, Poirier, Dhir, Saint-Aubin, Tehan, and Hampton (2011) considered the role of both semantic (categorical) relatedness and word associations on immediate serial recall. Whilst these researchers acknowledged that long-term associations between items may limit memory search to an activated network or at least make the items within this network easier to retrieve, this could not solely explain semantic similarity effects. Instead, Poirier et al. suggested that long-term semantic memory was also important for short-term recall. It was proposed that activation of items within a network meant that the memory set was strengthened which, in turn, aided the maintenance of item representations. Taxonomic category was presumed to be an additional cue for the retrieval process when the items needed to be recalled. To summarise, these researchers suggested that both long-term memory associative strength and category similarity played a role in short-term memory.

The proposition that both associative and semantic relationships are important in short-term memory was further emphasised in a recent study by Nelson, Kitto, Galea, McEvoy and Bruza (2013). These researchers discussed the influence of a semantic/associative network on episodic memory in the short-term domain. For the purposes of their investigation, Nelson et al. shortened the name of this network to "semantic," however, it is clear that these researchers proposed that their research applied to both semantic and associative relationships. Indeed, Nelson et al. emphasised that the development of this network was the consequence of meaningful or associatively related connections. These researchers proposed that words existed within semantic neighbourhoods and inter-connected with other related words to form a greater semantic/associative network. These links were presumed to be dynamic and thus could become stronger over time with repetition and experience. Nelson et al. demonstrated, *inter alia,* that the semantic/associative network of a word was primed at encoding, which in turn could aid in its recall. However, this priming could also spread to other words within the network, which could result in confusion and recall error. The semantic/associative network, nonetheless, could provide meaning during the encoding process and guidance to the search process at retrieval. Moreover, Nelson et al. highlighted that neighbourhood density was an important contributor to recall and whether it was helpful to recall depended on the specific task and semantic context. In light of this research and the other investigations presented in this section, it is clear that the arrangement of semantic/associative and phonological concepts in long-term memory and the ways in which these concepts interrelate and communicate within pre-existing networks, makes a significant contribution to episodic recall.

2.3.6 The role of episodic context.

The current chapter has focused on models of immediate serial recall that have emphasised the importance and contribution of semantic memory in verbal short-term memory thus far. In particular, these approaches have highlighted the role of long-term phonological, semantic and lexical knowledge on immediate recall. While earlier reference was made to distinct semantic and episodic components of long-term memory, the use of the word "episodic" has been used as a descriptor of different memory task classes. The main aspect of episodic tasks is that temporal or spatial context are key elements in the memory. For example, in a free association task, participants are provided with a word such as *fruit* and are asked to generate the first fruit that comes to mind. However, in a cued recall task, the same cue might be provided, but the instructions are to recall a fruit that occurred in the most recent list that participants studied. “The most recent list” specifies the context that needs to be examined for the appropriate memory to be retrieved. In relation to the immediate serial recall task, episodic context relates to the items that have just been presented, as opposed to the items on the previous lists, and the order in which the words in a list are presented. Although several psycholinguistic models do acknowledge the need for a component to explain order effects in short-term memory tasks, typically these descriptions lack detail regarding how these processes are undertaken.

Essentially, a number of computational models have been developed to describe immediate serial recall and many of these accounts offer a detailed description of how serial order is represented and maintained in verbal short-term memory (e.g., Botvinick & Plaut, 2006; Brown, Neath, & Chater, 2007; Brown, Preece, & Hulme, 2000; Burgess & Hitch, 1992, 1999, 2006; Farrell & Lewandowsky, 2002; Grossberg & Pearson, 2008; Henson, 1998; Lewandowsky & Farrell, 2008; Page & Norris, 1998; for a review see Hurlstone, Hitch, & Baddeley, 2014). Computational models of immediate serial recall typically provide an explanation of how items in a list are bound or associated to their serial position. Some frameworks have focused on the role of inter-item associative chaining in maintaining serial order (e.g., Lewandowsky & Murdock, 1989). According to this perspective, the recall of each item acts as a prompt for the retrieval of subsequent items in the list (although for criticisms of this view see Brown et al., 2000; Burgess & Hitch, 1999; Henson, 1998; Page & Norris, 1998). More contemporary models, however, focus on the role of positional markers. The underlying premise to this proposition involves the concept of temporary episodic bindings between representations of the item and separate representations pertaining to order, such as list position (e.g., Henson, 1998; Lewandowsky & Farrell, 2008) or temporal context (e.g., Brown et al., 2000). Each item is presumably connected (or associated or bound) both to its list (and items within its list) and to its order within the list. The distinctiveness of these positions or contexts is also emphasised by various models (e.g., Brown et al., 2007; Brown et al., 2000; Henson 1998). The ability to distinguish between positional markers of each item is thought to ensure that items are recalled in their correct order of presentation.

Many of these models also discuss the idea of a primacy gradient in maintaining serial order (e.g., Brown et al., 2000; Burgess & Hitch, 1999; Farrell, 2006; Lewandowsky & Farrell, 2008). According to this notion, recall depends on the quality or strength of an item's representation (or activation) in memory (e.g., Page & Norris, 1998). Presumably, levels of activation (or quality of representations) differ across the list such that items positioned at the beginning of the list have greater activation (stronger representations) than items towards the end of the list (e.g., Brown et al., 2000; Page & Norris, 1998). Importantly, items with the highest level of activation (i.e., the first items in the list) are thought to be recalled first. Many models presume that, following recall, the activation/representation of that item is suppressed or inhibited (e.g., Henson, 1998; Page & Norris, 1998) so that the second item then has the highest level of activation/quality of representation and is consequently recalled. This process is thought to continue along each item in the sequence until recall is either completed or no more items can be retrieved. Taken together, the immediate serial recall models that have been presented in this section imply that serial recall depends on the representations of each item to-be-recalled, the temporary binding of each item to its list position or to the temporal context in which it was presented, and the distinctiveness of the position/temporal context of each item in relation to other items to-be-recalled. This idea has been a common assumption in contemporary short-term memory research. For instance, the role of item and context representations in short-term was recently discussed by Jones and Oberauer (2013) during their investigation of serial position effects. While these researchers did not focus specifically on immediate serial recall tasks, they did discuss relation memory that included the relationship (i.e., the order or position) of items within a list. Jones and Oberauer highlighted that the strength of the individual item activations, the strength of the item-context bindings, and the distinctiveness of those contexts were important to consider in regard to serial position, and this idea was consistent with the research presented in this section.

In comparison to the psycholinguistic frameworks, it is clear that computational models of immediate serial recall provide a more detailed understanding of the representation of serial order in verbal short-term memory. Nonetheless, these approaches are not without their own limitations. It has been suggested that, whilst these models focus on lexical representations in short-term memory, they do not readily address the role of phonological or semantic representations within the short-term system (Hurlstone et al., 2014). This criticism has arisen in light of the growing popularity of the idea that short-term memory is a system comprised of multiple levels of representations. In contrast, psycholinguistic models do emphasise the importance of different types of representations, however these models fail to provide a detailed explanation of many of the key immediate serial recall principles outlined in the computational models such as the ways in which serial order is represented and maintained in the verbal short-term memory system (N. Martin, 2009).

For example, while the activation model (N. Martin & Saffran, 1997; N. Martin & Gupta, 2004) has made attempts to accommodate for serial order via linguistic processes, N.

Martin and Gupta (2004) acknowledge that their framework does not encompass all aspects involved in the encoding of order information. Instead, the processes outlined in the activation model are presumed to work in combination with other mechanisms responsible for maintaining serial order. In particular, N. Martin and Gupta refer to the notion of a “sequence memory” mechanism described within a computational model of immediate serial recall, nonword repetition, and word learning (Gupta, 2003, 2009; Gupta & MacWhinney, 1997). According to the most recent version of this framework (Gupta, 2009), serial ordering in immediate serial recall tasks are encoded, maintained, and retrieved via activations of representations at both a sublexical (i.e., syllable) and lexical (i.e., word) level. This serial ordering (or sequence) mechanism is referred to as a time-varying context signal (Gupta, 2009) similar to the principles of other computational models of immediate serial recall (e.g., Brown et al., 2000; Burgess & Hitch, 1992, 1999; Hartley & Houghton, 1996). Accordingly, this mechanism takes “snapshots” of activated linguistic representations within a sequence at both lexical and sublexical levels. At recall, the sequence (i.e., snapshot) can be reproduced, although there are limits to one’s ability to recompose a sequence based on issues of decay. A more detailed description of this approach is outlined in Gupta (1996; see also Gupta & MacWhinney, 1997).

The point to highlight here is that while N. Martin and Gupta (2004) acknowledge that these processes are important to serial ordering, they do not specifically accommodate for them within their current framework. That is, psycholinguistic models still seem to be somewhat distinct to computational accounts of short-term memory, although attempts have been made to resolve this issue. For instance, Majerus (2009) has endeavoured to provide an account of short-term memory in which both item and order information are accounted for.

This perspective seemingly combines many of the assumptions of other short-term memory frameworks (e.g., Brown et al., 2000; Burgess & Hitch, 1999; Gupta, 2003) with some of the underlying principles of psycholinguistic frameworks (e.g., N. Martin & Saffran, 1992).

According to this approach (Majerus, 2009), phonological (sub-lexical), lexical and semantic nodes encode item information over the short-term through temporary activations. Seemingly, activations within each of these different types of nodes can interact, which help to maintain activated representations, although rehearsal is also required in order to prevent these activations from decay (Majerus, 2009). These ideas are consistent with many of the assumptions of the activation model (e.g., N. Martin & Saffran, 1992). To explain serial order effects, Majerus (2009) presumes that each item that is activated within the system is associated with a different timing signal. More specifically, the nature of the immediate serial recall task means that each item in a list is presented individually, and separated from all other items by time. The connection of a unique timing signal to each item is thus thought to aid in the encoding of memory for serial order (Brown et al., 2000; Burgess & Hitch, 1999). Essentially, item and order information encoding are thought to occur in different systems, although both systems can seemingly influence one another. The system responsible for encoding order information is noted to be akin to depictions within the model by Gupta and MacWhinney (1997) or Burgess and Hitch (1999). Unique to the work of Majerus, however, an attentional control modulator is also included. The role of this modulator is to direct attention to item or order processing, depending on the demands of the task. While Majerus promotes the computational model as a point of reference for future work, the demand for a more detailed investigation into serial order storage in verbal short-term memory is also acknowledged.

2.3.7 Semantic/associative, phonological and episodic binding.

To date, there is limited research that has directly compared the episodic and semantic contribution to immediate serial recall. In particular, the ways in which these different components or representations of memory may interact (or bind) to assist in serial order have not been extensively examined. An investigation by Tehan (2010) examining associative coding and episodic context, however, provides a recent and relevant example. More precisely, Tehan examined the role of associative relatedness in producing false memories (Deese, 1959; Roediger & McDermott, 1995) in verbal short-term memory. This research was based on an update to the embedded components model of working memory by Oberauer (2002) and the notion of associative links in long-term memory (Stuart & Hulme, 2000). The embedded components model (Oberauer, 2002) was founded on the earlier work of Cowan (1995, 1999), Garavan (1998) and Ericsson and Kintsch (1995) in which short-term memory was defined as an activated portion of long-term memory. This framework (depicted in Figure 4) also acknowledged the theory of spreading activation (Collins & Loftus, 1975), and the presence of a long-term semantic/associative network that could communicate via spreading activation.

The embedded components model presumes that there are three states (or regions) of representations in working memory that differ on the basis of their level of accessibility (Oberauer, 2002). These include an activated region of long-term memory, a limited capacity region of direct access, and the focus of attention (Oberauer, 2002). Representations within each of these regions are connected via associative links. The activated region is described as the activated part of long-term memory. Representations in this region can be accessed (indirectly) by the direct access region through spreading activation between the associative links. The direct access region consists of the representations in working memory that are available for the task at hand. This region is thought to contribute to the creation of new temporary episodic bindings between existing representations (Oberauer, 2005a). Importantly, this region has a limit to how many bindings can be maintained simultaneously. In turn, this limit to working memory capacity means that only the most relevant information can be held at any given time. Finally, the focus of attention describes the information that is actively involved in the cognitive task at hand. During recall, this would include the items that have already being selected and are actively being output (Oberauer, 2002).

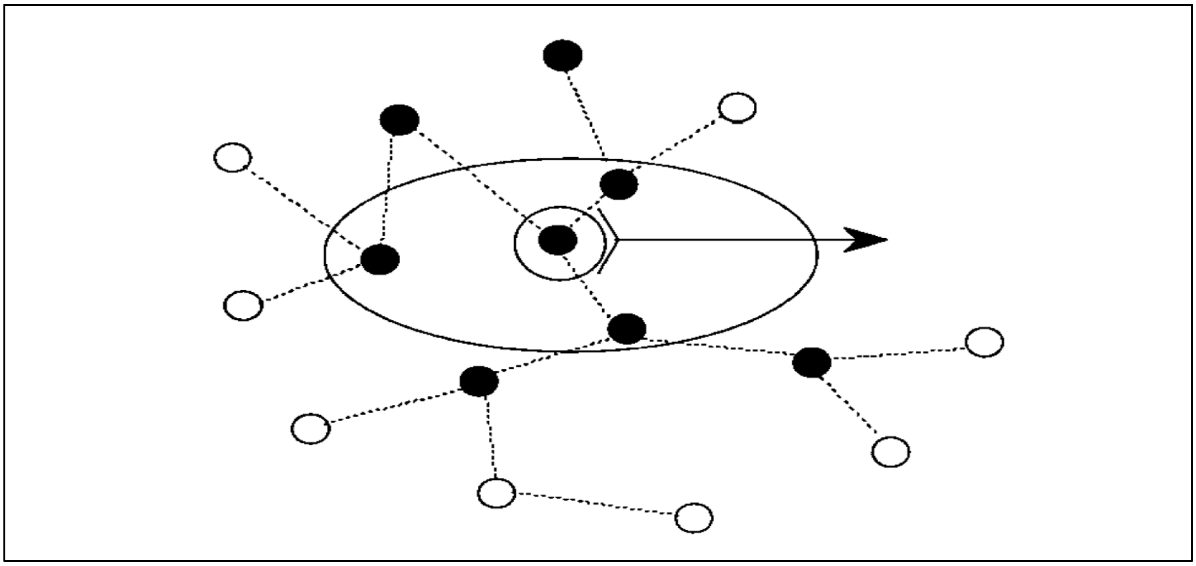

Figure 4. The embedded components model of working memory. Activated (black) and non-activated (white) nodes existing within long-term network. Larger oval represents region of direct access, smaller oval represents focus of attention and dotted lines represent associative links. From “Access to Information in Working Memory: Exploring the Focus of Attention,” by Oberauer, 2002, *Journal of Experimental Psychology, 28,* p. 412.

Based on this approach, for an item to be recalled during a serial recall task it must be brought into the focus of attention, but only items within the direct access region are able to undertake this process. This does not necessarily indicate that activations in long-term memory do not have the ability to influence the current task. Indeed, Oberauer (2002) presumed that when information was no longer relevant it could be quickly removed from the direct access region, but long-term activations would take much longer to subside. Therefore, once representations in long-term memory were activated, they were thought to persist for some time, even when they were irrelevant to the current cognitive task. In turn, this continued activation of long-term representations has been shown to cause intrusion errors at recall.

Although this framework was not initially intended to examine serial recall or the concept of associative similarity effects, Tehan (2010) was able to adapt the embedded components model to test such predictions. Tehan employed serial recall tasks containing associatively related and associatively unrelated lists. Associatively related lists were comprised of the six words most strongly associated to a never presented critical word (i.e., referred to as a critical lure) in accordance with word association norms (Nelson et al., 1998). In contrast, associatively unrelated lists contained six words that were not related to a common lure or to each other. Tehan predicted that spreading activation should ensure that associatively related lists received higher levels of activation than associatively unrelated lists, and thus related lists would be recalled in position more often than unrelated lists. It was also anticipated that this activation would spread to other related items within the network and thus raise the potential for related but non-presented words (particularly the critical lure) to be recalled by mistake. Moreover, it was presumed that the likelihood of other items interfering during the task would be greatest during conditions in which the most amount of episodic information had degraded or been lost, that is, during recall of items towards the end of the list.

In line with expectations, Tehan (2010) established that during immediate recall, lists containing associatively related words were better recalled than associatively unrelated lists and nearly half (45%) of the participants recalled at least one critical lure. Also consistent with predictions, lures were often recalled in later serial positions. Based on these findings, Tehan concluded that a breakdown in episodic context led to false (associative) memories, highlighting the impact of associative and episodic binding in verbal short-term memory. That is, when associative (item) information and episodic (item-context) information work together, correct recall is more likely because one is able to use both sources of information to recall an item from the list. When episodic information has broken down and only item information is available, the potential for false (lure) recall increases. However, this was the first study to consider the specific ways in which semantic and episodic representations could connect and contribute to immediate serial recall. Thus there were no existing immediate computational frameworks that could readily account for the false memory effects observed by Tehan. Evidently, further exploration into the area of false memory and immediate serial recall would be advantageous to this field of research.

2.4 Chapter Summary

It is clear that immediate serial recall requires semantic/associative, phonological, lexical, and episodic information to be successful, although the ways in which these different forms of knowledge interact has yet to be adequately conceptualised within one comprehensive, overarching framework. Whilst some propose a link between linguistic processing and order information in short-term memory (e.g., Leclercq & Majerus, 2010; Majerus, Poncelet, Greffe et al., 2006; Majerus, Poncelet, Elsen et al., 2006; Majerus, Poncelet, Van der Linden, & Weekes, 2008; Martin-Perez, Majerus, & Poncelet, 2012), limits to current language models in accounting for a mechanism of serial order have been acknowledged (e.g., Jefferies et al., 2008; Majerus, 2009; N. Martin, 2009). Conversely, computational models of immediate serial recall have yet to fully describe the concept of a short-term system comprised of multiple representations (Hurlstone et al., 2014). Tehan (2010) reported evidence that associative information and episodic context could bind together and both facilitate and hinder immediate serial recall, providing some convergence on the role of semantic and episodic memory on verbal short-term memory. The aim of the current project was to build on this line of inquiry by considering the binding of episodic, semantic/associative, *and* phonological information in short-term recall. The purpose of the next chapter in this thesis was to provide an overview of the associative and phonological false memory effect in order to form a basis for the current research project.

Chapter Three: Manipulating Semantic Memory: The False Memory Effect

3.1 Chapter Outline

The objective of this chapter was to outline the false memory effect and the influence of associative and phonological relationships on long-term memory. The major experimental and theoretical frameworks of false memory in the long-term domain are discussed. In addition, the chapter provides an examination of the false memory procedure in short-term memory to form the foundation for its use in the current thesis.

3.2 False Memory and the Deese-Roediger-McDermott Paradigm

The human memory system is not infallible. This is a key assumption held by all current computational models of memory. The study of memory errors has made major contributions to the understanding of the memory system. Many attribute Bartlett's War of Ghost experiment (1932) to the first notable exploration of memory distortion. This study has been considered a well-known demonstration of the memory system's vulnerability. In this classic study Bartlett asked West-European participants to read and remember a short Native American folk story. Over time, participants were instructed to repeatedly recall the passage from memory. Interestingly, with repetitions much of the story was forgotten or modified to align with the participants' cultural expectations. The memory distortions observed in Bartlett's research appeared to demonstrate the constructive nature of memory. From this investigation it became apparent that memories were the summation of multiple information sources, reflective of the actual event plus an individual's knowledge, beliefs and experiences. Consequently, memories are rarely (if ever) a perfect replication of an event. Information sources can be misattributed (e.g., Jacoby, Kelley, Brown, & Jasechko, 1989; Marsh, Cook, &

Hicks, 2006) and memories can be misled or susceptible to suggestion (e.g., Loftus, Miller, & Burns, 1978; Loftus & Palmer, 1974).

The implications of such distortions have been far reaching and interest has often been focused on eyewitness testimonies (e.g., Loftus et al., 1978; McCloskey & Zaragoza, 1985; Ross, Ceci, Dunning, & Toglia, 1994; Wells & Bradfield, 1998) and memories “recovered” during therapy (e.g., Hyman, Husband, & Billings, 1995; Lindsay & Read, 1994; Loftus, 1993). These investigations have commonly relied on some form of narrative to induce false memory. Roediger and McDermott (1995), however, posited that even a list-learning methodology could invoke false memories and thus developed the now well-known and readily employed Deese-Roediger-McDermott (DRM) false memory task (Deese, 1959; Roediger & McDermott, 1995). Indeed, over the last two decades, examination of false memory has largely been through the employment of the DRM task under long-term memory conditions.

3.2.1 Semantic/associative false memory.

The popularity of the DRM (Deese, 1959; Roediger & McDermott, 1995) framework has been attributed to the simplicity in its employment which, in turn, is thought to allow greater control, reliability and adaptability across many domains, populations, test designs, and other manipulations (for a review see Gallo, 2010). The creation of the DRM paradigm was motivated by Deese’s (1959) work on intrusions and associative lists. Deese investigated the relationship between frequency of word associations and the likelihood of intrusions in immediate free recall. In this research, lists were comprised of the 12 words most strongly associated to a critical (never presented) word. Deese observed that on some lists the critical word was recalled even though participants were never exposed to the word, referring to this error as an intrusion. Moreover, Deese found that the likelihood of a critical word being recalled as an intrusion depended on its association to the list words. Such conclusions formed the impetus for Roediger and McDermott's work on false memory.

In its traditional form, the DRM task (Deese, 1959; Roediger & McDermott, 1995) involves the presentation of 15-word lists that are related to a never presented critical item or lure. These words are typically the 15 strongest associates (i.e., the words most likely to be produced in response) to each critical lure, as taken from word association norms (e.g., Nelson et al., 1998). For example, *thread, pin, eye, sewing, sharp, point, prick, thimble, haystack, thorn, hurt, injection, syringe, cloth,* and *knitting* are associates of the lure *needle* (Stadler, Roediger, & McDermott, 1999). The extent to which an item is related to a lure is referred to as its backward associative strength (BAS) and has been considered the strongest predictor of false memory within the DRM paradigm (Deese, 1959; McEvoy, Nelson, & Komatsu, 1999; Roediger, Watson, McDermott, & Gallo, 2001). Immediately after a list presentation in the standard DRM task, a free recall task and subsequent recognition task are employed. That is, participants initially recite the presented items in any order without guessing and are then asked to identify the studied items from a list.

When Roediger and McDermott (1995) initially employed the DRM task, critical lures were often falsely recalled and recognised even though they were never presented. Moreover, participants frequently reported high levels of confidence that these lures had appeared in the studied list. False recognition of the critical lures was also close to that of the presented items. In response, Roediger and McDermott proposed that participants appeared to have difficulty in differentiating words that were studied from their critical lures. Since their initial investigation Roediger and McDermott's results have been replicated extensively (e.g., McDermott, 1996; Payne, Elie, Blackwell, & Neuschatz, 1996) and the false memory effect has been reported across the lifespan (e.g., Balota, Cortese, et al., 1999; Sugrue & Hayne, 2006), and even when participants are explicitly forewarned about the effect (e.g., McDermott & Roediger, 1998). Furthermore, participants often report memories of seeing the critical lure in the list as opposed to just guessing (e.g., Mather, Henkel, & Johnson, 1997; Payne et al., 1996). These investigations highlight the robustness of the false memory effect.

One of the most prevailing accounts of semantic/associative false memory is the activation/monitoring theory (AMT) (McDermott & Watson, 2001; Robinson & Roediger, 1997; Roediger, Balota, & Watson, 2001; Roediger & McDermott, 1995, 2000). AMT consists of two processes, aptly named activation and monitoring, both of which are deemed important during encoding and retrieval (Roediger, Watson, et al., 2001). The activation process of AMT in particular has been largely influenced by the theory of spreading activation. According to AMT, when list items are presented in a false recall task (e.g., *bed, snooze, tired*) and participants are required to encode the information for later recall, the representations within the pre-existing semantic/associative network can become activated. This activation can spread both consciously (e.g., McDermott, 1997) or unconsciously (e.g., Seamon, Luo, & Gallo, 1998) to other related concepts (e.g., *sleep*) (Collins & Loftus, 1975; Roediger, Watson, et al., 2001). In the DRM task (Deese, 1959; Roediger & McDermott, 1995), list items are selected based on being the strongest associates to the critical lure, therefore the lure is highly likely to also be activated during this process. At recall, those items with high levels of activation (including the lure) are more likely to be recalled.

The other key process of AMT is monitoring, which has been influenced heavily by source monitoring accounts of memory (Johnson, Hashtroudi, & Lindsay, 1993; Johnson &

Raye, 1981). According to this view, the ability to distinguish among sources of information in a memory task during both encoding and retrieval will impact performance. That is, one must differentiate between the information they are required to remember/recall (i.e., the information or event actually taking place in the task) and thoughts that may have arisen as a result of the task (Roediger, Watson, et al., 2001). In the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) this ability to discriminate between information sources is thought to be particularly difficult. Assuming that the critical lure has received a high level of activation during encoding, it may be challenging to discern the list items from other non-presented but related items at retrieval (Roediger, Watson, et al., 2001) even when one is given warning about the critical lure (Gallo, Roberts, & Seamon, 1997; Gallo, Roediger, & McDermott, 2001; McDermott & Roediger, 1998).

Whilst AMT has been a prominent model in the false memory literature, there are several other frameworks that may also account for the false memory effect. Historically, the other leading theory of false memory that provides an explanation for semantic/associative false memory in the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) is gist theory, described within the fuzzy trace theory (FTT) (Brainerd & Reyna, 1990; Brainerd, Reyna, Wright, & Mojardin, 2003; Reyna & Brainerd, 1995). According to gist theory, there are two types of memory representations or traces that are created during memory task information encoding, namely, gist traces and verbatim traces. Presumably, gist traces form a summary of the information presented while verbatim traces provide more specific representations of the stimuli (Brainerd & Reyna, 1998; Schacter, Verfaellie, & Pradere, 1996). In the DRM task, the information that one remembers is thought to include specific items within the list (i.e., verbatim traces) as well as the essence of the list items, that is, any (semantic/associative) commonalities between items (i.e., gist traces). The gist trace is considered to be strongest for the critical lure rather than for any individual list items (Brainerd & Reyna, 1998), therefore ensuring a high likelihood that it will be remembered (and thus recalled/recognised). Whilst the false memory literature has yet to reach a consensus on an overarching framework as noted by Gallo (2010) in a 15-year review of the DRM illusion, when comparing gist theory to AMT, the underlying processes may not be mutually exclusive.

3.2.2 Phonological false memory.

Irrespective of whether AMT or FFT is used to explain the false memory effect, most false memory investigations have focused on semantic/associative over phonological presentations. This is noteworthy given that early examinations of false memory suggested that phonemic lists were associated with memory errors comparable to (Anisfeld, 1969) or even greater than, the level of errors arising from semantic lists (Cramer & Eagle, 1972). The dominance of semantic/associative false memory may not be that surprising, however, when one considers the history of false memory inquiry and the traditional view of long- versus short-term memory. Previous false memory studies have focused almost exclusively on the effects in a long-term memory paradigm. This has included the DRM framework (Deese, 1959; Roediger & McDermott, 1995), which has been the principal procedure for investigating false memory over recent decades. In its typical form, the DRM task contains long lists of items and may include delays between list presentation and recall/recognition. Long-term memory has been presumed to store information predominately as semantic codes (e.g., Sachs, 1967). In contrast, encoding in short-term memory has been assumed to be largely auditory (e.g., Conrad, 1964) or visual (e.g., Della Sala, Gray, Baddeley, Allamano, &

Wilson, 1999). Given the main focus of false memory has been in the long-term domain, it is not unexpected that a large number of studies have concentrated on such distortions in semantic information.

Sommers and Lewis (1999), however, noted that several processes proposed to account for semantic/associative false memory (e.g., Collins & Loftus, 1975) appeared to be similar to the processes underlying models of spoken word recognition. These models provided similar accounts of the relationship between words in memory and the notion of shared (or spreading) activation between words (e.g., Coltheart, Curtis, Atkins, & Haller, 1993; Luce & Pisoni, 1998; Marslen-Wilson, 1987; Plaut, McClelland, Seidenberg, & Patterson, 1996). In turn, Sommers and Lewis investigated phonologically related lists within a DRM framework (Deese, 1959; Roediger & McDermott, 1995) under the assumption that phonological similarity should act in much the same way as associative relatedness. These researchers based their investigation on the neighbourhood activation model (NAM) by Luce and Pisoni (1998) as well as other studies that supported the notion of phonological false memory (e.g., Schacter, Verfaellie, & Anes, 1997; Wallace, Stewart, Sherman, & Mellor, 1995). Sommers and Lewis predicted that the presentation of lists that were phonologically similar (i.e., differed by only one phoneme) to a critical lure would enhance the spreading activation to that critical item. In line with predictions, phonological similarity was found to enhance both true recall and false recall. Consequently, Sommers and Lewis proposed that regardless of whether lists were associatively related or phonologically similar to a critical lure, the effects of false memory were governed by similar underlying processes.

Of course, not all studies concur with the assumptions made by Sommers and Lewis (1999). There is some contention around whether the underlying process of false memory in phonological lists is analogous to those in associative lists (e.g., Ballardini, Yamashita, & Wallace, 2008; Ballou & Sommers, 2008; McDermott & Watson, 2001; Tse et al., 2011; Watson, Balota, & Roediger, 2003). Nonetheless, there does appear to be a general consensus that the false memory effect can extend to lists that are phonologically related to a critical lure in the DRM paradigm (e.g., McDermott & Watson, 2001; Tse et al., 2011; Westbury, Buchanan, & Brown, 2001).

For instance, Westbury, Buchanan and Brown (2001) investigated phonological false memory using the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) in an effort to understand the organisation of the phonological network. In particular, these researchers aimed to determine if there was a specific part of a word that was most important to the phonological false memory effect. In Experiment 1, there were four different list types that participants had to study: a HEAD condition in which list items shared the first and second phonemes with the critical lure; an IP condition in which list items shared the first phoneme with the lure; a RIME condition in which list items shared the last two phonemes with the lure; and an UNRELATED condition in which list items had no phonemes in common with the lure. In this experiment, significantly more false memories were produced during the HEAD ($p < .001$), IP ($p < .005$), and RIME ($p < .005$) conditions when compared to the unrelated condition. Significantly more false memories were also produced during the HEAD condition as opposed to the IP ($p < .005$) or RIME ($p < .005$) condition (these conditions did not significantly differ from one another). In Experiment 2, when HEADS and RIMES were combined on the same list, the magnitude of false memories produced had increased further (when compared to Experiment 1). Westbury et al. suggested that by creating a phonological conjunction (i.e., by combining HEADS and RIMES on the same list), information about the critical lure could converge, leading to greater false memory. In short, these researchers concluded that the extent of phonological overlap between list items and the lure impacted false memory and provided support for the notion of a phonological neighbourhood.

3.2.3 Hybrid lists: Associative and phonological false memory.

Phonological false memory has also been explored through the employment of hybrid lists. In false memory studies, hybrid lists are comprised of words that are associatively related (e.g., *ill*) as well as words that are phonologically similar (e.g., *sit*) to a common critical lure (e.g., *sick*). For instance, Watson, Balota and Sergent-Marshall (2001) investigated false memory using hybrid lists. The impact of healthy ageing and dementia of the Alzheimer's Type (DAT) on the false memory effect was also investigated. A mixture of younger and older adults were included in the study. The older adults' health status ranged from healthy, to very mild DAT, to mild DAT. The study contained lists that converged on a critical lure via semantic association, or phonological association, or both. Lists comprised of only semantic or phonological associates were referred to as pure lists while those that contained a mixture of association types were defined as hybrid lists. Hybrid lists were interleaved such that associate list order was either semantic-phonological-semantic-phonological and so on, or phonological-semantic-phonological-semantic and so forth. Using these lists, list type was found to significantly impact veridical and false recall. Irrespective of age or disorder, veridical recall was significantly greater ($p < .001$) for pure semantic lists compared to pure phonological lists or hybrid lists. For false recall, a different pattern of results emerged. False recall was significantly greater ($p < .001$) for hybrid lists than for pure semantic lists and pure phonological lists. Based on these results, Watson et al. (2001)

concluded that the hybrid lists had “superadditive” effects on false memory and other studies have supported this presumption (e.g., Watson et al., 2003).

Some researchers have proposed that the superadditive effects of hybrid lists are due to an interaction between the long-term semantic/associative and phonological networks (Roediger, Balota, & Watson, 2001; Watson et al., 2003). Based on the interaction activation model of speech production (Dell & O’Seaghda, 1992; Dell et al., 1997), it has been suggested that the convergence of phonological and semantic activation representations in memory push activations over some type of threshold necessary for them to be recalled (Watson et al., 2001, 2003). Consistent with this notion, Rubin and Wallace (1989) used a word generation task to demonstrate that there was an enhanced likelihood of generating the desired word if a cue was related to that word both phonologically and semantically, as opposed to conditions in which the cue was only associated to the to-be-generated word on one dimension (i.e., semantically or phonologically). Related to this idea, as an extension to AMT, Roediger, Balota, and Watson (2001) suggested that when lists were only related on one dimension (i.e., semantic *or* phonemic), the processes that follow may lead to many items (including the critical lure) being activated. However, when lists were similar on two independent (yet interacting) dimensions (i.e., both semantic *and* phonemic), the number of items that will be activated by subsequent processes was narrowed, increasing the likelihood of falsely recalling the critical item.

An important point to highlight is that while hybrid lists often exhibit superadditive effects on false memory, they do not appear to consistently influence veridical memory. For instance, Watson et al. (2001) observed that correct recall was significantly lower on hybrid lists when compared to pure semantic lists, but comparable to performance on pure phonological lists. Watson, Balota and Roediger (2003) also looked at the effect of hybrid lists on the false memory effect using a similar methodology to Watson et al. (2001). While hybrid lists had an increased susceptibility to false memories, veridical recall remained somewhat stable across list type. Likewise, Budson, Sullivan, Daffner and Schacter (2003) examined the role of semantic, phonological and hybrid lists on true and false recognition, and failed to find an effect of list type on true memory. Together, these results highlight that in the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995), list type manipulation is more likely to influence false memory as opposed to true memory. This observation may not be that remarkable though given that the nature of the DRM task is to create lists that induce the false memory effect. The DRM methodology involve the selection of items based on their connection to a non-presented critical lure as opposed to any relationship they may have with other items in the list. Consequently, the finding that the items within the list were more likely to impact false as opposed to true memory arguably provides support for using the DRM task for the specific purpose of inducing memory intrusions.

3.3 False Memory in the Short-term Domain

It is important to note that while false memory has been subjected to numerous investigations, most of these studies have not considered the effect in short-term recall. Several recent investigations, however, suggest that false memories do extend to short-term (and working) memory tasks (e.g., Atkins & Reuter-Lorenz, 2008, 2011; Coane, McBride, Raulerson, & Jordan, 2007; Flegal, Atkins, & Reuter-Lorenz, 2010; MacDuffie, Atkins, Flegal, Clark, & Reuter-Lorenz, 2012; Tehan, 2010; Tehan, Humphreys, Tolan, & Pitcher, 2004).

Tehan, Humphreys, Tolan and Pitcher (2004) for instance, examined the influence of pre-existing semantic networks on episodic information in short-term memory. One aim of this study was to consider the creation of false memories in a short-term cued recall task. Forty taxonomic categories were chosen from a norm database and within each category one word was chosen as the ‘target’ word which might or might not then appear in the list. The label of each category was used as a çue in the study. Words that were phonologically similar to each target item were also generated and filler items that were unrelated to the target words or cues were also created. This process resulted in the creation of four list types: (1) lists that contained filler items and a target word; (2) lists that contained filler items and a word that was phonologically similar to the target word; (3) lists that contained filler items and both a target word and a phonologically similar word; and (4) control lists of filler items that did not contain a target word or a phonologically similar word. Under cued recall conditions, participants were instructed to remember lists of four to eight words. After list presentation, participants were provided with a cue (i.e., the category label) and instructed to recall a list word from that category. Participants were subsequently asked to recall the entire list in serial order. This procedure was employed across five experiments, with slight modifications in stimuli and task conditions within each experiment.

In the study, Tehan et al. (2004) reported evidence of false memories. More specifically, during cued recall participants recalled the target word at times even when it was never presented in the list. Moreover, participants were significantly more likely to falsely recall the non-presented target word when the lists contained the phonologically similar item as opposed to during the control lists in which no phonologically similar word was present. However, when the target word was contained within the list, participants were more likely to correctly recall it if a phonologically similar word was also included. Tehan et al. proposed that the presentation of a phonologically similar word activated a contextual cue, prompting episodic memory for the list. Exposure to the phonologically similar word was also presumed to activate some of the features common to the target word (regardless of whether it was actually presented in the list). In addition, presentation of the category label was deemed to act as an experimental cue, eliciting a pre-existing semantic/associative network. In turn, these researchers proposed that the combination of semantic information (of the cue) and episodic information (pertaining to the list), could assist in recall but could also result in the creation of false memories. These conclusions are in some ways similar to those that involve the semantic binding hypothesis (e.g., Jefferies et al., 2006; Jefferies et al., 2008). That is, the combination of phonemic and categorical/associative information may assist in supporting short-term recall.

False memories have also been observed using short-term recognitions tasks. Coane, McBride, Raulerson, and Jordan (2007) for example looked at false memory in the short-term domain by employing an immediate recognition task containing DRM (Deese, 1959; Roediger & McDermott, 1995) lists of three, five, and seven associates. In comparison to other non-presented items (i.e., weak associates or unrelated items), critical lures were more likely to be falsely recognised and slower to be rejected as incorrect. Accordingly, Coane et al. concluded that false memories could be produced over a relatively short time period and thus be observed in short-term memory tasks. Likewise, Atkins and Reuter-Lorenz (2008) investigated false memory in a short-term recognition task, although a free recall task was also included in their study. Across four experiments, participants were required to learn 4-item lists of semantically related words. Items on each list were associates of a common critical lure. Following a 3-4 second filled or unfilled delay, participants performed either a recognition task or a free recall task. During the recognition task, participants were presented with a probe word and asked to decide whether that probe had appeared on the original list. During the free recall task, no probe word was presented. Instead, participants were required to freely recall the list aloud in any order. False memory was evident across both tasks, and during both filled and unfilled retention periods. Critical lures were falsely recognised and also more likely to be falsely recalled than other unrelated items. Atkins and Reuter-Lorenz suggested that such findings supported the idea of an overlap between short- and long-term memory processes. Indeed these researchers proposed that false memory research might provide the means to continue to investigate short- and long-term memory connections.

Flegal, Atkins, and Reuter-Lorenz (2010) employed a similar recognition task to that of Atkins and Reuter-Lorenz (2008) in order to measure false memory within a short-term framework. The study also included a surprise recognition task 20 minutes after list presentation in order to test long-term memory. Confidence ratings (Experiment 1) and a Remember/Know judgement task (Experiment 2) were also included. In Experiment 1, when participants reported that an item had appeared in a list they were subsequently asked to rate how confident they were with that decision. In Experiment 2, participants were requested to signify if they had: (a) remembered that the word had been in the list; (b) recognised the word but were unable to specifically recall details of studying it during the task; or (c) just guessed. Flegal et al. found that during both short- and long-term memory tasks, levels of confidence ratings, false recognition errors and remember/know decisions were comparable. Furthermore, items were confidently falsely recalled and remembered across both tasks. In short, false memory did not appear to be limited to the long-term domain.

More recently, MacDuffie, Atkins, Flegal, Clark, and Reuter-Lorenz (2012) considered false memory across both short- and long-term memory paradigms. Using DRM lists (Deese, 1959; Roediger & McDermott, 1995) that were semantically associated to a non-presented critical lure, healthy older adults were compared to adults diagnosed with mild-to-moderate Alzheimer's disease. The study included both a short- and long-term memory free recall task. In the short-term memory task, lists were comprised of four items presented simultaneously and participants were required to read the items aloud. Following list presentation, there was a 3-4 second filled retention interval after which participants were prompted to freely recall the list. In the long-term memory task, lists included 12 words, with each word presented individually. Participants were asked to read the items aloud as they appeared. Immediately following list presentation, participants were instructed to freely recall the list. In both tasks, incorrect responses were classified as either semantic intrusions, phonological intrusions, or other intrusions. Semantic intrusions included the recall of either the critical lure or another word that was semantically related to at least two list words. Phonological intrusions described the recall of a word that rhymed with a list word. Other intrusions referred to the recall of words from other lists, as well as nonwords and unrelated words. Across both participant groups, all three types of intrusions were evident during both short- and long-term memory tasks. With regard to the semantic intrusions, there was no significant difference in these types of errors between groups during either task. These researchers proposed that the underlying processes of semantic intrusions may be apparent over both the short- and long-term.

These conclusions are also supported by neurological research, although to date there appears to be only one study that has examined false memory over the short-term. Atkins and

Reuter-Lorenz (2011) used a DRM framework (Deese, 1959; Roediger & McDermott, 1995) and employed a short-term recognition task comprising 4-word lists that were semantically associated to a non-presented critical lure. A *f*MRI was used to measure the neural mechanisms involved in true and false recognition. After 4-second filled retention intervals, participants were given a probe word and asked to decide whether the probe had appeared in the presented list. The probe was either a list word, a related but non-presented word (i.e., a lure), or an unrelated non-presented word. Using this methodology, Atkins and Reuter-Lorenz successfully demonstrated false memory effects. Participants falsely recognised significantly ($p < .001$) more lures than unrelated words. Neuroimaging was used to examine the neural activity common to both true and false recognition memory. In line with long-term memory research (e.g., Cabeza, 2008; Cabeza, Ciaramelli, Olson, & Moscovitch, 2008; Kompus, Eichele, Hugdahl, & Nyberg, 2011), both true and false recognition was associated with greater activation in the left anterior prefrontal cortex (PFC) and bilateral posterior parietal cortex (PPC). Neuroimaging was also used to explore whether neural activity could distinguish true versus false memory. Unique to true recognition, there was greater activity in the left parahippocampal gyrus (PHG), the left fusiform gyrus, and the right ventrolateral prefrontal cortex (VLPFC). These results were consistent with long-term memory research. For example, greater activation of the left PHG has been reported in true (versus false) long-term memory (e.g., Cabeza, Rao, Wagner, Mayer, & Schacter, 2001), and higher activity levels in the right VLPFC are associated with tasks requiring inhibitory control (e.g., Chikazoe et al., 2009; Chikazoe, Konishi, Asari, Jimura, & Miyashita, 2007; Garavan, Ross, & Stein, 1999). Furthermore, enhanced perceptual processing has been used to differentiate true and false long-term recognition memory (e.g., Slotnick & Schacter, 2004). Based on these results, Atkins and Reuter-Lorenz concluded that the neural mechanisms underlying false memory in short-term memory may overlap those of the long-term domain.

3.4 Current Understandings of False Memory based on Immediate Serial Recall Models

While no current immediate serial recall frameworks were able to describe false memory effects, given that psycholinguistic accounts of verbal short-term memory acknowledge the theory of spreading activation (similar to the underlying principles of AMT; Roediger, Watson, et al., 2001), these models may provide the foundation to understand false memory effects in immediate serial recall. Firstly, however, it is important to reiterate how semantic and phonological memory network arrangements may contribute to the false memory effect over the short-term. As a review, current network models presume that long-term knowledge is arranged on the basis of semantic or phonemic relationships (Luce & Pisoni, 1998; Nelson et al., 2013; Poirier et al., 2011; Poirier et al., 2015; Vitevitch, 2008; Vitevitch et al., 2012). These relationships are described in the form of links that create distinct yet inter-related networks. These networks are envisioned to be dynamic and able to be strengthened with repetition and experience. Encoding words into memory may prime the to-be-recalled information within the network, providing meaning and assistance during retrieval (Nelson et al., 2013). Through the action of spreading activation, the priming of one word may lead to the priming of other related words that exist within the same network. In turn, this may make it difficult to decipher whether a word was activated due to prior exposure or simply because of the spreading nature of network activation. This confusion can lead to memory errors if one incorrectly outputs a related, but non-presented word at recall. From this perspective, words can impact performance without actually appearing in the memory task (Tehan, 2010).

Several psycholinguistic investigations have considered the way in which spreading activation can cause interference, most notably through the recall of intrusions. Indeed a current theme of research by R. C. Martin and colleagues (e.g., Biegler, Crowther, & R. C. Martin, 2008; Hamilton & R. C. Martin, 2005, 2007; R. C. Martin & He, 2004) includes a focus on the relationship between inhibition, attentional control, and intrusions in immediate serial recall. This research generally postulates that previously presented memory traces/activated representations compete with one another and can cause interference during memory tasks. In turn, this has been blamed for difficulties in short-term recall (Hamilton & R. C. Martin, 2007, 2005; R. C. Martin & He, 2004). Presumably, this interference could be due to representations of items on previous lists, other items in the same list, or (through the process of spreading activation) other related but non-presented items. Based on this interpretation, the nature of spreading activation coupled with the arrangement of pre-existing associative and phonological memory can lead to errors at recall, most notably in the form of intrusions of related concepts, indicative of a false memory effect over the short-term. Importantly, these suggestions are purely speculative as this psycholinguistic account has never been formally tested in the context of the DRM false memory effect.

Other psycholinguistic accounts have emphasised the role of decay as opposed to interference in short-term memory. Based on the activation framework (N. Martin, 2009; N. Martin, Ayala, & Saffran, 2002; N. Martin & Gupta, 2004; N. Martin & Saffran, 1997), activated semantic and phonological representations of words are strengthened over time through a feedback/feedforward process. In particular, activation is thought to spread (and be processed) in the order of phonological to lexical to semantic representations. Moreover, it is at the semantic level that activated representations can accumulate in strength. Critically, however, if these activated representations decay too quickly, they are presumably unable to make use of this process. This framework highlights the importance of spreading activation both for the comprehension (i.e., semantics) and production (i.e., phonology) of language. Difficulties in maintaining activation are likely to impact a range of memory and linguistic processes. Importantly, this model assumes that the spreading activation process is also important in maintaining serial order. Consequently, if information decays too rapidly, not only will items in a list be forgotten, but the order in which they are to be recalled will also be impaired and this is predominantly due to deficits in the process of spreading activation.

Some psycholinguistic accounts have focused on neurological (ageing) samples during their investigations on intrusions and individual differences (e.g., Hamilton & R. C. Martin, 2005, 2007; R. C. Martin & Lesch, 1996). Patients with semantic short-term memory impairments have been found to be vulnerable to making intrusion errors in immediate serial recall tasks by recalling items from previous lists (R. C. Martin & Lesch, 1996). These individuals have also been shown to be susceptible to proactive interference, particularly when that interference is semantically or phonologically related to the to-be-remembered information (Hamilton & R. C. Martin, 2007). This liability for proactive interference has been linked to impairments in short-term memory control processes and/or difficulty in inhibition (Hamilton & R. C. Martin, 2007). Hamilton and R. C. Martin (2005) have also discussed the role of inhibition in the ability to suppress irrelevant information and R. C. Martin and He (2004) have found that deficits in semantic short-term memory are linked to problems in inhibition in short-term memory tasks. The impact of immediate serial recall interference on healthy participants, however, requires further consideration in the context of these models.

While the assumptions thus far have concentrated on how contemporary immediate serial recall accounts may explain associative *or* phonological false memories, the focus has yet to be on interpreting superadditive effects of associative *and* phonological lists. While the hybrid lists study has been generally limited to the long-term domain, it appears that similar effects may be witnessed in short-term memory. The semantic binding hypothesis (Jefferies et al., 2006; Jefferies et al., 2008; Knott et al., 1997; Patterson et al., 1994) dictates that semantic and phonological information are bound together during serial recall tasks. Moreover, while psycholinguistic accounts have advocated for a dissociation between phonological and semantic representations in memory (e.g., N. Martin & Saffran, 1997; R. C. Martin et al., 1999), these models stress that activations of an item's representation can spread back and forth between semantic and phonological levels. Indeed, semantic and phonological networks appear to be able to interact with each other. The potential that a non-presented but related word (i.e., a critical lure) would be activated (and activated more strongly) in memory would seemingly be greater if both its semantic and phonology representations/networks were also activated. One could argue that this process could also decrease the likelihood of other items being activated in memory (or at least not activated as strongly) because the inclusion criteria for activation would be narrowed. Indeed, these are general assumptions held by Roediger, Balota et al. (2001) to explain the superadditive effects of hybrid lists on long-term false memories. In short, hybrid lists should increase vulnerability to false memories in the short-term system in much the same way as observed in long-term memory studies.

A final framework to consider that may provide further clarification to false memory effects in the short-term domain is the embedded components model (Cowan, 1995, 1999; Oberauer, 2002), which was described earlier in this thesis and is based on the theory of spreading activation and a long-term network of associations. According to this model, during a short-term memory task, representations of list items are presumed to become activated in the long-term network. In turn, this activation is thought to spread through the network to other related, but non-presented items, which may then assist or interfere with recall. Using the embedded components model as a theoretical framework, Oberauer (2001, 2005a, 2005b) conducted several investigations on the ability to remove information from working memory, within the context of ageing. These studies established age-related differences in the rejection of intrusions. More precisely, this research reported that older adults had trouble discounting irrelevant information (activations) from long-term memory, and this was linked to problems in the binding of content-context representations. Influenced by dual-process accounts of recall and recognition memory (Yonelinas, 2002), Oberauer (2005a) defined familiarity as the matching of items (probes) at recognition to the activations in long-term memory. Conversely, recollection was conceptualised as the comparison of the probes at recognition to the memory representations in the focus of attention (Atkinson, Herrmann, & Wescourt, 1974; Oberauer, 2005a). Oberauer (2005a, 2005b) proposed that older adults had difficulty in discounting intrusions in working memory because of impairments in recollection. Problems in (temporary episodic) content-context bindings were alleged to lead to (false) familiarity with intrusions and, in turn, cause these intrusions to be incorrectly output as a response (Oberauer, 2005b). Based on this view, one’s vulnerability to intrusion errors was related to temporary episodic bindings of the task.

In accordance with the embedded components framework (Oberauer, 2002), the presentation of associatively related lists would presumably activate both these items and (via spreading activation) their associates in long-term memory. At recall this process of spreading activation may mean that irrelevant (but connected) items influence performance, leading to output of the lure. Although this model does not account for a phonological network, similar predictions could be made regarding phonologically related lists. While this section has attempted to explain the false memory effect in the context of short-term memory models, this discussion has remained somewhat hypothetical. Undoubtedly, greater exploration of this topic would provide the opportunity to better accommodate for false memory effects within contemporary accounts of immediate serial recall.

