A dual-route model of proactive interference in working memory, and its application in schizotypy

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Abstract

Proactive interference (PI), the negative impact of previously encoded information on the ability to represent current information that is similar in some way, has recently been shown to impair working memory (WM) performance. In this thesis, two types of interference were separated, one related to the content of encoded information, the other to contextual aspects of encoded information.

Context-related interference was altered by a manipulation of context, and was related to a quadratic serial position curve. This type of interference was related to the process of recollection, and was argued to be mediated by an associative mechanism in WM. Content-related interference was altered by a manipulation of content. This type of interference was related to the process of familiarity, and is argued to be mediated by a binding mechanism in WM. A further differentiation between the two types of interference was demonstrated in their relationship to positive and negative schizotypy traits.

Current theories of the relationship between PI and WM suggest that it is mediated by a unitary process or mechanism. The findings here demonstrate the validity of a dual-route description of this relationship. In addition, they show the potential of distinguishing between a binding mechanism and an associative mechanism within the WM system. Finally, they demonstrate how this distinction between binding and associating may benefit an understanding of the relationship between schizotypy traits and cognition.

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Chapter 1: Overview

Memories are imprecise, and are often fraught with the loss of particular details that were initially present in an observed event. One theoretical position on the cause of imprecise memory is that representations of features and events in memory are susceptible to interference. In simple terms, all events can be decomposed into features that can essentially be shared across several events; thus, the memory for any one event will depend on the degree to which it can be protected from the interference of representing other memories that consist of either similar or the same features. Proactive interference (PI) describes the development of interference as an individual seeks to represent events in memory that have the ability to interfere with one another. Key to the purpose of the current thesis, PI has recently been related to working memory (WM).

The WM system acts as a principal interface in cognition into which information is integrated in accordance with individuals' goals and motivations, current actions associated with intentions are monitored, and information is packaged for an appropriate outlet of action. The system is limited in terms of the quantity and quality of information it can handle. In order to make this limit tangible and thus fit for measurement, it is encompassed in the construct of WM capacity (WMC). Inherent in this construct is the notion that the WM system is limited in what it can achieve. PI has recently been related to WMC. The general trust of this research suggests a reduced susceptibility to PI is related to a 'better' WMC. The primary aim of this thesis is to present a framework that describes the relationship between PI and WM.

1. Interference reduces the integrity of memory

As a dependent variable in memory tasks, the proactive nature of PI provides a window through which several interference-related measures can be collected. Memory can be measured before interference build-up, during interference build-up, and also when participants continue to represent events in the presence of high levels of interference. Two types of interference were recently investigated at the level of WM. Item-non-specific PI was measured as a cumulative decrease in accuracy, and/or an increase in reaction times (RTs) over a number of trials when items belonged to the same category. Item-specific PI was manipulated through re-presenting an item from a previous memory trial (n-1) as a lure on the current trial (n)—the item was not in the target set for the current trial. Lures, or recent negatives, tend to illicit false alarms and increase response times. Preliminary evidence has suggested that both types of interference are mediated by a common mechanism. This thesis sets out to test the accuracy of a single mechanism view, contrasting it with the view that there might be distinct sets of processes and mechanisms affected by the two types of interference.

An initial instinct that a single mechanism view may be too simplistic in describing the relationship between PI and WM was prompted by short-term-memory (STM) research on PI. It is possible to post-categorise the manipulations of interference in STM research as been either content-related or context-related. In content-related manipulations of interference, it is the features that make up separate stimuli in memory that interfere with one another; for example, presenting items from the same category in a memory task. In context-related manipulations of interference, the source of interference can be described as extrinsic to the content being encoded; for example, presenting the same items at different time points induces interference related to temporal context. Chapter 2 considers research in STM that supports this distinction. In WM research, a link can be made between item-non-specific PI and content, and item-specific PI and context. Item-non-specific interference is a consequence of representing items of similar content; item-specific PI is a consequence of representing items of similar context.