3.5 Chapter Summary

Recent studies clearly demonstrate that the false memory effect is not limited to long-term memory, a finding that extends to both younger and older participants (Flegal et al., 2010; MacDuffie et al., 2012). With the exception of Tehan (2010), however, no published verbal short-term memory studies to date have investigated the false memory effect in relation to immediate serial recall. Moreover, none of the investigations that have been discussed have considered the notion of hybrid lists within the traditional DRM paradigm (Deese, 1959; Roediger & McDermott, 1995). On the basis of the research presented thus far, the intention of the current research project was to use hybrid lists in order to examine the binding of associative and phonological information in immediate serial recall tasks. Likewise, an aim of this thesis was to study the way in which episodic information may bind to the multiple representations within the verbal short-term system. Although Tehan (2010) presumed that a breakdown in episodic binding led to an increase in false memories, support for this proposition was only based on the finding that false lures were typically recalled in later serial positions in the list (when episodic information was at its weakest). Arguably, a more direct manipulation of episodic context would provide the opportunity for a more comprehensive examination of the semantic and episodic binding impacts in immediate serial recall. Therefore, the purpose of the subsequent two chapters was to outline the key variables that will be used in the current research project to manipulate episodic context.

Chapter Four: Manipulating the Episodic Context with Healthy Ageing

4.1 Chapter Outline

The goal of this chapter was to outline how episodic context would be manipulated in this project. In particular, this project investigated immediate serial recall within the context of healthy ageing to influence episodic information and test the notion of an integrative model. Older participants have been employed to test underlying assumptions of short-term memory models including psycholinguistic frameworks (e.g., Hamilton & R. C. Martin, 2007) and the embedded components model of working memory (Oberauer, 2002). The primary aim of this chapter, therefore, was to provide an overview of the effects of ageing on memory performance and a rationale for the inclusion of an ageing sample in this project.

4.2 Ageing effects on Episodic and Semantic Memory

There is a general consensus in memory research that normal ageing is associated with a decline in performance (e.g., see Zacks, Hasher, & Li, 2000 for a review), although the relationship between memory and ageing is complex. It is not as simple as just presuming that advanced age leads to memory failure. Episodic memory in particular has been linked to significant age-related impairments (e.g., Burke & Light, 1981; Craik & Rose, 2012; Kausler, 1994; Moscovitch & Winocur, 1992; Rönnlund, Nyberg, Bäckman, & Nilsson, 2005; Zacks & Hasher, 2006). In contrast, implicit memory (e.g., Light, La Voie, & Kennison, 1995; Winocur, Moscovitch, & Stuss, 1996) and semantic memory (e.g., Burke & Mackay, 1997; Piolino, Lamidey, Desgranes, & Eustache, 2007; Rönnlund et al., 2005; Wingfield & Kahana, 2002; Wingfield, Lindfield, & Kahana, 1998) seem to be related to less senescent changes (although see e.g., Light & Burke, 1993).

Normal ageing is presumed to impact performance on a range of episodic memory measures (Bopp & Verhaeghen 2005; Zacks et al., 2000) including both short-term memory tasks (e.g., Maylor, Vousden, & Brown, 1999) and working memory tasks with short retention intervals (e.g., Salthouse & Babcock, 1991; Salthouse, Babcock, & Shaw, 1991). Moreover, age differences in these tasks have been posited to either directly or indirectly relate to impairments in other cognitive abilities (Bopp & Verhaeghen, 2005). On recall tasks more specifically, results may vary. Some studies have reported age-related differences in performance (e.g., Babcock & Salthouse, 1990) whilst others have observed comparable levels of recall between younger and older adults (e.g., Myerson, Emery, White, & Hale, 2003). Nevertheless, older individuals have shown impairments in memory for order (e.g., Cabeza, Anderson, Houle, Mangels, & Nyberg, 2000; Li et al., 2010), and age-related deficits have been established in short-term/immediate serial recall (e.g., Bopp & Verhaeghen, 2005; Golomb et al., 2008; Neale & Tehan, 2007, Experiment 1; Noack, Lövdén, Schmiedek, & Lindenberger, 2013; Scicluna & Tolan, 2011; Surprenant, Neath, & Brown, 2006).

There are various theoretical perspectives explaining the course of memory performance across the lifespan. Some propose that age-related declines in episodic memory are the result of a general decrease in (or lack of) cognitive resources needed for processing information in a meaningful way (Craik, 1983, 1986), as well as a reduction in executive function (e.g., Bugaiska et al., 2007; Crawford, Bryan, Luszcz, Obonsawin, & Stewart, 2000). Declines in working memory processes (e.g., Park et al., 1996; Salthouse, 1990), controlled attention and inhibition (e.g., Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999), processing speed (e.g., Salthouse, 1996), and sensory/perceptual ability (e.g., Surprenant et al., 2006) have also been suggested to play a role in age-related decreases in episodic memory. Whilst the underlying assumptions of each of these account may diverge, all tend to agree that the relationship between memory and normal ageing is complex and multi-faceted.

A review of the cognitive and neurocognitive implications of ageing by Craik and Rose (2012) provides one way to consolidate current understandings in this field. These researchers suggest that declines in attentional resources (e.g., Anderson, Craik, & Naveh-Benjamin, 1998; Jennings & Jacoby, 1993) and cognitive control lead to decreases in both the speed (e.g., Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1996) and efficiency of processing. This is presumed to make it more difficult for older adults to encode information into memory and thus reduce the number of representations available at retrieval (Craik & Rose, 2012). Consequently, encoding (and retrieval) for older adults is presumed to require more effort/attention and self-initiation, when compared to younger adults (Craik & Rose, 2012).

Neuroimaging and neuropsychological research also supports the notion that older individuals have difficulty with encoding, and that this contributes to age-related declines in episodic memory (for reviews see Craik & Rose, 2012; Grady, 2008). The frontal lobes in particular are considered important for encoding processes (Craik & Rose, 2012; Dannhauser et al., 2008; Shing et al., 2010; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994) and studies have reported age-related reductions in frontal lobe function (e.g., Kalpouzos et al., 2009; Rosen et al., 2002; West, 1996). Moreover, older adults have exhibited changes in the frontal regions while encoding or learning new information (Cabeza et al., 2004; Cabeza et al., 1997; Logan, Sanders, Snyder, Morris, & Buckner, 2002; Stebbins et al., 2002). Reduced activity in the medial temporal lobe (MTL) at both encoding and retrieval has also been reported (Cabeza et al., 2004; Grady, 2008; Gutchess et al., 2005). Within the MTL, impairments in the hippocampal formation have been connected to difficulty encoding item-specific information (Cabeza, 2006) and age-related declines in the ability to recollect (Cabeza et al., 2004; Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006).

Other neurological changes that have been linked to age-related memory decline include reductions in the size of brain structure (Raz et al., 2005; Raz, Rodrigue, Head, Kennedy, & Acker, 2004), decreases in the quality of white matter and thinning of white matter tracts (Giorgio et al., 2010), as well as decreases in dopamine production and receptors (Bäckman, Lindenberger, Li, & Nyberg, 2010; Braver & Barch, 2002; Park & Reuter-Lorenz, 2009). Some neural regions also show an increase in activation with ageing, including the frontal lobes (e.g., Gutchess et al., 2005) and specifically the prefrontal cortex (PFC) (Cabeza et al., 2004; Dennis & Cabeza, 2008; Grady, 2008; Park & Reuter-Lorenz, 2009). This over-recruitment has been described not only as evidence of inefficiency (Grady, 2008), but also as a compensatory mechanism in response to an ageing brain (Craik & Rose, 2012; Dennis & Cabeza, 2008; Grady, 2008). Others have proposed that it may be a process of adaption due to difficulty in the ability to encode episodic information into memory (Friedman & Johnson, 2014). In short, there are a range of neurological changes that appear to coincide with an age-related decline in memory and many of these changes emphasise the role of encoding/retrieval processes on performance.

Some investigations have also reported a link between impairments in content-context bindings/associations and age-related decreases in the capacity, maintenance and performance of short-term and/or working memory (e.g., Fandakova, Sander, Werkle-Bergner, & Shing, 2014). This has included the binding between an item and its position in serial recall tasks (Golomb et al., 2008; Howard & Kahana, 2002; Murdock, 1962). Older adults routinely experience problems in creating connections between different pieces of information and it is presumed that ageing impacts memory for associations to a greater extent than memory for individual items (Naveh-Benjamin, 2000). Difficulty in creating or retrieving associations has been linked to age-related deficits in episodic memory (Chalfonte & Johnson, 1996; Li, Naveh-Benjamin, & Lindenberger, 2005; Naveh-Benjamin, 2000; Naveh-Benjamin, Guez, & Shulman, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003), and has been reported in the short-term domain (e.g., Chen & Naveh-Benjamin, 2012; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; although see Bopp & Verhaeghen, 2009; Brockmole, Parra, Della Sala, & Logie, 2008) and in immediate serial recall tasks (e.g., Naveh-Benjamin, Cowan, Kilb, & Chen, 2007). Some suggest that age-related impairments in associations may be due to difficulties in producing associative links in memory (e.g., MacKay & Burke, 1990). Naveh-Benjamin (2000) referred to this notion as the associative deficit hypothesis and subsequent studies have provided support for this proposition (e.g., Kahana, Howard, Zaromb, & Wingfield, 2002; Naveh-Benjamin, Guez, Kilb & Reedy, 2004; Naveh-Benjamin, Guez, & Shulman, 2004; Naveh-Benjamin, et al., 2003).

Whilst normal ageing is related to a general decline in memory for associations, this decline is particularly apparent for temporal relationships (e.g., Balota, Duchek, & Paullin, 1989; Howard, Kahana, & Wingfield, 2006; Kahana et al., 2002). Indeed, older adults tend to have difficulty in representing, processing, maintaining, and/or updating contextual information in memory (e.g., Braver & Barch, 2002; Braver et al., 2001; Haarmann, Ashling, Davelaar, & Usher, 2005; Spencer & Raz, 1994, 1995) and this is evident in the ability to organise, associate or remember temporal context or temporal order (e.g., Noack et al., 2013). To illustrate, Golomb, Peelle, Addis, Kahana, and Wingfield (2008) investigated temporal and semantic associations in younger and older adults by employing free recall and serial recall tasks. Temporal organisation was defined as the temporal order of items within a list, which meant taking into consideration the other list items (Howard & Kahana, 2002). Semantic organisation was measured as the arrangement of items within a list, based on list items belonging to similar categories. In line with predictions, younger adults performed better than older adults on both recall tasks, although the difference in performance between age groups was greater for serial recall. Moreover, the older adults tended to rely on semantic (as opposed to temporal) associations even during serial recall when such a strategy was deemed to be detrimental to performance. Based on their findings, Golomb et al. described a temporal association deficit in older adults in which it was proposed that older adults had difficulty in the temporal organisation of lists and (perhaps to compensate) relied on semantic associations.

Other investigations have also established that older adults are able to make use of semantic relationships or semantic processing to aid memory performance (e.g., Morcom, Good, Frackowiak, & Rugg, 2003; Troyer, Häfliger, Cadieux, & Craik, 2006). For example, semantic similarity has been found to reduce the extent of age-related impairments in associative memory (e.g., Badham, Estes, & Maylor, 2012; Naveh-Benjamin, 2000, Experiment 4; Naveh-Benjamin et al., 2003, Experiment 2). To explain these results, some propose that the features shared by semantically related items may lead to stronger associative representations or links in memory (MacKay & Burke, 1990). Others suggest that semantic relatedness may aid older adults through the use of strategies for encoding and retrieval (Badham et al., 2012).

More generally, age-related problems with temporal as opposed to semantic associations may be partly explained by the presumption that the latter are pre-existing whilst the former are a product of the task (Wingfield & Kahana, 2002). Indeed, older adults have demonstrated difficulty in creating new or novel associations in a task (e.g., Castel, 2005; 2007; MacKay & Burke, 1990; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2003). These propositions may explain why older adults experience impairments in serial recall. For instance, whilst participants may be familiar with the concepts (items) presented in the list during an immediate serial recall task (e.g., *dog, hat, car, sun*), it is unlikely that they would be familiar with the order of these items prior to list presentation. In this way, the item-position (content-context) bindings/associations could be considered novel to the task and this may explain why older adults have difficulty remembering this information.

Further evidence for this proposal comes from an investigation by Badham, Estes, and Maylor (2012). These researchers found that creating integrative relationships between word pairs, in which two words created a logical expression (e.g., rice-paper), reduced age-related differences in associative memory to a level comparable to that of semantic relatedness. In explaining their findings, Badham et al. suggested that integrative relationships, whilst not derived from pre-existing associations, were in line with general knowledge, making them easier to be encoded/retrieved than unrelated word pairs. Indeed, general knowledge (or crystallised intelligence) is often considered an important predictor of episodic memory across the lifespan, although not presumed to be influenced by age (Craik & Bialystok, 2006). In contrast, control/adaptive processes (or fluid intelligence) have been found to decline with age and are considered a main predictor of performance on episodic memory tasks for older adults (Vanderaspoilden, Adam, Van der Linden, & Morais, 2007).

Related to this argument, it is important to note that whilst research tends to presume that normal ageing impacts episodic memory but spares semantic memory, there are several studies that propose that the effects of ageing are not so straightforward. For instance, Light and Burke (1993) have highlighted that there are circumstances in which older adults show deficits in semantic memory but exhibit no impairment in episodic processes. These researchers propose that a better approach to memory and ageing is to separate memory on the basis of old versus new information, with the former tending to be more preserved than the latter in advanced age.

A review of ageing and language research by Burke and Shaft (2008) also emphasises the complexity in understanding normal ageing effects on semantic memory. These researchers discussed the impact of ageing on linguistic abilities in the context of an interactive activation language model (e.g., Dell et al., 1997). The general assumptions of this framework were that language existed within an interconnected network of representations. These representations (or units) were thought to exist within semantic, lexical and phonological layers; however, these layers were arranged in a hierarchical fashion such that the semantic system was placed above the phonological system. Nonetheless, representations could communicate with each other through the process of priming in both bottom-up and top-down actions. That is, the priming of one unit could cause the priming of other phonologically or semantically related units within the system. Essentially, the speed and efficiency of this priming mechanism was considered critical for language comprehension and production (Burke & Shaft, 2008).

In the review, Burke and Shaft (2008) discussed the effects of ageing on both semantic and phonological processes. With respect to semantic processes, these researchers acknowledged that the semantic system within the language model remained largely unaffected by the ageing process. Consistent with this notion, memory for word meanings (e.g., Verhaeghen, 2003), semantic priming effects (Balota, Watson, Duchek, & Ferraro, 1999; Burke, White, & Diaz, 1987; Faust, Balota, & Multhaup, 2004; Howard, McAndrews, & Lasaga, 1981; Lazzara, Yonelinas, & Ober, 2002; Tree & Hirsh, 2003), language comprehension (Burke & MacKay, 1997) and semantic relatedness effects (e.g., Madden, 1992) are thought to be generally maintained in old age. Semantic information arrangement is also seemingly comparable in younger and older adults (Burke, MacKay, & James, 2000; Light, 1991; Thornton & Light, 2006; Wingfield & Stine-Morrow, 2000 although see Hirsh & Tree, 2001; White & Abrams, 2004). Moreover, older adults can make use of semantic information to reduce age-related differences. For example, fast speech rates may impair the recall of older adults to a greater extent than younger adults (Stine, Wingfield, & Poon, 1986; Tun, Wingfield, Stine, & Mecsas, 1992; Wingfield, Poon, Lombardi, & Lowe, 1985; Wingfield, Tun, Koh, & Rosen, 1999), however, if the information is meaningful (e.g., constructed into a sentence), age differences are reduced (Wingfield, Peele, & Grossman, 2003).

In contrast, phonological processes such as memory for the sounds of words (James & Burke, 2000) and language production (Burke & MacKay, 1997) seem to be largely impaired during normal ageing. Indeed, older adults have also been found to have more difficulty than younger adults in their ability to perceive words from dense phonological neighbourhoods (Sommers 1996; Sommers & Danielson, 1999). Taken together, these findings highlight the complexity in predicting the effects of ageing on semantic memory.

The transmission deficit theory represents one explanation for why ageing seems to impair phonological, more so than semantic, mechanisms. According to this theory, connections between representations within the language system are strengthened when they are activated frequently and recently, but are weakened with age (Burke & MacKay, 1997; Burke & Shaft, 2008). Weaker connections presumably result in less priming between representations (i.e., less communication within the network) and less activation in general within the system (Burke & MacKay, 1997; MacKay & Abrams, 1996; MacKay & Burke, 1990). Essentially, the semantic system is thought to contain more interconnections than the phonological system (i.e., the meaning of a complete sentence is presumed to consist of more connections than a single phoneme) (Burke & Shaft, 2008). That is, it has been suggested that the semantic network may become more dense (i.e., develop more connections) with age and experience (Laver & Burke, 1993, although see Giffard, Desgranges, & Kerrouche, 2003 for an alternative view). The notion that the semantic network is comprised of a denser network has been suggested to account for why semantic processes are less affected by ageing than phonological processes. That is, the semantic network is thought to have more connections available if others are lost/weakened during the ageing process.

The transmission deficit theory has also been posited to explain the enhanced semantic priming effects that are sometimes reported with ageing (Laver & Burke, 1993; Myerson, Ferraro, Hale, & Lima, 1992) and the tendency for older adults to be more prone to distraction by the presentation of semantically related (as opposed to phonologically related) information (Taylor & Burke, 2002). That is, if the semantic networks of older adults involve many interconnections, then presumably the priming of one word will likely lead to the priming of many other connected representations (Taylor & Burke, 2002). Additional support for the transmission deficit theory (Burke & MacKay, 1997) involves the impact of repetition on memory. According to this framework, connections between representations in the language network can be strengthened with repetition/practice (Rastle & Burke, 1996), and research has shown that both younger and older adults can improve their memory performance with repetition (Light & Albertson, 1989; Light & Singh, 1987; Rastle & Burke, 1996).

Critically, the consideration of ageing within an interactive activation model (Dell et al., 1997) provides a direct correlation to many of the principles underpinning the psycholinguistic models of verbal short-term memory discussed earlier in this project (N. Martin & Gupta, 2004; R. C. Martin et al., 199; Romani et al., 2008). The transmission deficit theory's underlying assumptions can also be (hypothetically) applied to these models. That is, assuming that the phonological network/buffer/processing level has fewer connections than the semantic network/buffer/processing level, it could be presumed that ageing would be more likely to impact phonological (as opposed to semantic) processes within the memory/language system. Another interesting point that was raised by the transmission deficit theory pertains to the influence of repetition on performance. According to this framework, connections between representations build up over time through experience and repetition, and this could provide the basis for how other psycholinguistic short-term memory models might explain repetition effects. Although this discussion is purely speculative, it does provide guidance around the predictions of this project. Irrespective of this point, it is clear that ageing has varying effects on memory and language, and it is difficult to propose any absolute rules on specific memory systems or processes that are affected. Instead, the impact that advancing age has on cognitive performance appears to depend on the demands of the task.

4.3 False Memory and Ageing

Interestingly, age-related declines in true (episodic) memory could lead one to predict that older adults would also exhibit reductions in false memory. This idea was highlighted by Sommers and Huff (2003) in a study of false memory and ageing using the DRM paradigm

(Deese, 1959; Roediger & McDermott, 1995). These researchers looked at the impact of healthy ageing and early stage dementia of the Alzheimer's type (DAT) on phonological false recall and recognition. In their investigation, Sommers and Huff pointed out that if false memories arise from list (i.e., episodic) memory, one could presume that a decline in true memory might serve as protection from the false memory effect. In support of this proposition, amnesic patients have shown lower levels of true recall/recognition and are also less vulnerable to false memory (Schacter, Verfaellie, & Pradere, 1996). In contrast to these predictions however, Sommers and Huff established that healthy older adults had an increased vulnerability to phonological false recall and recognition in comparison to younger adults. This finding reflects the patterns reported in the wider false memory literature.

Compared to younger adults, older adults tend to be more vulnerable to suggestions and memory distortions (e.g., Bartlett, Strater, & Hulton, 1991; Dywan & Jacoby, 1990; Koutstaal & Schacter, 1997; Loftus, Levidow, & Duensing, 1993; Norman & Schacter, 1997; Schacter, Koutstaal, & Norman, 1997). In the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995), older participants have been found to recall and recognise more false lures (Balota, Cortese, et al., 1999; Norman & Schacter, 1997; Tun et al., 1998; Watson et al., 2001) and exhibit less true recall/recognition than their younger counterparts (e.g., Balota, Cortese, et al., 1999; Kensinger & Schacter, 1999; Norman & Schacter, 1997; Tun et al., 1998; Watson et al., 2001). Such age-related differences in DRM false memories have been evident in hybrid lists (e.g., Budson, Sullivan, Daffner, & Schacter, 2003; Watson et al., 2001) as well as both purely semantically (e.g., Balota, Cortese, et al., 1999; Budson et al., 2003; Norman & Schacter, 1997; Tun et al., 1998; Watson et al., 2001) and purely phonemically related lists (e.g., Budson, et al., 2003; Watson et al., 2001). Neuroimaging investigations also reinforce age-related differences in the DRM task (e.g., Dennis, Kim, & Cabeza, 2007, 2008; Schmitz, Dehon, & Peigneux, 2013). In particular, impaired frontal lobe function (e.g., Butler, McDaniel, Dornburg, Price, & Roediger, 2004) and decreased cerebral asymmetry (Dennis et al., 2007; Schmitz et al., 2013) have been linked to age-related increases in false memories.

There are several proposals to explain the relationship between ageing and false memory. Some claim that increased false memories in older adults reflects a more general age-related decline in episodic memory (e.g., Lövdén, 2003). For instance, older adults often exhibit deficits in item-specific information encoding (i.e., verbatim material), and some propose that to compensate these individuals may over-rely on more general information about the list (i.e., gist-based details) (Kensinger & Schacter, 1999; Koutstaal & Schacter, 1997; Tun et al., 1998). This over dependence may in turn mean that older adults are more likely to make a mistake (i.e., a false error) during retrieval (Kensinger & Schacter, 1999; Koutstaal & Schacter, 1997; Tun et al., 1998). Other dual-process conceptualisations of ageing and false memory have highlighted the role of recollection and familiarity (e.g., Jacoby, 1991, 1999). These mechanisms feature heavily in dual-process theories of recall and recognition memory (e.g., for a review see Yonelinas, 2002). Research has suggested that age detrimentally impacts recollection while leaving familiarity relatively intact (e.g., Bastin & Van der Linden, 2003; Davidson & Glisky, 2002; Jacoby, 1999; Light, Prull, La Voie, & Healy, 2000; Yonelinas, 2002; Zacks et al., 2000). Neuroimaging studies also support the view that older adults exhibit impaired recollection or item-specific encoding, but also produce additional familiarity or gist-based encoding, and that this may play a role in age-related differences in false memory (e.g., Dennis et al., 2007, 2008).

Alternative explanations have focused on a specific deficit associated with age-related false memories rather than just a general decline in episodic memory. For example, decreased inhibition/attentional control has often been cited as a factor in associate false memory (e.g., Balota, Dolan, & Duchek, 2000; Watson et al., 2001). The basic premise of this argument is that with advancing age, one's capacity to inhibit irrelevant information or restrict attention to only relevant details declines (Hasher & Zacks, 1988; Hasher et al., 1999; Zacks, Radansky, & Hasher, 1996, Experiment 3). Consequently, older adults are presumed to have both relevant (i.e., true) and irrelevant (i.e., false) material available/activated during a memory task, making them more prone to errors.

Other theories have attributed individual differences in the susceptibility to interference from irrelevant information to source monitoring deficits rather than differences in inhibition (e.g., Lilienthal, Rose, Tamez, Myerson, & Hale, 2015). From this perspective, it is not that older adults have more activations during retrieval that leads to a greater number of false memories, but rather it is difficulty in determining the source of these activations (Johnson et al., 1993; Watson et al., 2004). Age-related source monitoring problems extend beyond false memory tasks to source memory more generally and older adults have been shown to have difficulty in differentiating and remembering the source of information across a range of methodologies (e.g., Craik, Morris, Morris, & Loewen, 1990; Henkel, 2008; Johnson et al.,1993; Siedlecki, Salthouse, & Berish, 2005; Simons, Dodson, Bell, & Schacter, 2004; Spencer & Raz, 1994).

It may not be surprising that source monitoring processes are routinely discussed in relation to individual differences in the false memory effect (e.g., Unsworth & Brewer, 2010) given that activation/monitoring theory (AMT; McDermott & Watson, 2001; Robinson &

Roediger, 1997; Roediger, Balota, & Watson, 2001) is grounded in source-monitoring theory (Johnson et al., 1993). According to AMT, both attentional control and self-initiated source monitoring processes are important in reducing the false memory effect (Roediger, Balota, & Watson, 2001). The DRM task (Deese, 1959; Roediger & McDermott, 1995) requires one to distinguish between external activations presented at encoding (i.e., a to-be-remembered item) versus internal activations triggered within associative networks in memory (i.e., a related critical lure). Deficits in controlling the system responsible for monitoring the source of information, therefore, may lead to difficulty in differentiating list items from their critical lures (Balota, Cortese, et al., 1999; Balota et al., 2000; Roediger, Balota, & Watson, 2001; Schacter, Koutstaal, et al., 1997; Watson et al., 2001). Importantly, the mechanisms of monitoring and control are considered separate to the process of (automatic) spreading activation that, according to AMT, contributes to the false memory effect but is not necessarily impacted by age (Roediger, Balota, & Watson, 2001). Taken together, this research suggests that age-related increases in the DRM false memory effect are more likely to be due to problems in source monitoring as opposed to spreading activation.

4.4 Short-Term False Memories and Intrusions in Older Adults

Working memory studies also support the idea that source monitoring mechanisms are important with regard to understanding individual differences in the false memory effect (Gallo, 2010). As highlighted in a review by Gallo (2010), prefrontal regions (Curtis & D'Esposito, 2003) involved in working memory processes are also involved in DRM (Deese, 1959; Roediger & McDermott, 1995) retrieval monitoring. Moreover, working memory has been found to predict age-related false memory (McCabe & Smith, 2002). Several other studies have also established a relationship between working memory and false memory (e.g., Parker, Garry, Engle, Harper, & Clifasefi, 2008; Peters, Jelicic, Verbeek, & Merckelbach, 2007), and source-monitoring problems have been linked to age-related forgetting in verbal working memory tasks (Hedden & Park, 2003).

Despite this connection between working memory and false memory with respect to individual differences, to date there appears to be only one published study that has looked specifically at the DRM false memory effect (Deese, 1959; Roediger & McDermott, 1995) in the short-term domain, in the context of ageing (MacDuffie et al., 2012). MacDuffie et al. (2012) investigated the impact of mild-to-moderate DAT on short- and long-term free recall DRM tasks. False recall was evident across both tasks, although there was no significant difference in the number of critical lures recalled (calculated as proportion of total recall) between healthy older adults and older adults with DAT. Adults with DAT, however, output significantly more nonsemantic intrusions than healthy participants. Unfortunately, no younger participants were included in the study, so it is difficult to draw age-based conclusions from the results. Nevertheless, it does suggest that semantic intrusions are evident in healthy older adults.

Further support for this notion comes from research by Oberauer (2001, 2005a, 2005b). This research was presented earlier in this project during an initial discussion of short-term false memory effects. As a review, these investigations were based on the embedded components framework, and they examined the effects of ageing on the ability to move information in and out of the limited capacity direct-access region of working memory. Interestingly, the ability to remove information from this region was shown to be somewhat comparable between younger and older adults (Oberauer, 2005b). Older participants did however have more difficulty in the rejection of intrusions (presumably from the activated component of working memory). In turn, Oberauer (2005b) concluded that age differences in working memory performance were not owing to older adults having problems in controlling the direct-access region, but rather due to difficulty in controlling (or discounting) lingering activations in long-term memory. Oberauer (2005a) also proposed that age differences in working memory and vulnerability to intrusions were partially due to older adults experiencing difficulties in maintaining and accessing content-context bindings. Such problems were alleged to be the result of a false sense of familiarity with intrusions leading to the incorrect recall of these items (Oberauer, 2005b).

Indeed these presumptions are in line with the research discussed earlier in this chapter that posits a link between impaired episodic bindings and age-related declines in short-term recall (e.g., Fandakova et al., 2014; Golomb et al., 2008). With the exception of Oberauer's research, however, there appears to be no other comparisons of short-term false memories (or intrusions) on younger and older adults. Clearly, there is a need for additional research surrounding the effects of ageing on short-term false memories in order to better understand the processes that make older adults more susceptible to memory distortions and misattributions.

4.5 Chapter Summary

To conclude, the purpose of this thesis was to explore the connections between associative/semantic, phonological and episodic information in short-term memory. Initially, these concepts were to be considered in relation to the general adult population. The proposition for an integrative model nonetheless requires one to consider its extension to other samples. For instance, ageing samples have been used to test the embedded components model assumptions (Oberauer, 2001, 2002, 2005a, 2005b). The psycholinguistic frameworks introduced in the earlier chapters of this thesis (e.g., R. C. Martin et al., 1999) have also been examined in the context of ageing and other related declines in cognition. Therefore, the inclusion of an ageing sample in this project was intended to provide an additional means to explore the role of semantic and episodic memory in short-term recall and contribute to the development of an integrative approach to immediate serial recall.

Across both short- and long-term frameworks, episodic memory routinely declines with age. A range of neurological and behavioural studies provide support for this finding and there are various theoretical viewpoints on the issue. Some accounts highlight specific deficits whilst others promote a more general age-related decline in cognition. Particularly relevant to the current project is the notion that older adults have difficulty with (or weakening in) temporary episodic bindings. Such impairments have been linked to age-related declines in short-term recall (e.g., Golomb et al., 2008) and intrusions in working memory tasks (Oberauer, 2005a). Whilst there is limited research on the ageing process and short-term false memories, long-term false memory studies have emphasised an age-related vulnerability to misattributions and memory distortions.

Chapter Five: Further Manipulations of the Episodic Context: Task Repetition and Rapid Presentation

5.1 Chapter Outline

So far this project has discussed ageing as a means to manipulate the episodic context of the immediate serial recall task. Examining the ageing process in the context of the DRM false memory paradigm (Deese, 1959; Roediger & McDermott, 1995) was expected to contribute to the development of an integrative framework of immediate serial recall. As an additional method to manipulate episodic information, task repetition and rapid presentation rate were chosen. The aim of this chapter was to provide a rationale for this decision. The intention was also to discuss the effects of repetition and presentation rate in both immediate serial recall and false memory.

5.2 Manipulating the Episodic Context in Immediate Serial Recall Tasks

Various computational frameworks of immediate serial recall highlight the notion that item representations within a list are in some way associated (or bound) to their respective serial positions (e.g., Brown et al., 2007; Brown et al., 2000; Burgess & Hitch, 1999; Henson, 1998; Lewandowsky & Farrell, 2008). Based on these accounts, disruptions to item-position bindings (e.g., Henson, 1998; Lewandowsky & Farrell, 2008) or item-temporal context bindings (e.g., Brown et al., 2000) are detrimental to both the representation and maintenance of order memory. In a standard immediate serial recall task, items are presented one at a time, at a rate of one item per second**.** Participants are required to silently read items during presentation and then immediately recall aloud the list in the order of presentation. Participants are usually only given one exposure to each trial. Modification of this episodic task's standard conditions has been shown to impact serial recall performance. This is often discussed in relation to the notion of task difficulty; that is, by increasing the difficulty of the task, memory performance is generally reduced. Indeed, many benchmark effects of short-term/working memory have been based on the context manipulation in which the immediate serial recall task is performed.

5.2.1 Presentation rate.

One way in which an immediate serial recall task can be readily modified is through manipulating the rate at which items are presented. Rapid serial visual presentation (RSVP) denotes the production of visual information at very fast rates (Forster, 1970). Traditionally, RSVP referred to the rapid presentation of sequences of words in a sentence (e.g., Forster, 1970; Potter, Kroll, Yachzel, Carpenter, & Sherman, 1986), however, the effects have also been examined using sequences of letters (e.g., Conrad, Baddeley, & Hull, 1966; Laughery & Pinkus, 1968), pictures (e.g., Potter, 1975, 1976; Potter & Levy, 1969), nonwords (e.g., Potter, Moryadas, Abrams, & Noel, 1993) and unrelated words not presented within a sentence (e.g., Potter, 1982). In recall tasks, RSVP may involve presenting up to 10 items per second and has been found to reduce serial recall (e.g., Coltheart & Langdon, 1998).

The concept of item-temporal or item-positional bindings provides one way to interpret the effects of rapid presentation. For instance, the oscillator-based associative recall (OSCAR) model for serial order by Brown, Preece, and Hulme (2000) describes the importance of the learning context for correct serial recall. The learning context is presumed to be dynamic, constantly changing over time, such that each item within a list becomes associated to the context specific to their moment of presentation (Brown et al., 2000). Presumably, these item-context associations serve to aid serial recall by acting as a prompt at retrieval. More specifically, the reconstruction of the learning context during retrieval is thought to cue recall of the item to which it is bound. Thus the OSCAR model assumes that the learning context of each item is separated by a temporal dimension. Moreover, it suggests that the greater the temporal separation of each list item's learning context, the more distinct and thus more successful that context will be as a recall cue.

Whilst the OSCAR model presumes that timing has an impact on serial recall performance not all studies have reached this consensus (e.g., Lewandowsky, Brown, Wright, & Nimmo, 2006). This research notes that in comparison to free recall tasks, timing effects on serial recall tasks tend to produce only small effects. Nonetheless, based on the OSCAR framework, slower presentation rates help to discriminate between the items within a list because each item is associated with a more distinct learning context (i.e., they are separated by greater periods of time). Conversely, rapid presentation rates reduce this distinction because list items are much closer on a temporal dimension.

These concepts have also been emphasised in the temporal distinctiveness model referred to as the scale-invariant memory, perception and learning (SIMPLE) approach by Brown, Chater and Neath (2007), and presumably other accounts may provide similar predictions. For instance, the primacy model (Page & Norris, 1998) dictates that the preservation of order in immediate serial recall tasks is reliant on the fidelity of list item representations in memory. This model proposes that items at the beginning of a list have the advantage of receiving stronger activations than items towards the end of the list. However, if a list is presented rapidly, it would seem that the earlier list item representations would not have enough time to benefit from greater activation.

A related issue involves the contribution of rehearsal to the effects of presentation (Bhatarah, Ward, Smith, & Hayes, 2009; Conrad & Hille, 1958; Tan & Ward, 2008). Clearly, at faster rates one would have less time to rehearse information in the list when compared to slower presentation rates. Indeed slower rates are thought to lead to enhanced encoding of to-be-recalled information (Laughery & Pinkus, 1968) and thus better recall. Presumably, however, the benefit of slower presentation speeds is also dependent on one's ability to rehearse (Tan & Ward, 2008). Bhatarah, Ward, Smith, and Hayes (2009) discussed the influence of rehearsal on presentation speed in the context of the phonological loop model (e.g., Baddeley, 1986; Burgess & Hitch, 1999; Page & Norris, 1998). According to this framework, rehearsal helps to maintain the memory trace of the to-be-recalled information until output is required, and slower rates generally provide more opportunity for this process to occur. Nevertheless, it is argued that slower presentations may actually lead to greater retention intervals between list presentation and recall if rehearsal is prevented, particularly for the early items in the list (Bhatarah et al., 2009). Under these circumstances, slower presentation rates may be detrimental to immediate serial recall performance. Typically, the opportunity for rehearsal provided by slower presentation rates is thought to override problems in longer retention intervals (Tan & Ward, 2008), although differences between studies involving slower presentation rates (e.g., Conrad & Hille, 1958; Mackworth, 1962; Posner, 1964) have been attributed (at least in part) to issues of rehearsal.

Nonetheless, there appears to be some consensus in the literature that rapid rates are detrimental to memory performance, particularly for order information recall. Interestingly, however, despite this impact, some research suggests that even when items in a sequence are presented at fast rates, individuals may still be able make sense of this information (e.g., Forster, 1970; Laughery & Pinkus, 1968; Potter, 1976; Potter 1984; Potter & Levy, 1969). Some have argued that under these circumstances, items presented at rapid speeds may still be able to activate representations in long-term memory (Potter, 1993). Potter (1993, 1999; Potter et al., 1993; Potter, Chun, Banks, & Muckenhoupt, 1998) for instance suggests that semantic representations in long-term memory may be temporarily activated and reconstructed in order to aid recall of RSVP lists. There is also evidence that phonological coding of information can still take place during RSVP. This is supported by the finding that the phonological similarity effect can persist during rapid presentation (e.g., during speeds of one item per 250 milliseconds) (Coltheart, 1993, 1999; Coltheart & Langdon, 1998; Conrad et al., 1966).

This topic of research thus leads to interesting predictions regarding how rapid rates would impact false memories. Initially, one may presume that rapid presentation would not provide enough time for list items to be activated, let alone for this activation to spread to other related concepts in memory. However, this prediction may not be as straight forward as originally expected, based on the finding that phonological and semantic representations may still be activated and influence short-term memory during rapid speeds. In the standard DRM false memory task (Deese, 1959; Roediger & McDermott, 1995), items are usually presented at one item per one second and increasing the speed of item presentation above the standard rate can impact false memory (e.g., Arndt & Hirshman, 1998; Ballardini, Yamashita, & Wallace, 2008; Buchanan, Brown, & Westbury, 1999; Gallo & Seamon, 2004; McDermott & Watson, 2001; Seamon, Luo, Schlegel, Greene, & Goldberg, 2000; Seamon, Luo, Schwartz, et al., 2002; Seamon, Luo, & Gallo, 1998).

McDermott and Watson (2001) for example, performed an immediate free recall test based on the DRM false memory task procedures (Deese, 1959; Roediger & McDermott, 1995). Lists containing 16 associates were presented at various rates (i.e., one word per 20, 250, 1000, 3000 or 5000 milliseconds). Associates were either semantically or phonologically related to a non-presented critical lure. A between-subjects design was used such that participants were assigned to only one presentation rate condition. McDermott and Watson combined their results with an unpublished study by Roediger, Robinson, and Balota (as cited in McDermott & Watson, 2001) and found that regardless of list type, as presentation speed slowed, true recall improved. For false memory however, a different pattern of results emerged. On the semantically related lists, at the fastest presentation speed (i.e., one word per 20 milliseconds), false recall was relatively low but increased as presentation rate slowed (i.e., one word per 250 milliseconds). As presentation rate continued to slow however (i.e., one word per 1000, 3000, 5000 milliseconds), false recall began to decline. The results for phonologically related lists were somewhat similar, although for these lists false recall was quite high even at the fastest presentation speed (i.e., one word per 20 milliseconds).

In explaining their findings, McDermott and Watson (2001) suggested that at slower rates there was an increasing accumulation and spread of semantic activation as opposed to rapid presentation rates. Under these circumstances, list items were presumed to be given additional study time for encoding. This was thought to explain why true recall improved as presentation rate slowed. The rise in spreading activation as presentation rates slowed, however, was also alleged to increase the likelihood that the critical lures would be activated and falsely remembered. This was postulated to explain the relatively high levels of semantic false recall at the presentation rate of one word per 250 milliseconds. Although false recall was high for the phonological list even at the fastest rate (i.e., one word per 20 milliseconds), McDermott and Watson proposed that this may have been due to a perceptual (as opposed to a memory) illusion. That is, the features of the words within the list may have recombined due to visual persistence or iconic memory (Treisman & Souther, 1986) rather than specifically due to the false memory effect. Irrespective of list type however, at slower rates (i.e., one word per 1000 milliseconds or more), the use of strategies was implied to counteract spreading activation and explain the reduction in false recall at these rates (McDermott & Watson, 2001).

Roediger, Balota, and Watson (2001) provided an argument consistent with the findings of McDermott and Watson (2001). These researchers suggested that at fast presentation rates there was a positive relationship between false recall and study time, while at slow presentation rates there was a negative relationship between false recall and study time. This assumption appears counterintuitive to the theory of spreading activation. If one were to take the spreading activation theory at face value, presumably slower presentations should lead to greater spreading activation and thus a higher potential for lure recall. However, it may be that when items are presented for longer durations, one is able to gain more information relating to each item (Gallo & Roediger, 2002). In accordance with the assumptions of activation/monitoring theory (AMT) this would then aid the monitoring process during retrieval and subsequently increase the potential that one would correctly reject any critical lures (Gallo & Roediger, 2002).

Fuzzy trace theory (FTT) has also been used to explain the effects of presentation rate on false memory observed by McDermott and Watson (2001). For instance, in line with the key principles of FTT, Brainerd and Reyna (2005) suggested that gist traces were able to be created within a very short period of time while verbatim traces were created more slowly. According to this perspective the formation of gist traces at fast rates means that false memories can be produced even when presentation speed is high. Conversely, because no verbatim traces can be stored at these high speeds, true recall is likely to be minimal. As presentation rate slows, however, this theory proposes that item information can be better encoded, leading to verbatim trace formation and an improvement in true memory. Additional semantic information processing means that gist traces are more intact, and therefore false memories also increase. As rate continues to slow, however, there is presumably a threshold at which all semantic information can be processed. In turn, while verbatim traces will continue to be supported, gist traces will not. In this instance, false memory will decline even though true memory will continue to improve.

More recently, Smith and Kimball (2012; Experiment 3) employed an immediate free recall task of 15-item DRM lists (Deese, 1959; Roediger & McDermott, 1995) with six different rates of presentation (i.e., one word per 33, 67, 100, 250, 433 and 600 milliseconds). In contrast to McDermott and Watson (2001), a repeated measures design was used such that participants completed the recall task at every presentation rate. Both AMT and FTT were discussed in relation to this study. In particular, Smith and Kimball noted that AMT and FTT made similar predictions regarding false memory and presentation rate in the immediate recall task. These researchers suggested that both theories implied that false recall should be minimal at fast rates because very few words would be consciously processed. These researchers also posited that both frameworks would predict that during slower presentation rates, true recall should improve. That is, slower speeds were expected to facilitate encoding; whether that was because of AMT’s notion that the ability to distinguish the source of activations was enhanced, or because of FTT’s proposition that the number of intact verbatim traces would increase.

In line with these suggestions, Smith and Kimball (2012; Experiment 3) observed that using a within-subjects design, during immediate free recall, true recall increased as presentation rate slowed. False recall also initially increased as presentation rate slowed, but then declined, consistent with the findings of McDermott and Watson (2001) and their between-groups design. Smith and Kimball defined false recall as being related to the degree to which one could search long-term memory prior to recall. According to this view, slower presentation rates may allow one to encode memory traces to a greater extent and increase activation of these items, improving correct recall. Similar to the suggestions by McDermott and Watson, slower rates were also assumed to allow one more time to search long-term memory, leading to greater activation of related items and increasing false recall. However, as rate slowed further (i.e., beyond one word per 500 milliseconds), the amount of information encoded was assumed to outweigh the increased activation. This was thought to allow participants to better distinguish between the to-be-recalled information and false items, leading to reduced false recall and increased correct recall (Gallo & Roediger, 2002; McDermott & Watson, 2001; Smith & Kimball, 2012). This view is in line with the notions put forth by both AMT and FTT in that factors that enhance the processing of the list's item-specific information (in this case slowing the rate that items are presented) will reduce the potential for false memories to occur (Burns, 2006).

In short, these findings propose that at very rapid rates (e.g., one word per 20 milliseconds), false recall and true recall are low because the task does not allow enough time for the list items to be attended to (and thus activated in memory or for episodic bindings to be formed). If lists are presented at slower rates (e.g., one word per 250 milliseconds), there is enough time for items to be activated in long-term memory, and thus the likelihood that false recall occurs should increase. At more standard presentation rates (e.g., one word per 1000 milliseconds), additional strategies and encoding should aid correct recall. In turn, true recall should improve and false recall should decline. Critically, the studies that have been mentioned thus far have largely examined false memory and presentation rate over the long-term domain (Brainerd & Reyna, 2005; Gallo, 2006; Smith & Kimball, 2012). Although presentation rate has been routinely used in the study of standard immediate serial recall, there are no published studies to date that have considered the impact of false memory and rapid presentation on the immediate serial recall task.

5.2.2 Repetition.

In contrast to the reduction in episodic binding witnessed during rapid presentation, other task manipulations can actually improve immediate serial recall performance. For instance, repetition has been consistently shown to enhance memory (Crowder, 1976), assisting in both accuracy and response speed in memory tasks (Bertelson, 1961, 1963, 1965; Tulving & Schacter, 1990). Arguably, Ebbinghaus (1885/1964) provided the foundation for the scientific enquiry of memory and repetition when he explored the ability to remember nonsense syllables over extended periods of time (i.e., up to 7 days). Ebbinghaus demonstrated that repeating lists of items resulted in better recall than non-repeated lists, and these effects were found to persist for some time after the initial learning period. Moreover, Ebbinghaus observed that it took less time to relearn information than it did to learn information for the first time. In short, this research highlighted the long-lasting effects of repetition on memory performance.

More specific to immediate serial recall literature, Hebb (1961) has provided one of the most pertinent repetition studies. Hebb demonstrated that repeating whole lists in immediate serial recall tasks could enhance recall performance. More precisely, Hebb established that when the third sequence of a list of digits was repeated in a recall task, memory performance for the repeated list improved across trials to a much greater extent than non-repeated lists. This *Hebb repetition effect* has been replicated extensively using a wide range of list stimuli including digits (Cumming, Page, & Norris, 2003; Oberauer & Meyer, 2009; Schwartz & Bryden, 1971), letters (Cunningham, Healy, & Williams, 1984; Page, Cumming, Norris, Hitch, & McNeil, 2006), pictures (Page et al., 2006), words (Majerus, Perez, & Oberauer, 2012; Page et al., 2006), and nonwords (Majerus et al., 2012). Furthermore, the effect has also been found to be resistant to interference (Seger, 1994) and can be observed even when participants are not consciously aware of the repetition (e.g., Hebb, 1961; McKelvie, 1987). Recently, Page, Cumming, Norris, McNeil, and Hitch (2013) demonstrated that the Hebb repetition effect could persevere even months after the original testing session, and even when only every 12th trial was repeated, highlighting the strength of the effect.

Several computational immediate serial recall models have attempted to explain the effects of repetition (for a review see Hurlstone et al., 2014). Some accounts highlight the role of cumulative matching on repetition effects (e.g., Burgess & Hitch, 2006; Page & Norris, 2009) proposing that during a serial recall task, representations of the items in a list are checked in memory against long-term representations. This process is thought to explain the superior recall for repeated items. For instance, Burgess and Hitch (2006) emphasise a cumulative matching process to explain the Hebb effect. These researchers implied that long-term item-context representations are matched to the representations of the current list. The more frequently this process occurs (i.e., the more an item/list is repeated), the stronger these item-context associations become, leading to better recall over time (Burgess & Hitch, 2006). Unlike earlier models (e.g., Burgess & Hitch, 1999), this framework acknowledges that there are multiple context signals involved in list learning. The updated model stresses that item-position associations are important in learning, and the ability to learn the list of items as a whole, is also important to this process (e.g., Hitch, Fastame, & Flude, 2005). Page and Norris (2009) describe a comparable process in an update to their primacy model, emphasising the role of increasing the strength of connections between short and long-term representations with repetition.

The discussion of repetition has focused thus far on the Hebb repetition effect. This is because it has been the predominant method to investigate repetition in immediate serial recall. Moreover, contemporary short-term memory models offer repetition interpretations based on the Hebb effect. It is important to note, however, that the current project will be employing a novel form of repetition. That is, rather than repeating every third sequence of the task as described in the typical Hebb repetition procedure, the current project will examine repetition of the *whole* serial recall task. Using this method, participants will be given a second attempt at the same immediate serial recall task, with the same trials, in the same order. This procedure has been used in the wider false memory literature as a way to investigate the effects of repetition on the false memory effect.

There have been various long-term false memory studies that have examined the effects of repetition. Several of these investigations have demonstrated a reduction (although not an elimination) in false memory with repetition (e.g., Benjamin, 2001; Brainerd, Reyna, & Kneer, 1995; Budson, Daffner, Desikan, & Schacter, 2000; Hall & Kozloff, 1970; Kensinger & Schacter, 1999; McDermott, 1996; Schacter, Verfaellie, Anes, & Racine, 1998; Tussing &

Greene, 1999: Experiment 5; Watson, Bunting, Poole, & Conway, 2005; Watson, McDermott, & Balota, 2004). Generally, studies that observe a decrease in false memory with repetition also tend to report that memory for studied list items improves (e.g., Kensinger & Schacter, 1999; Schacter et al., 1998).

For instance, in the first investigation of repetition effects in the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995), McDermott (1996) presented a false memory recall task comprising three lists of 15 associates. Participants were required to complete the recall task five times. That is, they were given five opportunities to study the lists and five opportunities to recall the lists. Across the study-test repetitions, false recall declined (although was not completely eliminated) while true recall improved. To explain these findings it was proposed that the multiple study opportunities may have allowed participants to review their responses and self-correct (McDermott, 1996), an idea that has been proposed by other researchers (e.g., Dodson, Koutstaal, & Schacter, 2000; Watson et al., 2005).

Critically, not all studies have found a reduction in false memory as a result of repetition. Some studies have reported that repetition does not impact false memory (e.g., Mintzer & Griffiths, 2001; Schacter et al., 1998; Shiffrin, Huber, & Marinelli, 1995; Tussing & Greene, 1997, 1999: Experiments 1 - 4) and others suggest that repetition may actually enhance false memory (Benjamin, 2001; Payne et al., 1996; Underwood, 1965). Payne, Elie, Blackwell, and Neuschatz (1996: Experiment 2 and 3) for example, reported an increase in false recall across repetition. In explaining their findings, Payne et al. compared their methodology to McDermott’s (1996) investigation. In particular, Payne et al. stressed that in their experiment participants were given a list only once and were then asked to complete three recall tests. That is, only the test phase (not the study phase) was repeated. This was in contrast to McDermott's experiment in which participants were administered alternating study and test phases. This argument is consistent with several points raised by McDermott. More specifically, they were cautious in generalising these findings even though McDermott observed a reduction in false memory with repetition, highlighting that if individuals could not make sufficient use of the study trials to update or modify their previous responses, they may continue to make the same errors (i.e., continue to recall the critical lure) across repetitions.

This argument underlines the potentially detrimental effects of repetition. Indeed, whilst repetition may strengthen memory performance, it can also reinforce any errors that are made. Errors may be replicated and even amplified across repetition of lists in serial recall tasks (e.g., Couture, Lafond, & Tremblay, 2008; Lafond, Tremblay, & Parmentier, 2010). For example, Couture, Lafond, and Tremblay (2008) investigated the probability of correct and incorrect responses in relation to the Hebb effect (1961) in serial recall. Across repetitions, Couture et al. observed that when a particular response was made, there was an increased likelihood that the same response would be made again. Perhaps surprisingly, this increased probability was reported for both correct and incorrect responses. Indeed, this research emphasised that across repetitions, responses may be learned and recurringly produced during retrieval, regardless of whether the initial response was actually correct.

In relation to the false memory task, without feedback, a participant may continue to recall the critical lure across repetitions if they believe that they are making the correct response. Such a proposition is supported by DeSoto and Roediger (2013). These researchers looked at the effects of study and test repetition on false memory using lists that contained items from the same semantic categories. Participants were assigned to one of three conditions and were required to either (1) study the list once and then take a recognition test; (2) study the list twice and then take a recognition test; or (3) study the list once, take an immediate recognition test with feedback, study the list again and then take a final recognition test. Five minute distractor tasks were also employed between each study and test phase on all conditions. Importantly, false recall was shown to be lowest for those participants who were given the opportunity to repeat both a study phase and test phase when compared to the other two conditions. These results emphasise the use of feedback in reducing the false memory effect with repetition.