Research described in Chapter 3 is generally supportive of the need to recognise a distinction been a process more related to representing the contextual features of encoded information –recollection– and a process more related to representing the content-based features of encoded information—familiarity. It was considered that context-related manipulations of interference may be related to recollection, and content-related manipulations of interference may be related to familiarity. Recollection and familiarity are argued to be independent; thus, this thesis investigated whether a dual-route model of PI that separated processes and mechanisms related to content and context in WM may be more accurate than a single mechanism model.

In the first empirical Chapter, Chapter 5, a method was devised to measure item-non-specific and item-specific PI in separate conditions (Experiment 1). Each type of interference was then independently manipulated by the introduction of other variables (Experiment 2). A further experiment (Experiment 3) examined memory as a function of serial position during encoding, and found distinct serial response functions in each condition. Chapter 5 laid the initial ground work to suggest that both types of interference are independent.

In Chapter 6, an effort was made to differentially relate both types of interference to recollection and familiarity. Experiment 4 introduced a means of collecting valid measures of recollection and familiarity in a WM task. In Experiment

5, it was demonstrated that item-non-specific PI is related to familiarity, and item-specific PI is related to recollection. Given that recollection and familiarity are claimed to be independent, this was strong evidence to suggest that both types of interference may indeed be independent.

2. The working memory system and its role in cognition

Earlier research in WM emphasised the role that the system plays in maintaining information available for continued processing. A shift in focus centred on the role that control plays in the WM system. Inherent in descriptions of control is the notion that the WM system can be made to adapt in order to provide better support for individuals' current goals and motivations. The majority of current work on the relationship between PI and WM, as reviewed in Chapter 2, suggests that it is mediated by some aspect of control. With regard to the construct of WMC, it is postulated that a 'better' WMC can reduce the disruptive impact that PI can have on the quality of the information held in WM, and that this relationship is mediated by control. Only a limited amount of research gives credence to the role that lower-level, content-related, features could potentially play in creating interference in WM.

Within the WM system, a separation between processes and mechanisms related to the representation of content, and processes and mechanisms related to the representation of context is rarely considered. In order to test whether a dual-route model of interference is preferable to a single mechanism model, this thesis needed to demonstrate that it is necessary to separate between the representation of context and content in WM. Demonstrating this separation is the second goal of this thesis, and is directly linked to the primary goal of testing whether item-non-specific and item-specific PI are independent effects. In Chapter 3, relevant research was framed to demonstrate the need for a separation between two mechanisms in WM. One mechanism is responsible for binding the intrinsic features of a stimulus to form a coherent whole in memory, and the other mechanism is responsible for associating a set of intrinsic features to an extrinsic, context-based, feature.

A framework is presented at the end of Chapter 3 that is intended to guide interpretation of the empirical findings should a dual-route model of the relationship between PI and WM be supported. The recollection process is proposed to be supported by the associative mechanism in WM, and the associative mechanism works to combat the influence of item-specific PI in WM. The familiarity process is proposed to be supported by the binding mechanism in WM, and the binding mechanism works to combat the influence of item-non-specific PI in WM. In Chapter 7, Experiment 6 demonstrates the convergence between item-non-specific interference and a measure of binding, and item-specific interference and a measure of associating.

3. Cognition in schizotypy: an insight into schizophrenia

A cognitive approach to schizophrenia suggests that it should be possible to relate the symptoms experienced in schizophrenia to cognitive processes and mechanisms. Given the prominent role of WM in cognition, the WM system is researched intensely in schizophrenia. Schizotypy personality traits represent attenuated levels of schizophrenia-related symptoms in the normal population. Schizotypy traits can be studied with a view to providing insight into cognition in schizophrenia, as described in Chapter 4.

The experiments in this thesis suggest the need to separate between two mechanisms in WM: one mechanism that is more related to the processing of context, and the other mechanism that is more related to the processing of content. The final goal of this thesis was to demonstrate the usefulness of this distinction in an applied setting. Chapter 8 investigated whether the distinction between associating and binding might be useful in specifying the relationship between different schizotypy traits and cognition. Experiments 7-9 (Experiment 7, measures of PI; Experiment 8, measures of recollection and familiarity; Experiment 9, a measure of associating) found evidence of distinct relationships between different schizotypy traits and the proposed WM mechanisms.