Critically, repetition is not the only variable that can impact false memory. There are various factors that can reduce (although not completely abolish) the occurrence of false memories in long-term memory. For example, presenting lists visually as opposed to aurally (e.g., Cleary & Greene, 2002; Gallo, McDermott, Percer, & Roediger, 2001; Hunt, Smith, & Dunlap, 2011; Kellogg, 2001; Smith & Hunt, 1998) or as pictures rather than words (e.g., Dodson & Schacter, 2002; Hege & Dodson, 2004; Israel & Schacter, 1997) can reduce the false memory effect. Saying words aloud (e.g., Dodson & Schacter, 2001) or generating studied words from audio anagrams (e.g., McCabe & Smith, 2006) can also reduce false memories when compared to hearing words at study. List length (i.e., short vs. long lists of associates) (e.g., Robinson & Roediger, 1997), pleasantness ratings (i.e., rating associates on pleasantness vs. a standard study condition) (e.g., Smith & Hunt, 1998), and even font type (i.e., presenting associates in different fonts vs. the same font) (e.g., Arndt & Reder, 2003) can also decrease the likelihood of false memories. In contrast, providing feedback (e.g., Jou & Forman, 2007), explicit warnings (e.g., Jou & Forman, 2007; McCabe & Smith, 2002;

McDermott & Roediger, 1998) or financial gain (e.g., Jou & Forman, 2007) has been found to weaken the false memory effect.

Several theories have been devised to explain why false memories can be reduced under certain conditions. Most common accounts are based on AMT (Gallo & Roediger, 2002; McDermott & Watson, 2001; Roediger, Watson, et al., 2001) or FTT (Brainerd & Reyna, 1993, 1998; Brainerd, Reyna, & Brandse, 1995). AMT for example suggests that false memory depends on the levels of activation and the semantic processing of associations between list items and the critical lure (Gallo, 2001). Thus, conditions that reduce the processing and activation of associations between list items and the critical lure will presumably lead to less false memories (Gallo, 2010). AMT also highlights the role of monitoring in the occurrence of false memories, suggesting that false memories are the result of misattributing the lure activation source as coming from the presented list (Roediger, Watson, et al., 2001). This model assumes that item-specific list information processing will aid source memory and reduce the likelihood of false memories (McDermott & Watson, 2001; Roediger, Watson, et al., 2001).

In contrast, FTT suggests it is verbatim memory that benefits from the processing of information relating specifically to list items (Brainerd & Reyna, 1993, 1998; Reyna & Brainerd, 1995). This model assumes that factors that increase the reliance on gist memory traces (as opposed to verbatim traces) will enhance false memories. This notion is similar to the proposals of the distinctiveness heuristic hypothesis, a related theory that has traditionally focused on false recognition memory (Dodson & Schacter, 2001; Gallo, Meadow, Johnson, & Foster, 2008; Gallo, Weis, & Schacter, 2004; Israel & Schacter, 1997; Schacter, Cendan, Dodson, & Clifford, 2001; Schacter, Israel, & Racine, 1999). Like FTT, the distinctive heuristic hypothesis assumes that a greater dependence on gist memory will result in more false memories. This framework suggests that one can make use of gist memory at retrieval, if there is minimal access to distinct details about the list items (Israel & Schacter, 1997; Schacter et al., 1999). Conversely, if information relating directly to the list items is able to be processed, then there will be a higher probability that one will be able to distinguish list items from critical lures during retrieval. According to this view, factors that enhance the distinctiveness of the to-be-remembered information should decrease the likelihood of false memories (Gallo, 2010). Similarly, factors that enrich the critical lure's uniqueness will also attenuate the false memory effect. Indeed, using taboo (e.g., Starns, Cook, Hicks, & Marsh, 2006), concrete (e.g., Pérez-Mata, Read, & Diges, 2002) or long words (e.g., Madigan & Neuse, 2004) as critical lures, have been shown to minimise the potential for falsely remembering that item. Essentially, whilst AMT, FTT and the distinctive heuristic framework may diverge in their descriptions, all theories tend to agree that factors that enhance the item-specific information processing of the list items will reduce the potential for false memories (Burns, 2006).

5.3. Ageing, Presentation Rate and Task Repetition

A final point to discuss involves the influence of ageing on the effects of presentation rate and task repetition. Given that these variables formed a major manipulation of episodic context in this project, it was important to consider how they relate to the ageing process and, in particular, how they might impact the serial and false recall of older adults. With respect to presentation rate, slowing the time between the presentations of each word in a list (i.e., increasing the inter-stimulus interval, ISI) during free and serial recall tasks, has been shown to benefit older adults (Golomb et al., 2008). Slowing presentation speed can also affect the performance of older adults in the DRM task (Deese, 1959; Roediger & McDermott, 1995). For instance, McCabe and Smith (2002) examined age-related differences in a DRM recognition task and presented lists at either a slow (one word per 4000 milliseconds) or fast (one word per 2000 milliseconds) rate. Participants were given a warning about the nature of the false memory effect either before study, after study but before test, or not at all. McCabe and Smith found that the slower presentation rate generally aided both age groups in their true memory but only helped the younger participants in false recognition, and only then when these participants were given a warning before study.

Watson, McDermott, and Balota (2004) also considered the impact of presentation rate and warnings on reducing age-related differences in false memory. The impact of repetition was also examined in this study. Younger and older adults were given five study/test trials, and lists were presented at either a slow rate (one word per 2500 milliseconds) or fast rate (one word per 1250 milliseconds). In addition, half of the participants were given warnings about the DRM (Deese, 1959; Roediger & McDermott, 1995) false memory effect before study. Watson et al. found that older adults had lower levels of false recall during the slow versus fast presentation rates. In contrast, the younger adults' false recall did not differ between presentation rates, although the younger group still recalled less lures than the older group during both presentation speeds. Giving older adults more time for source monitoring was presumed to help these participants to reduce their false memories in the DRM task (Watson et al., 2004). These results were in contrast to the findings of McCabe and Smith (2002), however Watson et al. proposed that this was because McCabe and Smith had used different speeds of presentation. More specifically Watson et al. implied that McCabe and

Smith may have used a rate that was not optimal to see any age differences in controlled processing.

Another interesting finding by Watson et al. (2004) involved the impact of repetition. In particular, Watson et al. observed that, irrespective of age group, true memory improved across multiple trials. However, only the younger adults appeared to be able to make use of repetition to decrease false recall. In response, Watson et al. proposed that age-related increases in false memory were due to declines in self-initiated source monitoring. Consistent with AMT, older adults were thought to have difficulty in differentiating between the activations of the lure and the activations of the list, as well as between information that came up during testing versus the material presented at study (Watson et al., 2004). In turn, these participants were presumed to rely on prior recall/recognition (which contained both list items *and* critical lures) as a way to encode words into memory. The results of Watson et al. reflect the patterns observed in the broader false memory literature. Whilst the true memory of older adults has often been shown to improve with repetition (e.g., Henkel, 2007, 2008; Kensinger & Schacter, 1999; Light, Patterson, Chung, & Healy, 2004) (although usually to a lesser extent than younger adults), their false memory has been found to remain stable (e.g., Kensinger & Schacter, 1999) or even increase (e.g., Benjamin, 2001; Jacoby, 1999; Light et al., 2004; Skinner & Fernandes, 2009).

In a discussion of repitition's advantages and disadvantages, Henkel (2008) emphasised the point that while repetition can be helpful in improving recall, it can also be detrimental, causing more source errors or misattributions. Older adults in particular are presumed to experience more of the costs associated with repetition and less of the benefits (Henkel, 2007, 2008). The increased costs have been attributed to age-related problems in binding and susceptibility to source misattributions (Henkel, 2007, 2008; Lyle, Bloise, & Johnson, 2006) while the reduced benefits have been related to age-related decreases in processing speed, lower levels of recall in general, and reductions in strategic retrieval processes (Bluck, Levine, & Laulhere, 1999; Henkel, 2007, 2008; Widner, Otani, & Smith, 2000).

Interestingly, younger adults have been found to exhibit a similar false memory performance to older adults when under time pressure (Benjamin, 2001; Jacoby, 1999) when presented with a second task simultaneously (Jacoby, 1999), under divided attention (Skinner & Fernandes, 2009) or by decreasing their available resources at encoding (Dehon, 2006). For instance, Benjamin (2001) presented younger and older adults with a DRM (recognition) task (Deese, 1959; Roediger & McDermott, 1995) in which words were studied either once or three times. Repetition enhanced false memory for older adults. In contrast, younger adults made less false errors with repeated lists. Under time pressure, however, younger participants exhibited greater false recognition with repetition. Based on these results, Benjamin proposed that list repetition enhanced two conflicting processes, namely; (1) activation/familiarity of the lure and; (2) knowledge of the list items to improve monitoring. Younger (but not older) adults were presumed to be able to exert control over these processes so that they could be used in opposition and thereby aid performance with repetition.

Skinner and Fernandes (2009) extended Benjamin's (2001) study, utilising the same DRM false recognition framework (Deese, 1959; Roediger & McDermott, 1995). Replicating Benjamin's findings, Skinner and Fernandes established that younger adults had lower levels of false memory for lists presented three times versus only once, while in contrast, older adults' false recognition increased with repetition. Under divided attention, however, younger adults had a comparable performance to older adults (i.e., more false memories with repetition). In turn, Skinner and Fernandes suggested that the vulnerability to false memories with repetition experienced by both groups (i.e., older adults and younger adults under divided attention), was associated with a limited number of available attentional resources required for controlled monitoring during encoding.

5.4 Chapter Summary

This chapter has discussed the episodic context manipulation in the immediate serial recall task and how varying temporary episodic bindings can impact short-term recall. Specifically, the focus has been on the effects of rapid presentation and task repetition. The benefits of repetition on correct memory are well established (Hebb, 1961) and generally extend to false memory tasks (e.g., McDermott, 1996). Provided that participants are given the opportunity for feedback between repetitions, false memory is typically reduced over time (DeSoto & Roediger, 2013). Presentation rate has also been shown to influence the performance on false memory tasks. Usually, increasing the presentation rate beyond the standard rate of one word per second will reduce serial recall (e.g., Coltheart & Langdon, 1998) but also increase the likelihood of false memories (e.g., McDermott & Watson, 2001). Furthermore, repetition and presentation rate have been examined almost exclusively in long-term false memory research. Short-term memory research does suggest, however, that manipulating both presentation rate and task repetition has the potential to influence memory performance. The inclusion of these variables in the current research project was intended to test these assumptions. In addition, presentation rate and task repetition have varying effects on the memory performance of older adults which is important to consider when making predictions about this project. In light of the research discussed so far, the next chapter will provide a general rationale and overview to the experiments of this thesis. This will include the general aims of the research and the underlying framework on which the project will be grounded.

Chapter Six: General Rationale and Overview

6.1 Introduction and Rationale

Psycholinguistic accounts represent a category of models that provide leading theories on the structure of verbal short-term memory (e.g., N. Martin & Gupta, 2004; N. Martin & Saffran, 1992; R. C. Martin & Lesch, 1996; R. C. Martin et al., 1999; R. C. Martin & Romani, 1994; Romani et al., 2008). These models acknowledge that memory is comprised of a multitude of representations important for short-term retention/recall and long-term learning (e.g., Freedman & R. C. Martin, 2001; N. Martin, Dell, Saffran, & Schwartz, 1994; N. Martin et al., 1996; R. C. Martin et al., 1999; R. C. Martin et al., 1994; Romani et al., 2008; Saffran & N. Martin, 1990) and continue to provide popular accounts of verbal short-term memory.

The rise in psycholinguistic frameworks has occurred, at least in part, because many computational models of short-term memory have been unable to completely explain how semantic, phonological and lexical representations contribute to performance on immediate serial recall tasks. Psycholinguistic models stress that linguistic factors make an important contribution to both encoding and maintenance of serial order (e.g., N. Martin, Ayala, & Saffran, 2002; N. Martin & Saffran, 1997). The question of how serial order is maintained in short-term memory, however, has been an ongoing issue for these frameworks (N. Martin, 2009). In contrast, computational models of immediate serial recall (e.g., Brown, et al., 2007, Brown et al., 2000; Burgess & Hitch, 1992, 1999, 2006; Farrell & Lewandowsky, 2002; Henson, 1998; Lewandowsky & Farrell, 2008; Page & Norris, 1998, 2009) provide a more comprehensive understanding of how order is represented and maintained in verbal short-term memory. Serial order is often discussed in relation to strength and quality of activated representations in memory. This includes the representations of the to-be-recalled items as well as the representations pertaining to context (i.e., position) in which the items are presented (e.g., Brown et al., 2000; Henson, 1998; Lewandowsky & Farrell, 2008). Indeed, these frameworks provide a more detailed interpretation of the underlying processes involved in preserving serial order. Unlike psycholinguistic accounts, however, most computational models of immediate serial recall do not readily account for the arrangement of multiple representation types in short-term memory (Hurlstone et al., 2014). Taken together, it is clear that additional research is required to provide further understanding regarding how both semantic and episodic memory contribute to verbal short-term memory. The overarching purpose of this project was to investigate the possibility of developing a more comprehensive framework of immediate serial recall. That is, a model that could handle the key assumptions of psycholinguistic frameworks whilst also being able to accommodate the main principles of computational models of short-term memory.

Despite the discrepancies in current models of immediate serial recall, there does appear to be some consensus regarding the organisation of long-term memory. Contemporary views of verbal short-term memory (e.g., Nelson et al., 2013; Poirier et al., 2011; Poirier et al., 2015) highlight the notion that long-term knowledge is arranged within pre-existing interconnected networks. These pre-existing networks are often speculated to impact performance on short-term episodic memory tasks through the process of spreading activation (Collins & Loftus, 1975). According to this notion, activation of one concept in memory can spread via interconnections in the network to other related concepts. The more strongly two concepts are related, the more likely it is that this process will occur. In recall tasks, this can mean that the list item presentation may activate not only representations pertaining to the list, but other related items within the network. During retrieval, these related (but non-presented) items may be falsely recalled if one incorrectly attributes the source of these items to the previously presented list.

Arguably, the clearest demonstration of this potential for confusion can be seen in false memory literature using the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995). This framework involves the presentation of lists of words that are associatively or phonologically related to a common, non-presented critical lure. Studies employing the DRM task report that lures are frequently remembered and recalled despite never being presented in the list (Gallo, 2010). Referred to as the false memory effect, such findings have often been discussed in the context of long-term semantic and phonological networks (Roediger, Watson, et al., 2001). Based on this perspective, it is presumed that the activations of the list spread to related items, most notably to the critical lure, which may lead to false production of the lure at recall (Collins & Loftus, 1975). Indeed the false memory effect has been observed with purely associatively related lists, purely phonologically related lists, and with hybrid lists comprised of both associatively and phonologically related items.

Hybrid lists have commonly be shown to produce greater levels of false memories, when compared to pure list types (Roediger, Balota et al., 2001; Watson et al., 2001; Watson et al., 2003). This superadditive effect has been explained in terms of an interaction between long-term semantic and phonological networks. For instance Watson (et al., 2001; Watson et al., 2003) suggested that the activation of both phonological and semantic representations in hybrid lists increased the overall strength of activations in memory, including the representations of the lure. The higher the activations are, the more likely that those items (including the lure) are recalled. Roediger, Balota, et al. (2001) also proposed that hybrid effects were due to the interaction of phonological and semantic representations. These researchers suggested that the activation of both phonological and semantic networks meant that the criteria for words to be output is narrowed, enhancing the probability that the critical lure is recalled. In short, the investigation of hybrid lists in long-term false memory studies provides evidence that semantic and phonological representations can combine to impact recall. In particular, this convergence appears to have a detrimental impact on performance in that it greatly enhances the potential that false memory errors will be made (e.g., Watson et al., 2001).

Nonetheless, it is important to realise that the binding of semantic and phonological information can also assist memory performance. According to the semantic binding hypothesis, semantic and phonological representations can combine in a way that reduces the potential for errors during serial recall (Jefferies et al., 2006, 2008; Knott et al., 1997; Patterson et al., 1994). Taken together, semantic and phonological binding has the ability to both facilitate and hinder immediate serial recall (Tehan, 2010). This point was emphasised by Tehan (2010) when employing associatively related lists within the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995). Tehan demonstrated that the semantic network could concurrently aid and impede immediate serial recall by way of spreading activation. Associatively related lists were shown to produce both correct and false recall, presumably because these lists received high levels of activation. In addition, lures were typically produced towards the end of the list and Tehan proposed that this was when episodic information was at its weakest, providing evidence of the impact of associative and episodic binding on immediate serial recall. Whilst Tehan’s research has made an important contribution to verbal short-term memory understandings, given that no phonologically related lists or hybrid lists were included in the study, any conclusions drawn are limited to the semantic network.

Critically, contemporary short-term memory research emphasises that one cannot consider semantic/associative or phonological factors in isolation. Leading theories on the structure of verbal short-term memory and language, particularly psycholinguistic approaches and long-term network accounts, highlight that there are multiple representations within the memory system. Even those computational models that are not yet able to readily account for the different types of representations in memory, generally acknowledge this point. Consequently, research that examines *both* associative and phonological representations in immediate serial recall would provide an opportunity to not only investigate the structure of the independent semantic and phonological networks, but also (through the employment of hybrid lists) the chance to explore how the representations within these networks interact (and bind) to influence correct and false recall.

Tehan's (2010) research also highlights the role of episodic context on immediate serial recall, although this was only considered in relation to the position of lure output. Variations to the standard conditions of the recall task can also impact episodic representations. For instance, in verbal short-term memory research, the effects of presentation rate and repetition have often been described in relation to the ability to weaken or strengthen item-context (episodic) bindings. Some presume that reduced serial recall under rapid presentation rate is due to a decline in the distinctiveness of an item binding to its context or position within a list (e.g., Brown et al., 2007; Brown et al., 2000). In contrast, superior serial recall on repeated versus non-repeated lists is seemingly because repetition strengthens these episodic bindings (e.g., Burgess & Hitch, 2006; Page & Norris, 2009).

The study of presentation rate and task repetition has significantly influenced the understanding of immediate serial recall. Repetition effects are considered to be of particular importance in serial order memory (Hurlstone et al., 2014) and various short-term memory models have attempted to accommodate for these effects. Issues around timing and item presentation have also contributed to computational accounts of short-term recall (e.g., Brown et al., 2007; Brown et al., 2000; Page & Norris, 1998). Moreover, the manipulation of presentation rate has informed research on rehearsal (Bhatarah et al., 2009; Conrad & Hille, 1958; Tan & Ward, 2008) which is considered to be a key issue in retaining verbal information over the short-term (e.g., Baddeley, 2000).

Research on presentation rate and task repetition has also contributed to the development of false memory frameworks. For instance, the investigation of presentation rate and false memory by McDermott and Watson (2001) played an integral role in the development of the activation/monitoring framework (AMT). Moreover, the examination of task repetition (e.g., McDermott, 1996) has been used to support the notion of monitoring processes in AMT (Roediger & Watson, 2001). Frameworks grounded on spreading activation theory generally presume that variables that limit associations (and spreading activation) between list items and their critical lures will reduce the false memory effect (Burns, 2006; Gallo, 2010). Rapid presentation rates are thought to limit the opportunity for spreading activation, resulting in minimal levels of both false recall and true recall (e.g., McDermott & Watson, 2001; Smith & Kimball, 2012). As presentation rates slows, however, both true and false recall increase, presumably because more items within the pre-existing network are able to be activated, and in turn this activation is able to spread to related items. Nonetheless, if presentation rates slow further, while true memory continues to improve, false recall starts to decline. It is presumed that at slower rates other strategies are recruited to assist in differentiating between true and false activations in the network, increasing the potential for correct recall (Gallo & Roediger, 2002; McDermott & Watson, 2001; Smith & Kimball, 2012). False memory studies have also found that correct recall is enhanced via repetition (e.g., McDermott, 1996). Spreading activation is presumed to strengthen with repetition so that the likelihood that an activated item is recalled should increase with each re-exposure. This highlights the point that if a critical lure is continually activated, it too may continue to be recalled across repetitions. False memories, however, usually decrease across repeated trials when provided with the opportunity for feedback, although this need not be in the form of explicit feedback by an experimenter. Even re-exposure to the list stimuli may provide participants with the chance to perform checks between the list and their previous responses (McDermott, 1996). In light of this research, the manipulation of task repetition and presentation rate in the current project was expected to assist in exploring the effects of episodic binding and contribute to the understanding of short-term serial (and false) recall.

Reductions in temporary episodic bindings have also been associated with the normal ageing process. Older adults routinely exhibit declines in episodic memory (e.g., Zacks et al., 2000) and some have attributed this to problems producing associations (Naveh-Benjamin, 2000), particularly with regard to temporal relationships (e.g., Golomb et al., 2008). Older adults are also more likely to be susceptible to false memories than younger individuals (e.g., Balota, Cortese, et al., 1999; Norman & Schacter, 1997; Tun et al., 1998; Watson et al., 2001) and this has been deemed the results of impaired memory for item-context bindings (Oberauer, 2001, 2005a, 2005b). While there are a variety of frameworks that have attempted to explain age-related cognitive decline and the increased vulnerability to intrusions, this project focused on the link between content-context bindings/associations and short-term memory deficits in older adults (e.g., Fandakova et al., 2014; Golomb et al., 2008; Oberauer, 2002). The reason for this was that one of the primary objectives of this thesis was to understand the role of episodic binding within the context of immediate serial recall, and the inclusion of older participants was intended to provide a way to manipulate episodic context in the recall task. Moreover, the idea that content-context bindings play a role in age-related intrusions in short-term memory was consistent with the embedded components model (Oberauer, 2002), which forms the basis for many of the assumptions of this project. It is acknowledged, nonetheless, that there may be other ways to explain any age-related results that arise in this project and these will be considered in the general discussion of this thesis.

6.2 General Theoretical Framework of the Thesis

Consistent with the rationale for this study, it was also considered important to acknowledge the general theoretical/computational frameworks that would underlie the experiments' predictions in the project. One of the underlying assumptions of this thesis was that semantic/associative and phonological memory were organised in long-term pre-existing, interconnected networks. The arrangement of these networks was presumed to be able to impact performance on the immediate serial recall task. That is, the representation of items presented in a list could become activated in long-term networks, and activate other related items through the process of spreading activation (Collins & Loftus, 1975). This view was in line with the growing consensus (e.g., Luce & Pisoni, 1998; Nelson et al., 2013; Oberauer, 2002; Poirier et al., 2011; Poirier et al., 2015; Vitevitch, 2008; Vitevitch et al., 2012) that semantic and phonological knowledge is organised in such a way that semantically or phonologically related concepts are linked by associations and communication between these concepts, which contributes to short-term recall. Moreover, in line with current psycholinguistic models (e.g., N. Martin & Gupta, 2004) that emphasise the communication between semantic and phonemic representations in short-term memory, a related assumption of this thesis was that pre-existing semantic/associative and phonological networks were separate but able to interact (i.e., bind together) and influence short-term recall.

Another major presumption underpinning this research project was that immediate serial recall depended on both (1) the strength of pre-existing item (associative/semantic and phonological) representations, and (2) the strength and distinctiveness of temporary (episodic) item-context bindings. Item-context bindings referred to the temporary episodic binding of the list items to their serial position/temporal order, in accordance with many current immediate serial recall computational models (e.g., Brown et al., 2007; Brown et al., 2000). Item representations referred to those concepts within long-term associative/semantic and phonological networks that became activated in memory as a result of the recall task, in line with psycholinguistic accounts of verbal short-term memory that highlight the role of different item representations in memory (e.g., N. Martin & Gupta, 2004; R. C. Martin et al., 1999; Romani et al., 2008). Many of these models also acknowledge that the strength of these representations are important for correct recall and that over time, the to-be-recalled representations dissipate, either due to decay (e.g., N. Martin & Gupta, 2004) or interference (e.g., Romani et al., 2008).

Although no current contemporary models of immediate serial recall are able to readily account for false memory effects in the short-term system, there are some studies that have attempted to explain intrusion errors in the context of short-term frameworks. Some psycholinguistic research (e.g., Biegler et al., 2008; Hamilton & R. C. Martin, 2005, 2007; R.

C. Martin & He, 2004) has emphasised the role of interference in making intrusions during immediate serial recall. This research is largely centred on the principles of the multiple buffer model (R C. Martin et al., 1999) and place holder model (Romani et al., 2008). Based on this view, intrusions are the consequence of failure to inhibit other activated representations in memory that are irrelevant to the task. Failure to inhibit these other representations means that they compete with the list representations, potentially causing errors at recall. Whilst this perspective does not specifically discuss the false memory effect, it is reasoned that a similar argument could be made to explain how false memories are output in short-term recall. Based on this view, one could deduce that related lists activate a common lure that ends up competing/interfering with the list items at recall. Presumably, this would occur for associatively related or phonologically similar lists, although it would be greater for hybrid lists. This is because the general assumptions of this work (e.g., R. C. Martin, 2006) also predict that interactions between the semantic and phonemic levels of short-term memory reinforce the memory trace. If both semantic and phonemic representations of the lure are activated in memory, it would seem likely that this would strengthen connections (and interference), enhancing the potential for (false) recall errors to occur. Similar predictions could be made using the activation model (N. Martin, 2009; N. Martin et al., 2002; N. Martin & Gupta, 2004; N. Martin & Saffran, 1997) although it should be noted that this framework typically emphasises the role of decay (rather than interference) and research based on this model has not examined the role of intrusions to the same extent as R. C. Martin and colleagues.

It may seem appropriate to use psycholinguistic frameworks (e.g., N. Martin & Gupta, 2004; R. C. Martin et al., 1999; Romani et al., 2008) to make other predictions pertaining to the current research. One could simply suggest that any variables that increase false recall (e.g., rapid presentation) are merely increasing interference (or decay) within the network. However, it is difficult to explain in specific detail how rapid presentation would impact spreading activation within the network and the potential for correct (and false) recall. It is also hard to see how these models would explain any benefits of repetition as they do not seem to propose a specific mechanism that could account for repetition effects.

The transmission deficit theory of ageing, which is based on a language network not unlike that of psycholinguistic frameworks (Dell et al., 1997) has proposed that connections within long-term networks become strengthened over time with experience and repetition (Burke & MacKay, 1997; Burke & Shaft, 2008). Stronger connections are proposed to lead to more priming/communication between representations and hence greater activation levels within the network (Burke & MacKay, 1997; MacKay & Abrams, 1996; MacKay & Burke, 1990). From this perspective, task repetition should lead to stronger associative links in long-term knowledge and greater communication within pre-existing networks. Despite these predictions, it is important to note that current psycholinguistic models do not seem to have a specific mechanism within their architecture that can accommodate for repetition (or presentation rate) effects.

In turn, some of these predictions that are difficult to account for by psycholinguistic models may be better explained by the embedded components model (Cowan, 1995, 1999; Oberauer, 2002), which has also been used to describe the role of intrusions in short-term memory. This work is founded on spreading activation theory (Collins & Loftus, 1975) and presumes that short-term memory is at least partially the activated proportion of the long-term system. Thus, there are several parallels between this framework and the general assumptions underlying psycholinguistic accounts (e.g., N. Martin & Gupta, 2004). According to the embedded components model, intrusions (and therefore presumably false errors also) are the consequence of problems in the activated region of short-term memory (Oberauer, 2002). More specifically they are thought to be due to problems in discounting lingering (but irrelevant) activations. This model would seem to expect that through the process of spreading activation, the presentation of associatively related lists would activate the critical lure in memory and, in turn, this could impact performance. The model does not specifically discuss phonological representations, however pure phonological lists could be thought to act in much the same way as the model would describe associative lists.

Research related to the embedded components model has also supposed that one's vulnerability to the irrelevant information in long-term activated memory is dependent on content-context (temporary episodic) task bindings (Oberauer, 2005a). Presumably, impairments in these episodic bindings are thought to increase the potential that one will incorrectly recall an irrelevant item from memory, including the critical lure. This model predicts that under conditions in which item-context bindings are compromised (i.e., during rapid presentation and/or normal ageing) there should be an increased likelihood that false lures will be recalled (when compared to a standard presentation rate). In contrast, circumstances that strengthen these item-context bindings (i.e., with task repetition) should assist in reducing the number of false memories recalled. In some ways then these assumptions align with computation models of immediate serial recall that stress the importance in content-context (episodic) bindings for successful recall (e.g., Brown et al., 2007; Brown et al., 2000).

Indeed this leads into another important assumption of this thesis. That is, only those items actually presented in an immediate serial recall task were expected to benefit from episodic bindings because only these items were associated with a specific serial position (Tehan, 2010). Related items (i.e., critical lures) may be activated internally via spreading activation, but because these items are not presented in a list they are not linked to a specific temporal position/order. Presumably, when temporary episodic bindings of the list items are strong, false recall should be relatively low because one can use this information to distinguish between list items and their critical lures (Tehan, 2010). Conversely, when episodic context is weak, false recall should increase because there is less information to differentiate between the activated items in memory (Tehan, 2010). This point highlights a key underlying supposition of this thesis; temporary episodic bindings were expected to be able to interact with associative/semantic and phonological representations and together, this information would impact serial recall performance.

6.3 General Aims

To summate, the primary aim of this thesis was to investigate the binding of semantic/associative, phonological and episodic representations in immediate serial recall in order to contribute to current models of verbal short-term memory. This was considered an important area of research because, to date, most immediate serial recall frameworks have focused on either explaining the contribution of semantic memory (i.e., associative and phonological representations) or the role of episodic memory (i.e., episodic representations) to short-term recall. Therefore, the intention of this thesis was to provide support for the demand for an immediate serial recall model that was able to adequately integrate these two lines of research. It was not the intention of this project to develop a specific model to resolve the gap in the research. Nonetheless, it was hoped that by exploring the way in which episodic information bound to multiple representations within the verbal short-term system, this project would go some way to understanding the connection.

In order to achieve these aims, the intention of this thesis was to use the DRM false memory paradigm (Deese, 1959; Roediger & McDermott, 1995) in immediate serial recall tasks. In particular, in order to explore the organisation and impact of pre-existing phonological and semantic networks on short-term recall, the phonological similarity and associative relatedness of list items were varied. These manipulations led to four types of lists: associatively related lists; phonologically similar lists; hybrid lists; and unrelated/dissimilar lists. These lists differed with respect to whether they contained words that were associatively related and/or words that were phonologically similar to a common (non-presented) critical lure. Further details about each of these list constructions are outlined in the method section of the subsequent chapter.

To examine the influence of temporary bindings on associative and phonological representations, the episodic context of the task was manipulated. The aim of these manipulations was to investigate how changing the strength and distinctiveness of item-context bindings would impact correct and false immediate serial recall. Presentation rate, task repetition and healthy ageing were used to vary episodic context. More specifically, some of the lists were presented at rapid presentation rates to weaken item-context bindings, whereas the immediate serial recall task was repeated to strengthen the associations between item and context. An additional manipulation of episodic binding was undertaken by examining the influence of healthy ageing on recall performance. Presumably, temporary episodic bindings reduce in strength with age. The inclusion of this population was expected to provide further support for the notion that the interaction of associative, phonological and episodic information contributes to verbal short-term memory, and in turn supporting the demand for a model of immediate serial recall that could adequately accommodate these effects.

Chapter Seven: Experiments 1 and 2

7.1 Experiment 1

7.1.1 Aims.

The aim of Experiment 1 was to explore the binding of semantic/associative, phonological and episodic information and the ways in which this information would impact true and false memory in immediate serial recall tasks. Episodic information was investigated by varying the presentation rate and repetition of the task. Semantic/associative and phonological information was examined via manipulating the associative relatedness and phonological similarity of items in each list to a critical, non-presented lure. Hybrid lists that manipulated *both* associative relatedness and phonological similarity were also included in order to look at the interaction between the semantic/associative and phonological networks.

7.1.2 Predictions.

7.1.2.1 Serial recall. Associative similarity has been shown to aid immediate serial recall (e.g., Tse, 2009; Tse et al., 2011) through the spreading activation of associations within pre-existing semantic/associative networks (Nelson et al., 2013; Poirier et al., 2011; Poirier et al., 2015). Pre-existing phonological networks are also thought to play a role in episodic memory tasks (Luce & Pisoni, 1998; Vitevitch, 2008; Vitevitch et al., 2012) in that phonological similarity has been found to be detrimental to immediate recall (Baddeley, 1966a, 1966b; Conrad, 1964; Conrad & Hull, 1964). It was unclear, however, whether there would be any significant differences in serial recall between the different list types employed in this study. This was because, based on the DRM procedure (Deese, 1959; Roediger & McDermott, 1995), the associates and phonologically related words of this experiment were selected based on their relationship to a critical lure as opposed to being associatively related or phonologically similar to other items in the list. Using a DRM framework, associative lists have been shown to lead to significantly greater levels of veridical recall when compared to phonological lists and hybrid lists (Watson et al., 2001), although other investigations have reported that list type does not influence patterns of veridical recall (Watson et al., 2003).

In regards to episodic context, based on the previous research that found that rapid presentation rate reduced immediate serial recall (e.g., Coltheart & Langdon, 1998), it was expected that serial recall would be significantly greater when items were presented at a standard presentation rate versus a rapid presentation rate. During rapid presentation it was expected that temporary episodic (item-context) bindings would be relatively weak, thereby reducing the distinctiveness (Brown et al., 2007; Brown et al., 2000) and fidelity (Page & Norris, 1998) of to-be-recalled representations. In contrast, these item-context bindings were anticipated to strengthen over time with repetition (Burgess & Hitch, 2006; Page & Norris, 2009). Consequently, it was expected that serial recall would be significantly greater with repetition, that is, at time two as opposed to time one.

7.1.2.2 False recall. As a general assumption it was projected that the false memory effect would be observed in the current experiment. This prediction was based on the results of previous studies that have reported false memories in short-term (and working) memory tasks (e.g., Atkins & Reuter-Lorenz, 2008, 2011; Coane et al., 2007; Flegal et al., 2010; MacDuffie et al., 2012; Tehan, 2010; Tehan et al., 2004). It was also assumed that the associative lists presentation would activate long-term list representations and (via the process of spreading activation) other associatively related items (including the critical lure). In turn, given that activated (but irrelevant) semantic/associative representations in short-term memory can be incorrectly output as intrusions (Biegler et al., 2008; Hamilton & R. C.

Martin, 2007, 2005; R. C. Martin & He, 2004; Oberauer, 2002) or false memories (Tehan, 2010), it was predicted that at times the non-presented critical lure would be falsely recalled during recall of these associatively related lists. Through a similar process, it was also assumed that false memories would be recalled on phonological lists. That is, it was hypothesised that during recall of phonologically similar lists, the critical lure would often also be recalled.

When compared to either the associative lists or the phonological lists however, it was expected that the false memory effect would be most pronounced on hybrid lists containing items that were *both* associatively related and phonologically similar to a common lure. This was based on the presumptions of contemporary immediate serial recall models, which suggested that semantic and phonological representations could serve to reinforce one another in long-term activated memory via spreading activation (e.g., N. Martin & Saffran, 1997; R. C. Martin, 2006; R. C. Martin et al., 1999). It was expected that hybrid lists would activate the critical lure within both semantic/associative and phonemic networks, and through the process of back and forth activations, connections to the lure and the list items would be strengthened. In short, the binding of semantic/associative and phonological information should induce a superadditive effect on false recall (R. C. Martin et al., 1999; Roediger, Balota, & Watson, 2001; Watson et al., 2001; Watson et al., 2003).

With respect to episodic memory, it was predicted that false memories would be most likely under conditions in which temporary episodic bindings were at their weakest (Oberauer, 2002; Tehan, 2010). It was assumed that a breakdown in item-context associations would cause increased confusion as to the source/context of activated representations (including the critical lure) (Tehan, 2010). In turn, this was expected to result in one misattributing the activated representation of the lure to having come from the previously presented list. In particular, rapid presentation was expected to weaken these episodic bindings, and lead to interference within the network (Biegler et al., 2008; Hamilton & R. C. Martin, 2007, 2005; R. C. Martin & He, 2004). Thus, it was predicted that false recall would be significantly greater for lists that were presented at a rapid rate as opposed to lists that were presented at a standard rate. The predictions for repetition were less straight forward. Repetition was expected to strengthen the connections between item and context as outlined in the predictions for serial recall. Presumably stronger connections to list items would aid participants in discounting non-presented lures leading to significantly lower false recall after repetition, at time two versus time one. It is important to note however these suggestions are somewhat speculative given that models of serial recall that consider item-context associations do not readily address the effects of false recall within their frameworks..

7.1.3 Method.

7.1.3.1 Participants. Twenty voluntary participants aged between 18 and 48 years (*M* = 30.45, *SD* = 8.51) from the Australian Catholic University and from the wider Australian community took part in this experiment. This project referred to these participants (and the participants in Experiments 2, 3 and 4) as “younger adults” when compared to the “older adults” recruited in the later studies (Experiments 5 and 6). This name was chosen purely for readability although it is noted that participants in the “younger adult” samples ranged from young adulthood to middle-age. In order to be eligible for the “younger adult” samples, individuals were required to be between the ages of 18 to 55 years. The upper age limit of 55 years was chosen in order to provide a substantial break between the age of the “younger” samples and the “older” samples of this thesis.

A variety of methods were used to recruit participants for this study (and subsequent studies) including word-of-mouth, the Australian Catholic University’s National School of Psychology online research participation system, announcements during undergraduate psychology classes, and via email to undergraduate psychology students. For copies of these advertisements please see Appendices A, B, C, and D. Undergraduate psychology students received partial course credit (1.5%) towards a nominated unit for participation. Members of the general community did not receive any incentive to participate. Prior to testing, all participants were given a brief self-report background questionnaire regarding age, sex, education, general health and sleep, level of English and current feelings of stress and alertness. This information was collected in order to compare the current group of participants to the samples recruited in the subsequent experiments of this thesis. That is, to consider the similarities and differences between the participants within each individual study. Please see Appendix E for a copy of the self-report background questionnaire. All participants received an information letter and were required to sign a consent form prior to testing (please see Appendix F and G).

Participants were not told that they would be undertaking the same recall task twice. After testing was completed, however, participants were asked whether they were aware that they had repeated an identical task. Only one participant reported being unaware that the task at time two was the same as the task at time one. Please see Appendix I for further information collected via a background questionnaire. Ethics approval for all studies in this thesis was obtained from the Australian Catholic University’s Human Research Ethics Committee (reference number: 2013-81Q). Please see Appendix J for a copy of the initial approval. Confidentiality was maintained throughout the testing, storing and reporting of results of all studies in this research project.

7.1.3.2 Design. The experiment consisted of a 2 x 2 x 4 repeated measures design. The within-subjects independent variables were: (1) presentation rate (standard presentation rate: one word per 1000 milliseconds vs. rapid presentation rate: one word per 250 milliseconds); (2) time of test (time one vs. time two); (3) list type (associative lists vs. phonological lists vs. hybrid lists vs. unrelated/dissimilar lists). The dependent variables were: (1) serial (correct-in-position) recall score measured as the number of items correctly recalled in serial position; and (2) false recall score measured as the number of total critical lures recalled.

7.1.3.3 Materials. The DRM framework (Deese, 1959; Roediger & McDermott, 1995) was used to create two immediate serial recall tasks. The critical lures and the semantic associates were taken from the University of South Florida Free Association Norms (Nelson et al., 1998). In order to increase the likelihood that false memories would be created, the three strongest monosyllabic or disyllabic associates for each lure were selected. Words that were phonologically related to the critical lures were then developed based on the phoneme substitution method by Sommers and Lewis (1999) such that items were selected based on having certain phonemes in common with the critical lure.

A total word pool of 560 monosyllabic and disyllabic words was created. Within this pool there were 80 lists of words. Each list comprised one critical lure, three words associatively related to that lure, and three words phonologically similar to that lure (please see Appendix K for a copy of the word lists). Within each list, associates were assigned to the first, third and fifth serial position. The items with the greatest associative strength to the lure were presented in the first serial position, the second strongest in the third position and the third strongest associates were positioned in fifth place in the list. Words that were phonologically related to the lure were placed in second, fourth and sixth serial position in each list. Items in second serial position had the same beginning and middle phonemes as the critical lure, items in fourth serial position had the same beginning and end phonemes as the lure, and items in sixth serial position had the same middle and end phonemes as the lure.

Once all 80 lists were constructed they were put into an excel program that was designed in line with the constraints of the experiments. The word pool was checked for duplicates, missing items, and consistency with Australian spelling. Through random assortment, the 80 lists were then split in half. Forty lists were used to create serial recall task one and the remaining 40 lists were employed to develop serial recall task two. No word in task one appeared in task two. Within each group of 40 trials, 10 trials were assigned to the associatively related/phonologically similar (hybrid) condition. In these trials, items in position one, three and five were associates to a critical (non-presented) lure, while items in position two, four and six were phonetically similar to this same lure. For example, the word list for the critical lure *wet* in this condition included: *dry, when, soak, wait, damp, met*. Interleaving the associates and words phonologically related to the lure in the hybrid lists was undertaken in order to be consistent with the construction of lists in other false memory studies that had also employed hybrid lists (e.g., Watson et al., 2001).

Ten trials were allocated to the associatively related condition. In these trials, items in position one, three and five were associates to a non-presented lure. The remaining items in the list were phonologically dissimilar to this lure. For example, the word list for the critical lure *bug* in this condition included: *beetle, panel, insect, gross, roach, ton*. Ten trials were allotted to the phonologically similar condition. In these trials, items in position two, four and six were phonologically similar while the remaining items were associatively unrelated to the lure. For example, the word list for the critical lure *horse* in this condition included: *tulip, hoard, cloud, hiss, paper, force*. The remaining 10 trials made up the associatively unrelated/phonologically dissimilar condition. Items in these trials were randomly chosen from the word pool and were not related to a common lure or to each other. An example of a word list in this condition was: *icing, fret, liquid, called, near, wire*. All unrelated and phonologically dissimilar items in each condition were derived from the general word pool. Each word always appeared in the same serial position regardless of which condition it was assigned to and no word appeared more than once throughout the task.

The construction of the lists in this manner was slightly different to other false memory investigations that tend to use “pure” lists composed entirely of associates or phonologically related items without any interleaving items in between. The intention of this thesis, however, was to study the interaction of the long-term networks and the impact of associative-phonemic binding on short-term serial recall within each list type. Hence the development of the lists as described above was deemed to be in line with this aim. In short, manipulating the lists in this way was intended to activate items that were both connected and unconnected to a critical item and to determine how this information would interact in immediate serial recall tasks.

The orders of trials and the lists that were assigned to each condition were randomised for each participant so that 40 unique sets of trials were created. Forty trials (20 from task one and 20 from task two) were allocated to the rapid condition to be presented at a rate of one word per 250 milliseconds. This rapid rate was chosen because it had been consistently shown to induce high levels of false recall when compared to standard presentation rates for both phonological and semantic lists (Ballardini et al., 2008; Hutchison & Balota, 2005; McDermott & Watson, 2001; Smith & Kimball, 2012). The other 40 trials (20 from task one and 20 from task two) were allocated to the standard condition to be presented at a rate of one word per 1000 milliseconds. Items that had been generated during the recall task creation process, but which had not been used in the 80 lists, were randomly chosen to make up four practice trials. For each participant, each set of 80 trials (40 trials for each recall task) and four practice trials were copied into a notepad document and then loaded into Memdisp, a program used to test serial recall. Presentation rate was presented in a block and also counterbalanced across participants. That is, within each task, half of the participants completed 20 trials at rapid presentation followed by 20 trials at the standard rate while the remaining participants completed 20 trials at the standard rate and then 20 trials at rapid presentation rate. For an example of the trials in task one for participant one please see Appendix L.

7.1.3.4 Procedure. The experiment commenced with participants reading the information letter, signing the consent forms and completing the background questionnaire. Participants were then seated in front of a laptop screen and provided with an instruction sheet detailing the task requirements (please see Appendix M for a copy of this instruction sheet). They were advised that the aim of the experiment was to remember lists of six words and that at the end of the list they would be asked to immediately recall the words aloud in the order in which they were presented.

After completing the first task, participants were required to immediately repeat the same task with the same 40 trials in the same order. The task that was repeated was counterbalanced across the sample such that 10 participants completed task one twice and 10 participants completed task two twice. If participants could not remember an item they were instructed to substitute it for the word “pass,” “something” or “space” to ensure that the sequence order was maintained. Items were presented one at a time in lowercase on a monochrome laptop screen. Each trial commenced when the participant pressed enter on the keyboard. At the end of each trial a row of question marks was displayed. This acted as a prompt for participants to begin recalling the items aloud. When they had finished responding, participants were directed to press the space key on the keyboard and wait for the next trial to commence. Four practice trials were given before the task began and no time limits were enforced while participants were completing each task. The researcher was present to record responses on a hard copy score sheet. All testing was undertaken in one individual face-to-face session of approximately 40 - 60 minutes in duration. Upon completion of both tasks, participants were given the opportunity to discuss the study with the researcher. Scores were then input into the data analysis software Statistical Package for the Social Sciences (SPSS).

7.1.4 Results.

7.1.4.1 Data scoring. Responses were scored using the measure of serial scoring. Serial or correct-in-position recall scores were calculated for each condition as the proportion of items correctly recalled in the exact order of presentation. A false recall score was also calculated for each condition, measured as the proportion of critical lures recalled.

7.1.4.2 Data screening. Data screening was undertaken prior to analysis, in line with Tabachnick and Fidell (2007) and Field (2005). The data was checked for accuracy of calculations and input, missing data, outliers, deviation from normality, homogeneity, and multicollinearity/singularity. Screening revealed no missing data and all values were within expected range. No univariate outliers appeared to be far removed from the distribution when observing the histograms and there were no significant multivariate outliers ($p < .001$).

Screening did reveal deviations in normality (skew and kurtosis) and homogeneity in the false recall data. Transformations were attempted but for the most part were unsuccessful in improving these deviations. Importantly, the variables manipulated in this study (and the subsequent studies of this thesis) were not necessarily expected to be normally distributed. Due to the nature of this study's design, the decision was made not to transform the data set.

7.1.4.3 Descriptive statistics. Table 1 represents the means and standard deviations for correct serial recall scores across each condition. At a mean level it appeared that participants improved in performance from time one to time two. Performance also appeared to be better during standard presentation (as opposed to rapid presentation). With respect to list type, generally performance appeared to be best for the associative lists and unrelated/dissimilar lists as opposed to the hybrid lists and phonological lists.

Table 1

Experiment 1: Mean Proportion (and Standard Deviations) of Serial Recall as a Function of Presentation Rate, List Type, and Time of Test

Rate	List	Time One	Time Two
		M (SD)	*M (SD)*
Rapid	Hybrid	.34 (.13)	.38 (.13)
	Associative	.41 (.17)	.51 (.19)
	Phonological	.40 (.12)	.41 (.17)
	Unrelated/dissimilar	.37 (.15)	.46 (.18)
Standard	Hybrid	.42 (.16)	.56 (.19)
	Associative	.44 (.19)	.61 (.21)
	Phonological	.43 (.18)	.57 (.20)
	Unrelated/dissimilar	.49 (.20)	.58 (.21)

Note. *There was no delay between time one and time two.*

Table 2 displays the frequency of critical lures recalled. The pattern of false recall appeared to be fairly similar across time of test and presentation rate. The majority of lures appeared to have been recalled during the hybrid lists.

Table 2

Experiment 1: Number of Participants Recalling a Critical Lure

		Number of Lures Recalled					
Rate	List	0	1	2	3	4	5
		Time One					
Rapid	Hybrid	1	5	8	4	2	
	Associative	20					
	Phonological	11	7	2			
Standard	Hybrid	3	4	9	4		
	Associative	17	3				
	Phonological	16	4				
		Time Two					
Rapid	Hybrid	3	6	5	3	2	1
	Associative	19	1				
	Phonological	13	5	2			
Standard	Hybrid	6	6	5	3		
	Associative	20					
	Phonological	16	4				

Note. There was no delay between time one and time two. No lures were recalled during the unrelated/dissimilar lists because the items in these lists were not related to a shared critical lure.

7.1.4.4 Inferential statistics. To analyse the serial recall and false recall data of this experiment (and subsequent experiments), a sequence of ANOVA's were run. Prior to conducting these analyses it was decided that any resulting significant interactions would be further investigated via post-hoc comparisons in a manner that was deemed to be consistent with the general assumptions of this research project. This meant that if there was a significant interaction between presentation rate and time of test, follow-up tests would compare the results at all levels. That is, the effect of presentation rate at both time one and time two, and the effect of time of test at both standard and rapid presentation rates. These variables were employed to manipulate episodic bindings. Rapid presentation rate was expected to weaken these bindings whilst task repetition was anticipated to strengthen them. Exploring any interactions between these variables would presumably contribute to understanding the role of episodic context on immediate serial recall. It would also seemingly assist in determining the robustness of task repetition and rapid presentation on true and false memory.

It was also decided that if the main effect of list type was significant, each list would be compared against all other list types. This was because there was limited research around the effects of list type on true memory, and in the short-term domain on false memory. Whilst it was expected that hybrid lists would produce a superadditive effect on false recall, the impact of the other list types on false memory and the effects of list type on true memory were largely unknown. Hence, exploring all possible effects of list type was predicted to make an important contribution to short-term memory and false memory research. These underlying assumptions formed the basis for the current experiment and all subsequent experiments of this thesis.

7.1.4.4.1 Serial recall. Serial recall performance during time one was highly correlated ($p < .001$) with performance during time two ($r = .914$). This suggested that those who performed well during time one also performed well during time two. A 2 (time of test) x 2 (presentation rate) x 4 (list type) repeated measures factorial ANOVA was performed on the correct-in-position data. There was a significant main effect for presentation rate, F (1, 19) = 32.89, $MSE = .03$, $p < .001$, $\eta_p^2 = .63$, list type, F (3, 57) = 6.06, $MSE = .01$, $p = .001$, $\eta_p^2 = .24$, and time of test, F (1, 19) = 48.11, $MSE = .02$, $p < .001$, $\eta_p^2 = .72$. Serial recall was significantly greater for items presented at the standard ($M = .51$, $SE = .04$) versus rapid rate ($M = .41$, $SE = .03$), and at time two ($M = .51$, $SE = .03$) as opposed to time one ($M = .41$, $SE = .03$).

Post-hoc analyses were run to further investigate the main effect of list type. To control for familywise error, a new alpha value of $p < .008$ was employed. Performance was significantly greater on the associative lists ($M = .49$, $SE = .04$) when compared to the hybrid lists ($M = .43$, $SE = .03$), $t(19) = 4.37$, $p < .001$, $r = .68$. Serial recall was also significantly greater on the unrelated/dissimilar lists ($M = .48$, $SE = .04$), as opposed to the hybrid lists, $t(19) = 3.05$, $p = .007$, $r = .58$. However, there was no significant difference in serial recall between the hybrid lists and the phonological lists ($M = .45$, $SE = .03$), $t(19) = 1.74$, $p = .098$, $r = .38$, the phonological lists and unrelated/dissimilar lists, $t(19) = 1.27$, $p = .221$, $r = .29$, the associative lists and phonological lists, $t(19) = 2.11$, $p = .048$, $r = .45$, or the associative lists and unrelated/dissimilar lists, $t(19) = 1.07$, $p = .296$, $r = .25$.

The 2-way interaction between presentation rate and time of test was significant, F (1, 19) = 6.78, $MSE = .02$, $p = .017$, $\eta_p^2 = .26$. A simple main effects analysis revealed that presentation rate influenced recall irrespective of time of test. At time one, serial recall was significantly greater during standard (*M* = .45, *SE* = .03) versus rapid presentation (*M* = .38, *SE* = .03), *t*(19) = 2.99, *p* = .008, *r* = .58. Likewise, at time two, serial recall was significantly higher during the standard (*M* = .58, *SE* = .04) versus rapid rate (*M* = .44, *SE* = .03), *t*(19) = 5.85, *p* < .001, *r* = .68. Simple main effect analyses also indicated that repetition effects were evident at both presentation rates. Serial recall improved significantly between time one and time two, during both rapid, *t*(19) = 3.82, *p* = .001, *r* = .68, and standard presentation, *t*(19) = 5.76, *p* < .001, *r* = .68. No other interactions were significant.

7.1.4.4.2 False recall. In order to analyse the false recall data, only three variable list type levels were analysed (hybrid lists vs. associative lists vs. phonological lists). This was because there were no lures to be recalled on the unrelated/dissimilar lists. A 2 (time of test) x 2 (presentation rate) x 3 (list type) repeated measures ANOVA was performed on the false recall data. The results of this analysis are displayed in Figure 5. There was a significant main effect for presentation rate, *F* (1, 19) = 5.66, *MSE* = .03, *p* = .028, η_p^2 = .23. Significantly more lures were recalled during rapid (*M* = .17, *SE* = .02) versus standard presentation (*M* = .12, *SE* = .01). There was also a significant main effect for list type, *F* (2, 38) = 85.99, *MSE* = .03, *p* < .001, η_p^2 = .82. Post-hoc comparisons indicated that significantly more lures were recalled during the hybrid lists (*M* = .35, *SE* = .03) compared to the associative lists (*M* = .01, *SE* = .01), *t*(19) = 10.66, *p* < .001, *r* = .68 and the phonological lists (*M* = .07, *SE* = .01), *t*(19) = 8.50, *p* < .001, *r* = .68. These two latter conditions also differed significantly from each other, *t*(19) = 4.33, *p* < .001, *r* = .68. Finally, there was a significant main effect for time of test, *F* (1, 19) = 5.63, *MSE* = .01, *p* =.028, η_p^2 = .23. Significantly more lures were recalled at time one (*M* = .16, *SE* = .01) compared to time two (*M* = .13, *SE* = .02). No interactions were significant.

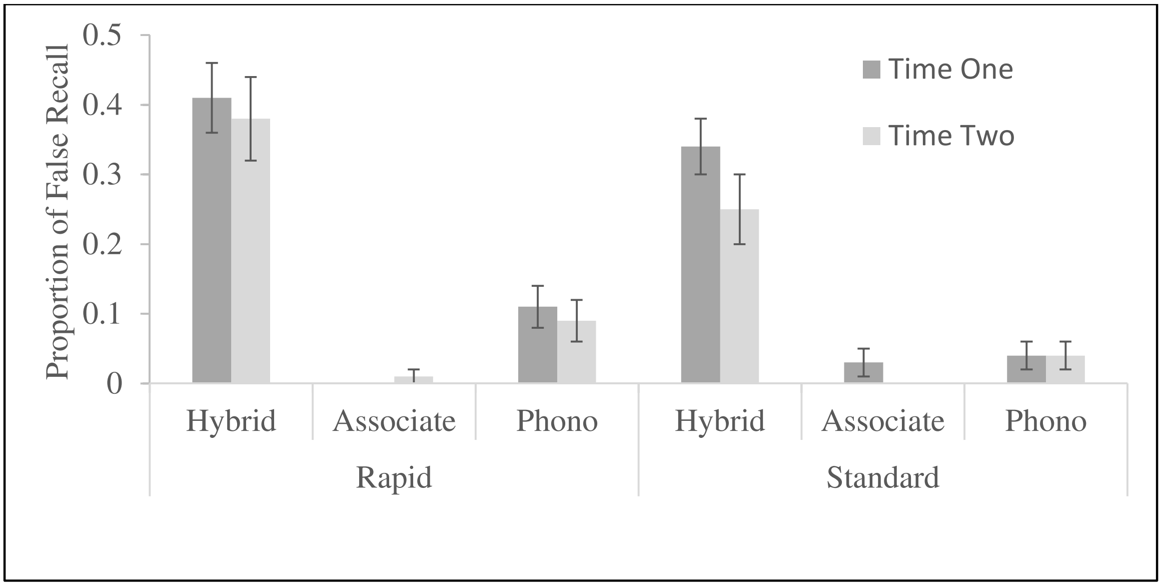

Figure 5. Experiment 1: Mean proportion of false recall as a function of presentation rate, list type, and time of test. Hybrid = hybrid lists; Associate = associatively related lists; Phono = phonologically similar lists; Rapid = rapid presentation rate; Standard = standard presentation rate. Error bars represent standard error of the mean. There was no delay between time one and time two.

The output position of the lure as a function of the number of items that were recalled were also analysed. In the hybrid lists, lures were often recalled as the second last or last item (52%). This pattern was observed frequently during rapid presentation at time one (71%) and time two (60%) but less often during the standard rate at time one (41%) and time two (27%). In the phonological lists, lures were also output as the second last or last item (46%) to some extent. There did not appear to be any pattern in the output position, however, for the very few lures recalled in associative lists.

7.1.5 Discussion.

In this experiment, list type had a significant impact on serial recall. Performance tended to be greater for associative lists compared to other list types, although this difference was only significant for the hybrid lists. This result is consistent with the notion that associative similarity can aid serial recall (Tehan, 2010; Tse, 2009; Tse et al., 2011), and with previous research (Watson et al., 2001) that has also established a recall advantage for associative lists as opposed to hybrid lists in a DRM task (Deese, 1959; Roediger & McDermott, 1995). All of the items on the hybrid lists converged on a common lure, on both associative and phonological dimensions, and this may have led to greater levels of interference and confusion at recall. Interestingly, serial recall also tended to be high on unrelated/dissimilar lists. Information in these lists were not connected to a common lure or to other items in the list and thus may have provided more distinct representations for recall.

In relation to presentation rate, as predicted, serial recall was superior for lists presented at a standard rate as opposed to lists presented at a rapid rate. This finding is consistent with other studies that have found that rapid presentation can have a detrimental effect on recall performance (e.g., Coltheart & Langdon, 1998). These results are also in line with computational models of immediate serial recall that promote the role of temporal or contextual distinctiveness in learning list information (e.g., Brown et al., 2007; Brown et al., 2000; Page & Norris, 1998). Interpretations based on these models suggest that rapid presentation rates reduce the distinction between the learning contexts of each item in a to-be-recalled list and in turn, lead to declines in memory performance. The current study's findings are also consistent with literature surrounding rehearsal. According to this view, participants had less time to rehearse the list during rapid presentation, and this would have reduced the potential for correct recall (Bhatarah et al., 2009; Conrad & Hille, 1958; Tan & Ward, 2008).

As expected, repetition effects were evident for true memory, such that serial recall improved between time one and time two. These findings support the notion that repetition can facilitate recall (Hebb, 1961) even when participants are not explicitly made aware of the repetition (Page et al., 2013). The current results also fit well with computational models of immediate serial recall that propose a cumulative matching process underlying the effects of repetition (e.g., Burgess & Hitch, 2006; Page & Norris, 2009). These frameworks imply that serial recall involves matching the list's short-term representations to long-term item-context representations. Critically, repeating this process is presumed to lead to stronger connections and greater serial recall over time. Post-hoc tests in the current study confirmed that the effects of presentation persisted regardless of time of test. Similarly, the advantage of repetition was evident irrespective of presentation rate. This suggests that both variables had quite robust effects on serial recall.

For false recall, in line with predictions, the false memory effect was observed under immediate serial recall conditions. This finding fits well with growing literature proposing that false memories are not limited to the long-term domain (Atkins & Reuter-Lorenz, 2008, 2011; Coane et al., 2007; Flegal et al., 2010; MacDuffie et al., 2012; Tehan, 2010; Tehan et al., 2004). False recall was greatest for hybrid lists that contained both associates and phonologically related items of a non-presented critical lure, replicating the superadditive effects observed in long-term false memory (e.g., Roediger, Balota et al., 2001; Watson et al., 2003; Watson et al., 2001). False recall was also significantly more likely during rapid as opposed to standard presentation rate, and was significantly reduced following task repetition.

These results are consistent with studies that have investigated presentation rate and task repetition in the long-term domain (e.g., McDermott, 1996; McDermott & Watson, 2001; Smith & Kimball, 2012).

Dominant frameworks of long-term false memory propose that the ability to encode item-specific information in memory impacts the number of false memories recalled (Burns, 2006). The finding that false recall declined between time one and time two in the current study suggests that task repetition helped to strengthen verbatim information as well as item-context connections. In contrast, the increase in false memories reported during rapid (as opposed to standard) presentation implies that participants found it more difficult to encode item-specific representations and item-context associations under this condition. Lures were also often recalled towards the end of the lists, particularly during conditions in which the episodic bindings would presumably have been weakened. This observation was in line with predictions and the assumptions made by Tehan (2010). Taken together, the results of this experiment supported the view that in an immediate serial recall task, manipulating episodic bindings can have a direct effect on the potential for false lures to be recalled.

7.2 Experiment 2

Before discussing how the results of Experiment 1 relate to the current understandings of immediate serial recall and verbal short-term memory, it was important to ensure that the effects of repetition observed were not simply due to practice effects alone. Experiment 1 established that false recall could be reduced through task repetition whilst serial recall improved, presumably due to episodic context strengthening. It is also possible that the item representations within long-term networks remained active over time so that at time two, representing the list reinforced those list activations (Oberauer, 2002). If this was indeed the case, then presenting a different task at time two should not have the same effect on performance. More specifically, if the second task was not the same as the first task, one would presume that the opportunity for a second study phase would be of no benefit to performance (as the trials and lures would not be the same). Therefore, the aim of Experiment 2 was to test these propositions.

7.2.1 Aims.

While Experiment 1 explored the influence of true and false memory during the immediate repetition of the *same* serial recall task, the intention of Experiment 2 was to examine these variables by employing two *different* serial recall tasks. The aim was to provide support for the notion that the decrease in false memory (and increase in true memory) with repetition observed in Experiment 1 was due to the persistence of activations over time and strengthening of episodic bindings (as opposed to simply practice effects of the task).

7.2.2 Predictions.

7.2.2.1 Serial recall. In line with the findings of Experiment 1 it was expected that serial recall would be significantly greater for associative lists as opposed to hybrid lists. It was unclear whether there would be any difference between the other list types, although based on the results of Experiment 1 any differences were not necessarily expected to reach significance. Serial recall was anticipated to be superior during standard compared to rapid presentation. In contrast to the results of the previous study however, it was hypothesised that there would be no significant improvement in serial recall between time one and time two. Given that the recall tasks in the current experiment contained different word lists (and lures), it was presumed that any activations remaining from time one would not assist (or hinder) the recall of the new lists at time two.

7.2.2.2 False recall. Consistent with the findings of the first experiment, it was predicted that a false memory effect would be demonstrated in the current study. It was anticipated that lures would be falsely recalled during phonological lists and associative lists. However, hybrid lists were expected to show superior false recall when compared to the other list types. It was also predicted that false recall would be significantly greater during rapid as opposed to standard presentation, however, a decrease in false recall with repetition (i.e., at time two as opposed to time one) was not expected. Again, this was because the two different tasks would contain different lists and have different critical lures. Thus, any activations (or episodic bindings) remaining from time one were not expected to influence performance at time two. Lures to be recalled were anticipated more often, however, towards later serial positions of the list, in line with the results of Experiment 1.

7.2.3 Method.

7.2.3.1 Participants. Twenty voluntary participants aged between 20 and 48 years (*M* = 32.1, *SD* = 8.84) participated in this study. Appendix I contains additional information regarding the sample collected via a background questionnaire. No participants who had taken part in Experiment 1 were able to take part in Experiment 2.

7.2.3.2 Design. The experiment consisted of a 2 x 2 x 4 repeated measures design. The within-subjects independent variables were: (1) presentation rate (one word per 1000 milliseconds vs. one word per 250 milliseconds); (2) time of test (time one vs. time two); (3) list type (associative lists vs. phonological lists vs. hybrid lists vs. unrelated/dissimilar lists). The dependent variables were (1) serial (correct-in-position) recall score and (2) false recall score.

7.2.3.3 Materials. The current study employed the same immediate serial recall tasks that were created in Experiment 1. These tasks were constructed using the DRM framework (Deese, 1959; Roediger & McDermott, 1995) and consisted of 40 six-word lists. There were four types of lists including (1) hybrid lists, (2) associative lists, (3) phonological lists, and (4) unrelated/dissimilar lists. At time one, the task given to participant one in the previous experiment was also given to participant one in the present study and so on. At time two, participants were given the alternative recall task to complete. This was a similar recall task but one that contained a new set of 40 trials with a new set of associates, phonologically related words, and (non-presented) lures. The order of these two recall tasks was counterbalanced across participants. That is, 10 participants received task one and then task two while 10 other participants undertook task two and then task one.

7.2.3.4 Procedure. The procedure of Experiment 1 was replicated as much as possible for Experiment 2. Participants were told that they would be completing two recall tasks and that they would complete the second task immediately after the first task. After the first task was completed, participants immediately commenced the second task. All participants were randomly allocated to each condition and all testing was undertaken in an individual face-to-face session lasting approximately 40 - 60 minutes.

7.2.4 Results.

7.2.4.1 Data scoring. For each condition, responses were scored using (1) serial scoring, calculated as the proportion of items correctly recalled in order of presentation, and (2) false recall calculated as the proportion of critical lures recalled.

7.2.4.2 Data screening. Data screening was undertaken prior to analysis based on the principles of Tabachnick and Fidell (2007) and Field (2005). Screening checked for accuracy of calculations and input, missing data, outliers, deviation from normality, homogeneity, and multicollinearity/singularity. There was no missing data and all values were within expected range. At a univariate level, the distribution did not contain any far removed outliers when observing the histograms and there were no significant multivariate outliers ($p < .001$). There were some deviations in normality (skew and kurtosis) and homogeneity in the false recall data. Two variables in the false recall data were also highly correlated suggesting singularity. These variables, however, were the associative lists for the first task and the associative lists for the second task, both of which were presented at a standard presentation rate. It was not unexpected that these variables may have been highly related and resulted in the same false recall scores given they were the same condition across only two different tasks. A number of transformation attempts were made, although these attempts for the most part were unsuccessful in improving deviations in normality or homogeneity. Similar to Experiment 1, it was decided that the original data set would be used.

A series of independent t-tests were run to compare the key variables collected via the background questionnaire between participants from Experiment 1 and participants from the current experiment. This included age, sex, education level, first language, level of English, state of physical health and sleep over the last month and on the day of testing, and current level of alertness and stress. The Bonferroni correction for familywise error was applied and a new alpha of $p < .005$ was applied. Using this new alpha level, there were no significant differences on any of the self-report variables between the three groups.

7.2.4.3 Descriptive statistics. The means and standard deviations for correct serial recall across each condition are displayed in Table 3. At a mean level it appeared that performance was comparable between time one and time two, and similar across all list types. Recall seemed to be superior, however, for standard (versus rapid) presentation.

Table 3

Experiment 2: Mean Proportion (and Standard Deviations) of Serial Recall as a Function of Presentation Rate, List Type, and Time of Test

Rate	List	Time One	Time Two
		M (SD)	*M (SD)*
Rapid	Hybrid	.34 (.12)	.33 (.18)
	Associative	.36 (.15)	.36 (.19)
	Phonological	.32 (.15)	.34 (.14)
	Unrelated/Dissimilar	.36 (.15)	.38 (.15)
Standard	Hybrid	.49 (.16)	.48 (.17)
	Associative	.46 (.19)	.52 (.23)
	Phonological	.49 (.19)	.47 (.21)
	Unrelated/Dissimilar	.47 (.21)	.48 (.27)

Note. There was no delay between time one and time two.

The lure recall frequency is outlined in Table 4. The pattern of lures recalled appeared to be fairly similar between time one and time two, and the majority of lures appeared to have been recalled during the hybrid lists.

Table 4

Experiment 2: Number of Participants Recalling a Critical Lure

		Number of Lures Recalled				
Rate	List	0	1	2	3	4
		Time One				
Rapid	Hybrid	1	8	8	2	1
	Associative	14	6			
	Phonological	15	5			
Standard	Hybrid	5	6	7	2	
	Associative	19	1			
	Phonological	16	4			
		Time Two				
Rapid	Hybrid	5	5	5	2	3
	Associative	18	2			
	Phonological	15	4	1		
Standard	Hybrid	4	9	6	1	
	Associative	19	1			
	Phonological	15	5			

Note. There was no delay between time one and time two. No lures were recalled during the unrelated/dissimilar lists because the items in these lists were not related to a shared critical lure.

7.2.4.4 Inferential statistics.

7.2.4.4.1 Serial recall. Serial recall during time one was highly correlated ($p < .001$) with performance during time two ($r = .903$). This suggested that those who performed well during time one also performed well during time two. A 2 (time of test) x 2 (presentation rate) x 4 (list type) repeated measures factorial ANOVA was performed on the correct-in-position data. There was a significant main effect for presentation rate, F (1, 19) = 47.43, $MSE = .03$, $p < .001$, $\eta_p^2 = .71$. Serial recall was significantly greater for items presented at the standard ($M = .48$, $SE = .04$) versus rapid rate ($M = .35$, $SE = .03$). There was no significant main effect however for list type, F (3, 57) = 0.51, $MSE = .01$, $p = .680$, $\eta_p^2 = .03$ or time of test, F (1, 19) = 0.50, $MSE = .02$, $p = .487$, $\eta_p^2 = .03$. There was no significant difference in serial recall between hybrid lists ($M = .41$, $SE = .03$), associative lists ($M = .42$, $SE = .04$), phonological lists ($M = .41$, S$E = .03$) or unrelated/dissimilar lists ($M = .42$, $SE = .04$). There was also no significant difference in performance at time two ($M = .42$, $SE = .04$) as opposed to time one ($M = .41$, $SE = .03$). No interactions were significant.

7.2.4.4.2 False recall. A 2 (time of test) x 2 (presentation rate) x 3 (list type) repeated measures ANOVA was performed on the false recall data. The results of this analysis are displayed in Figure 6. There was a significant main effect for presentation rate, F (2, 38) = 5.51, $MSE = .02$, $p = .030$, $\eta_p^2 = .23$. Significantly more lures were recalled during the rapid ($M = .14$, $SE = .02$) versus standard presentation ($M = .10$, $SE = .01$). There was also a significant main effect for list type, F (2, 38) = 104.74, $MSE = .02$, $p < .001$, $\eta_p^2 = .85$. Post-hoc comparisons indicated that significantly more lures were recalled during the hybrid lists ($M = .29$, $SE = .02$) compared to the associative lists ($M = .03$, $SE = .01$), $t(19) = 11.62$, $p < .001$, $r = .68$, and the phonological lists ($M = .05$, $SE = .01$), $t(19) = 10.81$, $p < .001$. $r = .68$.

These two latter conditions did not differ significantly from each other, $t(19) = 1.70$, $p = .106$, $r = .37$. There was no significant main effect for time of test, $F\ (1, 19) = 0.20$, $MSE = .02$, $p = .664$, $\eta_p^2 = .01$. This meant that there was no significant difference in the number of lures recalled at time one ($M = .13$, $SE = .01$) compared to time two ($M = .12$, $SE = .01$). No interactions were significant.

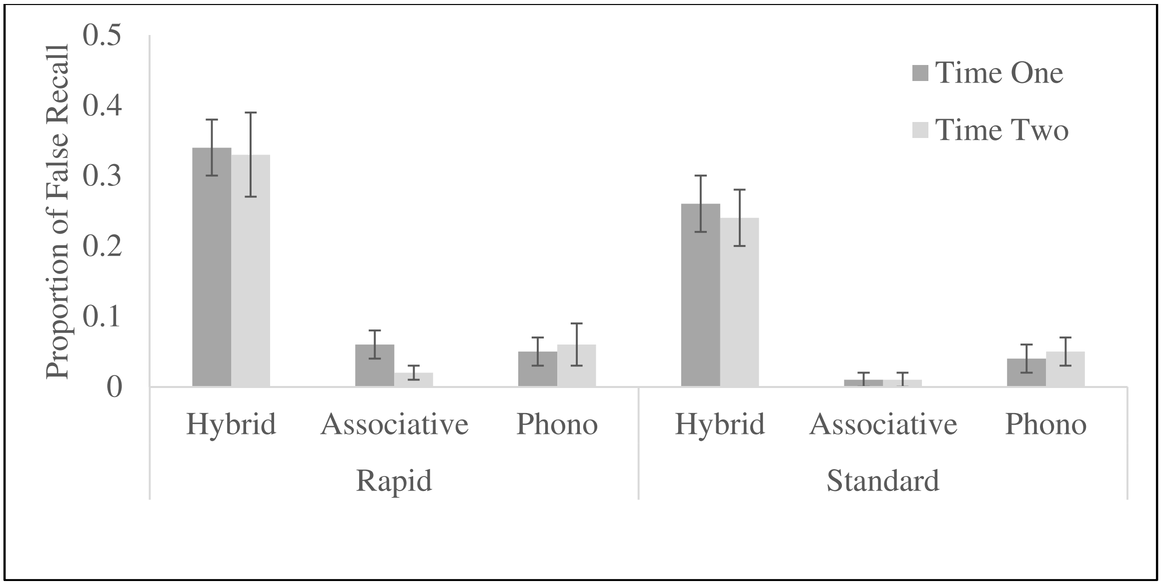

Figure 6. Experiment 2: Mean proportion of false recall as a function of presentation rate, list type, and time of test. Hybrid = hybrid lists; Associate = associatively related lists; Phono = phonologically similar lists; Rapid = rapid presentation rate; Standard = standard presentation rate. Error bars represent standard error of the mean. There was no delay between time one and time two.

The output position of the lure as a function of the number of items that were recalled were examined. For the hybrid lists, the majority of lures were recalled as the second last or last item (60%). This was indicated during rapid presentation at time one (58%) and time two

(66%), and during the standard rate at time one (54%) and time two (63%). In the phonological lists, lures were typically recalled as the second last or last item (74%). In the associative lists, no pattern in output position was evident for the minimal lures recalled in these lists.

7.2.5 Discussion.

In contrast to the first experiment, list type did not significantly impact serial recall in Experiment 2. For presentation rate, however, the current findings were in line with expectations such that serial recall was superior during standard as opposed to rapid presentation. These results were in line with other studies that have reported declines in serial recall when rapid presentation rates are employed (e.g., Coltheart & Langdon, 1998). The predictions surrounding repetition were also supported. Unlike the previous study (Experiment 1), which established an improvement in serial recall with task repetition, no such increase was observed in the current study. Both Experiments 1 and 2 utilised the same methodology except that in the former study participants were given the *same* task twice while in the present study participants completed two *different* recall tasks. Taken together, these results support the view that the improvement in serial recall in Experiment 1 was not due to practice effects but rather due to the specific repetition of the same lists.

With respect to false recall, this study was successful in eliciting the false memory effect, and in general, the patterns of lure recall were similar to Experiment 1. False recall was greatest during hybrid lists, and lures were typically recalled as the second or last item in a list. Together, these findings support the idea that false recall can extend to the short-term domain (Atkins & Reuter-Lorenz, 2008, 2011; Coane et al., 2007; Flegal et al., 2010; MacDuffie et al., 2012; Tehan, 2010; Tehan et al., 2004). They also support the notion of a superadditive effect of mixed lists (Watson et al., 2003) and the suggestion that episodic context plays a role in false errors (Tehan 2010). The effects of presentation rate were also comparable across Experiments 1 and 2. Rapid presentation significantly increased the number of lures recalled, in line with other false memory studies employing similar presentation rates (McDermott & Watson, 2001). The effects of task repetition also supported predictions. That is, in contrast to the findings of the first study, false recall did not significantly decline between time one and time two.

In combination, the findings of Experiments 1 and 2 support the notion that semantic/associative, phonological and episodic information can interact in ways that influence short-term memory performance. Across both experiments, false memories were much more likely to occur on hybrid lists as opposed to associative or phonological lists. These results fit well with psycholinguistic models (e.g., N. Martin & Gupta, 2004; R. C. Martin et al., 1999; Romani et al., 2008) that depict short-term memory as multiple levels of representations that influence immediate serial recall. The general assumption of the activation model (N. Martin & Gupta, 2004) is that different types of representations serve to continually reinforce each other through spreading activation within the network. This connection between semantic/associative and phonological representations seemingly helps to stabilise the memory trace and aid recall performance.

The findings of the current project suggest that, under certain conditions, this process can also be detrimental to recall. More precisely, the spreading activation between semantic/associative and phonological representations may have reinforced not only the list items, but also other related items including the critical lure, leading to increased vulnerability to false memories on hybrid lists. Presumably, this supperadditive effect is the product of an interaction between the long-term semantic and phonological networks and the spreading back and forth of an item's representation between phonological and semantic levels of short-term memory which serve to reinforce the memory trace (R. C. Martin, 2006). Additionally, because hybrid lists seemingly activate both semantic and phonological representations of the lure, the criteria for items to be activated is narrowed, reducing the chance that other items are activated and increasing the likelihood that the critical item is later recalled (Roediger, Balota et al., 2001). The activation model (N. Martin & Gupta, 2004) also presumes that representations decay rapidly without the continued reinforcement of spreading activation. According to this approach, representations are activated in the order of phonological, lexical and semantic levels, and this in turn actually assists in the maintenance of serial order. Thus, in the immediate serial recall task, items at the beginning of the list have a greater amount of time for representations to be activated at the semantic level. Moreover, through a process of feedback/feedforward within the network, the activation of the semantic representations is continually strengthened. Presenting items at a rapid speed would presumably mean that none of the items in the list would have much opportunity for their semantic representations to be activated and strengthened (potentially leading to more errors at recall). This would explain the superior recall during standard versus rapid presentation observed in this research project. However, this model does not say how long this feedback/feedforward process continues. Presumably, after the items have been recalled, the process would stop. According to this view, the activated representations would then rapidly decay. It may have been expected that there would be no benefit to task repetition because none of the representations at time one would have persisted at time two. The findings of this research project so far, however, report the opposite. In Experiment 1 when the same task was repeated, serial recall improved whilst false recall declined. These results are not able to be explained by only suggesting that with time episodic, semantic/associative, and phonological bindings just decay. Indeed, these bindings appear to maintain some level of persistence. This is further supported by the results of Experiment 2, which demonstrated that when two different tasks were repeated there was no benefit to repetition (i.e., serial recall and false recall remained constant from time one to time two).

R. C. Martin and colleagues (R. C. Martin et al., 1999; Romani et al., 2008) emphasise the role of interference in creating intrusion errors in immediate serial recall tasks. Presumably, interference in the network would be greatest towards the end of the list, when more representations have become activated in short-term memory. It is unclear at this stage what conditions would constitute interference within the network. Hence, it is difficult to see how this model would account for the effects of presentation rate and task repetition observed in the current thesis. In turn, this highlights the limitation of psycholinguistic models more generally in being able to provide a detailed account of episodic context. Psycholinguistic models have not been readily applied to false errors, rapid presentation or task repetition, thus these proposals are purely speculative. It is clear that further work is needed in order to understand the implications of psycholinguistic frameworks in the context of episodic, semantic/associative, and phonological bindings.

Some of the findings of Experiments 1 and 2 are more readily able to be explained by the embedded components model (Cowan, 1995, 1999; Oberauer, 2002). However, it should be noted that this model does not account for multiple types of representation in short-term memory; thus it is difficult to explicate the effects of phonological similarity or superadditive hybrid effects on false memory. With regard to associative effects however, in a sense this model presumes that intrusion errors are a by-product of the spreading activation process within the long-term associative network. More specifically, they are thought to be caused by problems in episodic bindings. As representations pertaining to the list become activated, other related concepts may also become activated via links of association. If item-context bindings are impaired, however, it may be difficult to establish the origin of the currently activated representations. Under these conditions, one may incorrectly attribute a related item to having been derived from the presented list, and in turn falsely recalling this item at output.

According to computation accounts of immediate serial recall, rapid presentation is presumed to impair serial recall by reducing the distinctiveness of episodic bindings (Brown et al., 2007; Brown et al., 2000). Thus, the embedded components model (Oberauer, 2002) is able to account for the greater number of lures during rapid presentation observed in the experiments of this study. Moreover, the framework is able to explain the repetition effects, if one is to presume that increasing the strength of episodic bindings would have the reverse effect on performance and lead to a reduction in intrusion/false errors at recall. The model says that long-term activations may continue to influence episodic context, but it does not specify for how long. Based on the findings of the current research project, it would seem that these temporary activations may persist even after the list has been recalled. It is clear that further research is needed to understand more thoroughly how long these activations may be able to influence short-term performance.

A final point to note relates to the influence of list type on performance. Across the studies reported so far, list type did not appear to consistently impact serial recall. In Experiment 1, associative lists exhibited higher levels of correct recall when compared to hybrid lists, although in Experiment 2 correct recall appeared to be somewhat comparable across the different list types. These results appear to be somewhat in line with the previous literature in that sometimes differences in veridical recall between lists emerge (e.g., Watson et al., 2001) and other times they do not (e.g., Watson et al., 2003). Importantly, associative lists in this thesis only contained three associates, and each associate was separated by a dissimilar item. Likewise, phonological lists were comprised of three words that were phonologically related to the lure, interleaved between three unrelated items. The intention here was to look at the binding of associatively related/unrelated and phonologically similar/dissimilar material and the impact this would have on false memory. Nevertheless, constructing lists in this manner may have meant that there were not enough related or similar items within a list to have created an observable effect. Arguably, associative and phonological effects in the current study would have been more pronounced if the lists had been comprised entirely of six associates or six phonologically related items. Irrespective of this view, it is not unanticipated that the effects of list type were much more robust on false recall as opposed to correct recall given that the DRM framework (Deese, 1959; Roediger & McDermott, 1995) employed in Experiments 1 and 2 was specifically designed to create false memories. Further support for this notion comes from other investigations that have found limited impact of list type on true memory even when they have consistently used lists comprised entirely of associates or phonologically related words (e.g., Budson et al., 2003; Watson et al., 2003). In short, as expected, the DRM framework has a much more pronounced (and consistent) impact on false memory when compared to true memory.

To summarise, the experiments reported in this thesis thus far provide support for the idea that semantic/associative, phonological and episodic bindings can combine in different ways to influence performance on an immediate serial recall task. The results support contemporary models of verbal short-term memory that describe short-term memory as a network of multiple levels of representations. Moreover, the findings reinforce the role of episodic binding in short-term memory in line with several computational models of immediate serial recall. However, there are no current models that can account for all of the effects observed in this project, highlighting a need for additional focus on this topic.

Chapter Eight: Experiments 3 and 4

8.1 Introduction and Rationale

Experiment 1 of this research project demonstrated that task repetition was able to improve correct recall and reduce false recall on an immediate serial recall task, even when participants were not informed prior to testing that they would be repeating the same task. This result is interesting because long-term false memory research suggests that participants are only able to benefit from task repetition if they are given the opportunity for feedback. Given that the majority of participants in Experiment 1 reported retrospectively that they were aware that the task at time two had been the same as the task at time one, it is possible that re-exposure to the list provided participants with the chance to conduct their own (perhaps unconscious) self-checks. That is, participants may have been able to compare the second list presentation against their previous responses to improve their performance with repetition.

In addition, being tested on the material may have also contributed to the increase in recall observed in Experiment 1 (e.g., Roediger & Karpicke, 2006). In a discussion of long-term learning, Oberauer and Meyer (2009) highlighted the importance of being able to engage with and attend to information, as opposed to simply just rehearsing that material in short-term memory. These researchers have highlighted that during an immediate serial recall task one needs to reproduce the to-be-recalled information in memory. This reproduction is thought to assist with additional encoding and subsequently help strengthen long-term representations of the material (see also Karpicke & Roediger, 2007). Based on this perspective, participants’ first attempt at the task in Experiment 1 may have provided them with the opportunity to engage with the information and initiate long-term learning processes. A subsequent presentation of the list then arguably served to reinforce these long-term activations and provided another opportunity for participants to study and test their knowledge of the lists.

The effects of repetition reported in this project so far appear to generally align with the embedded components model principles (Oberauer, 2002). This model proposes that representations within the activated region of short-term memory can influence representations in the direct-access region of the short-term store. According to this framework, information can be readily removed from the direct-access region when it is deemed irrelevant to the cognitive task at hand. In contrast, information within the activated region of short-term memory is thought to persist even when it is no longer required. Indeed, the results of the previous experiments demonstrate that activated representations can continue to influence temporary episodic bindings (and thus the potential for correct and incorrect recall) even after the list has been recalled and the information should no longer be relevant. An important question, however, that Experiments 1 and 2 are unable to answer is how long these activations may persevere.

Presumably, there would be a limit to how long list activations are able to persist in memory and continue to impact episodic binding of future tasks. Research surrounding the Hebb effect (Hebb, 1961), however, emphasises the persistence of long-term learning in short-term memory tasks (e.g., Majerus et al., 2012). Indeed, the benefits of Hebb learning appear to arise quickly (e.g., Page & Norris, 2009) and persist for a long time, even months after the initial testing period (Page et al., 2013). Nevertheless, it is important to note that the current thesis has been investigating the task repetition as a whole and has included only one task repetition. In contrast, the Hebb procedure (Hebb, 1961) typically involves multiple repetitions of every third or more sequence in a task. Indeed, even those computational models that highlight the importance in cumulative matching in list learning (e.g., Burgess & Hitch, 2006; Page & Norris, 2009) are driven towards a focus on the Hebb effect. In short, there is a need to better understand how to interpret repetition effects in immediate serial recall tasks more generally. The results of this thesis so far support the proposition that long-term activations may persist after recall and impact performance in subsequent tasks. In addition, the project’s findings suggest that the binding of semantic/associative, phonological and episodic information plays a role in this process. However, the focus so far has been on immediate task repetition. To provide a greater understanding of the duration which such activations may persist, additional research was undertaken. In particular, the goal was to further investigate the effects of repetition over longer intervals.

8.2 Experiment 3

8.2.1 Aims.

The purpose of Experiment 3 was to extend the findings of the earlier studies in this thesis by employing a 15-minute delay between task repetitions. A 15-minute delay was chosen because it was assumed that after 15 minutes the temporary episodic representations of the task would be well and truly forgotten. This assumption was in line with the usual constraints of the short-term store proposed by a wide range of theoretical frameworks (e.g., Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Cowan, 2008; Miller, 1956; Peterson & Peterson, 1959; Neath & Surprenant, 2003). In turn, it was expected that any change in performance with repetition would more likely be due to long-term activations persisting over time.

8.2.2 Predictions.

8.2.2.1 Serial recall. It was unclear whether list type would influence true memory. This was because list type had shown varying impacts on performance during Experiments 1 and 2. Serial recall was expected to be significantly greater during standard versus rapid presentation. This was based on the earlier experiments of this project and previous investigations of rapid presentation and serial recall (e.g., Coltheart & Langdon, 1999). In regards to repetition, it was anticipated that even with a 15-minute delay before repetition, serial recall would improve significantly between time one and time two. This was grounded on previous research that had demonstrated the benefits of repetition in immediate serial recall tasks over longer periods, even months after the original testing session (e.g., Page et al., 2013).

8.2.2.2 False recall. Consistent with the results of Experiments 1 and 2 it was predicted that the false memory effect wold be evident in the current experiment. It was expected that false memories would occur during lists containing items that were associatively related *or* phonologically similar to a non-presented critical lure. It was also anticipated that false recall would be greatest for hybrid lists that contained items that were *both* associatively related and phonologically similar to the critical lure. For presentation rate, it was expected that false recall would be significantly greater during rapid as opposed to standard presentation. It was unclear, however, whether false recall would be significantly greater at time two as opposed to time one when a 15-minute delay was introduced between tasks.

8.2.3 Method.

8.2.3.1 Participants. The sample consisted of 20 voluntary participants aged between 18 and 45 years (*M* = 24.60, *SD* = 6.76). Additional information obtained from the background questionnaire is presented in Appendix I. As a prerequisite, no participants who had taken part in the previous experiments were able to take part in Experiment 3. All participants in this study repeated the same recall task twice. Participants were not informed prior to completing the study that they would be repeating the same task. After testing however, no participants reported that they had been unaware that the task at time two was identical to the task at time one.

8.2.3.2 Design. The experimental design was a 2 x 2 x 4 repeated measures design. The within-subjects independent variables were: (1) presentation rate (one word per 1000 milliseconds vs. one word per 250 milliseconds); (2) time of test (time one vs. time two); (3) list type (hybrid vs. associative vs. phonological vs. unrelated/dissimilar). The dependent variables were (1) serial (correct-in-position) recall score and (2) false recall score.

8.2.3.3 Materials. The same immediate serial recall tasks that were employed in the previous experiments were used in the present study. For consistency, the task given to participant one in Experiment 1 was also given to participant one in Experiment 3, and so forth.

8.2.3.4 Procedure. Participants undertook a similar procedure to that of the previous experiments. Participants were informed that they would be completing two recall tasks with a 15-minute break between these tasks. The task that was repeated was counterbalanced across the sample such that 10 participants completed task one twice and 10 participants completed task two twice. Testing took place during two individual face-to-face sessions.

Each session lasted approximately 20 – 30 minutes and the two sessions were separated by a 15-minute break. During this break, participants were able to leave the room of testing to use the bathroom or have a drink of water. If participants stayed in the room they were not encouraged to discuss details of the task. No other controls were put in place during this delay period. After both tasks were completed however, participants were given the opportunity to debrief with the researcher.

8.2.4 Results.

8.2.4.1 Data scoring. Recall was measured through serial scoring, referred to as the proportion of items recalled in correct order and false recall scores, defined as the proportion of critical lures recalled.

8.2.4.2 Data screening. Prior to analysis, data screening was undertaken following the same procedures of the earlier experiments. Screening established no missing data, univariate outliers, multicollinearity or singularity, and all scores were within the expected range. Four multivariate outliers in the false recall data set were discovered ($p < .001$), and there was evidence of deviation in normality (skew and kurtosis) in the false recall data and serial recall data. As outlined in Experiment 1 however, the variables in the current study were not presumed to have a normal distribution. In combination with the design of the study, and the fact that efforts to transform the data were somewhat unsuccessful, the decision was made to keep with the original scores for analysis.

8.2.4.3 Descriptive statistics. The means and standard deviations for correct serial recall scores across each condition are presented in Table 5. At a mean level, performance seemed to improve from time one to time two and appeared to be greater during standard as opposed to rapid presentation. There did not appear to be any obvious trends for serial recall across list types.

Table 5

Experiment 3: Mean Proportion (and Standard Deviations) of Serial Recall as a Function of Presentation Rate, List Type, and Time of Test

		Time One	Time Two
Rate	List	*M (SD)*	*M (SD)*
Rapid	Hybrid	.31 (.08)	.34 (.10)
	Associative	.34 (.13)	.39 (.12)
	Phonological	.32 (.11)	.39 (.10)
	Unrelated/Dissimilar	.32 (.10)	.38 (.11)
Standard	Hybrid	.39 (.16)	.42 (.18)
	Associative	.37 (.17)	.46 (.18)
	Phonological	.34 (.20)	.43 (.21)
	Unrelated/Dissimilar	.33 (.16)	.46 (.22)

Note. There was a 15-minute delay between time one and time two.

Table 6 depicts the number of participants recalling a critical lure. The pattern of lure recall at time one appeared to be similar to the pattern at time two. Lure recall during standard presentation and rapid presentation also appeared to be comparable. The majority of lures seemed to be recalled during the hybrid lists.

Table 6

Experiment 3: Number of Participants Recalling a Critical Lure

Rate	List	Number of Lures Recalled				
		0	1	2	3	4
	Time One					
Rapid	Hybrid	3	4	8	4	1
	Associative	19	1			
	Phonological	13	7			
Standard	Hybrid	3	4	8	3	2
	Associative	19	1			
	Phonological	15	3	2		
	Time Two					
Rapid	Hybrid	2	6	9	2	1
	Associative	19	1			
	Phonological	12	8			
Standard	Hybrid	5	9	1	4	1
	Associative	19	1			
	Phonological	15	5			

Note. There was a 15-minute delay between time one and time two. No lures were recalled during the unrelated/dissimilar lists because the items in these lists were not related to a shared critical lure.

8.2.4.4 Inferential statistics.

8.2.4.4.1 Serial recall. Serial recall performance at time one was highly correlated ($p < .001$) with performance at time two ($r = .916$) signifying that those who performed well initially, also performed well after a 15-minute delay. A 2 (time of test) x 2 (presentation rate) x 4 (list type) repeated measures factorial ANOVA was performed on the correct-in-position data. There was a significant main effect for presentation rate, F (1, 19) = 4.63, $MSE = .05$, $p = .045$, $\eta_p^2 = .20$ and time of test, F (1, 19) = 39.71, $MSE = .01$, $p < .001$, $\eta_p^2 = .68$. Serial recall was significantly greater when items were presented at the standard ($M = .40$, $SE = .04$) versus rapid rate ($M = .35$, $SE = .02$) and at time two ($M = .41$, $SE = .03$) as opposed to time one ($M = .34$, $SE = .03$). There was no significant main effect, however, for list type, F (3, 57) = 1.08, $MSE = .01$, $p = .367$, $\eta_p^2 = .05$. This meant that there was no significant difference in the serial recall between hybrid lists ($M = .36$, $SE = .02$), associative lists ($M = .39$, $SE = .03$), phonological lists ($M = .37$, S$E = .03$) or unrelated/dissimilar lists ($M = .37$, $SE = .03$).

The 2-way interaction between presentation rate and time of test was significant, F (1, 19) = 6.08, $MSE = .01$, $p =.023$, $\eta_p^2 = .24$. Simple main effects revealed that repetition effects were evident during both presentation rates. When items were presented at a standard rate, serial recall was significantly greater at time two ($M = .44$, $SE = .04$) compared to time one ($M = .36$, $SE = .03$), $t(19) = 5.14$, $p < .001$. $r = .68$. Likewise, serial recall was significantly greater at time two ($M = .37$, $SE = .02$) compared to time one ($M = .32$, $SE = .02$) when items were presented at a rapid rate, $t(19) = 5.88$, $p < .001$, $r = .68$. Simple main effects also revealed that presentation rate only impacted performance during the second attempt at the task. Serial recall was significantly greater during the standard compared to rapid rate at time two, $t(19) = 2.60$, $p = .018$, $r = .52$, but at time one there was no significant difference in recall between the two rates, $t(19) = 1.4$, $p = .178$, $r = .31$. No other interactions were significant.

8.2.4.4.2 False recall. A 2 (time of test) x 2 (presentation rate) x 3 (list type) repeated measures factorial ANOVA was performed on the false recall data. These results are presented in Figure 7. There was a significant main effect for list type, $F\ (1.25, 23.66) = 106.29$, $MSE = .04$, $p < .001$, $\eta_p^2 = .84$. Post-hoc comparisons indicated that significantly more lures were recalled during the hybrid lists ($M = .34$, $SE = .03$) compared to the associative lists ($M = .01$, $SE = .01$), $t(19) = 11.07$, $p < .001$, $r = .68$, and the phonological lists ($M = .07$, $SE = .01$), $t(19) = 10.10$, $p < .001$, $r = .68$. These two latter conditions also differed significantly from each other, $t(19) = 4.95$, $p < .001$, $r = .68$. There was no significant main effect for presentation rate, $F\ (1, 19) = 0.57$, $MSE = .02$, $p =.459$, $\eta_p^2 = .03$ or time of test, $F\ (1, 19) = 2.94$, $MSE = .01$, $p = .103$, $\eta_p^2 = .13$. This meant that there was no significant difference in the number of lures recalled during standard ($M = .13$, $SE = .02$) versus rapid presentation ($M = .15$, $SE = .01$) or at time one ($M = .15$, $SE = .02$) compared to time two ($M = .13$, $SE = .01$). No interactions were significant.

The lure’s output position as a function of the number of items that were recalled was examined. For the hybrid lists, lures were frequently recalled as the second last or last list item (63%). This was indicated during rapid presentation at time one (83%) and time two (57%), and during the standard rate at both time one (60%) and to a lesser extent at time two (48%). In the phonological lists, lures were commonly output as the second last or last item (71%). For the associative lists, there were very few lures recalled and no pattern in output position was apparent.

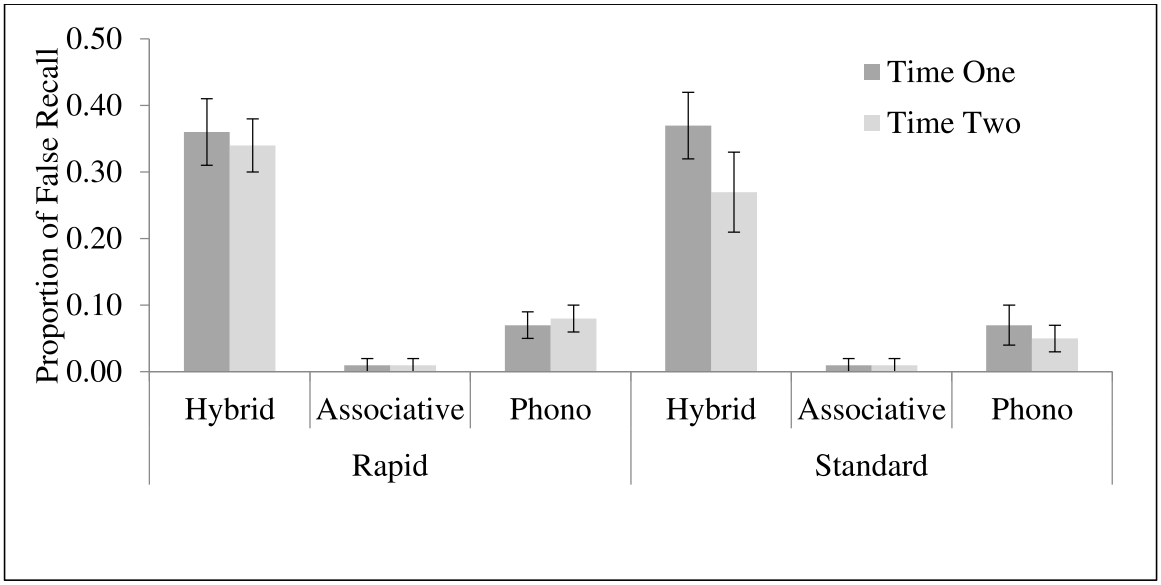

Figure 7. Experiment 3: Mean proportion of false recall as a function of presentation rate, list type, and time of test. Hybrid = hybrid lists; Associate = associatively related lists; Phono = phonologically similar lists; Rapid = rapid presentation rate; Standard = standard presentation rate. Error bars represent standard error of the mean. There was no delay between time one and time two.

8.2.5 Discussion.

Although there was a mean trend for greater serial recall on associative lists, correct recall was not significantly impacted by list type. These results are consistent with Experiment 2 of this project but not Experiment 1, highlighting the variation in results reported by other studies with regard to list type and true memory (e.g., Watson et al., 2003; Watson et al., 2001). In line with predictions, however, recall was facilitated by standard presentation and task repetition. These results align with previous research that has considered the role of rapid presentation rates (e.g., Coltheart & Langdon, 1998) and delayed repetition (e.g., Page et al., 2013) on serial recall performance. Similar to the outcomes of Experiment 1, post-hoc investigations established that repetition improved recall irrespective of presentation rate. This suggests that connections between episodic, semantic/associative and phonological information can be established very quickly. Indeed, previous research has found that individuals can make sense of information even when it is presented at very fast rates (e.g., Forster, 1970; Laughery & Pinkus, 1968; Potter, 1976; Potter 1984 cited in Potter, 1993; Potter & Levy, 1969). In contrast to the first experiment however, standard presentation rate only assisted recall at time two in the current study. At time one, memory performance was comparable across both rates, whist at time two, a clear advantage for standard presentation rate emerged. In short, the standard rate was associated with a greater level of improvement with repetition. The advantage for standard presentation rate with repetition makes sense given that items presented at slower rates may benefit from additional encoding, leading to stronger connections that persist over time as proposed in long-term false memory studies (McDermott & Watson, 2001; Smith & Kimball, 2012). Presumably these rates have a greater potential to benefit from repetition. It is unclear, however, why participants did not recall more items during the standard versus rapid rates at time one as established in Experiment 1. Upon inspection of the main effects of Experiments 1, 2 and 3, the overall influence of presentation rate on true memory in the current study appeared to be much weaker than the earlier experiments.

In line with expectations, the false memory effect was observed under immediate serial recall conditions. Moreover, false recall was greatest for hybrid lists, and lures were typically output towards the end of the list, particularly during task conditions in which episodic context would have seemingly been weaker. These results reinforce the notion that episodic binding strength impacts the likelihood of false recall (Tehan, 2010). In contrast to predictions and the findings of Experiments 1 and 2, however, false memory was not significantly impacted by presentation rate even though there was a mean trend for more lures to be recalled during rapid presentation. Importantly, there are other studies that look at presentation rate and the false memory effect, and report a somewhat consistent pattern between true recall and presentation speed but observe more variation with regard to false recall (e.g., McDermott & Watson, 2001). While slower presentation rates can provide more opportunity to encode the to-be-remembered information, they are also presumed to enhance the processes of spreading activation (McDermott & Watson, 2001; Smith & Kimball, 2012). Moreover, slower rates are only presumed to be beneficial if one can make use of the opportunity for rehearsal, otherwise these rates introduce longer retention intervals which may actually be detrimental to performance (Bhatarah et al., 2009; Tan & Ward, 2008). In contrast, if items are presented too quickly and participants are unable to make sense of the information, there will be limited opportunities for spreading activation to occur and limited chance for the lists to be consciously processed (McDermott & Watson, 2001; Smith & Kimball, 2012). At these rates, both true and false recall will be relatively low. In light of the presentation rate effects in this experiment, it appears that even the standard rate may have been too fast for participants to be able to benefit from any additional encoding time, at least with respect to reducing false memories.

Also in contrast to the results of Experiment 1, whilst there was a mean trend for false recall to decrease across time one and time two, task repetition did not significantly impact false recall. Importantly, there have been other studies that have failed to find a reduction in false memory with repetition (e.g., Mintzer & Griffiths, 2001; Schacter et al., 1998; Shiffrin et al., 1995; Tussing & Greene, 1997, 1999, Experiments 1 – 4). Some propose that unless participants can make use of the repeated study opportunities, they may continue to make the same errors across repetitions. It appears that such a notion may assist in explaining the current experiment's findings. Indeed, participants were not informed that they would be repeating the same test so perhaps they were not able to benefit from the chance for repetition. In Experiment 1, participants may have been able to use self-checks to evaluate their own performance because the two tasks were repeated in immediate succession. Conversely, in the current experiment, the 15-minute delay may have meant that participants were unable to conduct such a comparison. That is, the information from time one may not have been as readily available at time two (or representations were not as strongly activated) because there was a greater period of time before repetition. Thus, participants may not have been aware that they had made a false error. In this case, it could be that repetition just reinforced the same (false) errors made during the first attempt at the task. Indeed, repetition has been found to increase the likelihood that the same response is repeated, irrespective of whether that response is actually correct (Couture et al., 2008). Whilst the majority of participants in the current study reported that they were aware the tasks were identical, this question was asked after both tasks had been completed. It is unclear how far into the test participants realised that they were completing an identical task.

Of course it is important to note that true memory did improve significantly with repetition even with the delay. This would suggest that participants were able to make at least some use of the second study/test phase in order to enhance their performance. These results are important to consider in light of the suggestion that a delay leads to a reduction in activation and reinforcement of false recall. The leading frameworks of long-term false memory tend to agree that conditions that enhance the processing of information specific to the list will reduce the false memory effect (Burns, 2006). In turn, this is thought to help one distinguish between the list items and their critical lures. According to this view, for task repetition to be effective it must help strengthen the representations of the presented items. Based on Oberauer's (2002) account of the embedded components model, representations within the activated region of short-term memory remain active even after they have served their primary purpose (e.g., the list has been recalled). The results of this thesis were in line with this proposition.

To clarify, when participants were re-administered the same test immediately following their first attempt in Experiment 1, they were able to simultaneously improve their serial recall and reduce the number of false errors that were made. On the basis of the embedded components model (Oberauer, 2002) it could be proposed that re-exposure to the list strengthened the existing activated representations in memory, helping participants to differentiate between list items and their critical lures at recall. Presumably, both list items and their lures remained activated in memory, but the presentation of the list served to reinforce the list items, meaning that these items were more strongly represented in memory (as opposed to the lures) and thus more likely to be recalled. In a sense, the second (repeated) presentation of the list may have acted as a prompt or cue to these already activated representations in memory. In Experiment 3, when a 15-minute break was introduced, participants still improved in correct recall after repetition. This suggests that the representations of the first task were still activated to some degree and that re-presenting the list worked to reinforce the list items and assist in their output. Interestingly, however, repetition in this experiment did not reduce false recall. That is, repetition was no longer able to help with differentiating between the activated list and their related lures. This suggests that there is at least some temporal basis to these activations and that eventually they do subside.

8.3 Experiment 4

8.3.1 Aims.

In order to further understand the relationship between immediate serial recall and task repetition in the context of semantic/associative, phonological and episodic binding, an additional experiment was conducted. The aim of this experiment was to extend on the findings of the previous studies by introducing a 60-minute delay before task repetition in order to see whether serial recall would still improve (and false recall would remain stable) if a longer delay was employed.

8.3.2 Predictions.

8.3.2.1 Serial recall. Based on the findings of the previous studies, list type was not expected to demonstrate any observable impact on true memory. It was also anticipated that serial recall would be significantly greater during standard as opposed to rapid presentation, in line with the general trends of the earlier experiments. It was unclear, however, whether serial recall would improve with repetition after a 60-minute delay, although previous research (e.g., Page et al., 2013) suggests that it would.

8.3.2.2 False recall. Based on the earlier experiments, it was expected that a false memory effect would be observed. It was predicted that lures would be falsely recalled during lists that were associatively related *or* phonologically similar. Hybrid lists, however, were predicted to exhibit the highest levels of false recall. Whilst presentation rate did impact false recall during Experiments 1 and 2, in Experiment 3 there was no significant main effect for rate. Based on these findings, it was uncertain if there would be any significant difference in false recall between rapid versus standard presentation in the current experiment. With respect to repetition, it was expected that there would be no effect on false recall, similar to the findings of Experiment 3. That is, it was presumed that there would be no significant difference in false recall at time one versus time two when a 60-minute delay before repetition was introduced.

8.3.3 Method.

8.3.3.1 Participants. Twenty voluntary participants aged between 18 and 53 years (*M* = 28.15, *SD* = 10.14) were recruited for this study. Appendix I displays additional information gathered from the background questionnaire. As a prerequisite, no participants who had taken part in any of the earlier experiments were able to take part in this study. All participants completed the same recall task twice. Participants were not informed prior to completing the study that they would be repeating the same task, although at the end of the experiment only one participant indicated that they were unaware of the repetition.

8.3.3.2 Design. The present study included a 2 x 2 x 4 repeated measures factorial design. The within-subjects independent variables were: (1) presentation rate (one word per 1000 milliseconds vs. one word per 250 milliseconds); (2) time of test (time one vs. time two) (3) list type (hybrid vs. associative vs. phonological vs. unrelated/dissimilar lists). The dependent variables were (1) serial (correct-in-position) recall score and (2) false recall score.

8.3.3.3 Materials. The same immediate serial recall tasks that were created and employed in the earlier studies were used in this experiment. The task given to participant one in the previous experiments was also given to participant one in the present study, and so on.

8.3.3.4 Procedure. The procedure for this experiment was similar to that of the earlier studies. Participants were informed that they would be completing two recall tasks and that they would complete the second task 60 minutes after the first task. Upon completing the first task, participants were given the designated break before taking part in the same task again. Tasks were counterbalanced across participants so that 10 participants completed task one twice and 10 participants completed task two twice. Testing was undertaken across two individual face-to-face sessions. Each session was approximately 20 – 30 minutes in duration and the two sessions were divided by a 60-minute break. Participants were able to leave the room during this break although participants were not encouraged to discuss details of the task. No other controls were put in place regarding what the participant did during this delay period. Once participants had completed both tasks they were given the chance to debrief with the researcher.

8.3.4 Results.

8.3.4.1 Data scoring. Serial recall scores were calculated as the proportion of items correctly recalled in the exact order of presentation. False recall scores were measured as the proportion of critical lures recalled.

8.3.4.2 Data screening. Data screening was undertaken in line with the procedures of the previous studies. The results of this screening revealed that all scores were within the expected range and there was no missing data, multicollinearity or singularity. In the false recall data there were two univariate outliers and four multivariate outliers ($p < .001$) and deviations in normality (skew and kurtosis). Transformation attempts were for the most part ineffective in reducing the outliers or improving normality. In keeping with the other experiments, the decision was made not to transform the current data set.

8.3.4.3 Descriptive statistics. Table 7 represents the means and standard deviations for correct serial recall scores across each condition. Performance at a mean level appeared to improve from time one to time two and appeared to be superior for standard versus rapid presentation. Serial recall seemed to be comparable across list types during rapid presentation. During standard presentation and particularly at time two, a clear advantage for the associative lists appeared to emerge.

Table 7

Experiment 4: Mean Proportion (and Standard Deviations) of Serial Recall as a Function of Presentation Rate, List Type, and Time of Test

Rate	List	Time One	Time Two
		M (SD)	*M (SD)*
Rapid	Hybrid	.35 (.12)	.40 (.12)
	Associative	.35 (.11)	.41 (.14)
	Phonological	.36 (.13)	.44 (.12)
	Unrelated/Dissimilar	.36 (.13).	.44 (.14)
Standard	Hybrid	.42 (.14)	.54 (.16)
	Associative	.49 (.15)	.61 (.19)
	Phonological	.44 (.16)	.52 (.18)
	Unrelated/Dissimilar	.43 (.17)	.56 (.18)

Note. There was a 60-minute delay between time one and time two.

The frequency of lure recall is displayed in Table 8. The pattern of lure recall seemed somewhat comparable across task repetition and presentation rate. Most of the lures appeared to have been output during the hybrid lists.

Table 8

Experiment 4: Number of Participants Recalling a Critical Lure

Rate	List	Number of Lures Recalled				
		0	1	2	3	4
	Time One					
Rapid	Hybrid		7	7	5	1
	Associative	19	1			
	Phonological	10	8	2		
Standard	Hybrid	2	8	8	1	1
	Associative	19	1			
	Phonological	17	3			
	Time Two					
Rapid	Hybrid	4	6	6	3	1
	Associative	18	1		1	
	Phonological	16	3		1	
Standard	Hybrid	5	8	5	1	1
	Associative	17	3			
	Phonological	16	3	1		

Note. There was a 60-minute delay between time one and time two. No lures were recalled during the unrelated/dissimilar lists because the items in these lists were not related to a shared critical lure.

8.3.4.4 Inferential statistics.

8.3.4.4.1 Serial recall. Serial recall performance at time one was highly correlated ($p < .001$) with performance at time two ($r = .901$). This meant that participants who performed well on the task at time one appeared to also perform well after a 60-minute delay. A 2 (time of test) x 2 (presentation rate) x 4 (list type) repeated measures factorial ANOVA was performed on the correct-in-position data. There was a significant main effect for presentation rate, $F\ (1, 19) = 13.52$, $MSE = .08$, $p = .002$, $\eta_p^2 = .42$ and time of test, $F\ (1, 19) = 52.68$, $MSE = .01$, $p < .001$, $\eta_p^2 = .74$. Serial recall was significantly greater for items presented at the standard ($M = .50$, $SE = .03$) versus rapid rate ($M = .39$, $SE = .02$) and at time two ($M = .49$, $SE = .03$) as opposed to time one ($M = .40$, $SE = .02$). There was no significant main effect, however, for list type, $F\ (3, 57) = 1.70$, $MSE = .01$, $p = .177$, $\eta_p^2 = .08$. There was no significant difference in serial recall between hybrid lists ($M = .43$, $SE = .02$), associative lists ($M = .47$, $SE = .02$), phonological lists ($M = .44$, S$E = .02$), or unrelated/dissimilar lists ($M = .45$, $SE = .03$).

The 2-way interaction between list type and presentation rate was significant, $F\ (3, 57) = 3.06$, $MSE = .01$, $p =.035$, $\eta_p^2 = .14$. Simple main effects revealed that during standard presentation, serial recall was significantly greater on associative ($M = .55$, S$E = .03$) versus phonological lists ($M = .48$, S$E = .04$), $t(19) = 2.70$, $p = .014$, $r = .54$, and on associative versus hybrid lists ($M = .48$, S$E = .03$), $t(19) = 2.84$, $p = .011$, $r = .56$. During rapid presentation there was no significant difference in serial recall on associative ($M = .38$, S$E = .02$) versus phonological lists ($M = .40$, S$E = .03$), $t(19) = 0.90$, $p = .380$, $r = .21$, or on associative versus hybrid lists ($M = .38$, S$E = .03$), $t(19) = 0.28$, $p = .781$, $r = .07$.

The 2-way interaction between presentation rate and time of test was significant, *F* (1, 19) = 7.68, *MSE* = .01, *p* = .012, $\eta_p^2 = .29$. Simple main effects revealed that the effects of repetition were evident during both presentation rates. During standard presentation, performance was significantly greater at time two (*M* = .56, *SE* = .04) compared to time one (*M* = .45, *SE* = .03), *t*(19) = 6.90, *p* < .001, *r* = .68. Similarly, during rapid presentation, performance was significantly greater at time two (*M* = .42, *SE* = .02) compared to time one (*M* = .36, *SE* = .02), *t*(19) = 5.32, *p* < .001, *r* = .68. Simple main effects also revealed that the effects of presentation rate persisted irrespective of time of test. That is, serial recall was superior during standard compared to rapid presentation at both time one, *t*(19) = 2.71, *p* = .014, *r* = .54, and time two, *t*(19) = 4.54, *p* < .001, *r* = .68. No other interactions were significant.

8.3.4.4.2 False recall. A 2 (time of test) x 2 (presentation rate) x 3 (list type) repeated measures factorial ANOVA was performed on the false recall data. Figure 8 depicts the results of this analysis. There was a significant main effect for list type, *F* (2, 38) = 71.74, *MSE* = .03, *p* < .001, $\eta_p^2 = .79$. Post-hoc comparisons indicated that significantly more lures were recalled during the hybrid lists (*M* = .32, *SE* = .03) compared to the associative lists (*M* = .02, *SE* = .01), *t*(19) = 10.34, *p* < .001, *r* = .68, and phonological lists (*M* = .07, *SE* = .02), *t*(19) = 8.29, *p* < .001, *r* = .68. These two latter conditions also differed significantly from each other, *t*(19) = 2.17, *p* = .043, *r* = .46. There was no significant main effect, however, for presentation rate, *F* (1, 19) = 3.77, *MSE* = .03, *p* = .067, $\eta_p^2 = .17$ or time of test, *F* (1, 19) = 2.65, *MSE* = .01, *p* = .120, $\eta_p^2 = .12$. There was no significant difference in the number of lures recalled during the standard (*M* = .11, *SE* = .02) versus rapid rate (*M* = .16, *SE* = .02) or at time one (*M* = .15, *SE* = .02) compared to time two (*M* = .12, *SE* = .02). No interactions were significant.

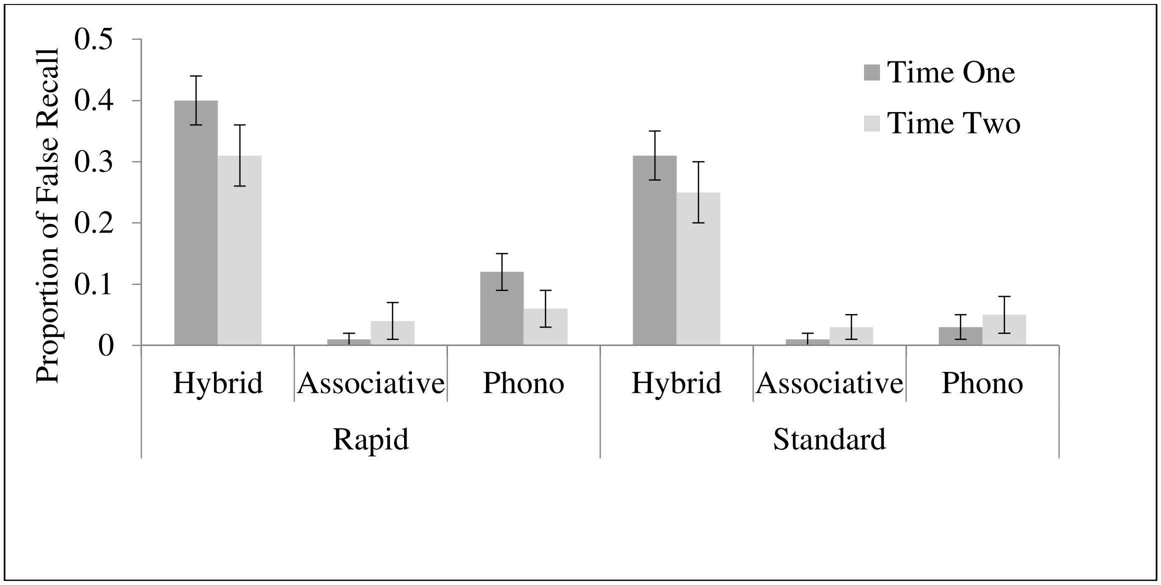

Figure 8. Experiment 4: Mean proportion of false recall as a function of presentation rate, list type, and time of test. Hybrid = hybrid lists; Associate = associatively related lists; Phono = phonologically similar lists; Rapid = rapid presentation rate; Standard = standard presentation rate. Error bars represent standard error of the mean. There was a 60-minute delay between time one and time two.

The lures' output positions as a function of the number of items that were recalled were analysed. In the hybrid lists, lures were often output as the second last or last list item (64%). This was observed during rapid presentation at time one (77%) and time two (61%), and to a lesser extent during the standard rate at time one (58%) and time two (50%). For the phonological lists, the majority of lures were also recalled as the second last or last item

(62%). There were only a limited number of lures recalled in the associative lists and thus there appeared to be no pattern in output position.

8.3.5 Discussion.

In line with predictions and the general results of the earlier studies (Experiments 2 and 3), the main effect for list type was not significant. Interestingly, however, post-hoc comparisons found that a significant difference between lists did occur during standard presentation. More specifically, when items were presented at a standard rate, associative lists were better recalled than phonological lists or hybrid lists. At this presentation speed, participants were able to make use of associations to aid serial recall. In contrast, rapid presentation appeared to be too quick for an advantage for associative lists to emerge. Although this specific interaction was not reported in the earlier studies, the finding that associative lists were better recalled than other list types is consistent with the results of Experiment 1 and the general mean trends of the earlier studies.

As expected, standard presentation and task repetition significantly enhanced true memory performance. These results are consistent with the general findings of the previous studies in this thesis and other serial recall investigations exploring delayed repetition (Page et al., 2013) and rapid presentation (Coltheart & Langdon, 1998). It is noteworthy that task repetition improved serial recall even with a 60-minute delay between time one and time two. This suggests that the processes that benefit repetition persist for some time, much longer than the typical constraints of short-term memory (Baddeley, 2000). In addition, simple main effects determined that the effects of repetition persisted across both rates of presentation in line with the earlier experiments (Experiments 1 and 3). It seemed that participants were able to create connections between multiple types of representations quite rapidly and then utilise these connections to improve performance over time. Post-hoc analyses also established that the influence of presentation rate persevered regardless of time of test, consistent with the outcomes of Experiment 1. Although this interaction was not observed in the most recent experiment (Experiment 3), in general, the studies of this project so far support the robustness of presentation rate on immediate serial recall.

As expected, the false memory effect was observed during immediate serial recall, supporting the findings of the earlier studies in this project and other false memory investigations examining short-term/working memory tasks (Atkins & Reuter-Lorenz, 2008, 2011; Coane et al., 2007; Flegal et al., 2010; MacDuffie et al., 2012; Tehan, 2010; Tehan et al., 2004). As anticipated, lures tended to be recalled towards the end of the list and false recall was higher for hybrid lists compared to other list types. These results provide strength to the results of the previous experiments in this thesis and to other studies that emphasise the effects of hybrid lists (e.g., Watson et al., 2003) and episodic bindings (Tehan, 2010) on the false memory effect. The predictions around presentation rate and task repetition were also supported. These variables did not significantly influence false recall as expected, although there was a mean trend for lures to increase with rapid presentation and decrease between time one and time two. These findings support the results of Experiment 3, and ultimately provide strength to the earlier experiments in this research project. In short, presentation rate appears to have varying effects on false memory and task repetition is more likely to reduce false recall when it is administered immediately (Experiment 1) as opposed to after a delay (Experiments 3 and 4).

8.4 Comparison of Experiments 1, 3, and 4

The experiments conducted in this thesis so far have shown some similarities in their findings, although they also exhibit several interesting differences. Essentially, the previous experiments (with the exception of Experiment 2) utilised the same methodology and followed the same analysis of results. The only difference in the procedure between these studies was in the amount of time before task repetition. To discern whether this variable (i.e., delay before repetition) was having any significant impact on serial or false recall, a series of additional analyses were undertaken. For the purposes of this investigation, however, it was decided that only data relating to the standard presentation rate would be included. This was based on the finding that presentation rate appeared to have fluctuating effects on performance across experiments. Although it is important to acknowledge the limitations in inspecting the data before deciding what data to analyse, the inclusion of only the standard presentation rate data was also undertaken to provide a more direct comparison of the results to other studies that have employed standard task conditions (i.e., Tehan, 2010).

8.4.1 Aims.

The aim was to analyse any between-group differences (i.e., no delay vs. 15-minute delay vs. 60-minute delay) that may have emerged during the previous experiments. Whilst all groups in Experiments 1, 3, and 4 improved significantly in serial recall with repetition, the intention was to establish whether there were any differences amongst groups in serial recall at time one and at time two. For false memory, the results in Experiments 1, 3, and 4 were more varied; however the purpose of the current analysis was to determine if there were any differences between groups in false recall at time one and at time two.

8.4.2 Predictions.

8.4.2.1 Serial recall. Based on the results of the individual studies, it was presumed that serial recall would be significantly greater at time two versus time one. It was unclear, however, whether there would be a significant difference between groups. Given that the same tasks were employed across all experiments, it was assumed that performance would be somewhat comparable across each group, at least at time one.

8.4.2.2 False recall. In accordance with the earlier studies it was expected that false recall would be reduced at time two versus time one, however it was not certain whether this difference would reach significance. It was also unclear whether there would be a significant difference between groups, although similar to the propositions made for serial recall, it was predicted that false recall should be similar across groups at least at time one.

8.4.3 Results.

The data sets from Experiments 1, 3 and 4 were combined in order to compare the results across the three studies during standard presentation. Data pertaining to Experiment 2 was excluded from the investigation. This was because the focus of the analysis was specifically on repetition of the same task, while Experiment 2 had involved two different tasks. To investigate between-group differences in serial recall, performance was collapsed over lists so that a total proportionate serial recall score was calculated for time one and for time two. To investigate between-group differences in false recall, only the hybrid lists were examined. This was because false recall in the hybrid lists had consistently decreased with repetition at a mean level across experiments and had constantly exhibited high levels of false recall. Conversely, the associative and phonological lists had shown varying patterns of lure recall with repetition, and had produced relatively low proportions of false recall on all conditions and all experiments in comparison.

A series of independent t-tests were run to compare the key variables collected via the background questionnaire between groups. This included age, sex, education level, first language, level of English, state of physical health and sleep over the last month and on the day of testing, and current level of alertness and stress. Awareness of task repetition was also included in this analysis. The Bonferroni correction for familywise error was applied and a new alpha of $p < .005$ was applied. Using this new alpha level, there were no significant differences on any of the self-report variables between the three groups. Please see Appendix N for further details of these analyses.

8.4.3.1 Descriptive statistics. The mean proportion of serial recall and false recall scores across time of test and delay between tasks are displayed in Table 9. At a mean level, serial recall appeared to improve from time one to time two across all groups, although the general performance of the 15-minute delay group appeared to be lower than the other two groups. There was also a trend for false recall on hybrid lists to decline from time one to time two across all groups and the performance of each group on this measure appeared to be comparable.

Table 9

Comparison of Experiments 1, 3, and 4: Mean Proportion (and Standard Deviations) of Serial Recall and False Recall as a Function of Time of Test and Delay Between Tests

	No Delay		15-minute Delay		60-minute Delay	
	Time		Time		Time	
	One	Two	One	Two	One	Two
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Serial Recall	.45 (.15)	.58 (.18)	.36 (.15)	.44 (.17)	.45 (.12)	.56 (.16)
False Recall	.34 (.20)	.25 (.21)	.37 (.24)	.27 (.25)	.31 (.19)	.25 (.21)

Note. Serial recall = total proportion of serial recall across all lists; False recall = total proportion of lure recall on hybrid lists.

8.4.3.2 Inferential statistics.

8.4.3.2.1 Serial recall. The following analysis employed a 2 x 3 mixed ANOVA design. The within-subjects independent variable was time of test (time one vs. time two). The between-subjects independent variable was delay between tasks (no delay vs. 15-minute delay vs. 60-minute delay). The dependent variable was total serial recall score, measured as the total mean proportion of items recalled in correct position within any list. There was a significant main effect for time of test, F (1, 57) = 101.59, MSE = .02, $p < .001$, $\eta_p^2 = .64$. Serial recall was significantly greater at time two (M = .53, SE = .02) as opposed to time one (M = .42, SE = .02). There was also a significant main effect for delay, F (2, 57) = 3.42, MSE

= .18, *p* = .040, η_p^2 = .11. Post-hoc comparisons indicated that serial recall was significantly greater for participants who did not receive a delay between time one and time two (*M* = .51, *SE* = .04) compared to those who were given a 15-minute break between the two tasks (*M* = .40, *SE* = .04), *t*(38) = 2.26, *p* = .029, *r* = .34. Participants who were required to wait 60 minutes between the two tasks also performed significantly better (*M* = .50, *SE* = .03) than the 15-minute delay group, *t*(38) = 2.19, *p* = .034, *r* = .34. There was no significant difference, however, between the no delay group and the 60-minute delay group, *t*(38) = 0.22, *p* = .825, *r* = .04. The interaction between time of test and delay was not significant.

8.4.3.2.2 False recall. The following analysis employed a 2 x 3 mixed ANOVA design. The within-subjects independent variable was time of test (time one vs. time two). The between-subjects independent variable was delay between tasks (no delay vs. 15-minute delay vs. 60-minute delay). The dependent variable was total false recall score on hybrid lists, calculated as the mean total proportion of false lures recalled on these lists. There was a significant main effect for time of test, *F* (1, 57) = 8.23, *MSE* = .03, *p* = .006, η_p^2 = .13indicating that false recall was significantly greater at time one (*M* = .34, *SE* = .03) compared to time two (*M* = .26, *SE* = .03). The main effect for delay was not significant, *F* (2, 57) = 0.24, *MSE* = .07, *p* = .789, η_p^2 = .01. There was no significant difference in the total number of lures recalled by the no delay group (*M* = .30, *SE* = .04), the 15-minute delay group (*M* = .32, *SE* = .04) or the 60-minute delay group (*M* = .28, *SE* = .04) in the hybrid lists. The interaction between time of test and delay was not significant.

8.4.4 Discussion.

In contrast to expectations, the group who were given a 15-minute delay recalled less items in position than the other two groups who did not differ from one another. This was in opposition to the prospect that all groups would perform somewhat comparably given the same methodology was used throughout all three studies. It is unclear why this sample performed worse on this task than the other two groups. All samples were recruited through similar processes and there were no significant differences in the demographics of the three groups. The majority of participants within each sample were female and had completed post-secondary education. They reported English to be their first language and rated their level of English as excellent. Most participants within each of the three groups indicated being in a good or very good state of physical health on the day of testing and over the previous month as well as having good, very good, or excellent levels of sleep over the previous month. In addition, the majority of participants from each of the three samples reported average or low levels of stress and alertness on the day of testing, and most participants reported being aware of task repetition.

The only notable difference between the three samples pertained to their age. At a mean level, Experiment 3 had the youngest participants particularly in contrast to the participants of Experiment 1. Nonetheless, when the revised alpha level was applied (in order to control for familywise error) this apparent difference was not significant. Indeed, it is important to remember that despite some variation in performances between experiments, serial recall improved significantly with task repetition across all groups. Moreover, there was no significant difference in the level of improvement between each group such that all three samples appeared to benefit in comparable ways from re-exposure to the list. This suggests that the strengthening of item-context bindings with repetition has pervasive effects in improving serial recall.

With respect to false memory, false recall significantly decreased with repetition and there was no significant difference in lure recall between groups. These outcomes support other investigations that have successfully used task repetition to reduce false memories (e.g., McDermott, 1996). These findings initially appear to contradict the results of the previous studies because Experiments 3 and 4 failed to establish a significant decrease in false recall after repetition. Critically, however, only hybrid lists were examined in the current analysis. These lists had consistently produced greater levels of false recall when compared to other list types. Arguably then, these lists had the most to gain from repetition. It is also important to remember that only the trials that were presented at a standard rate were included in the current analysis. Given that presentation rate had varying degrees of impact on false memory in the previous experiments, removing this variable provided a means to examine the impact of repetition on an otherwise standard employment of the immediate serial recall task. Whilst the increased level of power associated with combining the three studies is also important to acknowledge, these findings nonetheless provide an interesting contribution to the previous results of this thesis. Overall the results suggest that repeating a standard serial recall task comprised of hybrid lists can simultaneously enhance correct recall and decrease false recall. Before providing a general discussion of these results in the context of current short-term memory frameworks, however, the subsequent chapter outlines the final two experiments of this thesis.

Chapter Nine: Experiments 5 and 6

9.1 Experiment 5

The experiments so far have been limited to healthy participants from the general population typically in early adulthood. In order to expand the findings to another population, a group of older participants were also included in this thesis. Older adults have been examined in the study of the embedded components model and the role of intrusions in short-term memory (e.g., Oberauer, 2005a, 2005b) as well as in the context of psycholinguistic theories. In addition, ageing was considered another way to manipulate episodic binding. Together, this formed the basis for including a study of older participants in this thesis.

9.1.1 Aims.

The purpose of this study was to investigate the influence of normal ageing on representation binding in verbal short-term recall. The aim was to use the same methodology employed in the earlier experiments in this project with the inclusion of a group of healthy older adults. More precisely, the intention was to use the same procedure as Experiment 1 of this thesis. The replication of the procedure in Experiment 1 was chosen because it had shown the strongest effects with regard to task repetition, list type and presentation rate across both serial and false recall. Hence it was considered to provide a good basis for investigation.

9.1.2 Predictions.

9.1.2.1 Serial recall. Semantic processes were thought to be somewhat preserved during ageing (Burk & Shaft, 2008). For instance, older adults can make use of semantic relationships to aid recall (e.g., Badham et al., 2012; Golomb et al., 2008) and the semantic similarity effect has been shown to persist into old age (Madden, 1992). Therefore, it was expected that older adults would be able to make use of the associative lists in this experiment to assist their serial recall, although it was unclear whether these effects would reach significance. This was because list type had not significantly impacted the younger adults' serial recall in many of the earlier experiments of this thesis.

Older adults frequently experience impairments in episodic memory, and theories of ageing have often emphasised declines in both accuracy and speed of processing (e.g., Craik & Rose, 2012). Moreover, it has been noted that older adults can have problems in creating temporary episodic bindings during recall tasks (e.g., Golomb et al., 2008; Oberauer, 2002). Thus, manipulating the episodic context further with respect to presentation rate was expected to have detrimental impacts on serial recall. In particular, it was anticipated that serial recall would be significantly greater during standard versus rapid presentation rate. In contrast, the true memory of older adults has been shown to benefit from repetition (Light & Albertson, 1989; Light & Singh, 1987; Rastle & Burke, 1996). Consequently, it was expected that serial recall would be significantly greater at time two versus time one.

9.1.2.2 False recall. There is limited research looking at the performance of older adults on the DRM false memory task (Deese, 1959; Roediger & McDermott, 1995) in the short-term domain. Long-term false memory studies, however, have reported that older adults are vulnerable to the false memory effect (e.g., Balota, Cortese, et al., 1999; Norman & Schacter, 1997; Tun et al., 1998; Watson et al., 2001). This has been reported using pure semantic/associative lists, pure phonological lists, and hybrid associative-phonemic lists (e.g., Budson et al., 2003; Watson et al., 2001). In addition, intrusion studies (Oberauer, 2005a, 2005b) suggest that older adults have difficulty rejecting irrelevant information from memory and difficulty discounting activations that persist within the long-term network. Therefore it was expected that the false memory effect would be observed in this experiment. It was presumed that false lures would be recalled during both associative lists and phonological lists but that false memories would be most pronounced during hybrid lists.

It was also expected that lures would be recalled most often under conditions that weakened temporary episodic bindings (Oberauer, 2002), particularly because the older participants were expected to already have impairments in the ability to create these associations. Thus, it was expected that false recall would be significantly greater during rapid presentation rate versus standard presentation rate. It was also anticipated that older adults would tend to recall the lures in later serial positions when episodic information was reduced. In regards to task repetition, there was not expected to be any significant difference in false recall at time one and time two. This prediction was based on previous research, which has established that older adults are not able to make use of repetition to reduce false memories (e.g., Benjamin, 2001; Jacoby, 1999; Kensinger & Schacter, 1999; Light et al., 2004; Skinner & Fernandes, 2009).

9.1.3 Method.

9.1.3.1 Participants. Twenty voluntary participants aged between 72 and 92 years (*M* = 78.90, *SD* = 5.83) were gathered from the Australian community. To take part in the current study and the subsequent study (Experiment 6), participants had to be aged 65 years or above. This criteria was consistent with the definition of the Australian ageing population as outlined by the Australian Bureau of Statistics (2014) and the Australian Department of Health and Ageing (2007). Participants were recruited via word-of-mouth and through direct contact with specific organisations (e.g., retirement villages, independent living services). Initial contact with these organisations was generally made via an e-mail from the researcher. For those organisations that expressed interest in being involved in the study, advertisement to potential participants was then made in the form of a flyer (please see Appendix O) and/or through a brief verbal presentation provided by the researcher, depending on the preferences of each organisation. The Australian Catholic University's National School of Psychology Research Participation System was also utilised during the recruitment process (please see Appendix P for a copy of this invitation). Undergraduate psychology students were offered partial course credit (1.5%) for participation. Those students who did not meet the age requirements for this study but who were able to arrange for a volunteer to participate on their behalf were also eligible to receive the course credit. Members of the public did not receive any incentive to take part. As a prerequisite of the study, all participants were required to have no diagnosed cognitive impairments at time of testing. Furthermore, all participants within the sample reported that they had not been diagnosed with any current psychiatric disorders.

Before testing on this experiment and the subsequent experiment (Experiment 6), participants were given a background questionnaire (please see Appendix Q) that was similar to the questionnaire used in the project's earlier studies. Information gained from this questionnaire is described in Appendix R. Participants were also provided with an information letter and were required to sign a consent form prior to completing this study (and Experiment 6). These documents were slightly modified versions of the materials used in the previous studies (please see Appendix S and T). The inclusion of this study and the subsequent study (Experiment 6) was approved by the Australian Catholic University's Human Research Ethics Committee (reference number: 2013-81Q). Please see Appendix U for a copy of this approval. All participants completed the same task twice with no breaks between the two tasks. Participants were not notified prior to testing that they were repeating an identical task only two participants reported being unaware that there had been any repetition between the two tasks.

9.1.3.2 Design. The same 2 x 2 x 4 repeated measures design employed in Experiments 1 – 4 was also utilised in the current study. The within-subjects independent variables were: (1) presentation rate (one word per 1000 milliseconds vs. one word per 250 milliseconds); (2) time of test (time one vs. time two); (3) list type (hybrid vs. associative vs. phonological vs. unrelated/dissimilar lists). The dependent variables were (1) serial (correct-in-position) recall score and (2) false recall score.

9.1.3.3 Materials. The immediate serial recall tasks that were based on the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) and administered in the earlier studies were again employed in the present experiment. The task that had previously been given to participant one from the younger adults sample in Experiment 1 was also given to participant one from the older adults sample in the current study and so forth. The presentation rates employed in the task (i.e., one word per 1000 milliseconds vs. one word per 250 milliseconds) were faster than those used in other studies of false memory and ageing (e.g., McCabe & Smith, 2002; Watson et al., 2004). Nonetheless, these speeds were chosen in order to remain consistent with the earlier experiments of this thesis. Moreover, the aim of this project was to examine a “standard” rate of presentation (as opposed to a “slow” rate of presentation) and one word per 1000 milliseconds was considered to be in line with these requirements.

9.1.3.4 Procedure. The aim was to replicate the same procedure as discussed and administered in Experiment 1. After reading the information letter and completing the consent form and background questionnaire, participants were given an instruction sheet (please see Appendix M). Seated in front of a laptop screen, participants completed four practice trials followed by a set of 40 six-word trials. Presentation rate was again presented in a block, counterbalanced across the sample. After completing the first recall task, participants immediately completed the same recall task again. Consistent with the procedure of the earlier studies, 10 participants completed task one twice and 10 participants completed task two twice. Testing took place in an individual face-to-face session lasting approximately 60 minutes in duration.

9.1.4 Results.

9.1.4.1 Data scoring. Data in each condition was measured using (1) serial and (2) false recall scoring.

9.1.4.2 Data screening. Data was checked for calculation and input accuracy, missing data, outliers, deviations from normality, homogeneity, and multicollinearity/singularity (Field, 2005; Tabachnick & Fidell, 2007). No missing data, multicollinearity or singularity was found, and all scores were within the expected range. There was one univariate outlier in the false recall data that appeared to be removed from the distribution, although there were no significant multivariate outliers ($p < .001$). There was some evidence of deviations in normality (skew and kurtosis) and homogeneity in the false recall data. The attempts at transforming the data made in the earlier studies were also made here, however, these efforts were mostly unsuccessful in reducing outliers or improving the violations of normality or homogeneity. Again, in line with the previous experiments in this project, the decision was made not to transform the data set.

9.1.4.3 Descriptive statistics. Table 10 represents the means and standard deviations for correct serial recall scores across each condition. At a mean level, participants tended to improve in serial recall from time one to time two and performance was somewhat better during standard presentation as opposed to rapid presentation. There did not seem to be any consistent pattern to the recall across list types.

Table 10

Experiment 5: Mean Proportion (and Standard Deviations) of Serial Recall as a Function of Presentation Rate, List Type, and Time of Test

		Time One	Time Two
Rate	List	M (SD)	M (SD)
Rapid	Hybrid	.25 (.12)	.27 (.15)
	Associative	.26 (.13)	.30 (.15)
	Phonological	.25 (.13)	.26 (.13)
	Unrelated/Dissimilar	.28 (.16)	.28 (.16)
Standard	Hybrid	.25 (.10)	.29 (.12)
	Associative	.29 (.13)	.33 (.15)
	Phonological	.25 (.13)	.34 (.14)
	Unrelated/Dissimilar	.29 (.14)	.26 (.16)

Note. There was no delay between time one and time two.

Table 11 displays the frequency of lure recall by participants. The pattern of lure recall looked similar across time of test and most lures were recalled during hybrid lists.

Table 11

Experiment 5: Number of Participants Recalling a Critical Lure

		Number of Lures Recalled					
Rate	List	0	1	2	3	4	5
	Time One						
Rapid	Hybrid	2	4	8	3	2	1
	Associative	17	3				
	Phonological	14	4	2			
Standard	Hybrid	4	5	5	5	1	
	Associative	15	3	2			
	Phonological	13	7				
	Time Two						
Rapid	Hybrid	2	7	6	4	1	
	Associative	18	2				
	Phonological	12	8				
Standard	Hybrid	2	5	11	1	1	
	Associative	17	2		1		
	Phonological	17	2	1			

Note. There was no delay between time one and time two. No lures were recalled during the unrelated/dissimilar lists because the items in these lists were not related to a shared critical lure.

9.1.4.4 Inferential statistics.

9.1.4.4.1 Serial recall. Serial recall performance at time one was highly correlated ($p < .001$) with performance at time two ($r = .963$). Those who performed well at time one appeared to also perform well at time two. A 2 (time of test) x 2 (presentation rate) x 4 (list type) repeated measures factorial ANOVA was performed on the correct-in-position data. There was a significant main effect for time of test, F (1, 19) = 9.16, $MSE = .01$, $p = .007$, $\eta_p^2 = .33$. Serial recall was significantly greater at time two ($M = .29$, $SE = .03$) as opposed to time one ($M = .26$, $SE = .02$). There was no significant main effect, however, for list type, F (3, 57) = 1.19, $MSE = .01$, $p = .322$, $\eta_p^2 = .06$ or presentation rate, F (1, 19) = 1.13, $MSE = .03$, $p = .301$, $\eta_p^2 = .06$. Serial recall was not significantly different between hybrid lists ($M = .27$, $SE = .02$), associative lists ($M = .29$, $SE = .03$), phonological lists ($M = .27$, S$E = .02$) and unrelated/dissimilar lists ($M = .28$, $SE = .03$), or for items presented at standard ($M = .29$, $SE = .02$) versus rapid presentation ($M = .27$, $SE = .03$). No interactions were significant.

9.1.4.4.2 False recall. A 2 (time of test) x 2 (presentation rate) x 3 (list type) repeated measures factorial ANOVA was performed on the false recall data. These results are presented in Figure 9. There was a significant main effect for list type, F (2, 38) = 90.96, $MSE = .03$, $p < .001$, $\eta_p^2 = .83$. Post-hoc comparisons indicated that significantly more lures were recalled during the hybrid lists ($M = .36$, $SE = .03$) compared to the associative lists ($M = .04$, $SE = .01$), $t(19) = 11.85$, $p < .001$, $r = .68$, and phonological lists ($M = .07$, $SE = .01$), $t(19) = 9.04$, $p < .001$, $r = .68$. These two latter conditions did not differ significantly from each other, $t(19) = 1.45$, $p = .163$, $r = .32$. There was no significant main effect for presentation rate, F (1, 19) = 0.25, $MSE = .03$, $p =.623$, $\eta_p^2 = .13$ or time of test, F (1, 19) = 1.54, $MSE = .02$, $p = .230$, $\eta_p^2 = .08$. There was no significant difference in the number of lures recalled during the standard rate (*M* = .15, *SE* = .02) versus rapid rate (*M* = .16, *SE* = .02) or at time one (*M* = .17, *SE* = .02) compared to time two (*M* = .15, *SE* = .02). No interactions were significant.

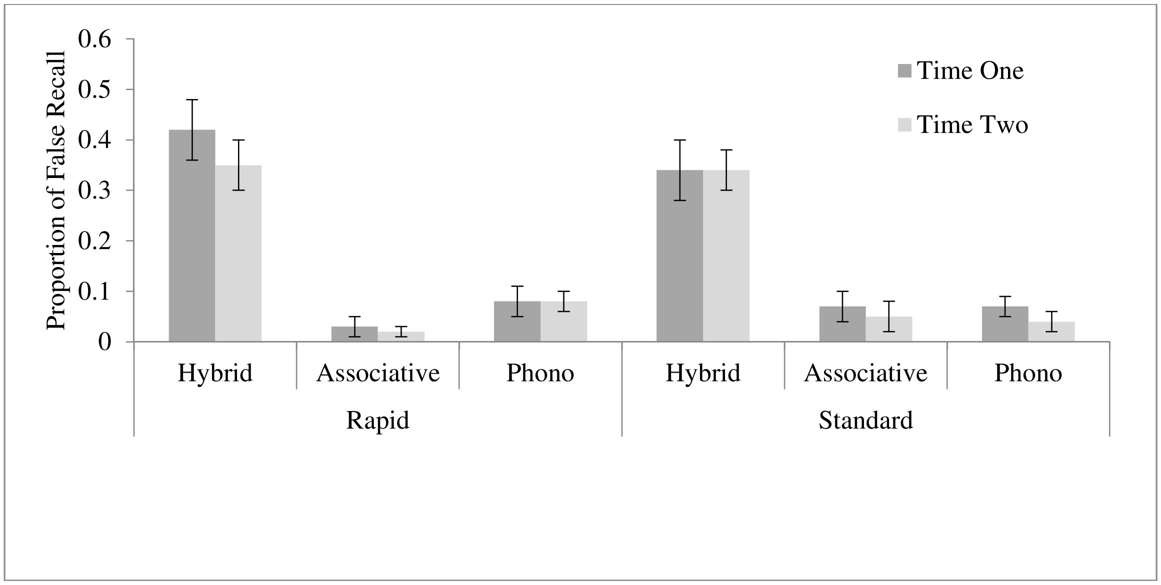

Figure 9. Experiment 5: Mean proportion of false recall as a function of presentation rate, list type, and time of test. Hybrid = hybrid lists; Associate = associatively related lists; Phono = phonologically similar lists; Rapid = rapid presentation rate; Standard = standard presentation rate. Error bars represent standard error of the mean. There was no delay between time one and time two.

The output position of the lure as a function of the number of items that were recalled were analysed. For the hybrid lists, the majority of lures were recalled as the second last or last list item (70%). This was apparent for rapid presentation at time one (86%) and time two (67%), and for standard presentation at time one (68%) and time two (56%). Likewise, lures were typically recalled as the second last or last item for the phonological lists (69%) and associative lists (84%).

9.1.5 Discussion.

In this experiment list type did not significantly influence serial recall, although at a mean level there was a slight advantage for associative lists over the other list types. These findings were in contrast to the results of Experiment 1 in which serial recall on associative lists did reach significance. Nevertheless, the current findings are somewhat consistent with the results reported in the other studies of this project. Taken together, the manipulation of list type in this thesis does not seem to consistently impact correct recall, and this finding is also reflected in the wider false memory literature (e.g., Watson et al., 2003; Watson et al., 2001). Interestingly, there was no significant difference in serial recall between the rapid versus standard presentation rates, although there was a slight mean trend for greater recall during the standard rate. This was in contrast to expectations and the results of the earlier studies in this thesis where younger adults were able to recall significantly more words in position when items were presented at a standard rate. The older adults in the current experiment appeared to have difficulty with the task irrespective of the rate of presentation. This could suggest that the standard rate was not slow enough to assist these participants in encoding (or rehearsing) the to-be-recalled information. Indeed, normal ageing has been associated with general cognitive slowing (Salthouse, 1996). Moreover, declines in attentional control mean that older adults have to use more effort/resources than younger adults when performing cognitive tasks (Craik & Rose, 2012). This may explain why older adults found the recall task difficult irrespective of the presentation speed.

With respect to task repetition, serial recall was significantly greater at time two versus time one in line with predictions, suggesting that participants were able to make use of repetition to improve their performance. The transmission deficit theory proposes that connections within the language/memory network are weakened by the ageing process (Burke & MacKay, 1997; Burke & Shaft, 2008) but can be strengthened through repetition (Rastle & Burke, 1996). The findings of this study fit well with these suggestions and are consistent with previous research that has reported the benefits of repetition on memory irrespective of age (Light & Albertson, 1989; Light & Singh, 1987; Rastle & Burke, 1996). Older adults have been shown to make use of repetition to improve their true memory successfully (e.g., Henkel, 2007, 2008; Kensinger & Schacter, 1999; Light et al., 2004; Watson et al., 2004), and the current experiment provides support for this view. It is important to note, however, that an underlying assumption of this explanation is that the change in serial recall across time one and time two was due to repetition of the same task as opposed to simply the results of general practice. This assumption was made on the basis of the earlier project studies' findings (Experiment 2) whereby serial recall did not improve when two different recall tasks were employed.

In regards to false memory, the false memory effect was observed in the current experiment as expected. False lures were recalled during associative lists and phonological lists but were significantly more likely during hybrid lists. Also in line with predictions, false lures tended to be recalled towards the end of the lists. In combination, these results align with the project's earlier studies and with the general trends in the wider false memory literature (e.g., Atkins & Reuter-Lorenz, 2008, 2011; Coane et al., 2007; Flegal et al., 2010; MacDuffie et al., 2012; Roediger, Balota et al., 2001; Tehan, 2010; Watson et al., 2001; Watson et al., 2003). Moreover, the findings of the current experiment extend the observations made in these previous studies to both the immediate serial recall task and a healthy ageing population.

In contrast to expectations, there was no significant difference in false recall between the standard and rapid presentation rates. However, this was not necessarily surprising given that the participants in this study had also been unable to make use of the slower presentation to aid their true memory. Again, these results could indicate that the standard presentation rate was too fast for the older adults to be able to benefit from this speed. Long-term false memory investigations, which have explored the relationship between age and presentation rate, have shown that presentation speed can have varying effects on older versus younger adults depending on the specific rates employed. For instance, Watson et al. (2004) established that when lists were presented at one word per 2000 or 4000 milliseconds, presentation rate manipulations impacted the false recall of older adults but did not affect the performance of younger participants. Conversely, by presenting lists at one word per 1250 or 2500 milliseconds, McCabe and Smith (2002) demonstrated that changes in presentation rate effected the false recognition of younger but not older individuals. The current experiment supports the idea that different presentation speeds will impact the false recall of older and younger adults in different ways, extending this finding to short-term memory tasks.

With regard to task repetition, there was no significant difference in false recall between time one and time two as anticipated. Unlike the younger participants in Experiment 1, the older sample in the current study were unable to attenuate the false memory effect with immediate repetition. These findings align with the patterns in long-term false memory literature. Older participations can often improve their true memory with repetition (e.g., Henkel, 2007, 2008; Kensinger & Schacter, 1999; Light et al., 2004), yet are unable to reduce their false memory (Benjamin, 2001; Jacoby, 1999; Kensinger & Schacter, 1999; Light et al., 2004; Skinner & Fernandes, 2009). This may be in part because of age-related declines in attentional resources making it difficult for older adults to apply monitoring processes at time of encoding (Benjamin, 2001; Skinner & Fernandes, 2009). Indeed, whilst both list and lure representations can be strengthened with repetition, if participants are unable to monitor the source of the activated lures (i.e., spreading activation rather than list presentation), re-exposure to a list is unlikely to assist in reducing false memories.

9.2 Experiment 6

9.2.1 Aims.

To provide further understanding regarding the role of ageing on correct and false immediate serial recall, a final experiment was run. The aim of this experiment was to provide additional comparisons to the earlier studies in this thesis by using a sample of older adults and a 15-minute delay before repetition. More precisely, the intention was to replicate Experiment 3 within the context of healthy ageing. Experiment 3 was chosen because it involved a short delay between repetitions. It was thought to be worthwhile investigating how older adults would perform on the recall task when a delay between time one and time two was introduced.

9.2.2 Predictions.

9.2.2.1 Serial recall. Based on the results of Experiment 5 it was presumed that serial recall would not be significantly impacted by presentation rate or list type. Task repetition was, however, expected to aid serial recall such that performance would improve significantly between time one and time two.

9.2.2.2 False recall. It was anticipated that a false memory effect would be evident in the current experiment across associative lists and phonological lists with significantly more lures being recalled during hybrid lists. There was not predicted to be any difference in false recall during standard versus rapid presentation rates or during time one versus time two, in light of the findings of Experiment 5.

9.2.3 Method.

9.2.3.1 Participants. Twenty voluntary participants aged between 67 and 86 years (*M* = 72.80, *SD* = 4.95) were recruited from the wider Australian community using the same processes and perquisites as described in Experiment 5. One of the participants initially included in the sample was later found to not meet minimum age requirements. A suitable replacement for this participant was found to ensure consistency with the previous experiment. No participants who had taken part in Experiment 5 were able to take part in Experiment 6. Information derived from the questionnaire is presented in Appendix R. All participants completed the same task twice with a 15-minute break between each task. Participants were not informed they were repeating an identical task until after testing was completed, only two participants) reported being unaware that there had been any repetition between the two tasks.

9.2.3.2 Design. The same 2 x 2 x 4 repeated measures factorial design, independent and dependent variables utilised in the earlier experiments was employed in Experiment 6.

9.2.3.3 Materials. The immediate serial recall tasks used in the project's earlier experiments were again employed in this study. For consistency, the task that had been given to participant one in Experiment 1 was also given to participant one of this sample and so forth.

9.2.3.4 Procedure. The same procedure utilised in Experiment 2 was employed in this study.

9.2.4 Results.

9.2.4.1 Data scoring. Serial and false recall scoring were used to measure data within each condition.

9.2.4.2 Data screening. Serial recall and false recall data were screened for accuracy of calculations and input, missing data, outliers, deviations from normality, homogeneity, and multicollinearity/singularity (Field, 2005; Tabachnick & Fidell, 2007). Screening revealed no missing data, univariate outliers, multivariate outliers ($p < .001$), homogeneity, multicollinearity or singularity, and all scores were within expected range. Deviations in normality (skew and kurtosis) in the false recall data were noted but transformations attempted were for the most part unsuccessful in reducing outliers or assisting with normality. Consistent with the earlier studies, the decision was made not to transform the data set.

9.2.4.3 Descriptive statistics. The means and standard deviations for correct serial recall scores across each condition are displayed in Table 12. Serial recall seemed to improve across time of test and appeared to be greater for standard (versus rapid) presentation. However, performance appeared to be generally comparable across list type.

Table 12

Experiment 6: Mean Proportion (and Standard Deviations) of Serial Recall as a Function of Presentation Rate, List Type, and Time of Test

Rate	List	Time One M (SD)	Time Two M (SD)
Rapid	Hybrid	.29 (.12)	.31 (.13)
	Associative	.28 (.11)	.32 (.16)
	Phonological	.27 (.13)	.30 (.12)
	Unrelated/Dissimilar	.28 (.08)	.30 (.14)
Standard	Hybrid	.30 (.12)	.32 (.16)
	Associative	.33 (.17)	.38 (.20)
	Phonological	.29 (.12)	.31 (.12)
	Unrelated/Dissimilar	.31 (.14)	.37 (.18)

Note. There was a 15-minute delay between time one and time two.

Table 13 displays the frequency of lure recall by participants. Patterns of false recall appeared relatively consistent across time one and time two, and lures were most often recalled on hybrid lists.

Table 13

Experiment 6: Number of Participants Recalling a Critical Lure

		Number of Lures Recalled				
Rate	List	0	1	2	3	4
		Time One				
Rapid	Hybrid	3	4	5	7	1
	Associative	19	1			
	Phonological	12	5	3		
Standard	Hybrid		6	9	3	2
	Associative	17	3			
	Phonological	14	4	1	1	
		Time Two				
Rapid	Hybrid	1	8	5	3	3
	Associative	16	4			
	Phonological	16	2	1	1	
Standard	Hybrid	3	6	4	6	1
	Associative	18	2			
	Phonological	13	4	3		

Note. There was a 15-minute delay between time one and time two. No lures were recalled during the unrelated/dissimilar lists because the items in these lists were not related to a shared critical lure.

9.2.4.4 Inferential statistics.

9.2.4.4.1 Serial recall. Serial recall performance on time one was highly correlated ($p < .001$) with performance on time two ($r = .916$) suggesting that those who performed well at time one also performed well at time two. A 2 (time of test) x 2 (presentation rate) x 4 (list type) repeated measures factorial ANOVA was performed on the correct-in-position data. There was a significant main effect for time of test, F (1, 19) = 6.00, $MSE = .01$, $p = .024$, $\eta_p^2 = .24$. Serial recall was significantly greater at time two ($M = .32$, $SE = .03$) as opposed to time one ($M = .29$, $SE = .02$). There was no significant main effect, however, for presentation rate, F (1, 19) = 2.14, $MSE = .04$, $p = .160$, $\eta_p^2 = .10$ or list type, F (3, 57) = 1.45, $MSE = .01$, $p = .238$, $\eta_p^2 = .07$. There was no significant difference in serial recall for items presented at the standard ($M = .32$, $SE = .03$) versus the rapid rate ($M = .29$, $SE = .02$) or between hybrid lists ($M = .30$, $SE = .02$), associative lists ($M = .33$, $SE = .03$), phonological lists ($M = .29$, $SE = .02$) and unrelated/dissimilar lists ($M = .32$, $SE = .03$). No interactions were significant.

9.2.4.4.2 False recall. A 2 (time of test) x 2 (presentation rate) x 3 (list type) repeated measures factorial ANOVA was performed on the false recall data. Figure 10 provides the results of this analysis. There was a significant main effect for list type, F (2, 38) = 94.65, $MSE = .03$, $p < .001$, $\eta_p^2 = .83$. Post-hoc comparisons showed that significantly more lures were recalled during the hybrid lists ($M = .39$, $SE = .03$) compared to the associative lists ($M = .03$, $SE = .01$), $t(19) = 11.79$, $p < .001$, $r = .68$, and the phonological lists ($M = .09$, $SE = .02$), $t(19) = 9.46$, $p < .001$, $r = .68$. These two latter conditions also differed significantly from each other, $t(19) = 3.23$, $p = .004$, $r = .61$. There was no significant main effect, however, for presentation rate, F (1, 19) = 0.00, $MSE = .03$, $p = 1.00$, $\eta_p^2 = .00$ or time of test, F (1, 19) = 0.19, $MSE = .03$, $p = .668$, $\eta_p^2 = .01$. That is, there was no significant difference in the number of lures recalled at time one (*M* = .17, *SE* = .02) versus time two (*M* = .16, *SE* = .02) or during standard (*M* = .17, *SE* = .02) compared to rapid presentation (*M* = .17, *SE* = .02). No interactions were significant.

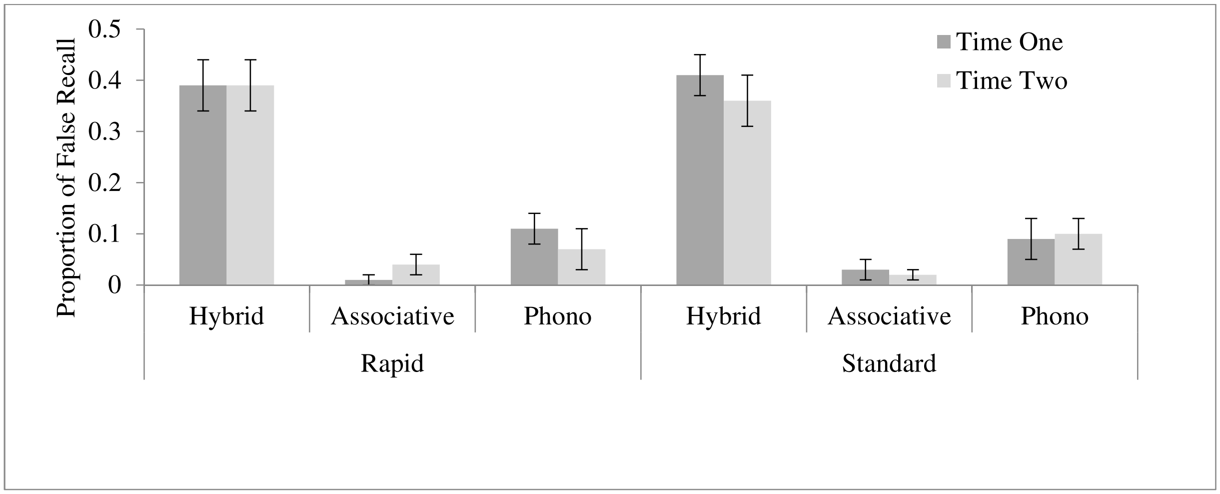

Figure 10. Experiment 6: Mean proportion of false recall as a function of presentation rate, list type, and time of test. Hybrid = hybrid lists; Associate = associatively related lists; Phono = phonologically similar lists; Rapid = rapid presentation rate; Standard = standard presentation rate. Error bars represent standard error of the mean. There was a 15-minute delay between time one and time two.

The lures' output positions as a function of the number of items that were recalled were examined. In the hybrid lists, lures were often output as the second last or last list item (57%). This was observed during rapid presentation at time one (51%) and time two (62%), and during the standard rate at time one (58%) and time two (57%). Lures were also commonly recalled as the second last or last item for both the phonological lists (68%) and associative lists (82%).

9.2.5 Discussion.

In general, Experiment 6 provides strong support for the results of Experiment 5. As expected, list type did not have any significant bearing on serial recall, although there was a slight mean trend for better recall on the associative lists versus the other list types. These results provide further strength to the earlier experiments of this project. Taken together, the manipulation of list type in this thesis had negligible impacts on true memory. Also in line with predictions, serial recall was not significantly influenced by presentation rate, although there was a minor mean trend for better recall during standard versus rapid presentation rate. These findings are consistent with the results of Experiment 5 and support the view that the standard rate employed in the current project was too fast for the older participants to benefit from any additional encoding (or rehearsal) opportunities potentially available. Again, this observation provides strength to theories of cognitive ageing that propose decreased processing speed (Salthouse, 1996) and/or attentional control may impact the memory performance of older adults (Craik & Rose, 2012). In addition, participants were able to significantly improve their performance with repetition as expected. These results are in line with the outcomes of Experiment 5 and the notion that repetition can improve the memory of older individuals (e.g., Henkel, 2007, 2008; Kensinger & Schacter, 1999; Light & Albertson, 1989; Light & Singh, 1987; Light et al., 2004; Watson et al., 2004).

For false recall, this experiment was successful in demonstrating the false memory effect, once more emphasising the underlying assumption that false memories are evident over the short-term (Atkins & Reuter-Lorenz, 2008, 2011; Coane et al., 2007; Flegal et al., 2010; MacDuffie et al., 2012; Tehan, 2010; Tehan et al., 2004). Consistent with long-term false memory research (e.g., Roediger, Balota et al., 2001; Watson et al., 2001; Watson et al., 2003), the superadditive effects of hybrid lists were also observed. Likewise, lures were often recalled as the last or second last item in the list as predicted, suggesting a link between episodic binding and false intrusions (Tehan, 2010). In regards to repetition and presentation rate, false recall was comparable at time one and time two, and during both standard and fast presentation speeds. These findings align with the results of Experiment 5 and previous studies that have reported an inability for older adults to reduce their false memories with repetition (Benjamin, 2001; Jacoby, 1999; Kensinger & Schacter, 1999; Light et al., 2004; Skinner & Fernandes, 2009) or with slower presentation rates (e.g., McCabe & Smith, 2002). Although ageing may play a role in these results, it is important to note that these findings are also consistent with the outcomes of Experiment 3 in which younger adults completed the same procedure as the one used in the current experiment.

9.3 Comparison of Experiments 5 and 6

9.3.1 Aims and rationale.

To compare the findings of Experiments 5 and 6, an additional analysis was undertaken. Once again, only data pertaining to the standard presentation rate was included in order to investigate the impact of repetition on “standard” task conditions. The purpose was to analyse between-group differences (i.e., no delay vs. 15-minute delay) that may have arisen between the samples from Experiments 5 and 6. In both experiments, serial recall improved significantly with repetition whilst false recall did not change; the aim, however, was to determine if there was any differences amongst groups in recall at time one and at time two.

9.3.2 Predictions.

9.3.2.1 Serial recall. Serial recall was expected to be significantly higher at time two compared to time one, in line with the results of the earlier investigations. Moreover, given that the same serial recall tasks were employed across both studies, it was expected that at least at time one there would be no significant difference in performance.

9.3.2.2 False recall. Based on the individual studies, it was predicted that there would be no significant difference in false recall between time one and time two. It was also expected that false recall would be comparable between groups, particularly for time one.

9.3.3 Results.

The data sets from Experiments 5 and 6 were combined to compare results across the two studies during standard presentation. Performance was collapsed over lists so that a total proportionate serial recall score was derived for time one and time two. In line with the earlier comparisons conducted in this thesis, only the hybrid lists were examined in this analysis because these lists had consistently produced high levels of false recall. A series of independent t-tests were run on the main variables collected through the background questionnaire to compare any between-group differences. These variables included age, sex, education level, first language, level of English, state of physical health and sleep over the last month and on the day of testing, and current level of alertness and stress. Awareness of task repetition was also included. The Bonferroni correction for familywise error was applied and a new alpha of $p < .005$ was applied. There was a significant difference in the age between groups, $t(38) = 3.57$, $p = .001$, $r = .50$ with the sample from Experiment 5 significantly older ($M = 78.9$, $SE = 1.3$) than the sample from Experiment 6 ($M = 72.8$, $SE = 1.1$), although both met the age requirements for the project. There was also a significant difference in the awareness of task repetition. Although only two participants in each experiment reported being unaware of the repetition, a greater number of participants from Experiment 6 (75%) compared to Experiment 5 (60%) were confident that the task at time one was the same as the task at time two, $t(38) = 3.57$, $p = .001$, $r = .50$. The remaining participants in these experiments reported being unsure although indicated that they had noticed some similarities between the tasks (e.g., some words or trials). There were no significant differences on any of the other self-report variables between the two groups. Please see Appendix V for further details of these analyses.

9.3.3.1 Descriptive statistics. The mean proportion of serial recall and false recall scores across time of test and delay between tasks are displayed in Table 14.

Table 14

Comparison of Experiments 5 and 6: Mean Proportion (and Standard Deviations) of Serial Recall and False Recall as a Function of Time of Test and Delay Between Tests

	No Delay		15-minute Delay	
	Time		Time	
	One	Two	One	Two
	M (SD)	M (SD)	M (SD)	M (SD)
Serial Recall	.27 (.10)	.31 (.12)	.31 (.11)	.34 (.14)
False Recall	.34 (.24)	.34 (.19)	.41 (.19)	.36 (.24)

Note. Serial recall = total proportion of serial recall across all lists; False recall = total proportion of lure recall on hybrid lists.

At a mean level, serial recall increased with repetition in both groups, although the general performance of the 15-minute delay group seemed to be slightly better than the no delay group. There was no change in false recall with repetition for the no delay group. For the 15-minute delay group, false recall appeared to decrease between time one and time two.

9.3.3.2 Inferential statistics.

9.3.3.2.1 Serial recall. A 2 x 2 mixed ANOVA design was employed. The within-subjects independent variable was time of test (time one vs. time two) and the between-subjects independent variable was delay between tasks (no delay vs. 15-minute delay). The dependent variable was total serial recall score, calculated as the total mean proportion of items recalled in correct position within any list. There was a significant main effect for time of test, F (1, 38) = 14.02, MSE = .002, p = .001, η_p^2 = .27. Serial recall was significantly greater at time two (M = .32, SE = .02) as opposed to time one (M = .29, SE = .02). There was no significant main effect for delay, F (1, 38) = 1.02, MSE = .03, p = .319, η_p^2 = .03. There was no significant difference in the serial recall of the no delay group (M = .29, SE = .02) versus the 15-minute delay group (M = .32, SE = .03). The interaction between time of test and delay was not significant.

9.3.3.2.2 False recall. A 2 x 2 mixed ANOVA design was used in the following analysis. The within-subjects independent variable was time of test (time one vs. time two) and the between-subjects independent variable was delay between tasks (no delay vs. 15-minute delay). The dependent variable was total false recall score on hybrid lists, measured as the mean total proportion of false lures recalled on these lists. There was no significant main effect for time of test, F (1, 38) = 0.33, MSE = .04, p = .568, η_p^2 = .01 or delay, F (1, 38) = 0.73, MSE = .06, p = .398, η_p^2 = .02. There was no significant difference in false recall at time one (*M* = .38, *SE* = .03) versus time two (*M* = .35, *SE* = .03) or by the no delay group (*M* = .34, *SE* = .04) versus the 15-minute delay group (*M* = .39, *SE* = .04) in the hybrid lists. The interaction between time of test and delay was not significant.

9.3.4 Discussion.

As expected, serial recall and false recall were comparable between groups. It is interesting to note nonetheless that the no delay group (Experiment 5) was significantly older than the 15-minute delay group (Experiment 6) even though both groups met the study's age requirements. It seems unlikely that this had any impact on the results (both groups were recruited through similar processes), although participants were significantly more likely to report being aware that the task at time one was the same as the task at time to if they were from Experiment 6. There is a possibility that the no delay group would have performed better if their mean age had been slightly younger. Importantly, there did not appear to be any other significant differences between groups. The majority of participants from both Experiments 5 and 6 were female and had completed post-secondary education. All participants reported English as their first language and most described their level of English as excellent or very good. State of physical health over the last month and on day of testing was most often reported as very good or good by both groups, and most participants rated their levels of stress and alertness on the day of testing as average or low. With regard to performance on the recall task, performance improved with repetition for both samples and there was no significant difference in the level of improvement between groups. Task repetition appeared to strengthen episodic binding and facilitate serial recall irrespective of whether repetition occurred in immediate succession or after a 15-minute delay. In regards to false memory, false recall for hybrid lists remained stable with repetition as predicted. There was also no significant difference between groups in the overall proportion of lures recalled.

Taken together, these results provide support to the individual experiments of this thesis (Experiments 5 and 6). They suggest that older adults can use repetition to improve correct recall without being able to take advantage of the re-exposure to reduce their false recall. While these outcomes are consistent with other false memory studies (e.g., Kensinger & Schacter, 1999; Light et al., 2004), they diverge from the performance of the younger samples in this project (Experiments 1, 3 and 4). The earlier study comparisons established a concurrent improvement in true memory and reduction in false memory with task repetition. Given these apparent differences, at this point it was considered most valuable to consider the current results in the context of the earlier studies.

9.4 Comparison of Experiments 1, 3, 5 and 6

9.4.1 Aims and rationale.

In order to compare any age-related differences in serial and false recall, Experiments 5 and 6 were compared to the earlier studies of this thesis. Once again, only those lists pertaining to the standard presentation rate were examined. The purpose was to analyse between-group differences between younger and older adults. That is, to see if there were any differences in the serial recall and false recall of younger and older adults, at time one and at time two.

9.4.2 Predictions.

9.4.2.1 Serial recall. Based on the notion that episodic memory declines with age (e.g., Craik & Rose, 2012), it was predicted that younger participants would recall significantly more items in position at both time one and time two compared to older adults. It was also expected, that serial recall would be significantly greater at time two compared to time one based on the results of the individual studies, irrespective of age.

9.4.2.2 False recall. Given that normal ageing is associated with increased vulnerability to false memories and difficulty in the rejection of intrusions (Oberauer, 2005a, 2005b), it was anticipated that older adults would recall significantly more lures than younger adults at both time one and time two. In line with the results of the individual experiments, it was expected that false recall would decrease with repetition for younger adults, but would remain stable for older participants.

9.4.3 Results.

The data sets from Experiments 1 and 5 were combined. The data sets from Experiments 3 and 6 were also combined. Performance was collapsed over lists so that a total proportionate serial recall score was derived for time one and time two. In line with the previous comparisons conducted in this thesis, only the hybrid lists were examined in this analysis. A series of independent t-tests were run on the main variables collected through the background questionnaire to compare any between-group differences. These variables included sex, education level, first language, level of English, state of physical health and sleep over the last month and on the day of testing, current level of alertness and stress, and awareness of task repetition. The Bonferroni correction for familywise error was applied and a new alpha of $p < .005$ was employed. There was a significant difference in the level of English, $t(38) = 3.42$, $p = .002$, $r = .49$ with the older adults in Experiment 5 reporting a poorer level of English ($M = 2.05$, $SE = .15$) than the younger adults in Experiment 1 ($M = 1.4$, $SE = .11$). There were no significant differences on any of the other self-report variables between these two groups or on any of the self-report variables between the older and younger adults in Experiments 2 and 6. Appendix V contains further details of these analyses.

9.4.3.1 Descriptive statistics. The mean proportion of serial recall and false recall scores across time of test, delay between tasks, and age are displayed in Table 15.

Table 15

Comparison of Experiments 1, 3, 5 and 6: Mean Proportion (and Standard Deviations) of Serial Recall and False Recall as a Function of Time of Test, Delay Between Tests, and Age

	No Delay		15-minute Delay	
	Time		Time	
	One	Two	One	Two
	M (SD)	M (SD)	M (SD)	M (SD)
Age	Serial Recall			
Younger	.45 (.15)	.58 (.18)	.36 (.15)	.44 (.17)
Older	.27 (.10)	.31 (.12)	.31 (.11)	.34 (.14)
	False Recall			
Younger	.34 (.20)	.25 (.21)	.37 (.24)	.27 (.25)
Older	.34 (.24)	.34 (.19)	.41 (.19)	.36 (.24)

Note. Serial recall = total proportion of serial recall across all lists; False recall = total proportion of lure recall on hybrid lists.

At a mean level, the younger participants seemed to perform better than the older adults and their serial recall seemed to improve to a greater extent with repetition. In general, the younger adults appeared to recall less lures than the older adults (with the exception of the no delay group at time one). False recall also appeared to decline to a greater extent with repetition for the younger compared to older participants.

9.4.3.2 Inferential statistics.

9.4.3.2.1 Serial recall. A 2 x 2 mixed ANOVA design was employed to compare the samples in Experiments 1 and 5. The within-subjects independent variable was time of test (time one vs. time two) and the between-subjects independent variable was age (younger adults vs. older adults). The dependent variable was total serial recall score, calculated as the total mean proportion of items recalled in correct position within any list during standard presentation. There was a significant main effect for time of test, F (1, 38) = 43.00, MSE = .003, $p < .001$, $\eta_p^2 = .53$ and age, F (1, 38) = 27.51, MSE = .04, $p < .001$, $\eta_p^2 = .42$. Serial recall was significantly greater at time two (M = .44, SE = .02) as opposed to time one (M = .36, SE = .02) and for younger (M = .51, SE = .03) versus older adults (M = .29, SE = .03). The interaction between time of test and age was significant, F (1, 38) = 14.82, MSE = .003, $p < .001$, $\eta_p^2 = .28$. Post-hoc analyses indicated that the younger adults performed significantly better than the older adults at time one, $t(38) = 4.26$, $p < .001$, $r = .57$ and at time two, $t(38) = 5.70$, $p < .001$, $r = .68$. Post-hoc analyses also revealed that the younger adults, $t(19) = 5.76$, $p < .001$, $r = .68$, and older adults, $t(19) = 3.16$, $p = .005$, $r = .60$, performed significantly better at time two as opposed to time one. Post-hoc analyses also determined that the level of improvement of the younger adults across time one to time two was significantly greater than the level of improvement by the older adults, $t(38) = 3.85$, $p < .001$, $r = .53$.

A 2 x 2 mixed ANOVA design was employed to compare the samples in Experiments 3 and 6. The within-subjects independent variable was time of test (time one vs. time two) and the between-subjects independent variable was age (younger adults vs. older adults). The dependent variable was total serial recall score, calculated as the total mean proportion of items recalled in correct position within any list. There was a significant main effect for time of test, F (1, 38) = 28.99, MSE = .003, p < .001, η_p^2 = .43. Serial recall was significantly greater at time two (M = .39, SE = .03) as opposed to time one (M = .33, SE = .02). There was no significant main effect, however, for age, F (1, 38) = 2.78, MSE = .04, p = .103, η_p^2 = .07. There was no significant difference in performance between the younger (M = .40, SE = .03) and older adults (M = .32, SE = .03). The interaction between time of test and age was significant, F (1, 38) = 5.35, MSE = .003, p = .026, η_p^2 = .12. Post-hoc tests established that there was no significant difference in serial recall between younger and older adults at time one, t(38) = 1.14, p = .261, r = .18. In contrast, the performance of younger adults was significantly better than the older adults at time two, t(38) = 2.04, p = .049, r = .31. Post-hoc tests also revealed that the younger adults, t(19) = 5.14, p < .001, r = .68, and older adults, t(19) = 2.32, p = .032, r = .48, performed significantly better at time two as opposed to time one. Finally, post-hoc analyses found that the younger adults' level of improvement across time one to time two was significantly greater than the level of improvement by the older adults, t(38) = 2.31, p = .026, r = .35.

9.4.3.2.2 False recall. A 2 x 2 mixed ANOVA design was used to contrast the samples in Experiments 1 and 5. The within-subjects independent variable was time of test (time one vs. time two) and the between-subjects independent variable was age (younger adults vs. older adults). The dependent variable was total false recall score on hybrid lists. There was no significant main effect for time of test, *F* (1, 38) = 1.4, *MSE* = .03, *p* = .244, η_p^2 = .04 or age, *F* (1, 38) = 0.68, *MSE* = .06, *p* = .416, η_p^2 = .02. There was no significant difference in the false recall at time one (*M* = .34, *SE* = .04) versus time two (*M* = .30, *SE* = .03) or by the younger (*M* = .30, *SE* = .04) versus older adults (*M* = .34, *SE* = .04) in the hybrid lists. The interaction between time of test and age was not significant.

A 2 x 2 mixed ANOVA design was used to contrast the samples in Experiments 3 and 6. The within-subjects independent variable was time of test (time one vs. time two) and the between-subjects independent variable was age (younger adults vs. older adults). The dependent variable was total false recall score on hybrid lists. There was no significant main effect for time of test, *F* (1, 38) = 2.79, *MSE* = .04, *p* = .103, η_p^2 = .07 or age, *F* (1, 38) = 1.32, *MSE* = .06, *p* = .258, η_p^2 = .03. There was no significant difference in the false recall at time one (*M* = .39, *SE* = .03) versus time two (*M* = .32, *SE* = .04) or by the younger (*M* = .32, *SE* = .04) versus older adults (*M* = .39, *SE* = .04). The interaction between time of test and age was not significant.

9.4.4 Discussion.

Regardless of age, participants who completed the serial recall task twice in immediate succession significantly improved their serial recall with repetition. The level of improvement, however, was significantly greater for the younger versus older adults, and the younger adults performed significantly better than the older adults at both time one and time two. Participants who were given a 15-minute delay also improved significantly with repetition, irrespective of age. Younger adults nevertheless produced a greater level of improvement, performing significantly better than the older adults after a 15-minute delay. In combination, these results are in line with predictions and consistent with previous research that has reported age-related declines in episodic memory (e.g., Craik & Rose, 2012), and specifically in immediate serial recall tasks (e.g., Golomb et al., 2008). These findings are also in line with research that suggests that although older adults can benefit from repetition, they do not experience as many of the benefits that younger adults do (Henkel, 2007, 2008).

Of course there is the possibility that other factors were also involved in differences between the project's serial recall of younger and older adults. In general, samples were comparable on reported levels of physical health, sleep, stress and alertness, and there was no significant difference in younger and older participants' awareness of task repetition. Interestingly, upon inspection of participant responses for education level, younger participants were much more likely to have completed year 12 or higher level of education when compared to the older participants. However, this was not that remarkable given that many of the younger samples were collected through undergraduate psychology classes. Critically, younger and older groups did not differ significantly on this variable. The only significant difference discovered between the samples pertained to level of English. More precisely, the younger participants of Experiment 1 reported significantly greater levels of English when compared to the older individuals of Experiment 5. Though whether this finding represents a true depiction of skills is beyond the scope of what was measured in this thesis. For instance, it could be argued that the older adults were just more conservative in their response to this question.

Another interesting finding was that while the younger participants exhibited greater serial recall after a 15-minute delay (i.e., at time two), there was no significant difference in serial recall between the younger and older adults at time one. It is worth remembering, however, that this particular group of younger adults had performed significantly worse than the other younger participants in this thesis. Hence, the group's lower performance in general may explain the lack of age differences observed at time one. These results emphasise, nonetheless, that not all studies identify age differences in short-term/working memory tasks. For instance, Neale and Tehan (2007) investigated short-term memory performance and semantic and phonological similarity effects in younger and older adults. Immediate serial recall tasks were employed and task difficulty was manipulated through retention interval, modality and list length. In Experiment 1, the serial recall of the younger participants was significantly greater than the older participants as predicted when semantic relatedness was manipulated. In Experiment 2, however, there were no differences in performance between groups when phonological similarity was examined. Moreover, none of the task difficulty variables were impacted by age across both experiments. Based on their findings, Neale and Tehan proposed that the processes underlying short-term memory performance were comparable across age groups and that any differences in short-term memory were due to age-related declines in the fidelity of the memory trace.

More recently, Baker, Tehan and Tehan (2012) considered age effects in relation to an item-order account in short-term memory using immediate serial recall tasks. These researchers predicted that older adults would use more resources during item identification, meaning that there would be less time/resources available for these participants to process order information when compared to younger adults. Similar to Neale and Tehan (2007, Experiment 2), however, in contrast to predictions, there was no significant effect of age when responses were scored based on forward serial recall. In response, Baker et al. proposed that the immediate serial recall task may not have been subtle enough to detect cognitive decline when compared to other more challenging tasks. Indeed, short-term memory tasks have been presumed to require less processing demands than other tasks, and this has been suggested to explain why age differences in these tasks might be less pronounced (Baker, Tehan, & Tehan, 2012; Bopp & Verhaeghen, 2005). In contrast, working memory tasks typically involve a high level of processing (Bopp & Verhaeghen, 2005) and are routinely associated with age-related impairments (although see Alloway & Alloway, 2013). Whilst immediate serial recall tasks may produce age-related differences in performance, these differences may not be as strong as those reported in other episodic tasks. This proposition is consistent with the results of the current thesis.

With respect to false memory effects, there was no significant difference in false recall between younger and older adults, nor were there any differences after repetition. This was in contrast to predictions and previous research that has found that normal ageing is associated with greater vulnerability to the DRM (Deese, 1959; Roediger & McDermott, 1995) false memory effect (Balota, Cortese, et al., 1999; Norman & Schacter, 1997; Tun et al., 1998; Watson et al., 2001) and to memory distortions more generally (Bartlett et al., 1991; Dywan & Jacoby, 1990; Koutstaal & Schacter, 1997; Loftus et al., 1993; Norman & Schacter, 1997; Schacter, Koutstaal et al., 1997). It is important to note, however, that not all long-term memory DRM investigations have found significant age differences on all measures of false memory (e.g., Balota, Cortese et al., 1999; Kensinger & Schacter, 1999; McCabe & Smith, 2002). Moreover, some propose that age-related impairments in false memory may not be as common as originally reported (Butler et al., 2004; Gallo & Roediger, 2003).

For example, Gallo and Roediger (2003) investigated the influence of ageing on false recognition. While younger adults had greater true memory than older adults, levels of false memory were comparable between groups. These researchers proposed that the processes of activation and monitoring appeared to remain intact for the older participants in their study, and this was presumed to play a role in why there were no age-related differences in false memory. Gallo and Roediger also speculated that because the younger adults had performed better than the older adults on true memory, these younger participants may have had other monitoring processes that were able to aid their true (but not false) memory.

Related to this point, it has been proposed that only certain samples of older adults may be more vulnerable to the false memory effect. Butler et al. (2004) looked at frontal lobe function and age-related differences in false recall using the DRM task (Deese, 1959; Roediger & McDermott, 1995). These researchers demonstrated that only older adults with low frontal lobe functioning exhibited higher false recall than younger adults. High frontal lobe functioning older adults instead performed comparably (in both true and false recall) to younger adults. Butler et al. suggested that their results supported the idea that age-related impairments in false memory were partly due to difficulties with control processes that were mediated by the frontal lobe. Indeed, these researchers proposed that the difference between the high and low performing older adults in their study was not the absence of decline associated with age but rather because the high performing group had been able to compensate for neurologically-based changes in function (Cabeza et al., 2002; Reuter-Lorenz, 2002). In short, the lack of age-related effects for false memory in the current thesis may highlight the need for more sensitive measures in selecting a population of older adults. It is essential to remember nonetheless that the aim of this project was to explore the impact of “healthy” ageing on serial and false recall. Arguably, the inclusion of an older adults sample experiencing frontal lobe dysfunction or cognitive impairments would have led to more pronounced age effects.

9.5 Chapter Summary

Experiments 5 and 6 supported the notion that interacting long-term semantic/associative and phonological networks could influence older adults' immediate serial recall in much the same ways as younger adults. The inclusion of older adults in these experiments was intended to further expand the findings of the earlier studies in this thesis. Older adults tended to report lower levels of serial recall, but were able to improve their performance when the task's episodic binding was strengthened via repetition. Conversely, false errors were comparable across age groups, suggesting that not all older adults experience increased vulnerability to false memories. In general, the results of Experiments 5 and 6 highlight the roles of semantic and episodic memory on verbal short-term memory supporting previous research and the earlier investigations in this project. The purpose of the next chapter was to provide a general discussion of these experiments in relation to the earlier studies of this thesis.

Chapter Ten: General Discussion

The primary aim of this thesis was to examine semantic/associative, phonological and episodic representations in verbal short-term memory. In particular, the intention was to look at the ways in which this information impacted correct and incorrect (false) memories on immediate serial recall tasks in order to contribute to current models of verbal short-term memory. It was hoped that by exploring this topic, the current project would provide support for the development of an integrative model that could sufficiently accommodate the effects of both semantic and episodic memory on short-term recall. In each experiment, the DRM false memory paradigm (Deese, 1959; Roediger & McDermott, 1995) formed the basis for investigating false memory.

Associative and phonological representations were studied by manipulating associative relatedness and phonological similarity of the presented lists. Lists were comprised of words that were either associates and/or phonologically related words of a non-presented critical item, or completely unrelated/dissimilar to any common lure. Episodic representations (i.e., episodic context) of the recall task were investigated via manipulating presentation rate and task repetition. The purpose of these manipulations was to consider how variations in strength and distinctiveness of temporary episodic bindings would impact true and false immediate serial recall, and the bindings of associative/semantic and phonological information. In Experiment 1, participants completed the same immediate serial recall task twice in immediate succession. In Experiment 2, participants undertook two different recall tasks, again in immediate succession. In Experiments 3 and 4, participants were administered the same recall task twice but with a 15-minute and 60-minute delay before repetition respectively. Across all experiments, half of the lists were presented at a (standard) rate of one word per 1000 milliseconds, and the other half of the lists were presented at a (rapid) rate of one word per 250 milliseconds. In Experiments 5 and 6, episodic context was further manipulated by examining the impact of healthy ageing on performance. Older participants were administered the same immediate serial recall task twice in immediate succession (Experiment 5) or after a 15-minute delay (Experiment 6).

10.1 Immediate Serial Recall Effects

10.1.1 Associative relatedness and phonological similarity.

A major principle underpinning this research project was that immediate serial recall depended on the strength of pre-existing item (associative/semantic and phonological) representations. This notion was in agreement with psycholinguistic models of verbal short-term memory (e.g., N. Martin & Gupta, 2004; R. C. Martin et al., 1999; Romani et al., 2008). Essentially, these models suggested that the activations of these representations would decrease over time whether through decay (e.g., N. Martin & Gupta, 2004) or interference (e.g., Romani et al., 2008). A related assumption of this thesis was that semantic/associative and phonological information was arranged in long-term networks that were connected via links of association (e.g., Luce & Pisoni, 1998; Nelson et al., 2013; Oberauer, 2002; Poirier et al., 2011; Poirier et al., 2015; Vitevitch, 2008; Vitevitch et al., 2012). Presumably, representations within this network communicate via a process of spreading activation (Collins & Loftus, 1975). More specifically, the presentation of one concept within a list is thought to activate its long-term representations and this activation can spread throughout the semantic/associative and phonological networks leading to the priming of related or similar items. This project supposed that the organisation of these networks would likely influence immediate serial recall such that the type of items contained within the list would impact performance on the task.

Inter-item associations (Stuart & Hulme, 2000) and associative relatedness have been found to enhance immediate serial recall (e.g., Tse, 2009; Tse et al., 2011). Some propose that this is because associates are activated not only through list presentation but also during the process of spreading activation, which in turn reinforce the connections within the network and strengthening the activations of the list over time (Nelson et al., 2013; Poirier et al., 2011). Presumably, this process provides meaningful information during encoding and helps to guide retrieval (Nelson et al., 2013; Poirier et al., 2011). Like the semantic/associative network, the phonemic network is thought to communicate via spreading activation, although phonological similarity has been found to be detrimental to short-term recall (Baddeley, 1966a, 1966b; Conrad, 1964; Conrad & Hull, 1964). Items in a phonologically similar sequence are likely to be activated during list presentation and also via connections to other list items within the network. Unlike associative lists whereby association is thought to aid meaning and retrieval, phonologically similar lists can increase confusion during recall, leading to difficulty in recalling the items in correct order (Luce & Pisoni, 1998; Vitevitch, 2008; Vitevitch et al., 2012). In short, serial recall is often enhanced by the presentation of associates but impaired by the presentation of phonologically similar lists.

Despite these suppositions, list type rarely had a significant impact on correct serial recall in the current project and there were several reasons why this may have been the case. For instance, the associative lists and phonological lists employed in the experiments of this thesis only contained three associates or three phonologically similar words of the critical lure. These items were interleaved between three other unrelated or dissimilar items. Typical investigations of associative relatedness or phonological similarity employ lists comprised *only* of associates or phonologically similar words. In a short-term immediate serial recall task this would generally involve a list of five or six related or similar items. Thus, participants may not have needed (or been able) to rely on relationships between list items during correct recall. Indeed, whilst list type did not typically reach significance, observations of the data at a mean level routinely found a recall advantage for associative lists. The effects of associative relatedness and phonological similarity may not have been strong enough to establish significant effects because of the list constructions in the study.

It is important to remember, however, that the purpose of arranging lists in the manner described was to manipulate associative-phonemic binding. That is, to explore how lists containing both items connected and unconnected to a critical non-presented lure would impact recall. Hence, items were chosen on the basis of their relationship to the critical lure. While this procedure was in line with the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) it did mean that list items were not necessarily the strongest associates or phonologically related to each other. To illustrate this point further, within a long-term network, the number of phonological neighbours of a target word that are also neighbours of one another is considered an important factor in memory performance and spreading activation, referred to as the clustering coefficient (Chan & Vitevitch, 2009, 2010; Vitevitch, 2008; Vitevitch et al., 2012; Vitevitch, Ercal, G., & Adagaria, 2011). Essentially, the clustering coefficient is different to the phonological neighbourhood frequency, which refers to the number of phonological neighbours that a target word possesses (e.g., Roodenrys et al., 2002). Chan and Vitevitch (2009, 2010) have proposed that words with low clustering coefficients have few phonological neighbours that are also neighbours of each other in the network. Hence, these words seemingly exist within phonological networks comprised of few interconnections. Consequently, when the target word is activated in these networks there are very few items that can also be activated via spreading activation. In contrast, words with high clustering coefficients are thought to have many phonological neighbours that are also related to each other. In turn, these words are thought to have highly interconnected networks of phonological similarity so that spreading activation within these networks activates many similar sounding items (Chan & Vitevitch, 2009, 2010). In this instance, there may be confusion as to what word(s) were actually presented, meaning that it takes longer to identify the original target word and that there is a greater chance of errors being made at recall. Investigations looking at clustering coefficients illustrate that correct serial recall depends not only on the relationship between the critical lure and the list item, but whether the list items are related to each other as well.

The results of the current project would suggest that the list items may not have been strong phonological neighbours or associates of each other. Hence, whilst individual list items may have activated the lure within long-term networks, they may not necessarily have re-activated other items within the list. Without this additional activation, the expected facilitation or interference of lists due to associative and phonemic relationships would be unlikely to occur. Indeed, long-term false memory studies have shown varying effects of list type on true memory. Some investigations have reported that associative lists produce significantly greater levels of true memory when compared to other lists (e.g., Watson et al., 2001) whilst others have observed no difference in true memory between list types (Watson et al., 2003). In this regard, the results of this thesis appear to fit in the wider findings of the literature.

These results do not necessarily mean that the project failed to demonstrate the binding of the semantic/associative and phonological network on correct recall. The semantic binding hypothesis has emphasised that semantic and phonological representations may combine to assist serial recall and actually reduce the potential for errors being made (Jefferies et al., 2006, 2008; Knott et al., 1997; Patterson et al., 1994). It could be argued that employing associative lists and phonological lists in the current project worked in a similar way. Having unrelated items interleaved between words that were phonologically similar to a lure may have helped to counteract the potential for any (phonological) similarity between these items to negatively affect serial recall. Likewise, having dissimilar items interleaved between associates of a lure may have attenuated any effects of associative relatedness. In this way, the results support the suggestion that serial recall depends on the combination of both semantic and phonemic list information, and that multiple representations in short-term memory can bind together to impact performance. This proposition is consistent with psycholinguistic models (e.g., N. Martin & Gupta, 2004) that have emphasised the interaction between semantic and phonemic representations in verbal short-term memory. It would be difficult to explain these ideas, however, within computational frameworks of immediate serial recall (e.g., Brown et al., 2007; Brown et al., 2000; Burgess & Hitch, 2006; Henson, 1998; Lewandowsky & Farrell, 2008; Page & Norris, 2009) because these models do not readily accommodate for the presence of multiple representations within the short-term system.

10.1.2 Presentation rate and task repetition.

Another major presumption underpinning this research project was that immediate serial recall depended on the strength and distinctiveness of temporary (episodic) item-context bindings, in line with contemporary short-term frameworks (e.g., Brown et al., 2007; Brown et al., 2000). In turn, it was anticipated that manipulating the presentation rate and task repetition would impact the episodic context, and this was consistently reported in this project. Throughout all experiments that involved younger adults (i.e., Experiments 1 – 4), the effect of presentation rate was confirmed such that serial recall was significantly greater during standard presentation as opposed to rapid presentation in line with predictions and previous research (e.g., Coltheart & Langdon, 1998). The effects of presentation rate are often discussed in relation to opportunities for rehearsal. From this perspective, participants may have had more opportunity to rehearse the list at the standard speed, which would have presumably outweighed the longer retention intervals associated with these rates (Bhatarah et al., 2009; Conrad & Hille, 1958; Tan & Ward, 2008). Also consistent with expectations, serial recall improved significantly between time one and time two across all investigations that involved repetition of the same task (i.e., Experiments 1, 3, 4, 5 and 6), and this was reported for both younger and older participants. This did not appear to just be the result of general practice at the recall task because in Experiment 2, when two different recall tasks were given, no improvement in serial recall occurred between time one and time two. In short, true memory increased with repetition but only during tasks in which the same lists (and same critical lures) were repeated.

It is also noteworthy that participants were never informed during any of the experiments that they would be repeating the same recall task. Whilst the majority of both younger and older adults reported retrospectively that they were aware the task at time two had been the same as task one, the fact that they were not told they would be repeating the test meant there should have been no need for participants to have to (consciously) remember the lists after initial recall. In turn, the repetition effects of this project seemed to have occurred through largely unconscious processes. These findings are consistent with other studies that report effects of Hebb repetition even when participants are not (consciously) aware of the repetition (e.g., Hebb, 1961; McKelvie, 1987).

In general, the results of this project appeared to fit well with computational models of immediate serial recall that have discussed the influence of presentation rate and repetition in the context of strengthening/weakening temporary episodic bindings. Models such as OSCAR (Brown et al., 2000) and SIMPLE (Brown et al., 2007) highlight the importance of considering the distinctiveness of each item-context association within a list. Items that are separated by greater temporal dimensions are thought to be associated with more distinct learning contexts. In the current project, presenting lists at faster rates arguably reduced the uniqueness of each list item's episodic binding (in relation to the other items in the list). Presumably, this would have made it difficult for participants to differentiate between the learning contexts of each item within the list, making it harder to ensure the correct order of output during retrieval. It is important to remember nonetheless, that these conclusions are based on the notion of timing effects on serial recall tasks. Other studies propose that timing only has a small (if any) impact on serial recall performance (Lewandowsky et al., 2006) Regardless, the results of the current thesis can also be interpreted within the assumptions of the primacy model (Page & Norris, 1998, 2009). This account presumes that the longer that representations of an item are active, the easier those items are to remember. Based on the current project, presenting items at a standard rate (as opposed to a fast rate) would seemingly mean that items within the list are able to be active for a longer duration.

Models that emphasise the role of cumulative matching (e.g., Burgess & Hitch, 2006; Page & Norris, 2009) can explain this project's repetition effects. According to these frameworks, the repeated matching of short- and long-term list representations can strengthen those connections over time and lead to improved performance. These models tend to focus on the Hebb effect (Hebb, 1961) when discussing the role of repetition and serial recall. The methodology of the current study diverged from the traditional Hebb procedure in that the *whole* task was repeated, and it was repeated only once. Usually the Hebb effect involves repeating select sequences within a task, often multiple times, and typically using digits (although it has also been observed with other stimuli including words, e.g., Majerus et al., 2012).

Importantly, cumulative matching does not specify how many representations are required to establish the benefits of repetition, nor the maximum amount of time permissible between each repetition for these benefits to be preserved. Based on the results of the current project, repetition effects appear to be established with minimal repetitions (i.e., with only one repetition of the task) and even when that repetition occurred 60 minutes after the initial testing session. In addition, there did not appear to be any advantage in repeating the recall task immediately or after a delay given that level of improvement in correct recall with repetition was comparable between these conditions for participants. This was the case for the younger participants when compared on immediate, 15-minute delayed and 60-minute delayed repetition, and for the older participants when compared on immediate and 15-minute delayed repetition.

Despite these results, it would seem that any representations activated in memory should eventually attenuate over time. In the current project however there was no effect of delay on repetition, such that the benefits of repetition to serial recall did not consistently reduce as the period of time delay between time one and time two increased (i.e., no delay to 15 mins to 30 mins to 60 mins). One argument then is that learning may have played a role in improving performance across repetitions. Oppenheim and Dell (2010) have proposed a model of lexical retrieval in speech production involving lexical activation, lexical selection and learning. According to this model, during presentation of a target (e.g., dog) semantic features (e.g., mammal) of that target are activated in memory leading to the activation of the target as well as words that share semantic features of the target (e.g., bat). Via a "boosting" mechanism the word that is most highly activated is chosen for output. This description is not unlike some of the activation models of speech production discussed previously in this thesis (e.g., Dell et al., 1997). Importantly however Oppenheim and Dell also emphasis the role of learning in their framework such that retrieval of the target word in the future is proposed to be aided by an error-driven learning process. Critically, this process is presumed to take place irrespective of whether the target is actually the one selected during retrieval because future exposure to the target serves to strengthen connections involving its semantic features whilst weakening such connections to other words that are also activated.

Such an account has been used to explain the persistence of cumulative semantic interference during picture naming tasks, that is, the observation that participants take longer to respond to items when they are from the same, as opposed to different, semantic categories (e.g., Damian & Alds, 2005). This effect has been shown to persist even when additional "filler" items are interleaved in trials between the semantically related objects, in turn suggesting that such interference is the result of learning/experience as opposed to just the persistence of activations over time (Oppenheim & Dell, 2010). From this view, participants in the current project may have been able to benefit from repetition and improve their serial recall performance over time due to a learning process unaffected by the delay between repetitions. Indeed, even though the period of time between repetitions (i.e., the delay) varied across experiments, all participants were only given two opportunities at the recall task. Hence any benefits due to learning with re-exposure to the list would presumably be comparable across experiments and this was consistent with the results of this project. Given that the serial recall task required both item and order information however participants would have to have learnt not only which activated items to recall but also the order in which to recall them (i.e., item-context bindings).

Of course, it is possible that if additional delays have been employed within the current project, performance may have eventually reduced. Nonetheless, this discussion highlights the limitations of cumulative matching theories in explaining the current findings and the need for such models to be able to specify how long activations can be preserved over time. Computational frameworks of immediate serial recall (e.g., Brown et al., 2007; Brown et al., 2000; Burgess & Hitch, 2006; Page & Norris, 2009) are still able to provide at least some contribution to understanding the impact of task repetition and presentation rate in this project. It is important to mention though that in contrast, psycholinguistic frameworks (e.g., R. C. Martin et al., 1999) would have a difficult time accommodating for the effects of episodic context of serial recall. This is because these models do not offer detailed accounts of how order information is encoded, represented and maintained in short-term memory.

10.1.3 Healthy ageing.

In regards to ageing effects, it was expected that serial recall would be greater for the younger versus older participants of this project, in line with other studies that have reported age-related impairments in performance on short-term/immediate serial recall tasks (e.g., Bopp & Verhaeghen, 2005; Golomb et al., 2008; Neale & Tehan, 2007, Experiment 1; Noack et al., 2013; Scicluna & Tolan, 2011; Surprenant et al., 2006). The results of this thesis support these predictions for the most part. Younger adults typically produced significantly higher levels of correct recall when compared to older participants.

Essentially, the inclusion of older adults in this project was considered another way to manipulate temporary episodic binding. Older adults are routinely thought to have declines in episodic memory (e.g., Craik & Rose, 2012) and this is often attributed to difficulty or weakening in temporary episodic bindings (e.g., Oberauer, 2005a, 2005b). Hence, it was anticipated that employing variables that further served to weaken the episodic bindings of the task (Brown et al., 2007; Brown et al., 2000) would lead to additional declines in performance. In particular, it was expected that serial recall would be significantly greater during fast as opposed to standard presentation rates. Fast speech rates have been found to decrease recall in older adults (Stine, Wingfield, & Poon, 1986; Tun et al., 1992; Wingfield et al., 1985; Wingfield et al., 1999), while slowing the presentation time between each item has been shown to aid the serial recall (Golomb et al., 2008) of these individuals. In contrast to predictions, however, the serial recall of older adults did not vary with presentation rate in this project.

One possibility is that ageing is not always associated with declines in episodic binding. Campbell, Hasher and Thomas (2010) for instance have proposed that older adults may actually experience hyper-binding, a consequence of age-related declines in attentional control and the ability to inhibit irrelevant information. These researchers performed a 1-back procedure in which younger and older adults were presented with various pictures and advised to respond each time the same pictures appeared in a row. Irrelevant words were superimposed over each picture although participants were requested to disregard them during the task. After a filled 10-min delay, participants subsequently completed a paired-associates task in which they were required to study a list of picture-word pairs, some of which had previously appeared in the 1-back task. Later, participants were presented with the pictures and were required to recall the words they were paired with. Interestingly, older adults were more likely to recall words that had formerly appeared in the 1-back task even though they had been asked to ignore those words during that task. Younger adults conversely performed similarly, irrespective of whether the word-picture pairs had been presented in the earlier task. Based on these results Campbell and colleagues proposed that when older adults are presented with both relevant and irrelevant information simultaneously they may encode this information together due to age-related impairments in inhibition. In turn, such associations may impact future task performance. Whether the performance of the older adults in the current project could have been impacted by hyper-binding is unclear and difficult to determine based on the findings of this thesis alone. However, if this was the case then it could explain why task manipulations designed to weaken the episodic bindings (e.g., rapid presentation rate) of these individuals had a much smaller effect than initially anticipated. It could also be proposed that the “standard” presentation rate employed in this thesis was just too fast for the older participants to be able to benefit from any additional time supplied by this rate. This makes sense given that processing speed can decline with advancing age (e.g., Salthouse, 1996), and as a result older adults presumably have to exert more (self-initiated) effort to encode and retrieve information from memory (Craik & Rose, 2012). Based on this view, older adults would seemingly have had to use more cognitive resources than the younger adults irrespective of presentation speed. Slower presentation rates are thought to provide more time to encode information into memory and allow greater opportunity for rehearsal (Bhatarah et al., 2009; Conrad & Hille, 1958; Tan & Ward, 2008) but perhaps the standard rate in the current thesis was still too quick for the older participants to be able to use this additional time effectively. The presentation rates employed in Experiments 5 and 6 were the same as those used in the earlier studies of this thesis. Although this was in order to maintain consistency across experiments, other research that has looked at false memory, presentation speed and ageing tends to use slower rates of presentation (e.g., McCabe & Smith, 2002).

With respect to task repetition, it was expected that this variable would aid the serial recall of older adults by helping to strengthen episodic bindings (Burgess & Hitch, 2006; Page & Norris, 2009). Indeed, older adults have been shown to make use of repetition to assist performance (Light & Albertson, 1989; Light & Singh, 1987; Rastle & Burke, 1996). In line with predictions, serial recall improved significantly for older adults between time one and time two, although the level of improvement with repetition by the younger participants was significantly greater than the level of improvement by the older adults, during both immediate and 15-minute delayed repetition. These results are in line with other research that has shown that older adults experience less benefits associated with repetition than younger adults (Henkel, 2007, 2008), presumably because of problems with processing speed, general declines in recall memory and problems with the ability to use effective retrieval strategies (Bluck et al., 1999; Henkel, 2007, 2008; Widner et al., 2000). In addition, it could also be argued that the ability for repetition to strengthen item-context associations (and hence serial recall) may be attenuated in older individuals because these participants had weaker episodic bindings to begin with.

In short, the significantly lower performance of the older groups on serial recall compared to the younger samples suggests that it is not just conditions imposed on the task that can weaken/strengthen bindings, but individual differences as well. Younger adults performed better than older adults, improved to a greater extent with repetition, and were able to make use of presentation rates to influence their recall. These observations suggest that in relation to correct recall, the impact of semantic/associative, phonemic and episodic binding is more likely to be beneficial to participants that have the capacity for stronger episodic associations compared to individuals who already have weaker episodic bindings.

The embedded components model (Oberauer, 2002) has considered episodic bindings in the context of ageing (Oberauer 2001, 2005a, 2005b) and thus appears to offer the best account for the current results. According to this model, older adults experience declines in content-context associations, leading to more errors in short-term/working memory tasks when compared to younger individuals. Importantly, however, this model does not account for multiple representations in memory nor was it originally designed to specifically explain the process of immediate serial recall. Hence many of the effects observed in this thesis are beyond the scope of the embedded-components model. Indeed, there does not appear to be any current immediate serial recall frameworks that can account for the range of serial recall results in this project. In short, the current results seem to be outside the domain of current models of immediate serial recall.

10.2 The False Memory Effect in Short-term Memory

10.2.1 Associative relatedness and phonological similarity.

Overall, the current thesis complements the growing area of research that suggests that the DRM false memory effect (Deese, 1959; Roediger & McDermott, 1995) can be observed within a short-term memory paradigm (e.g., Atkins & Reuter-Lorenz, 2008, 2011; Coane et al., 2007; Flegal et al., 2010; McDuffie et al., 2012; Tehan, 2010; Tehan et al., 2004). Moreover, the current research supports the view that the false memory effect extends to both phonological and semantic/associatively related lists. In line with predictions, across all studies, presenting lists of words that were associatively related and/or phonologically similar to a critical lure resulted in that lure being recalled despite it never appearing in the list. This occurred for associative lists and phonological lists, but mostly for hybrid lists comprised of words that were phonologically similar and associatively related to a common target word. Comparing the number of lures recalled on the associative versus phonological lists, lists containing words that were phonologically related to the lure produced greater levels of false recall than associative lists. The results are consistent with current understandings of the facilitative effects of associative relatedness and the detrimental effects of phonological similarity on serial recall more generally. That is, associative relatedness can support correct recall by strengthening the list item associations within pre-existing networks, helping to develop rich and meaning information to draw on during retrieval (Nelson et al., 2013; Poirier et al., 2011; Stuart & Hulme, 2000). Based on the findings of this project, it appears that this also leads to less (false) errors being recalled. In contrast, phonological similarity can impair correct recall by creating confusion between activated representations in the long-term network (Baddeley, 1966a, 1966b; Conrad, 1964; Conrad & Hull, 1964). The current results suggest that such confusions can also enhance the probability of false lures being recalled.

The inclusion of hybrid lists in the current project was intended to provide the means to investigate the semantic/associative and phonological representations binding and the impact that this binding would have on short-term recall. This was based on the assumptions of long-term false memory studies, which propose that hybrid lists are indicative of the convergence of the critical lure's associative/semantic and phonological representations (e.g., Watson et al., 2001; Watson et al., 2003). In keeping with this presumption, the results of all six experiments of this thesis have emphasised the detrimental impact that associative/semantic-phonemic binding can have on immediate serial recall. Irrespective of age, participants were much more likely to make false errors when hybrid lists contained information that (presumably) activated the lure on both a semantic/associative and phonemic dimension as opposed to associative or phonological lists that triggered only the semantic/associative or phonological representations of the critical item.

Previous research has proposed that the enhanced false memory effect in hybrid lists is due to the convergence of semantic/associative and phonological representations. Watson et al. (2001; Watson et al., 2003) suggested that there was a certain threshold of activation that representations must reach in order to be recalled. According to this view, hybrid lists activate both phonological and associative representations of the critical lure. The strength of these activations are thought to accumulate and drive the lure past the threshold required for it to be chosen during retrieval, leading to frequent recall of the critical item on hybrid lists. It has also been proposed that the combined activation of phonological and semantic/associative representations during hybrid lists may narrow the search criteria for to-be-recalled items at recall, increasing the likelihood of the lure being recalled (Roediger, Balota, et al., 2001). Both of these ideas emphasise that hybrid effects are the product of an interaction between semantic/associative and phonological information in memory and the findings of this project support this position. In short, the binding of semantic/associative and phonological information during hybrid lists appeared to enhance the false memory effect.

The associative lists and phonological lists employed in this thesis contained three items that were either similar or related to the critical lure, and three items that were either dissimilar or unrelated to the critical lure. In a sense, half of the items on these lists were encouraging the activation of the lure, but the other half were not. Hence, it may be that when this information combined in memory, items that were not related/similar to the lure actually discouraged the lure from being recalled. In this instance, the binding of semantic/associative and phonological information during the associative lists and the phonological lists appeared to decrease the potential for false errors. These ideas are in line with the semantic binding hypothesis that implies that the binding of semantic and phonological information can reduce recall errors (Jefferies et al., 2006; Jefferies et al., 2008; Knott et al., 1997; Patterson et al., 1994). Taken together, the binding of multiple representations in short-term memory appears to have varying effects on immediate serial recall. Depending on the information contained in the list and the demands of the task, semantic and phonemic binding can increase or decrease the potential for errors at recall. In general, these assumptions are consistent with psycholinguistic accounts of immediate serial recall (e.g., N. Martin & Gupta, 2004), although there does appear to be a need for a more comprehensive account of the DRM false memory effect (Deese, 1959; Roediger & McDermott, 1995) within the context of these models.

10.2.2 Presentation rate and task repetition.

Another major presumption of this thesis was that only list items would have the benefit of episodic bindings (Tehan, 2010). Critical lures were not expected to be linked to a specific temporal order/context because they never appeared in the list. In this respect, conditions that enhanced episodic binding were anticipated to decrease false recall (but facilitate serial recall) because the strengthened episodic context would help participants to differentiate between the list and the lure (Tehan, 2010). Conversely, conditions that weakened content-context bindings were posited to enhance false recall (and reduce serial recall) because the weakened episodic context was predicted to make it more difficult for participants to distinguish between presented versus non-presented items activated in memory.

One way in which observation was expected was through inspecting the serial position at which the lure was recalled. It was anticipated that lures would tend to be recalled towards the end of the list when episodic information was weaker. In support of this position, lures were typically recalled in the last or second last serial position throughout all experiments, particularly on hybrid lists in which a high proportion of lures were recalled. This pattern of lure output was also observed much more frequently during task conditions in which episodic binding would presumably have already been weakened (i.e., rapid presentation and time one) as opposed to conditions in which episodic binding would have presumably been strengthened (i.e., standard presentation and task repetition). These results support the earlier work of Tehan (2010) who observed that lures tended to be recalled in later serial positions on associative lists. Taken together, these results emphasise the role of temporary episodic bindings in the creation of memory intrusions in immediate serial recall tasks.

Episodic binding in this project was also examined by manipulating task repetition and presentation rate. This project predicted that presenting lists at fast rates (i.e., one word per 250 milliseconds) would cause higher levels of false recall when compared to presenting lists at standard rates (i.e., one word per 1000 milliseconds). This was based on previous studies that had demonstrated a similar result using comparable presentation speeds (McDermott & Watson, 2001; Smith & Kimball, 2012). It was also based on the assumptions of prominent accounts of false memory, which expect that providing more time for participants to study the list leads to improved performance because of better monitoring processes (Gallo & Roediger, 2002) or better intact verbatim trace processing (Brainerd & Reyna, 2005). The results of this project (at least with respect to the younger participants) generally support these predictions. Younger adults were more likely to recall false memories (at least at a mean level) during rapid presentation rates as opposed to standard presentation rates. This suggest that when episodic information is lost or weakened, participants may have difficulty in distinguishing between activated representations in memory.

It is important to recognise nonetheless that while presentation rate tended to have an influence on younger adults’ false memories at a mean level, these effects were not always significant. This may propose that the presentation rates employed in the study were not sensitive enough for the purposes of examining false memories in the immediate serial recall task. For instance, it could be suggested that the rapid presentation rate employed in this thesis was too fast for all list items to be consciously processed by participants. Consequently, there may not have been enough time for activation of many of the list items to spread to the representation of the critical word, or items were not activated strongly enough to cause spreading to the lure. In turn, at times the lure would be less likely to be activated and then recalled on this condition. It could also be proposed that the standard presentation rate was too fast for participants to be able to benefit from any additional encoding time such that false memories were not always significantly reduced in these instances.

With respect to task repetition, not all of the predictions of this project were supported. Long-term false memory studies generally report a decrease in the false memory effect with repetition (e.g., Benjamin, 2001; Brainerd et al., 1995; Budson et al., 2000; Hall & Kozloff, 1970; Kensinger & Schacter, 1999; McDermott, 1996; Schacter et al., 1998; Tussing & Greene, 1999, Experiment 5; Watson et al., 2005; Watson et al., 2004). In the current thesis this was not the case in every experiment. Indeed, when compared to the consistent effect that repetition had on true memory across experiments, the effects of repetition on false memory were less than robust. Moreover, even when repetition significantly influenced false recall (i.e., Experiment 1), the false memory effect was never eliminated. These observations appear to be in line with the general consensus of false memory literature, which emphasises the false memory effect's strength. Further evidence for the false memory effect's robustness was seen in Experiments 3 and 4 of this thesis. During these studies, when a delay was introduced before repetition there was no significant difference in false memory between time one and time two, although there was a mean trend for lure recall to decrease with repetition. These results are in line with other studies that highlight the persistence of the false memory effect across retention intervals (e.g., Neuschatz et al., 2001; Payne et al., 1996; Seamon, Luo, Kopecky, et al., 2002; Toglia et al., 1999, Experiment 2) and with repeated study and/or test opportunities (e.g., Mintzer & Griffiths, 2001; Schacter et al., 1998; Shiffrin et al., 1995; Tussing & Greene, 1997, 1999, Experiments 1 - 4).

Nonetheless, it is interesting to note that the effects of repetition only reached significance when repetition occurred immediately (Experiment 1) as opposed to when a delay was introduced (Experiments 3 and 4). It is important to remember that repetition is only thought to be beneficial in false memory tasks if participants are provided with feedback regarding their performance (DeSoto & Roediger, 2013). Without this feedback, repetition can actually be detrimental because across repetitions there is an increased probability that responses made at time one will be made at time two, irrespective of whether these responses were actually correct (e.g., Couture et al., 2008). Likewise, in explaining the persistence of false recall across multiple study and test trials, McDermott (1996) concluded that while repeated study trials may aid accuracy in recall, the impact of repeated testing could offset the benefits of repeated study. In light of these ideas, the ability for participants to use re-exposure to the list as an opportunity for feedback on their performance seemed to have been more likely when the repetition occurred immediately, as opposed to after a delay.

These suggestions are somewhat theoretical, however, because when Experiments 1, 3 and 4 were combined and only standard presentation rate was analysed, there was no overall difference between the three groups on the number of lures recalled. Furthermore, there was a significant reduction in lure recall on the hybrid lists, irrespective of whether there was a delay before repetition. The finding that repetition tended to reduce false recall when only the standard presentation rate was analysed could be considered in relation to opportunity for feedback. That is, the ability to self-correct would presumably have been easier during a standard rate of presentation as opposed to a rapid rate. More specifically, when lists were presented at a standard rate, participants may have been able to make use of repeated study (and test) opportunities to improve performance and reduce false recall. However, when lists were presented rapidly, the chance to review previous attempts may have been limited and hence errors made at time one would have been replicated at time two. The use of only hybrid lists when the three experiments involving the younger adults (Experiments 1, 3 and 4) were compared is also important to consider. The hybrid lists consistently produced the highest levels of false memories when compared to the associative lists and the phonological lists. Hence the hybrid lists had the greatest potential to benefit from repetition. Inspection of the false recall means with respect to list type supports this theory. Indeed, while false memories on the hybrid lists generally declined with repetition at a mean level as least, false recall on the associative and phonological lists tended to remain relatively constant.

It is important to stress, however, that discussions regarding the interacting effects of repetition, presentation rate and list type on false memory are purely speculative given there were no significant interactions between presentation rate and task repetition when false recall was analysed on any of the individual experiments. Moreover, any conclusions drawn from the comparison of Experiments 1, 3 and 4 should be considered with caution, given that the increase in sample size (and power) may play a role in explaining these results. Irrespective of this point, the results of this project support the idea that episodic context can impact associative and phonological false memory in short-term recall tasks. In turn, these findings highlight the requirement for an immediate serial recall model that can handle the effects of both semantic and episodic memory.

10.2.3 Healthy ageing.

Further support for the role of episodic context on the false memory effect was expected to come from the inclusion of healthy older adults in the project. Older adults have been found to be susceptible to memory distortions and illusions (e.g., Bartlett et al., 1991;

Dywan & Jacoby, 1990; Koutstaal & Schacter, 1997; Loftus et al., 1993; Norman & Schacter, 1997; Schacter, Koutstaal, & Norman, 1997), and to have difficulties with source monitoring (e.g., Craik et al., 1990; Henkel, 2008; Johnson et al., 1993; Siedlecki et al., 2005; Simons et al., 2004; Spencer & Raz, 1994). Age-related differences in DRM (Deese, 1959; Roediger & McDermott, 1995) false memories (Balota, Cortese, et al., 1999; Norman & Schacter, 1997; Tun et al., 1998; Watson, et al., 2001) have been reported. Moreover, older adults can be more likely to make short-term memory intrusions, seemingly as a result of weakening in temporary episodic bindings (Oberauer 2005a, 2005b).

In light of this previous research, this project predicted that false memory would be greater for older adults when compared to the younger adults. Interestingly, however, while older adults tended to recall more lures than the younger individuals at a mean level, there was no significant difference in the proportion of false memories recalled between the younger and older participants in this project. In combination, these results suggest that any age-related differences in vulnerability to false memories are relatively minimal in healthy older adults. These results provide support to other false memory studies that have failed to establish age-related differences (e.g., Balota, Cortese, et al., 1999; Kensinger & Schacter, 1999; McCabe & Smith, 2002). The findings are also consistent with the view that not all older adults experience declines in false memory. According to this prospective, the activation, monitoring and control processes involved in the false memory task may (at times) be unaffected by the normal process of ageing (Butler et al., 2004; Gallo & Roediger, 2003).

Also in contrast to predictions, presentation rate failed to impact false memory for older adults in this project. Given that presentation rate did not impact true memory of these samples, however, this result may not be that remarkable. Indeed, it seems that older adults had trouble with the recall task irrespective of the list's presentation speed. More specifically, participants may have had difficulty encoding (or consciously processing) the to-be-recalled items at either presentation rate. In turn, this would mean that there was no difference in the extent of spreading activation between standard versus rapid speeds, and therefore no observable changes in recall of the lure. Critically, these results diverge from other ageing studies that have established reductions in false memory during slow versus fast presentation rates (Watson et al., 2004). It is important to note, however (as emphasised earlier in this chapter), that other false memory studies examining ageing and presentation rate have tended to employ slower rates than what was presented in the current project. For instance, the "standard" rate for this thesis was one word per 1000 milliseconds compared to the "slow" rate employed by Watson et al. (2004) which was one word per 2500 milliseconds. Moreover, the "fast" rate in this thesis was one word per 250 milliseconds while Watson et al. employed a "fast" rate of one word per 1250 milliseconds. This comparison underlines the importance in considering what the optimal range may be for age-related differences to be produced in false memory studies. Indeed long-term false memory studies have shown that different speeds impact the false memory of older and younger adults in different ways (e.g., McCabe & Smith, 2002; Watson et al., 2004).

It is also worth mentioning that younger and older adults tend to be impacted by processing speeds differently, and this has been assumed to play a role in the number of intrusions made in short-term memory tasks. Oberauer (2001, 2005a) proposed that when a task depended on both speed and accuracy, older adults tended to be conservative when responding and were more likely to make errors in reaction time as opposed to accuracy. Hence the speed at which the task was undertaken in the current thesis may have meant that the older adults were more conservative in making a response. In turn, these participants may have been less likely to recall a familiar item that came to mind during recall (i.e., a false error) than if the task had been presented at a slower rate. There were no time limits imposed on the participants in the study but because the task was measuring short-term retention, participants would have presumably output their responses as quickly as possible during retrieval. Thus, the conditions of the immediate serial recall task may have created a time pressure for participants. In short, the nature of the immediate serial recall task may have encouraged older participants to be cautious in responding at recall and this may have meant that these participants made less correct (and incorrect) responses, reducing the potential for the project to observe any age-related differences in false recall.

In regards to task repetition, as predicted, false memory remained relatively stable during both immediate and 15-minute delayed repetition, and even when the data from these two studies were combined (that is when only standard presentation rate and hybrid lists were analysed). These results are interesting given that older adults were able to use repetition to improve their serial recall. In line with these findings, other research has also reported that older adults can use repetition to improve their true memory without being able to reduce their false memory (e.g., Kensinger & Schacter, 1999; Watson et al., 2004). Benjamin (2001) has proposed that although repetition can enhance source monitoring processes, it can also increase lure activation/familiarity. Older adults are thought to have trouble controlling these opposing processes (Benjamin, 2001), and this may have contributed to repetition being ineffective in reducing their false memories. A similar proposition has been made by Oberauer (2001, 2005a, 2005b) in relation to age-related vulnerability to intrusions in short-term memory. According to this view, intrusions are the consequence of older adults feeling (false) familiarity with irrelevant information, due in some respects to impairments in content-context bindings (Oberauer 2005a, 2005b). In short, in the current project task repetition may have actually just reinforced the older adults' sense of familiarity with the activated lures. Additionally, the older adults may not have been aware that they were making (false) errors during their first attempt at the task and thus had been unable to correct their responses with repetition (Couture et al., 2008). Indeed these individuals may not have been able to conduct their own feedback to aid performance, particularly if the lists were presented too quickly (DeSoto & Roediger, 2013).

It has also been proposed that giving older adults more encoding time (i.e., slower presentations and repetition) may not be enough to help them reduce their false memories. Instead, Dehon (2006) has suggested that contextual support such as warnings are also needed in order to compensate for age-related problems in self-initiated source monitoring processes. Studying the availability of processing resources in the context of ageing, Dehon established that by giving younger adults more resources (i.e., more encoding time by increasing the inter-stimulus interval, ISI), they were able to reduce their false memories and improve their true memory. It was proposed that providing younger adults with more time allowed these individuals to process and encode item-specific information in more detail and in turn, more easily reject the critical lures at recall. In contrast, while increasing the ISI also improved the true memory for older adults, in order to reduce false memory these participants needed additional contextual support (i.e., explicit warnings). Dehon suggested that providing extra time appeared to help these individuals with encoding but it was not enough to overcome age-related impairments in self-initiated source monitoring processes (Johnson et al., 1993). That is, older adults also required prompting to consider the source of their memories to be able to make use of the additional encoding in order to reduce their false memories (Dehon, 2006). Importantly, Dehon considered the additional encoding time of the ISI akin to providing participants with study/test repetitions. Based on this view, providing extra time for encoding (whether that be through providing multiple learning opportunities, slower presentation rates, or increasing the time between each item) may not be sufficient to compensate for age-related difficulties in source-monitoring. Older adults may need prompts to think about the source of their memory because they are unlikely to initiate this process on their own. Hence, whilst slower presentation rates and repeating the recall task may provide additional encoding time to process more item-specific information, without additional contextual support these conditions are unhelpful to older adults because other age-related memory impairments outweigh the benefits of these variables.

10.3 Chapter Summary

Through the manipulation of associative relatedness and phonological similarity, this thesis' experiments support the notion that pre-existing semantic/associative and phonological networks can influence immediate serial recall. Moreover, they provide evidence that the binding of long-term networks may impact the potential for false memories over the short-term. By employing task repetition and rapid presentation, the previous investigations have also highlighted the effects of episodic context on memory performance and the role of temporary episodic bindings in making intrusions. The results of this thesis also stress the complexity in predicting the effects of healthy ageing on true and false memory. Together, this project provides strong support for the role of episodic, semantic/associative and phonological representations in immediate serial recall. Some of the findings are able to be handled by computational frameworks (e.g., Brown et al., 2007) or psycholinguistic accounts (e.g., R. C. Martin et al., 1999). However, no contemporary models of immediate serial recall are able explain all of the results reported in this thesis. In turn, this emphasises the need to consider a more integrative approach to verbal short-term memory.

Chapter Eleven: Contributions to the Research and Directions for Future Work

11.1 Implications for Immediate Serial Recall Models

Overall, the findings of this project are in line with contemporary theories of short-term memory, the theory of spreading activation, and the notion that long-term information is organised within pre-existing, interconnected networks (e.g., Collins & Loftus, 1975; Nelson et al., 2013; Oberauer, 2002; Poirier et al., 2011; Poirier et al., 2015; Tehan, 2010). With respect to specific models of short-term memory, many outcomes of this thesis appear to fit within the embedded components framework (Oberauer, 2002). Critically, this model was not originally intended to explain the effects of immediate serial recall. Nonetheless, in the only other published account of short-term immediate serial recall, Tehan (2010) has advocated for the extension of the embedded component model (Oberauer, 2002) to the immediate serial recall task. The current project has, in turn, made similar presumptions.

The embedded components account (Oberauer, 2002) considers the representations of short-term memory with regard to their level of activation or availability. The focus of attention consists of item representations selected from the region of direct-access for output on a particular cognitive task. The direct-access region is thought to be limited in its capacity to hold information. Hence, when information is considered no longer needed for the task at hand, it is able to be quickly removed to make room for more relevant material. Importantly, representations that form the direct-access region can spread via associative links to other related items in memory and these related activations form the activated region of short-term memory. In contrast to the efficiency of the direct-access region, however, it may take a while for representations to be removed from the activated region of memory even when they become irrelevant to a task. Accordingly, these activated representations are able to indirectly influence performance (e.g., via intrusions or biases) even when they are considered no longer pertinent to the task (Oberauer, 2002).

Oberauer (2005a) poses that the direct-access region also has a binding function that is responsible for joining existing representations together, such as information pertaining to both the content and context of the task. This account proposes that irrelevant information within the activated region of memory is more likely to interfere with performance on a task if there are problems with these temporary episodic bindings in the direct-access region (Oberauer, 2005b). According to this framework, when a list was presented in the current project, both the list items and their related lures would have become activated in short-term memory. Under conditions in which the episodic binding remained intact (e.g., items at the beginning of the list, standard presentation rate) or were strengthened (e.g., task repetition), list information would have remained in the direct-access region at retrieval. Consequently, participants would have been able to use these items for recall with little error. During instances in which the temporary episodic bindings were weaker (e.g., items towards the end of the list, rapid presentation, first attempt at the task), participants would have had less information available to them in the direct-access region to assist recall. Thus, activated (but irrelevant) representations in memory would have been more likely to influence serial recall under these circumstances. Due to the nature of the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995), it is highly likely that the lure would have been activated and recalled as an intrusion under these conditions. Although Oberauer (2002) did not specify how long representations could remain activated in memory, the findings of the current thesis propose that they have the ability to impact performance well beyond recall of the list.

Importantly, the embedded components model (Oberauer, 2002) only describes the processes involved in the associative network, however it could accommodate a phonological network that worked in parallel and operated under similar principles to its associative counterpart. Indeed, the results of the current thesis highlight the need to consider multiple types of representations in short-term memory. In this respect, psycholinguistic models (e.g., N. Martin & Gupta, 2004; N. Martin & Saffran, 1992a, 1992b; R. C. Martin & Lesch, 1996; R. C. Martin et al., 1999; R. C. Martin & Romani, 1994; Romani et al., 2008) may provide a better way to explain some of the findings reported in this project. These accounts generally presume that short-term memory is made up of semantic, phonological and lexical layers/levels of activation. The multiple buffer model (R. C. Martin et al., 1999) and the place holder model (Romani et al., 2008) both acknowledge that these activations can compete or interfere with one another but that they can also interact in ways to reinforce the memory trace. Based on these frameworks, false recalls appear to be the result of interference within the language/memory network in the current project. That is, activations of the lure competing with activations of the list. Hybrid lists would presumably have activations of the lure at *both* a phonological and semantic level, and this should serve to increase the amount of interference within the memory network. In turn, presentation of these hybrid lists would lead to greater false errors. In contrast, if an associative or phonological list were presented, the lure would only be activated on *either* a phonological or semantic level. Hence, the potential for false recall on these lists should be remarkably lower than for hybrid lists. These propositions are consistent with what was demonstrated across all experiments of this project.

A similar proposal could be made using the activation model by N. Martin and Gupta (2004), although the emphasis of this approach would be focused on the role of decay (as opposed to interference). A key assumption of the activation model includes the role of spreading activation between semantic, lexical and phonological processing levels, and is based on an interactive model of word production (Dell & O'Seagha, 1992). Thus, this model seems to align well with the embedded components model (Oberauer, 2002) in which spreading activation theory (Collins & Loftus, 1975) is also an underlying principle.

With respect to ageing effects, psycholinguistic models have engaged older adults to test their frameworks. However, these individuals have often been diagnosed with cognitive impairments. It is difficult therefore to provide a direct comparison to the results of this project in which a group of healthy older adults were examined. Nonetheless, research by Burke and Shaft (2008) may provide a way to accommodate the results of this thesis within psycholinguistic accounts. These researchers discussed ageing and cognition in the context of an interactive model of language (e.g., Dell et al., 1997). This model included an interconnected system of multiple representations that communicate via the conduction of priming within the network. Essentially, the speed and efficiency of priming between representations within the system impacts language comprehension and production. Although this framework was not specifically designed for immediate serial recall and verbal short-term memory, it can be used to expand on the results of this thesis and place them within psycholinguistic accounts that propose many of the same underlying principles to memory.

In the review of ageing and language, Burke and Shaft (2008) discussed the transmission deficit theory. This theory proposes that with ageing, the connections within the memory/language system are weakened, resulting in less activity (spreading activation) within the network (Burke & MacKay, 1997; Burke & Shaft, 2008). It is also supposed, however, that with repetition and practice these connections can strengthen/increase (Burke & MacKay, 1997; Burke & Shaft, 2008; MacKay & Abrams, 1996; MacKay & Burke, 1990). From this perspective, psycholinguistic models may presume that associative links between long-term networks are weakened with normal ageing, which could lead to reduced performance on cognitive tasks. The results of this project support this view. While older adults had lower rates of serial recall when compared to younger participants (perhaps in part due to fewer or weaker long-term connections), these individuals were able to improve their performance with repetition. This theory may also explain the comparable levels of false recall between younger and older adults demonstrated within this thesis. Weaker long-term connections may limit the number of false recalls that may otherwise be seen in older adults maintaining them at a level that is somewhat consistent with younger participants. Some of the transmission deficit model proposals (Burke & MacKay, 1997; Burke & Shaft, 2008; MacKay & Abrams, 1996; MacKay & Burke, 1990) are also in line with the underlying assumptions of the embedded components model (Oberauer, 2002). Oberauer (2005a, 2005b) has theorised that older adults have problems with controlling/discounting lingering activations in long-term memory due to impairments in maintaining and accessing content-context associations. This proposition fits with the transmission deficit theory in that fewer connections/associations in the memory system lead to reductions in memory/language.

This discussion of content-context bindings brings up an important limitation to psycholinguistic frameworks (N. Martin & Gupta, 2004; R. C. Martin et al., 1999; Romani et al., 2008). These models do not outline the role of temporary episodic bindings within the short-term system to any great detail. Thus the consideration of variables that affect episodic context (i.e., presentation rate and repetition) is somewhat limited to the influence they would have on the items' representations (as opposed to item-context bindings). In this respect, psycholinguistic models might propose that levels of interference (or decay) would be smaller with repetition and slower presentation rates because the activated memory traces of the list items under these conditions should be strengthened, leading to better communication within the long-term network.

A more detailed interpretation of episodic effects, however, is outlined within computational models of immediate serial recall. These frameworks stress that while the strength of item representations/activations in the memory system are essential to serial recall, the associations between the items and their context/position are also crucial to consider (e.g., Brown et al., 2000; Henson, 1998; Page & Norris, 1998). In particular, many of these accounts emphasise the importance in the strength and distinctiveness of these bindings for correct serial recall (e.g., Brown et al., 2000; Henson, 1998; Lewandowsky & Farrell, 2008). These models thus appear to provide a more comprehensive interpretation of the serial order effects reported in the current project. In short, the influence of presentation rate and repetition in this thesis appears to be easier to conceptualise based on these computational models (e.g., Brown et al., 2000, 2007; Burgess & Hitch, 2006; Page & Norris, 2009).

Nonetheless there have been some attempts to reconcile the limitations of psycholinguistic accounts. For example, the activation model (N. Martin & Gupta, 2004) has endeavoured to represent order within the activation process. More precisely, it suggests that the priming of semantic and phonological representations help to retain serial position of the to-be-recalled items in a list (N. Martin, 2009). Strongly activated semantic representations help to recall items in early serial positions whilst recently activated phonological representations assist in the recall of items presented later in the list (N. Martin & Gupta, 2004). The place holder model (Romani et al., 2008) has also made efforts to depict how order may be represented within the short-term system. According to this framework, order is retained within the phonological input and output buffers as well as through communication between these buffers and semantic/lexical representations in memory (Romani et al., 2008). Although these models have attempted to include serial order within their architecture, a more detailed description of the representation and maintenance of serial order in verbal short-term memory is warranted.

Arguably the most comprehensive approach to date is by Majerus (2009) in which some of the ideas of the computational frameworks (Brown et al., 2000; Burgess & Hitch, 1999; Gupta, 2003) have been combined with psycholinguistic approaches (N. Martin & Sarran, 1992). This approach suggests that there are multiple types of (interacting) representations that can become activated in the memory system. Seemingly these representations are temporary and will decay without rehearsal. These ideas are largely consistent with the activation framework (N. Martin & Gupta, 2004). Where this approach extends beyond the activation model, however, is in its explanation of serial order. Majerus suggests that individual timing signals become linked to each item presented in a list, which assists in encoding the task's order information in line with many computational models of memory (Burgess & Hitch, 1999; Gupta & MacWhinney, 1997).

Whilst the model by Majerus (2009) emphasises the demand for further consideration of how serial order is represented within psycholinguistic models, it does not seem to accommodate for all of the findings in this project. In particular, the results of this thesis suggest that long-term representations can be activated rapidly (i.e., when items are presented at fast speeds and recall is required immediately) and can persist for extended periods of time (i.e., at least up to 60 minutes after initial presentation). In addition, the findings reported in this project highlight that the time between task repetitions may not necessarily impact the strength of these pre-existing activations. That is, any change in serial recall across repetition does not appear to depend on whether repetition is given in immediate succession or after a delay. In short, it appears that it is not just timing that is important in the processes of immediate serial recall.

Whilst some of the findings of the current project are better accounted for by the embedded components framework (Oberauer, 2002) or computational models (e.g., Brown et al., 2000, 2007; Burgess & Hitch, 2006; Page & Norris, 2009), other aspects may be more in line with psycholinguistic approaches (e.g., R. C. Martin et al., 1999). Thus, it is argued that a combination of these theories would provide the most comprehensive understanding of the results reported in this thesis. These ideas are also derived from Tehan’s (2010) exploration of these models during a general discussion of their findings. This discussion is deemed to be highly relevant to this project because Tehan’s research currently represents the only published account of false memory and immediate serial recall.

The addition of a phonological network to the embedded components model (in line with N. Martin & Gupta, 2004; R. C. Martin et al., 1999; Romani et al., 2008) appears to be warranted, based on the phonological effects reported in this project and short-term memory literature more generally. This could mean that representations are not only defined by their level of activation (and hence their accessibility) but also by the type of information that they represent. Whilst the semantic/associative network is responsible for holding semantic/associative representations, the phonological network would be required to maintain phonological information. It would seem (based on the impact of hybrid lists in the current project) that both semantic/associative and phonological representations in the respective networks are able to interact with each other during each state of accessibility (i.e., focus of attention, direct-access, and long-term activations). This would be consistent with the notion that long-term activations are able to influence memory immediately following list presentation.

Presumably, semantic/associative and phonological representations could bind together and this binding could impact on performance. For instance, the binding of information may help to strengthen the information relevant to the task within the direct-access region of memory. In turn, this may help one to ignore the irrelevant information that may have arisen as a by-product of spreading activation within the network's activated region. For example, when considering lists that contain phonologically similar items to the lure interleaved between associatively unrelated items, the lure would be activated in the phonological network but it would not be activated in the semantic/associative network. The binding of this information in memory would thus serve to strengthen the list items and reduce the potential that the lure would be recalled. Moreover, because interference (or decay) should be relatively low in these conditions (i.e., less items have been activated in memory), the information in the direct-access region should remain reasonably intact. Likewise, in lists that contain associates of the lure interleaved between phonologically dissimilar items, the semantic/associative (but not phonemic) representations of the lure would be activated within the long-term network, thus interference (decay) of irrelevant information should be low. Again this could mean that there is less chance of recalling the lure. Conversely, the lure would presumably be activated both semantically/associatively and phonologically in hybrid lists, and the binding of this information could mean that the lure is highly likely to be recalled (i.e., interference/decay in the system would be high).

In line with the assumptions of the embedded components model (Oberauer, 2002) and computational models of immediate serial recall (e.g., Brown et al., 2007; Brown et al., 2000), content-context associations would also be important in determining the level of interference/decay caused by irrelevant activated representations in memory. Presumably, if temporary episodic bindings have lost their fidelity, there would be a greater likelihood of interference/decay within the network. This is because only the list items (and not the lures) have temporary episodic bindings to their position within the presented list (Tehan, 2010). In these instances, participants would have difficulty in establishing the context in which the activated representations had appeared. That is, whether they were due exclusively to internal spreading activation or at least initially due to presentation within the list. Ultimately, order could be maintained in the system via the episodic bindings in short-term memory similar to the assumptions of many other computational models of immediate serial recall (e.g., Brown et al., 2000; Henson, 1998; Lewandowsky & Farrell, 2008) and the embedded components model (Oberauer, 2002).

Based on this perspective, under conditions in which the temporary episodic binding is weak (i.e., rapid presentation, items presented later in the list, normal ageing), there is an increased likelihood of: (1) recalling items in the wrong order, and (2) recalling false lures by mistake. The order of items within a list presumably also depends on the distinctiveness of these episodic bindings. If the conditions of the task make it difficult to distinguish between the respective contextual positions of each item there will again be greater potential for items to be recalled in incorrect positions. In contrast, during instances in which episodic bindings are strong (i.e., repetition of the task, items in early serial positions, slower presentation rates), there should be an increased potential for recalling list items in their respective positions and less chance that the lure will be incorrectly output.

In light of the results of the current project, however, it is important to remember that false recall and true recall were not always impacted by the same episodic context manipulations. This highlights the point that correct serial recall depends not only on the strength of these episodic bindings but also how they interact with the semantic and phonological representations in long-term networks. For instance, based on the project's results it appears that conditions that reduce/increase serial recall will not necessarily lead to an increase/decrease in false recall. Indeed, whether a lure will be recalled appears to depend not only on the strength of content-context bindings but also the strength of the lure's activation in long-term networks. Although rapid presentation may disrupt/weaken episodic bindings of the list and reduce the distinctiveness of the binding of each item to its context/position, if list presentation fails to activate the lure (perhaps due to the speed of presentation) then false recall output will be unlikely. Conversely, whilst task repetition may strengthen the temporary episodic bindings of the list, it may also reactivate the lure within pre-existing networks, particularly if the opportunity for feedback is absent.

The ageing results reported in this thesis provide further support for this notion. Whilst normal ageing may be associated with weakening in temporary episodic bindings and lead to declines in serial recall, this may not necessarily lead to increased lure recall because false memories also depend on additional processes that may not necessarily be impaired with healthy ageing. Indeed, the pattern of lure recall across list type in this project appeared to be somewhat similar between the younger and older adults of this project, suggesting that the facilitative and detrimental impact of semantic/associative and phonological binding was persistent across the “healthy” ageing process. In short, the relationship between correct and incorrect recall in immediate serial recall tasks is multi-faceted and complex, and depends on the task conditions and individual differences of the participant.

The notion of some type of integrative model between the embedded components model (Oberauer, 2002) and psycholinguistic accounts (e.g., R. C. Martin et al., 1999) is purely hypothetical and indeed may be overly simplistic in its nature, designed to fit the data observed in this thesis. Many of the general principles discussed, however, are consistent with long-term network models that promote the organisation of memory within pre-existing networks, which impact short-term memory (e.g., Luce & Pisoni, 1998; Nelson et al., 2013). Moreover, several of the assumptions fit with the activation/monitoring account (AMT) of false memory (Gallo & Roediger, 2002; McDermott & Watson, 2001), highlighting the role of spreading activation and the issue of source memory in the false memory effect. It is clear nonetheless that it would be important to conduct additional research to provide further understanding as to whether an integration of these frameworks would be a possibility. Areas for future research are considered in more detail later in this chapter.

11.2 Contribution to Other Areas of Research

11.2.1 Verbal short-term memory.

More generally, the current research supports the proposition (Acheson & MacDonald, 2009; Cowan, 1999; Cowan & Chen, 2009; Gupta, 2003, 2009; Majerus, 2009; N. Martin & Gupta, 2004; R. C. Martin, 2006; Romani et al., 2008) that verbal short-term memory is much greater than its original depiction in Baddeley’s working memory model (1986, 2000). For example, while the importance of the phonological loop for language has been acknowledged (Baddeley, 2003), the results of the current thesis suggest a much greater involvement of phonological information in verbal short-term memory. Although not the intention of this project, the results do support the notion of a more unitary (or at least a highly overlapping) memory system (Surprenant & Neath, 2009) given the proposal that the short-term store is largely the activated part of long-term knowledge (Oberauer, 2002). This creates another deviation from Baddeley's working memory model (2000), which has been predominately based on the belief that the short- and long-term stores are two distinct systems. The episodic buffer in Baddeley's (2000) updated model, however, does emphasise the contribution of permanent knowledge to short-term recall and highlights the communication between the two memory systems. Baddeley's model also highlights the role of decay (as opposed to interference, e.g., Brown & Hulme, 1995) in short-term forgetting. This thesis has not placed itself on either side of the decay versus interference debate, instead providing an integrative model that could accommodate for either position. In this way, there are at least some similarities between the traditional model of short-term memory (Baddeley, 2000) and the current approach taken by this thesis.

The findings of this research project are also consistent with frameworks that acknowledge the existence of semantic/associative representations in short-term memory (e.g., Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1999a, 1999b, 2000; Stuart & Hulme, 2000; Tse, 2009; Tse et al., 2011), and particularly those models that suggest that semantic/associative representations can influence memory very early in the recall task (e.g., Jefferies et al., 2006; Knott et al., 1997; N. Martin & Saffran, 1992, 1997; R. C. Martin et al., 1999; R. C. Martin & Romani, 1994, 1995; Romani et al., 2008; Romani & Martin, 1999). This notion is in contrast to the traditional redintegration account (Hulme et al., 1991; Schweickert, 1993) which poses that long-term memory is only involved during the retrieval of degraded memory traces for output. The current results also pose problems for item-based accounts of immediate serial recall (Hulme et al., 1997; Schweickert, 1993), instead suggesting that immediate serial recall depends not only on individual items in the list but the list as a whole, and the associations between list items and other representations in memory (e.g., Cowan et al., 2003; Hulme et al., 2003; Stuart & Hulme, 2000). More generally, the results of this thesis support the connection between memory and language, which has become an increasingly widespread topic of investigation (e.g., Caplan & Waters, 1999; Gathercole, 2006; Gathercole et al., 1997; Gupta & MacWhinney, 1997; Gupta & Tisdale, 2009b; Kempler et al., 1998; R. C. Martin & He, 2004; Miller et al., 2010; Monetta & Pell, 2007; Reilly et al., 2012; Saito et al., 2003).

11.2.2 False memory.

The findings of the current project are consistent with many of the underlying assumptions of the two most dominant false memory frameworks, namely activation/monitoring theory (AMT; Gallo & Roediger, 2002; McDermott & Watson, 2001; Roediger, Watson, et al., 2001) and fuzzy trace theory (FTT; Brainerd & Reyna, 1993, 1998; Reyna & Brainerd, 1995). The manipulations of variables like presentation rate and task repetition have been used extensively in the literature to contribute to both of these theoretical models. AMT (Gallo & Roediger, 2002; McDermott & Watson, 2001; Roediger, Watson, et al., 2001) emphasises the role of spreading activation in such discussions. This theory assumes that false memory will be reduced under conditions that limit the association/spreading activation between the presented items and their non-presented critical lures (Burns, 2006; Gallo, 2010). This framework also highlights the role of monitoring processes in helping one to differentiate between sources of activation.

Based on AMT (Gallo & Roediger, 2002; McDermott & Watson, 2001), lists comprised of words that were associatively related and/or phonologically similar to a critical non-presented lure in this current project activated representations pertaining to both the list items and (via spreading activation) their related lure. Consequently, at recall there was the potential for both the list and the lure to be recalled. In line with AMT, false errors were made at retrieval when participants misattributed the lure's representation for an item within the list. In line with this account, hybrid lists presumably enhanced the associations between the list and their lures, leading to greater levels of false memory. In contrast, because the phonological and associative lists contained items that were related/similar to a critical lure interleaved between items that were unrelated/dissimilar to the lure, these lists may have helped participants to focus on the item-specific information.

AMT emphasises that conditions where item-specific list information encoding is encouraged will aid source memory and reduce the potential for false lures to be recalled (McDermott & Watson, 2001; Roediger, Watson, et al., 2001). The general trend in this project for correct recall to improve and false recall to decline during the standard presentation rate (as opposed to the rapid presentation rate) suggests that under these conditions participants were better able to process information about the list. The slower presentation speed may have also allowed more time for the list items to be activated and for the specific list information to be encoded. With regard to repetition in this project, repetition generally tended to improve correct recall and reduce false recall (at least at a mean level). This may propose that re-exposure of the same list helped participants to better process item-specific material and benefit from source information, thereby helping them to distinguish between representations of the list versus the lure. Moreover, it may be presumed that re-exposure to the list allowed spreading activation to be repeated, strengthening connections within the network and thereby aiding true memory and reducing false memory.

Fuzzy trace theory is also able to account for many of the findings of this thesis (Brainerd & Reyna, 1993, 1998; Reyna & Brainerd, 1995). This framework stresses that verbatim (item specific) memory is facilitated via list information processing. Conditions that enhance one's dependence on gist (i.e., general list) memory will seemingly lead to more false lures being recalled (see also Israel & Schacter, 1997; Schacter et al., 1999). FTT posits that false memories are the consequence of a reliance on general list information when verbatim information is unavailable for recall. Based on this theory, hybrid lists encourage gist memory encoding but make it difficult to distinguish verbatim memory, leading to higher levels of false recall on these lists. In accordance with FTT, the trend for false recall to reduce and true memory to improve during standard (as opposed to rapid) presentation rate could be due to more encoding of additional distinct verbatim traces during the slower presentation rate. Likewise, repetition could be argued to help with the strengthening of verbatim memory, leading to the improvement in correct recall and the general trend for false recall to decline, as reported in this research project.

With respect to ageing effects, both theories note that conditions that increase item specific information will attenuate the false memory effect (Burns, 2006). For older adults, the slower presentation rates did not appear to be effective in reducing the strength of association between the lure and the list (or reliance on gist memory) or in item-specific (or verbatim) information processing. True memory improved with repetition, suggesting that participants were able to make some use of the second attempt at the task to process list-specific (verbatim) information. Given that false memory did not change with repetition, however, it appeared that a second attempt at the task was not effective in helping participants to distinguish between the list and the lure in order to reduce source misattributions (or dependence on gist traces at recall).

Essentially, whilst the general trends of this thesis can be accounted for by both AMT (Gallo & Roediger, 2002; McDermott & Watson, 2001; Roediger, Watson, et al., 2001) and FTT (Brainerd & Reyna, 1993, 1998; Reyna & Brainerd, 1995), these models do not explain all of the findings obtained by the experiments in this project. Indeed, the discussion of the results in this section has been simplified in order to show how they may align with the major false memory theories. Certainly interpreting the results of the current project within models specifically focused on the immediate serial recall task (as outlined earlier in this chapter) appears to provide a more detailed explanation of the findings.

11.2.3 Healthy ageing.

Overall, the results of this project align with investigations that demonstrate an age-related decline in performance on episodic memory tasks (Bopp & Verhaeghen 2005; Zacks et al., 2000). The results of this thesis also support research that has emphasised age-related impairments in memory for temporal relationships (e.g., Noack et al., 2013) and the view that older adults have problems with contextual information (e.g., Braver & Barch, 2002; Braver et al., 2001; Haarmann et al., 2005; Spencer & Raz, 1994, 1995). Based on the results of this project, however, it is difficult to conclude that older adults are more vulnerable to suggestions or memory distortions than younger adults, as proposed by other research (e.g., Bartlett et al., 1991; Dywan & Jacoby, 1990; Loftus et al., 1993; Koutstaal & Schacter, 1997; Norman & Schacter, 1997; Schacter, Koutstaal, et al., 1997). Indeed, the findings that older adults performed worse than the younger adults on serial recall but comparable on false recall seems to be in opposition to the idea that increasing age-related false memory is simply due to declines in episodic memory. Instead it seems that other issues are involved such as attentional control/inhibition (Hasher & Zacks, 1988) or source monitoring deficits (e.g., Liliental et al., 2015). Some studies have linked the decline in source monitoring abilities to reduced verbal working memory (Hedden & Park, 2003), and susceptibility to false memories has also been related to working memory processes (e.g., McCabe & Smith, 2002). Critically, this project represents the first investigation of false memory effects in immediate serial recall in the context of ageing and episodic manipulations. Therefore, it could argued that the immediate serial recall task is more sensitive to the effects of ageing on true as opposed to false recall. Future investigations of short-term false recall and ageing may provide further support for this proposal.

More broadly, ageing research tends to discuss memory deficits in relation to episodic versus semantic memory, emphasising the division of these types of information. Semantic memory is often thought to be spared with advancing age whilst episodic memory is frequently impaired (Craik & Rose, 2013). Other studies have disagreed with this view of ageing (e.g., Light & Burke, 1993) and some have argued that a more accurate way to conceptualise age-related decline is to consider whether the information to be remembered involves pre-existing or new associations (e.g., Badham et al., 2012; Light & Burke, 1993; Wingfield & Kahana, 2002). In particular, relationships involving general knowledge are assumed to be easier to encode and retrieve (Badham et al., 2012).

In the immediate serial recall task, items are often considered in association to each other by way of the order that they are presented. While participants may be familiar with the concepts represented by the items in the list, they presumably would not have any prior familiarity with the items' order presentation. In this way, the serial recall task involves novel relationships (serial order) amongst the list items. Conversely, the DRM procedure (Deese, 1959; Roediger & McDermott, 1995) is predominately based on prior knowledge of the relationship between the list items and the critical lure. Based on this perspective, age-related differences were typically observed during serial recall in the current project, which presumably depends on *new* relationships amongst list items and their position. In contrast, there were no significant differences in false recall between the younger and older adults of this thesis, which is arguably based on *pre-existing* relationships between list items and their critical lures. From this perspective, the current project supports the need to consider whether relationships are novel or pre-existing when predicting the likelihood of age-related impairments on memory.

11. 3 Limitations to the Research and Directions for Future Work

Whilst this project has made significant contributions to verbal short-term memory literature, there are several limitations that are also important to acknowledge. For example, the presentation rates employed in this thesis did not readily impact the true memory of older participants in contrast to expectations. The older adults in this project were unable to encode or activate item-specific information during the standard presentation rate any better than their attempts during the rapid presentation rate. Conversely, other false memory studies have established that older individuals can make use of slower speeds to improve their true memory, although these investigations have tended to use different rates to those employed in the current project. To demonstrate, McCabe and Smith (2002) utilised presentation speeds of one word per 2000 and 4000 milliseconds, and observed an improvement in the true memory of *both* young and older participants during the slower versus faster rate. It is noteworthy, however, that even the “faster” speed used by McCabe and Smith was slower than the “standard” speed included in this thesis.

Indeed, declines in processing speed and general cognitive slowing are routinely discussed in relation to the ageing process (e.g., Craik & Rose, 2012; Myerson et al., 1990; Salthouse, 1996) and may explain why the older participants in the current project were unable to benefit from the “standard” speed of presentation. That is, the “standard” rate used in the current project, whilst consistent with the standard rate of the immediate serial recall task, was seemingly too fast for participants to be able to make use of strategies that would aid their item-specific information encoding (Smith & Kimball, 2012). The decision to include the same presentation rates across both younger and older samples was based on maintaining consistency throughout the project. It was expected that this would provide the opportunity to compare findings across all studies of the thesis. In retrospective, employing a slower speed for the older individuals, or at least a greater range of presentation speeds, would have been a better choice.

The presentation rates employed in this thesis also failed to effect the false memory of either younger or older adults. The standard rate (as opposed to the rapid rate) had been expected to assist with rejecting false lures given that the monitoring and control processes are typically enhanced at slower speeds (Gallo & Roediger, 2002; McDermott & Watson, 2001). This presumption, however, was based on long-term false memory research, which was somewhat different to the methodology of the current thesis. The presentation rates in this project were chosen based on the results of long-term false memory studies using similar speeds. Long-term false memory studies typically employ long lists of items (i.e., 15 associates) and often include a delay between item presentation and recall. In contrast, the current study presented lists of six words and required immediate recall. Clearly, further research is required to understand the relationship between presentation rate and false memory, specifically within immediate serial recall and the short-term domain. Future studies that include a greater range of presentation rates would be worth undertaking in order to provide greater understanding around this topic. For instance, based on other ageing studies where observing differences in true/false memory of younger and/or older adults was successful (McCabe & Smith, 2002; Watson et al., 2004), presenting one word per 250, 1000, 2000, 3000, and 4000 milliseconds could be included. The findings of this project are nonetheless consistent with the general patterns observed in long-term false memory research. That is, whether presentation rate will impact the false and/or true memory of older and/or younger individuals appears to depend on the specific presentation speeds that are employed.

Another possible limitation pertaining to the methodology of this project involves the construction of the word lists. It is notable that list type, while enabling the false memory effect, did not readily produce an impact on serial recall. As discussed earlier in this thesis, this may have been in part because lists contained interleaving unrelated or dissimilar items as opposed to comprising *only* related or dissimilar items. One could presume that including these unrelated/dissimilar words reduced the possible effects of associative relatedness and phonological similarity. There is limited research surrounding the impact of mixed lists on associative relatedness but the phonological similarity effect has been reported even with lists of interleaving similar and dissimilar items (Baddeley, 1968, Experiment 5; Farrell & Lewandowsky, 2003; Henson et al., 1996; Lewandowsky & Farrell, 2007). In fact, dissimilar items on mixed, interleaving lists (i.e., similar-dissimilar-similar-dissimilar) have been shown to be better recalled than dissimilar items on purely dissimilar lists (i.e., dissimilar-dissimilar-

dissimilar-dissimilar), referred to as the mixed-list advantage (Farrell, 2006; Farrell & Lewandowsky, 2003; Lewandowsky & Farrell, 2007). Based on this research, it seems unlikely that the interleaving nature of the lists in the current project reduced phonological similarity effects.

Nonetheless, the examination of pure associative lists comprised of six associates and pure phonological lists of six phonologically similar words would make an interesting contribution to the current findings of this thesis. Similar to the procedure that was employed in this project to create semantic lists, the top six semantic associates for each critical lure based on word association norms (Nelson et al., 1998) could be selected to form each trial. Items could be arranged depending on the strength of their relationship to the critical item (i.e., strongest to weakest) in line with the DRM framework (Deese, 1959; Roediger & McDermott, 1995). To create the phonological lists, the phoneme substitution method (Sommers & Lewis, 1999) used in this project could again be adopted. Two words with the same beginning and middle phonemes as the critical lure, two items with the same beginning and end phonemes as the lure, and two items with the same middle and end phonemes as the lure could be selected to form each six-word trial.

Investigating “pure” associative lists and phonological lists might also assist in clarifying whether the often negligible effects of list type on serial recall was because lists contained few (i.e., three) associates/phonologically similar words. Presumably, using additional associates/phonologically similar words would have produced stronger effects of these variables. Indeed, increasing the list length of an immediate serial recall task has been linked to increases in the semantic similarity effect for both younger and older adults (Neale & Tehan, 2007). Longer lists are presumably more difficult to recall than shorter lists, hence why participants are more likely to use semantic information as a cue to guide retrieval during these longer sequences (Neale & Tehan, 2007). Phonological similarity effect, however, has been found to reverse during more difficult conditions (Neale & Tehan, 2007), highlighting that the impact of list length may not be so straightforward. Clearly, future research may warrant an exploration of this point.

Related to the issue of list length, it could be argued that the hybrid lists' superadditive false memory effects in this thesis were due to the *number* of words being connected to the lure in these lists rather than the *type* of words that were presented. That is, whilst hybrid lists had six items that were linked to the lure, the associative lists and phonological lists only had three items connected to the lure. Contrary to this notion though, the superadditive impact of hybrid lists on false memory has been reported even when the number of similar/related words within each respective list are equal. For example, Watson et al. (2003) found that lists that consisted of eight semantic and eight phonological associates resulted in greater levels of false recall and recognition than lists comprised of 16 semantic associates or 16phonological associates. In short, the effects of hybrid lists do not seem to be the result of increasing list length, rather they are the product of interacting long-term networks that increase lure activation and heighten lure recall/recognition (Roediger, Balota, & Watson, 2001; Watson et al., 2003; Watson et al., 2001).

In regards to the influence of task repetition, it is important to emphasise that this project compared the effects of repeating both the *same* and *different* recall tasks when repetition occurred in immediate succession (i.e., Experiments 1 and 2), but only looked at the effects of repeating the *same* task when repetition occurred after a delay (i.e., Experiments 3 and 4) and when older adults were included in the sample (i.e., Experiments 5 and 6).

Although this project assumed that repetition improved serial recall across time one to time two, it is acknowledged that practice effects cannot be ruled out in the later experiments. It would seem, however, that given practice effects did not impact performance on Experiment 2 with immediate repetition, it would be unlikely that longer intervals between attempts would actually increase the effects of practice. It would also seem unlikely that older participants would benefit from practice when younger individuals did not. Nevertheless, further investigation on this topic may be worthwhile to confirm these proposals. More specifically, presenting younger and older participants with two different recall tasks with varying delays between the two tasks would provide a meaningful addition to this project.

Another limitation concerning task repetition and delay relates to what participants actually did during their break between time one and time two. During the experiments that included a delay (i.e., Experiments 3, 4, and 6), participants were able to leave the room of testing when they completed the first task. There were no constraints on what participants did between time one and time two other than that they were not encouraged to discuss details of the task before completing the entire experiment. During the 15-minute delay, participants would typically use the bathroom, have a drink of water and/or engage in general conversation with the researcher. For the 60-minute delay, participants would generally leave the room of testing and return at the designated time to complete the second task. Arguably, this lack of control may have introduced interference effects into the study. There is a possibility that the level of activity participants engaged in during the two tasks may have influenced whether any improvements could be made with repetition (i.e., whether false recall decreased and/or serial recall increased). For example, research looking at the role of sleep and memory performance suggests that inactivity can improve performance on verbal memory tasks (e.g., Gais et al., 2007; Gais, Lucas, & Born, 2006; Plihal & Born, 1997, although see Siegel, 2001; Vertes, 2004). Unfortunately participant activity during the delay periods was not recorded for this project, therefore it is difficult to make any specific predictions or conclusions on this point. This issue, however, appears to reflect a general lack of constraint (or at least details regarding constraints) in the broader memory research involving delayed repetition. Clearly the logistics in being able to control for participant activity during delays, particularly those involving extended periods is difficult to enforce. Regardless, it is important to acknowledge the possible influence the lack of control may have had on the findings.

Another potential source of interference in this project pertains to the information letter given to participants prior to completing the experiment. The information letter described that the purpose of the project was to investigate false memory. Arguably, use of the term “false memory” may have impacted participant responses. More specifically, participants may have been less likely to divulge responses (recall items) that they were not confident about if they were aware their “false memories” were being tested. Research suggests that older adults in particular are likely to be more cautious in responding on memory tests, particularly on time-pressured tasks (Oberauer, 2001, 2005a). Nonetheless, including the term “false memory” in the information letter could be equated to giving participants a warning about the effect. In this respect, it is important to remember that even if participants were aware of the false memory effect, research says that providing warnings does not necessarily eliminate the effect (e.g., McDermott & Roediger, 1998). In retrospect, slight modification of the wording in the information letter (with full disclosure after the tasks were completed) may have reduced this potential confound. Essentially, the impact of participant expectations on the findings of this project would be more problematic if the false memory effect had failed to be reported. However, the false memory effect was observed across all six experiments and at both time one and time two, suggesting that participants were still somewhat unaware that they were making false errors.

Another limitation to acknowledge pertains to the relatively low effect sizes reported in some of the experiments. For instance, the main analysis of list type on serial recall routinely produced small effect sizes ($\eta_p^2 \leq .08$). Likewise, the effect of presentation rate on the serial recall of older adults (i.e., Experiments 5 and 6) also exhibited minimal effect sizes (($\eta_p^2 \leq .10$). With respect to false recall, effect size was also small ($\eta_p^2 \leq .17$) during the majority of main analyses looking at time of test and presentation rate. Similarly, the influence of delay and age on performance when studies were compared against each other also produced small effect sizes ($\eta_p^2 \leq .07$). Arguably, increasing sample size would have been helpful in these analyses. The number of participants recruited for each study was seemingly small ($n = 20$). Given the number of studies included in this project, increasing the sample size for all experiments would have required a substantial increase in the overall number of participants. The nature of the population (i.e., older adults without cognitive impairment), the task (i.e., face-to-face individual testings sessions with up to an hour delay between sessions) and lack of incentives to participate (with the exception of course credit for eligible undergraduate students) meant that data collection was a somewhat time-consuming and challenging process. Regardless, it is important to recognise the possible impacts that sample size may have had on the findings of this thesis particularly with respect to any non-significant results reported. Given that this is the first short-term false memory study to consider the role of normal ageing, rapid presentation, task repetition, and immediate serial recall, it is difficult to estimate the extent that sample size impacted the results. Clearly, future investigation on the variables examined in this project would be beneficial to this point.

A final project limitation also relating to sample size, is the number of participants who reported being unaware of the task repetition. It would have been interesting to conduct conditional analyses on those participants who did or did not report being aware of the task repetition to consider the impact on performance. Unfortunately, even pooling the experiments together, there were very few participants who reported being unaware that the task at time one was the same as the task at time two (only four older adults and two younger adults). Future research that was able to recruit larger samples might be able to explore this topic further. Whilst this thesis has attempted to outline an integrative approach to immediate serial recall, further research is required for such an approach to develop into a more detailed theoretical model. From the discussion in this chapter it is clear that many questions remained unanswered. For instance, this project chose to utilise presentation rate, task repetition, and the ageing process to manipulate episodic context. However, there are numerous ways to vary episodic conditions of the immediate serial recall task. Moreover, there are a range of working memory effects that would need to be accounted for within an immediate serial recall model. Examination of some of the short-term domain benchmark effects such as the irrelevant speech effect (i.e., irrelevant background speech during list presentation/recall reduces performance; Colle & Welsh, 1976), the word length effect (i.e., better recall of short versus long words; Baddeley, Thomson, & Buchanan, 1975), and the concurrent articulation effect (i.e., having to engage in irrelevant, concurrent articulation impairs recall; Murray, 1968) would be essential in the development of a comprehensive verbal short-term memory account.

The relationship between semantic versus associative similarity is also an important area for future research. Traditionally, short-term memory research has concentrated on semantic/categorical similarity and most current models of immediate serial recall either focus on semantic *or* associative similarity, or do not explicitly address the issue at all. For instance, psycholinguistic frameworks typically describe the semantic layer (e.g., R. C. Martin et al., 1999); the embedded components model (Oberauer, 2002) details an associative network; and during a discussion of concept arrangements within long-term networks/neighbourhoods, Nelson et al. (2013) uses the terms “associative” and “semantic” interchangeably. The question of whether or not to distinguish between associative and semantic/categorical similarity/relatedness is an ongoing debate (e.g., Crutch & Warrington, 2010; McRae et al., 2012; Thompson-Schill et al., 1998). In order to provide an overarching model of immediate serial recall, an integrative account would need to consider this point. Consequently, the inclusion of associative lists *and* semantic lists in future replications of this project would be helpful in addressing this issue. That is, presenting lists composed of words that are associatively related (e.g., *bark*) and semantically/categorically related (e.g., *cat*) to a non-presented critical item (e.g., *dog*) may assist in extending this topic to an integrative framework.

With respect to phonological similarity, and in particular the impact of clustering coefficients, the number of phonological neighbours of the critical lure that are neighbours of each other (Chan & Vitevitch, 2009, 2010), may provide an additional avenue for prospective research on false memories in the short-term domain. That is, controlling for the relationship *between* list items (as opposed to only their connection to the critical item) by measuring the clustering coefficients of these items may provide more robust effects of phonological similarity, and would be worth comparing to the findings of the current project.

For further exploration of phonological and semantic representations, it would seem highly valuable to extend this project to individuals suffering from specific semantic and phonological cognitive impairments. This line of research would arguably provide a direct comparison to psycholinguistic studies that have considered these populations to test their frameworks (e.g., Freedman & R. C. Martin, 2001; Hanten & R. C., Martin, 2000; Hoffman et al., 2009; N. Martin & Saffran, 1997; R.C. Martin & He, 2004; R. C. Martin et al., 1994; Reilly et al., 2012; Wong & Law, 2008). Additionally, it may supplement the existing research that has investigated the role of intrusions in verbal short-term memory. This topic has become a predominate focus in many recent psycholinguistic investigations (e.g., Biegler, Crowther, & R. C. Martin, 2008; Hamilton & R. C. Martin, 2005, 2007; R. C. Martin & He, 2004) and therefore suggests a trend for future research. Interestingly, some studies have found that ageing has been shown to be more detrimental to phonological processing as opposed to semantic processing (Burke & Shaft, 2008), highlighting the role of multiple representations in the memory system. One presumption for this has been that the ageing process has less effect on the semantic networks because they contain denser connections than phonological networks (Burke & MacKay, 1997). This project did not see any significant differences in the older participants' list recalls based on semantic versus phonological representations, although a study of older individuals with specific impairments in either semantic or phonological processes would be worthwhile.

More generally, while it is beyond the scope of this thesis, developing an integrative immediate serial recall approach into a computational model appears to be an important step in this line of research. Current computational immediate serial recall frameworks provide a detailed account of serial order but do not accommodate to any great extent for semantic or phonological representations in verbal short-term memory. Presumably, computational modelling would allow one to expand on some of the propositions made in this research project into a testable framework.

11.4 Conclusions

This thesis has been successful in demonstrating that the binding of episodic, semantic/associative and phonological representations can impact short-term recall. This topic was discussed within the context of psycholinguistic accounts of verbal short-term memory that emphasised the role of multiple representation in the memory system (e.g., N. Martin & Gupta, 2004; R. C. Martin et al., 1999; Romani et al., 2008), and contemporary computational models of immediate serial recall that promoted the influence of episodic context on performance (e.g., Brown et al., 2007; Brown et al., 2000; Burgess & Hitch, 2006; Page & Norris, 2009). Critically, these respective frameworks have difficulty in accommodating all immediate serial recall effects. Computational models have tended to under-estimate the impact of multiple representations in short-term memory (Hurlstone et al., 2014) whilst interactive/network based accounts of verbal short-term memory have tended to elaborate on the representation and influence of semantic memory, although they have not readily expanded on the order maintenance (episodic memory) within the system (Jefferies et al., 2008; Majerus, 2009; N. Martin, 2009). Thus, the aim of this project was to provide a way to converge on these different theories in order to form a more integrative model of immediate serial recall. The integrative framework put forth by this thesis was not able to explain all of the findings of the experiments. Hence, at the present time this account is purely hypothetical and further research is needed to outline some of the ideas presented in this thesis in more detail with adequate testing of such assumptions. Nonetheless, it is hoped that this project may serve as a reference point in the development of a comprehensive overarching account of immediate serial recall.

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Appendices

Appendix A. Australian Catholic University's National School of Psychology research participation system invitation for Experiment 1 and 2

Study Name: Short-term Memory and Serial Recall Tasks

Abstract: This research project will investigate memory performance in serial recall tasks. The primary aim of this project is to investigate false memory and the relationship between short and long-term memory.

Description: You will be asked to complete a short questionnaire about age, sex, education, general health and sleep rating, level of English and current feelings of stress and alertness. This study will also involve completing two memory tasks. In these tasks you will be asked to remember short lists of words. Each word will be presented one at a time on a computer screen. At the end of each list you will be asked to immediately recall the words aloud in the order they appeared. The researcher will be present to record your responses.

Eligibility requirements: In order to participate, you must be between 18 – 55 years of age.

Duration: 60 minutes

Credits: 1.5 Credits

Researcher: Gabrielle Ritchie

Deadlines: Sign-up: 24 hour(s) before the appointment
Cancellation: 24 hour(s) before the appointment

Appendix B. Australian Catholic University's National School of Psychology research participation system invitation for Experiment 3

Study Name: Short-term Memory

Description: This study involves completing a short demographic questionnaire, followed by two memory tasks 15 minutes apart. In these tasks you will be asked to remember short lists of words on a computer screen.

Eligibility requirements: Participants must be between 18 – 55 years of age.

Duration: 60 minutes

Credits: 1.5 Credits

Researcher: Gabrielle Ritchie

Deadlines: Sign-up: 24 hour(s) before the appointment
Cancellation: 24 hour(s) before the appointment

Appendix C. Australian Catholic University's National School of Psychology research participation system invitation for Experiment 4

Study Name: Short-term Memory Study 2

Description: This study is made up of two parts: Part A (30 minutes) – involves completing a short demographic questionnaire, followed by a memory task. Part B (30 minutes) – involves completing a second memory task. In both memory tasks you will be asked to remember short lists of words presented on a computer screen. You will be asked to return 60 minutes (1 hour) after finishing Part A of the study to complete Part B.

Eligibility requirements: Participants must be between 18 – 55 years of age.

Duration: 120 minutes

Credits: 1.5 Credits

Researcher: Gabrielle Ritchie

Deadlines: Sign-up: 24 hour(s) before the appointment

Cancellation: 24 hour(s) before the appointment

Appendix D. Invitation distributed via e-mail to students within Australian Catholic University's National School of Psychology for Experiment 4 recruitment

The School of Psychology warmly invites you to participate in a research project on:

Short-Term Memory

Dear students,

I am a Doctor of Philosophy student completing my research project on the topic of Short-Term Memory and I would like to invite you to participate in this interesting study.

ACU psychology undergraduate students may be eligible to receive additional course credit by participating.

To participate in this research, please click on the link below to sign up (participants must have a SONA account in order to access this link): https://acupsychology.sona-systems.com/

Thank you.
Gabrielle Ritchie
PhD Student - Psychology
Brisbane campus ACU

What will participants be required to do?
- Part A (30 minutes) - complete a demographic questionnaire and a memory task.
- Part B (30 minutes) - complete a second memory task.
- In both memory tasks you will be asked to remember short lists of words presented on a computer screen.
- You will be asked to return 60 minutes (1 hour) after finishing Part A of the study to complete Part B.

Who can participate?
- Participation is voluntary and you must be between 18 – 55 years of age.
- Participants must not have already completed the following studies:
  - Short-Term Memory (Brisbane)
  - Short-term Memory and Serial Recall Tasks (Brisbane)

The project has been approved by the Australian Catholic University Human Research Ethics Committee (Registration Approval Number 2013 81Q).

Should you require any further information, please do not hesitate to contact the student researcher, Gabrielle Ritchie via email.or Supervisor, Associate Professor Anne Tolan via email

Appendix E. Background questionnaire for Experiment 1 - 4

Background Information

ID Code… ………. Date: ……………………

Age:..............years

Male ☐ Female ☐

Secondary school: year level completed: ....

Post-secondary education or equivalent study: number of years (full-time) completed: ......

English Language Skills:

Is English your primary language? Yes ☐ No ☐

If not, how many years have you spoken English? ....

How do you rate your level of English?

Excellent ☐ Very good ☐ Good ☐ Not very good ☐ Poor ☐

Health and Sleep:

How would you describe your state of physical health over the last month or so?

Excellent ☐ Very good ☐ Good ☐ Not very good ☐ Poor ☐

How would you describe your state of physical health today?

Excellent ☐ Very good ☐ Good ☐ Not very good ☐ Poor ☐

How would you describe how you have been sleeping over the last month or so?

Excellent ☐ Very good ☐ Good ☐ Not very good ☐ Poor ☐

Stress and Alertness:

How would you describe your level of stress today?

Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐

How would you describe your feelings of alertness today?

Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐

Appendix F. Participant information letter for Experiments 1 - 4

PARTICIPANT INFORMATION LETTER

PROJECT TITLE: Short-term Memory and Serial Recall Tasks
PRINCIPAL INVESTIGATOR/SUPERVISOR: Associate Professor Anne Tolan
STUDENT RESEARCHER: Gabrielle Ritchie
STUDENT'S DEGREE: Doctor of Philosophy

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?
This research project will investigate memory performance and false memory effects in serial recall task. The aim of this project is to investigate the relationship between short and long-term memory looking at participants between 18 and 55 years of age.

Who is undertaking the project?
This project is being conducted by Gabrielle Ritchie and will form the basis for the degree of Doctor of Philosophy at Australian Catholic University (ACU) under the supervision of Associate Professor Anne Tolan.

Are there any risks associated with participating in this project?
There are no foreseeable risks associated with the project.

What will I be asked to do?
- The study will take place at a mutually convenient location.
- You will be asked to complete a questionnaire about age, sex, education, general health and sleep rating, level of English and current feelings of stress and alertness.
- This study will also involve completing two memory tasks. In these tasks you will be asked to remember short lists of words. Each word will be presented one at a time on a computer screen. At the end of each list you will be asked to immediately recall the words aloud in forward order. The student researcher will be present to record your responses.

How much time will the project take?
Participation will include two sessions of approximately 25 - 30 minutes each. Each session will include one memory task. These sessions will occur immediately after each other or after a designated break (15 minutes, 1 hour or 24 hours).

What are the benefits of the research project?
Those participants who are enrolled in psychology at ACU may be eligible for course credit for participating. Participants will have the opportunity to experience the processes involved in psychological lab experimentation, a method used regularly for studying memory performance. Introductory and advanced units in psychology require students to have a clear understanding of the processes of experimentation and cognition/memory. Participation may assist in understanding of concepts learnt in psychology units. Individuals from the wider community will not receive any incentives to participate. While no direct benefits for participation will be offered, it is hoped that

results from this study will be published in psychological journals, contributing to the understanding of short and long-term memory.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. Non-participation or withdrawal will not affect ongoing enrolment of ACU students.

Will anyone else know the results of the project?

The researchers will take every precaution to ensure confidentiality. All participants will be given a code and names will not be retained with any of the raw data. The results from this study may be summarised and appear in publications or may be provided to other researches in a form that does not identify the participants in any way. All data will be kept in a locked filing cabinet in the office of the supervisor or student researcher. Any computer files associated with this research project will be on a computer that is password protected. Data will be stored in this secure environment for the ACU required period of 5 years upon completion of the project or publication of the report. After this period all response sheets will be shredded and computer disks erased. All information obtained from this research will be the property of the researchers and ACU.

Will I be able to find out the results of the project?

If you wish to receive feedback on the results of the project you will be able to contact either the Principle Investigator/Supervisor or Student Researcher however individual results will not be communicated to participants as all participants will be given a code and names will not be retained with any of the raw data. You will have the opportunity to discuss your participation and the project in general after completion of the experiment.

Who do I contact if I have questions about the project?

You can direct any questions regarding this project to Associate Professor Anne Tolan and Gabrielle Ritchie:

Associate Professor Anne Tolan
(07) 3623 7256
School of Psychology
1100 Nudgee Road
Banyo QLD 4014

Gabrielle Ritchie
gelusi001@myacu.edu.au
School of Psychology
1100 Nudgee Road
Banyo QLD 4014

What if I have a complaint or any concerns?

The study has been approved by the Human Research Ethics Committee at Australian Catholic University (approval number 2013 81Q). If you have any complaints or concerns about the conduct of the project, you may write to the Chair of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).

Chair, HREC
c/o Office of the Deputy Vice Chancellor (Research)
Australian Catholic University
Melbourne Campus
Locked Bag 4115
FITZROY, VIC, 3065
Ph: 03 9953 3150
Fax: 03 9953 3315
Email: res.ethics@acu.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want to participate! How do I sign up?

If you agree to participate in this project, you should sign both copies of the Consent Form, retain one copy for your records and return the other copy to the Student Researcher. Your participation in this research project will be most appreciated.
Yours sincerely,

Associate Professor Anne Tolan
Principal Investigator/Supervisor

Gabrielle Ritchie
Student Researcher

Appendix G. Participant consent forms for Experiments 1 - 4

CONSENT FORM

Copy for Researcher

TITLE OF PROJECT: Short-term Memory and Serial Recall tasks

PRINCIPAL INVESTIGATOR/SUPERVISOR: Associate Professor Anne Tolan

STUDENT RESEARCHER: Gabrielle Ritchie

I .... *(the participant)* have read (*or, where appropriate, have had read to me)* and understood the information provided in the Letter to Participants. I am between 18 and 55 years of age. Any questions I have asked have been answered to my satisfaction. I agree to participate in this project which involves completing a background questionnaire and remembering lists of words for serial recall. I am aware that the activity will include two sessions of approximately 25-30 minutes each. I am aware that these sessions may occur immediately after each other or after a specified break (15 minutes, 1 hour or 24 hours), realising that I can withdraw my consent at any time without penalty. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT:…………………………………………………………………………

SIGNATURE .... DATE ....

SIGNATURE OF PRINCIPAL INVESTIGATOR/SUPERVISOR: DATE:

SIGNATURE OF STUDENT RESEARCHER: DATE:

CONSENT FORM

Copy for Participants to keep

TITLE OF PROJECT: Short-term Memory and Serial Recall tasks

PRINCIPAL INVESTIGATOR/SUPERVISOR: Associate Professor Anne Tolan

STUDENT RESEARCHER: Gabrielle Ritchie

I .... *(the participant)* have read (*or, where appropriate, have had read to me)* and understood the information provided in the Letter to Participants. I am between 18 and 55 years of age. Any questions I have asked have been answered to my satisfaction. I agree to participate in this project which involves completing a background questionnaire and remembering lists of words for serial recall. I am aware that the activity will include two sessions of approximately 25-30 minutes each. I am aware that these sessions may occur immediately after each other or after a specified break (15 minutes, 1 hour or 24 hours), realising that I can withdraw my consent at any time without penalty. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT: ………………………………………………………………………….

SIGNATURE .... DATE ....

SIGNATURE OF PRINCIPAL INVESTIGATOR/SUPERVISOR: DATE:

SIGNATURE OF STUDENT RESEARCHER: DATE:

Appendix H. Responses to Background Questionnaire for Experiments 1 - 4

	Experiment 1		Experiment 2		Experiment 3		Experiment 4	
	N	%	*N*	%	*N*	%	*N*	%
Sex								
Female	15	75	11	55	16	80	15	75
Male	5	25	9	45	4	20	5	25
Highest level of education completed								
Year 10 equivalent or lower	1	5	2	10	0	0	0	0
Year 11 equivalent	1	5	2	10	0	0	0	0
Year 12 equivalent	3	15	4	20	9	45	4	20
1 - 3 years post-secondary	11	55	8	40	7	35	12	60
4 - 6 years post-secondary	4	20	4	20	4	20	2	10
7 years or more post-secondary	0	0	0	0	0	0	2	10
First language								
English	18	90	20	100	19	95	19	95
Other	2	10	0	0	1	5	1	5
Level of English								

Excellent	12	60	12	60	11	55	13	65
Very good	8	40	8	40	6	30	6	30
Good	0	0	0	0	3	15	1	5
State of physical health over last month								
Excellent	2	10	6	30	3	15	2	10
Very good	7	35	6	30	7	35	12	60
Good	9	45	7	35	9	45	4	20
Not very good	2	10	1	5	1	5	2	10
State of physical health on day of testing								
Excellent	3	15	2	10	3	15	3	15
Very good	9	45	8	40	9	45	7	35
Good	7	35	10	50	6	30	8	40
Not very good	1	5	0	0	2	10	2	10
Level of sleep over the last month								
Excellent	1	5	1	5	1	5	1	5
Very good	4	20	6	30	3	15	5	25
Good	6	30	7	35	14	70	11	55
Not very good	8	40	6	30	1	5	3	15
Poor	1	5	0	0	1	5	0	0
Level of stress on day of testing								

High	4	20	3	15	1	5	4	20
Average	8	40	8	40	11	55	8	40
Low	5	25	5	25	6	30	7	35
Very low	3	15	4	20	2	10	1	5
Level of alertness on day of testing								
Very high	2	10	1	5	0	0	0	0
High	4	20	8	40	5	25	8	40
Average	10	50	10	50	13	65	11	55
Low	4	20	1	5	2	10	1	5

Note. $N = 20$

Appendix I. Australian Catholic University Human Research Ethics Committee approval

Dear Applicant,

Principal Investigator: A/Prof Georgina Tolan
Student Researcher: Ms Gabrielle Ritchie
Ethics Register Number: 2013 81Q
Project Title: False memory, presentation rate, task repetition and serial recall
Risk Level: Low Risk 2
Date Approved: 15/04/2013
Ethics Clearance End Date: 31/03/2015

This email is to advise that your application has been reviewed by the Australian Catholic University's Human Research Ethics Committee and confirmed as meeting the requirements of the National Statement on Ethical Conduct in Human Research.

This project has been awarded ethical clearance until 31/03/2015. In order to comply with the National Statment on Ethical Conduct in Human Research, progress reports are to be submitted on an annual basis. If an extension of time is required researchers must submit a progress report.

Whilst the data collection of your project has received ethical clearance, the decision and authority to commence may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance or permissions from other organisations to access staff. Therefore the proposed data collection should not commence until you have satisfied these requirements.

If you require a formal approval certificate, please respond via reply email and one will be issued.

Decisions related to low risk ethical review are subject to ratification at the next available Committee meeting. You will only be contacted again in relation to this matter if the Committee raises any additional questions or concerns.

Researchers who fail to submit an appropriate progress report may have their ethical clearance revoked and/or the ethical clearances of other projects suspended. When your project has been completed please complete and submit a progress/final report form and advise us by email at your earliest convenience. The information researchers provide on the security of records, compliance with approval consent procedures and documentation and responses to special conditions is reported to the NHMRC on an annual basis. In accordance with NHMRC the ACU HREC may undertake annual audits of any projects considered to be of more than low risk.

It is the Principal Investigators / Supervisors responsibility to ensure that:
1. All serious and unexpected adverse events should be reported to the HREC with 72 hours.
2. Any changes to the protocol must be approved by the HREC by submitting a Modification Form prior to the research commencing or continuing.
3. All research participants are to be provided with a Participant Information Letter and consent form, unless otherwise agreed by the Committee.

For progress and/or final reports, please complete and submit a Progress /
Final Report form:
www.acu.edu.au/465013

For modifications to your project, please complete and submit a Modification form:
www.acu.edu.au/465013

Researchers must immediately report to HREC any matter that might affect the ethical acceptability of the protocol eg: changes to protocols or unforeseen circumstances or adverse effects on participants.

Please do not hesitate to contact the office if you have any queries.

Kind regards,
Kylie Pashley

Ethics Officer | Research Services
Office of the Deputy Vice Chancellor (Research)
Australian Catholic University

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Appendix J. Word lists

Lures	**Associatively related**			**Phonologically similar s**		
sick	Ill	illness	Flu	Sit	Sack	Lick
lose	Win	Find	Gain	Loot	Lass	Chose
rain	Storm	cloud	Hail	Rail	Ran	Vain
boat	Row	Sail	Yacht	Bone	Bat	Wrote
close	Open	shut	Near	Cloak	crows	Flows
square	Circle	round	Cube	squawk	snare	cookware
horse	Saddle	pony	gallop	hoard	hiss	Force
sing	Hum	chorus	Choir	Sin	sung	Wing
friend	Pal	buddy	neighbour	Fret	found	defend
flower	Tulip	petals	Daisy	flounce	flutter	glower
house	Brick	home	Roof	Howl	hose	Douse
fire	Flame	smoke	Burn	Fine	fear	Wire
cold	Hot	shiver	Freeze	Coal	called	Told
bird	Nest	parrot	Robin	Birch	Bud	Third
run	Jog	walk	Track	Rum	rein	Ton
hate	Despise	dislike	Love	Hale	Hit	Rate
ghost	Ghoul	goblin	phantom	Goes	goat	Post
can	Tin	trash	Able	Care	con	Pan
clothes	wardrobe	hanger	Wear	Clone	claims	Oaths
stop	Halt	Go	Sign	Stock	step	Top
get	Obtain	acquire	receive	gecko	gut	Net
movie	Film	popcorn	Flick	mover	moody	groovy

pen	Ink	pencil	Paper	Pet	pun	ten
brush	Comb	bristle	Paint	Brunt	blush	crush
big	Huge	little	Small	Bib	beg	gig
coat	Jacket	mink	Fur	Code	cult	quote
dirt	Soil	filth	Mud	duress	dart	shirt
wet	Dry	soak	Damp	When	wait	met
baby	Crib	infant	diaper	Babe	barbie	maybe
mean	Cruel	nice	Bully	Meek	mine	bean
chair	Table	seat	Stool	chant	cheer	share
cat	Kitten	Dog	mouse	Cab	cot	rat
pants	Slacks	zipper	Jeans	panel	pots	hunts
water	Faucet	liquid	Pool	Warts	wander	daughter
meat	Raw	steak	Beef	Mere	moat	beat
hold	Grasp	Grip	Keep	Holt	held	gold
police	Cop	badge	Arrest	polar	price	release
grass	Weed	lawn	Mow	graph	gross	brass
bug	Beetle	insect	Roach	bun	bag	rug
cake	Icing	frosting	Bake	cape	coke	make
sleep	Bed	snooze	Tired	sleet	slope	leap
cry	Weep	Sob	Tears	crow	coy	try
fat	Thin	skinny	Slim	fad	fit	that
pig	Hog	pork	Sow	pit	pug	wig
want	Desire	need	Yearn	wand	wart	font
clam	Chowder	oyster	Mussel	clever	climb	slam
street	Road	main	Curb	stripe	state	greet

doctor	Nurse	surgeon	Patient	docket	door	factor
blue	Sky	red	Colour	blow	brew	flew
bread	Loaf	butter	Dough	bran	brood	tread
clean	Spotless	tidy	Dirty	cleave	clan	spleen
letter	Stamp	note	Mailbox	lettuce	lesser	better
light	Bulb	lamp	Switch	line	let	height
take	Give	grab	Steal	tame	tick	fake
hurt	Harm	pain	Ouch	herb	heart	squirt
book	Novel	page	Read	bought	back	took
king	Queen	crown	Monarch	kin	clang	swing
hear	Listen	ear	Deaf	heel	hair	deer
god	Lord	bible	Faith	gone	grid	pod
smell	Odour	scent	Stink	smooth	sale	camel
fight	Quarrel	argue	Struggle	five	fate	might
happy	Sad	glad	Joy	happen	hippie	nappy
fog	Mist	haze	Smog	fond	fig	log
drugs	Addict	dope	Cocaine	drunk	drives	slugs
nut	Cashew	pecan	Almond	nun	nit	rut
fly	Swatter	soar	Airplane	flow	fry	ally
teeth	Gums	braces	Dentist	team	tooth	wreath
foot	Toe	inch	Shoe	fool	feat	soot
sun	Rays	shine	Moon	suck	sane	none
work	Labour	job	Earn	word	weak	quirk
head	Hat	necklace	Brain	hem	hid	lead
money	Cash	bank	Spend	month	muddy	honey

fish	Trout	cod	Fin	fill	flush	dish
gun	Pistol	trigger	Bullet	gum	gin	fun
sweet	Bitter	sugar	Sour	sweep	sweat	tweet
tree	Oak	stump	Leaf	true	tea	three
write	Print	essay	Scribble	rye	rot	tight
break	Shatter	fix	Bend	braid	broke	rake
horn	Honk	bugle	Trumpet	hawk	hone	fawn
mix	Blend	stir	Combine	mint	max	six

Appendix K. Example of word trials for participant one

Task one: Rapid presentation rate

Ass-sim	icing	cape	frosting	coke	bake	make
Unrel-sim	win	goes	bristle	goat	mud	post
Unrel-sim	circle	hoard	goblin	hiss	gain	force
Unrel-sim	crib	holt	seat	held	gallop	gold
Ass-sim	raw	mere	steak	moat	beef	beat
Unrel-dis	nest	cab	walk	bat	roach	vain
Unrel-dis	cop	sin	parrot	cot	track	wrote
Unrel-dis	pal	cloak	badge	sung	robin	rat
Ass-sim	obtain	gecko	acquire	gut	receive	net
Unrel-dis	row	bun	cloud	found	near	release
Unrel-dis	kitten	rum	sail	bag	hail	defend
Ass-dis dry	code	soak	moody	damp	told	
Unrel-sim	soil	brunt	trash	blush	keep	crush
Ass-sim	faucet	warts	liquid	wander	pool	daughter
Unrel-sim	table	babe	pony	barbie	cube	maybe
Ass-sim	weed	graph	lawn	gross	mow	brass
Ass-dis	slacks	flounce	zipper	pun	jeans	rate
Ass-dis	brick	when	home	cult	roof	groovy
Ass-dis	jacket	mover	mink	called	fur	hunts
Ass-dis	despise	clone	dislike	hose	love	met

Task one: Standard presentation rate

Unrel-sim	comb	loot	filth	lass	able	chose
Unrel-dis	storm	fret	shut	price	choir	third
Unrel-sim	ghoul	squawk	find	snare	paint	cookware
Unrel-dis	hum	birch	dog	rein	yacht	rug
Unrel-dis	open	polar	chorus	bud	mouse	ton
Ass-sim	cruel	meek	nice	mine	bully	bean
Ass-dis hot	panel	shiver	flutter	freeze	ten	
Ass-dis	wardrobe	howl	hanger	wait	wear	quote
Ass-dis film	coal	popcorn		pots	flick	glower
Unrel-sim	tin	duress	grip	dart	diaper	shirt
Unrel-sim	grasp	care	infant	con	stool	pan
Ass-sim	huge	bib	little	beg	small	gig
Ass-dis	tulip	pet	petals	hit	daisy	oaths
Ass-sim	halt	stock	go	step	sign	top
Unrel-sim	saddle	chant	round	cheer	phantom	share
Ass-sim	flame	fine	smoke	fear	burn	wire
Ass-sim	ill	sit	illness	sack	flu	lick
Unrel-dis	jog	bone	insect	ran	neighbour	flows
Unrel-dis	beetle	rail	buddy	crows	arrest	wing
Ass-dis	ink	hale	pencil	claims	paper	douse

Appendix L. Instructions for Participants

This study will involve completing two memory tasks. In these tasks you will be asked to remember lists of six (6) words. Each word will be presented one at a time on a computer screen. You should remain silent throughout the presentation of the six words. At the end of each list you will be asked to immediately recall the words aloud in the order in which they presented. The student researcher will be present to record your responses.

Each trial begins when you press the space bar and ends with a row of question marks (????). The question marks indicate that the trial has finished and that you can begin recalling the words.

Example of a list: *Knife beer stool chalk surf grass*

If you cannot remember all six words, just use the word “pass” or “something” for any of the forgotten items. For instance, if you can only remember the first two and the last words you would respond by saying: *Knife beer something something something grass*

At the end of the task you will then need to complete a second memory task. You may complete this task immediately after finishing the first one or after a designated time period. If you need to wait for a specific time period the student researcher will let you know about this before you start. The student researcher will record your finish time and provide you with the time that you will need to begin the next task. The second memory task will be run in the same way as the first task.

Do you have any questions? If you do not understand any of these instructions please ask the experimenter to explain any confusion. It is important that you understand what is required.

Appendix M. Independent *t*-tests to compare responses to background questionnaire between groups of Experiments 1, 3 and 4.

	Experiments 1[a] and 3[b]			Experiments 1[a] and 4[c]			Experiments 3[b] and 4[c]		
Demographic variable	$t(38)$	p	r	$t(38)$	p	r	$t(38)$	p	r
Age	2.41	.021	.36	0.78	.442	.13	-1.30	.200	.21
Sex	-0.37	.741	.06	0.00	>.999	.00	0.37	.714	.06
Education level	0.73	.471	.12	-0.40	.695	.07	-1.05	.302	.17
First language	0.59	.560	.10	0.59	.560	.10	0.00	>.999	.00
Level of English	-0.99	.330	.16	0.00	>.999	.00	0.93	.359	.15
Health (last month)	0.58	.568	.09	0.97	.337	.16	0.39	.699	.06
Health (testing day)	-0.19	.852	.03	-0.56	.578	.09	-0.36	.722	.06
Sleep (last month)	1.05	.300	.17	1.41	.165	.22	0.41	.687	.07
Stress (testing day)	-0.36	.722	.06	0.34	.733	.06	0.78	.438	.13
Alertness (testing day)	-0.21	.836	.03	0.63	.534	.10	1.08	.288	.17
Aware of repetition	0.64	.524	.10	-0.75	.461	.12	-1.38	.175	.22

Note. [a] time of test = no delay between time one and time two. [b] time of test = 15-minute delay between time one and time two. [c] time of test = 60-minute delay between time one and time two.

Appendix N. Advertisement for recruitment in Experiment 5 and 6

Australian Catholic University warmly invites you to participate in a research project on:

Short-term Memory

What does the study involve?

- Completing a short demographic questionnaire.
- Completing two memory tasks over two sessions. In these tasks you will be asked to remember short lists of words presented on a computer screen.
- This study will take up to 1 hour of your time to complete.

What are the benefits to this study?

- Contribute to the understanding of short and long-term memory

Who can participate?

- We are looking for adults aged 65 years or above with no current diagnosis of a cognitive impairment.

How do I participate?

- If you would like to participate or would like further information, please contact **Gabrielle Ritchie:**
    - **Phone:**
    - **Email:**

- A convenient time and location for you to complete the study can be organised.
- The researcher will take every precaution to ensure confidentiality.

This project is being conducted by Gabrielle Ritchie and will form the basis for the degree of Doctor of Philosophy at Australian Catholic University (ACU). This project has been approved by the ACU Human Research Ethics Committee (Registration Approval Number 2013 81Q).

Thank-you for your interest.

Appendix O. Australian Catholic University's National School of Psychology research participation system invitation for Experiments 5 and 6

Study Name: Short-term Memory (Brisbane) Older Adults

Abstract: Those student who do not meet the age requirements for this study but who are able to arrange for an eligible volunteer (e.g. external to ACU) to participate in this study on their behalf will still be eligible to receive course credit.

Description: This study involves completing a short demographic questionnaire, followed by two memory tasks either immediately after each other or 15 minutes apart. In these tasks participants will be asked to remember short lists of words presented on a computer screen. A mutually convenient time and location can be arranged in order for those volunteers external to ACU to participate.

Eligibility requirements: Participants must be 65 years of age or older with no current diagnosis of a cognitive impairment.

Duration: 60 minutes

Credits: 1.5 Credits

Researcher: Gabrielle Ritchie

Email: gelusi001@myacu.edu.au

Deadlines: Sign-up: 24 hour(s) before the appointment

Cancellation: 24 hour(s) before the appointment

Appendix P. Background questionnaire for Experiments 5 and 6

Background Information

ID Code… ………. Date: ……………………

Age:..............years

Male ☐ Female ☐

Secondary school: year level completed: ....

Post-secondary education or equivalent study: number of years (full-time) completed: ....

English Language Skills:

Is English your primary language? Yes ☐ No ☐

If not, how many years have you spoken English? ....

How do you rate your level of English?

Excellent ☐ Very good ☐ Good ☐ Not very good ☐ Poor ☐

Health and Sleep:

How would you describe your state of physical health over the last month or so?

Excellent ☐ Very good ☐ Good ☐ Not very good ☐ Poor ☐

How would you describe your state of physical health today?

Excellent ☐ Very good ☐ Good ☐ Not very good ☐ Poor ☐

Have you been diagnosed with a current psychiatric disorder?

Yes ☐ No ☐ If yes, please specify: …………………………………………..

How would you describe how you have been sleeping over the last month or so?

Excellent ☐ Very good ☐ Good ☐ Not very good ☐ Poor ☐

Stress and Alertness:

How would you describe your level of stress today?

Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐

How would you describe your feelings of alertness today?

Very High ☐ High ☐ Average ☐ Low ☐ Very Low ☐

Appendix Q. Responses to Background Questionnaire for Experiments 5 – 6

	Experiment 5		Experiment 6	
	N	%	*N*	%
Sex				
Female	16	80	11	55
Male	4	20	9	45
Highest level of education completed				
Year 10 equivalent or lower	7	35	5	25
Year 11 equivalent	2	10	0	0
Year 12 equivalent	0	0	1	5
1 - 3 years post-secondary	6	30	4	20
4 - 6 years post-secondary	3	15	8	40
7 or more years post-secondary	2	10	2	10
First language				
English	20	100	20	100
Level of English				
Excellent	4	20	4	20
Very good	11	55	11	55

Good	5	25	5	25
State of physical health over the last month				
Excellent	2	10	3	15
Very good	5	25	10	50
Good	9	45	7	35
Not very good	4	20	0	0
State of physical health on day of testing				
Excellent	3	15	3	15
Very good	6	30	9	45
Good	8	40	7	35
Not very good	3	15	1	5
Level of sleep over the last month				
Excellent	3	15	2	10
Very good	3	15	4	20
Good	9	45	9	45
Not very good	4	20	5	25
Poor	1	5	0	0
Level of stress on day of testing				
High	0	0	1	5
Average	10	50	10	50

Low	3	15	4	20
Very low	7	35	5	25
Level of alertness on day of testing				
Very high	2	10	2	10
High	4	20	4	20
Average	14	70	14	70

Note. N = 20.

Appendix R. Participant information letter for Experiments 5 and 6

PARTICIPANT INFORMATION LETTER

PROJECT TITLE: Short-term Memory and Serial Recall Tasks
PRINCIPAL INVESTIGATOR/SUPERVISOR: Associate Professor Anne Tolan
STUDENT RESEARCHER: Gabrielle Ritchie
STUDENT'S DEGREE: Doctor of Philosophy

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

This research project will investigate memory performance and false memory effects in serial recall task. The aim of this project is to investigate the relationship between short and long-term memory looking at participants 65 years of age and older that do not have a cognitive impairment diagnosis.

Who is undertaking the project?

This project is being conducted by Gabrielle Ritchie and will form the basis for the degree of Doctor of Philosophy at Australian Catholic University (ACU) under the supervision of Associate Professor Anne Tolan.

Are there any risks associated with participating in this project?

There are no foreseeable risks associated with the project. This study will not attempt to provide a diagnosis or treatment of a cognitive or psychiatric disorder. However, if you have any concerns about these matters, you are encouraged to see your General Practitioner, or alternatively Lifeline: 13 11 14.

What will I be asked to do?

- The study will take place at a mutually convenient location.
- You will be asked to complete a questionnaire about age, sex, education, general and mental health, sleep rating, level of English and current feelings of stress and alertness.
- This study will also involve completing two memory tasks. In these tasks you will be asked to remember short lists of words. Each word will be presented one at a time on a computer screen. At the end of each list you will be asked to immediately recall the words aloud in forward order. The student researcher will be present to record your responses.

How much time will the project take?

Participation will include two sessions of approximately 25 - 30 minutes each. Each session will include one memory task. These sessions will occur immediately after each other or after a designated break (15 minutes, 1 hour or 24 hours).

What are the benefits of the research project?

Individuals from the wider community will not receive any incentives to participate. While no direct benefits for participation will be offered, it is hoped that results from this study will be published in psychological journals, contributing to the understanding of short and long-term memory.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences.

Will anyone else know the results of the project?

The researchers will take every precaution to ensure confidentiality. All participants will be given a code and names will not be retained with any of the raw data. The results from this study may be summarised and appear in publications or may be provided to other researches in a form that does not identify the participants in any way. All data will be kept in a locked filing cabinet in the office of the supervisor or student researcher. Any computer files associated with this research project will be on a computer that is password protected. Data will be stored in this secure environment for the ACU required period of 5 years upon completion of the project or publication of the report. After this period all response sheets will be shredded and computer disks erased. All information obtained from this research will be the property of the researchers and ACU.

Will I be able to find out the results of the project?

If you wish to receive feedback on the results of the project you will be able to contact either the Principle Investigator/Supervisor or Student Researcher however individual results will not be communicated to participants as all participants will be given a code and names will not be retained with any of the raw data. You will have the opportunity to discuss your participation and the project in general after completion of the experiment.

Who do I contact if I have questions about the project?

You can direct any questions regarding this project to Associate Professor Anne Tolan and Gabrielle Ritchie:

Associate Professor Anne Tolan	Gabrielle Ritchie
(07) 3623 7256	gelusi001@myacu.edu.au
School of Psychology	School of Psychology
1100 Nudgee Road	1100 Nudgee Road
Banyo QLD 4014	Banyo QLD 4014

What if I have a complaint or any concerns?

The study has been approved by the Human Research Ethics Committee at Australian Catholic University (approval number 2013 81Q). If you have any complaints or concerns about the conduct of the project, you may write to the Chair of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).

Chair, HREC

c/o Office of the Deputy Vice Chancellor (Research)
Australian Catholic University
Melbourne Campus
Locked Bag 4115
FITZROY, VIC, 3065
Ph: 03 9953 3150
Fax: 03 9953 3315
Email: res.ethics@acu.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want to participate! How do I sign up?

If you agree to participate in this project, you should sign both copies of the Consent Form, retain one copy for your records and return the other copy to the Student Researcher. Your participation in this research project will be most appreciated.

Yours sincerely,

Associate Professor Anne Tolan	**Gabrielle Ritchie**
Principal Investigator/Supervisor	Student Researcher

Appendix S. Participant consent forms for Experiments 5 and 6

CONSENT FORM
Copy for Researcher

TITLE OF PROJECT: Short-term Memory and Serial Recall tasks

PRINCIPAL INVESTIGATOR/SUPERVISOR: Associate Professor Anne Tolan

STUDENT RESEARCHER: Gabrielle Ritchie

I .... *(the participant)* have read (*or, where appropriate, have had read to me)* and understood the information provided in the Letter to Participants. I am 65 years of age or older. I do not have a current diagnosis of a cognitive impairment. Any questions I have asked have been answered to my satisfaction. I agree to participate in this project which involves completing a background questionnaire and remembering lists of words for serial recall. I am aware that the activity will include two sessions of approximately 25-30 minutes each. I am aware that these sessions may occur immediately after each other or after a specified break (15 minutes, 1 hour or 24 hours), realising that I can withdraw my consent at any time without penalty. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT: ....

SIGNATURE .... DATE ....

SIGNATURE OF PRINCIPAL INVESTIGATOR/SUPERVISOR: DATE:

SIGNATURE OF STUDENT RESEARCHER: DATE:

CONSENT FORM

Copy for Participants to keep

TITLE OF PROJECT: Short-term Memory and Serial Recall tasks

PRINCIPAL INVESTIGATOR/SUPERVISOR: Associate Professor Anne Tolan

STUDENT RESEARCHER: Gabrielle Ritchie

I .... *(the participant)* have read (*or, where appropriate, have had read to me)* and understood the information provided in the Letter to Participants. I am 65 years of age or older. I do not have a current diagnosis of a cognitive impairment. Any questions I have asked have been answered to my satisfaction. I agree to participate in this project which involves completing a background questionnaire and remembering lists of words for serial recall. I am aware that the activity will include two sessions of approximately 25-30 minutes each. I am aware that these sessions may occur immediately after each other or after a specified break (15 minutes, 1 hour or 24 hours), realising that I can withdraw my consent at any time without penalty. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT: ....

SIGNATURE .... DATE ....

SIGNATURE OF PRINCIPAL INVESTIGATOR/SUPERVISOR: DATE:

SIGNATURE OF STUDENT RESEARCHER: DATE:

Appendix T. Australian Catholic University Human Research Ethics Committee approval of modification for project to include an older adults sample

Dear Georgina,

Ethics Register Number : 2013 81Q
Project Title : False memory, presentation rate, task repetition and serial recall
End Date : 31/03/2015

Thank you for submitting the request to modify form for the above project.

The Chair of the Human Research Ethics Committee has approved the following modification(s):

1. Amend recruitment to include a sample of 40 older adults (65 years or older with no current diagnosis of cognitive impairment and normal state of health).

2. Please ensure that appropriate written permissions from organisations are obtained prior to contact with any participants.

We wish you well in this ongoing research project.

Kind regards,
Kylie Pashley

Ethics Officer | Research Services
Office of the Deputy Vice Chancellor (Research)
Australian Catholic University

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Appendix U. Independent *t*-tests to compare responses to background questionnaire between groups of Experiments 1, 3, 5 and 6.

	Experiments 5 $^{a\ c}$ and 6 $^{a\ d}$			Experiments 1 $^{b\ c}$ and 5 $^{a\ c}$			Experiments 3 $^{b\ d}$ and 6 $^{a\ d}$		
Demographic variable	$t(38)$	p	r	$t(38)$	P	R	$t(38)$	p	r
Age	3.57	.001	.50						
Sex	0.00	>.999	.00	1.32	.194	.21	1.71	.096	.27
Education level	-1.23	.226	.20	1.03	.309	.17	-0.99	.328	.16
First language	*	*	*	1.45	.154	.23	1.00	.324	.16
Level of English	0.84	.406	.14	-3.42	.002	.49	-1.01	.320	.16
Health (last month)	2.15	.038	.33	-0.73	.471	.12	0.83	.411	.13
Health (testing day)	0.90	.372	.15	-0.90	.372	.15	0.19	.852	.03
Sleep (last month)	0.00	>.999	.00	1.06	.298	.17	0.18	.856	.03
Stress (testing day)	0.68	.502	.11	-1.65	.108	.26	-0.74	.462	.12
Alertness (testing day)	0.00	>.999	.00	0.80	.431	.13	1.24	.221	.20
Aware of repetition	3.57	.001	.50	-1.30	.200	.21	-0.86	.394	.14

Note. ^{a} n = older adults. ^{b} n = younger adults. ^{c} time of test = no delay between time one and time two. ^{d} time of test = 15-minute delay between time one and time two.

* No analysis undertaken for this variable as standard deviation of both groups = 0.