The empirical work supports a distinction between two types of PI, one related to variability in representing content-related features in memory, the other to variability in representing context-related features in memory. Content-related PI is mediated by a binding mechanism that supports the process of familiarity; context-related PI is mediated by an associative mechanism that supports the process of recollection. Different schizotypy traits were distinctly related to both sets of processes and mechanisms, further demonstrating their separateness.

Chapter 2

Proactive interference in immediate memory

PI describes the negative impact of interference generated by previously encoded items on the ability to represent current items that are similar in some way. There is consensus that 'better' WM is linked to a reduced susceptibility to PI (e.g. Bunting, Conway, & Heitz, 2004; Conway & Engle, 1994). Postle and colleagues (Postle & Brush, 2004; Postle, Brush, & Nick, 2004) recently highlighted a distinction between two manipulations that induce PI in WM tasks. In one manipulation, participants are exposed to items from the same category across a number of trials. In the second manipulation, the focus is on memory for items that repeat across consecutive trials, and that can potentially act as lures, eliciting false-alarms. The former manipulation gives rise to interference that is linked to the category of presentation, not any specific item, and is called item-non-specific PI. The latter manipulation gives rise to interference that is linked to specific items, and is called item-specific PI. The question addressed by Postle and colleagues was whether this difference in manipulation influences the relationship between WM and PI. They accumulated evidence that suggested that both types of interference are mediated by a common mechanism; hence the manipulation that brings about interference was claimed not to influence the relationship between PI and WM.

This Chapter reviews the evidence for PI in immediate memory (IM) tasks (STM and WM), and theories describing potential processes and mechanisms that mediate PI. In studies of PI in STM, it is possible to separate two types of manipulations that bring about PI. In one manipulation, content-related features interfere with one another and memory for the content of what was encoded is degraded. In the other manipulation, context-related features interfere with one another and memory for context is degraded. In the STM domain, there is some evidence to suggest that content- and context-related manipulations of interference are independent.

Item-non-specific PI can be mapped onto interference that is related to content: the content-features of items in the came category interfere with one another. Item-specific PI can be mapped onto interference that is related to context: in order to avoid a false-alarm, participants must recognise that a lure was presented in the encoding phase of the previous trial. However, a single mechanism view of the relationship between PI and memory suggests that a separation between content and context does not play a role in understanding the relationship between PI and memory. Evidence described below, and in the following Chapter, that supports a distinction between content and context is memory indirectly implies that a dual-route model of PI that acknowledges this separation may be necessary in describing the how PI is related to memory.

PI plays a key role in memory deterioration, with initial demonstrations showing a 75% decrement in long-term-memory (LTM) recall (Underwood, 1957), and recognition (Schulman, 1974). Similar drops in performance in STM tasks have long been studied through procedures such as the Brown-Peterson paradigm (Brown, 1958; Peterson & Peterson, 1959). One variable that is common in both short- and long-term manipulations of interference is similarity. The general supposition is that when the content of memory items is similar, or the context in which items are encoded is similar, there is a greater likelihood of PI development.

1. Manipulations of interference

1.1. Content-related manipulations of interference

1.1.1 Short term memory

Content-related interference was initially demonstrated in the Brown-Peterson procedure, in which a number of items are presented for encoding, and following an interpolated delay, memory is tested with serial recall or probed recognition. Keppel and Underwood (1962) showed that even at minimum levels of load (1/3 items), PI accumulated and reduced recall after distracter filled delays of 3-18 sec. Peterson and James (1967) replicated the findings of Keppel and Underwood, and also showed that intrusions in later test trials manifested a recency effect i.e. intrusions from more recent trials were more likely than intrusions from more distant trials. Petrusic and Dillon (1972) showed that probed recognition judgements were influenced by comparable levels of PI to recall in Brown Peterson tasks. When recognition is tested, recent items have a strong ability to elicit false-alarms (Gorfein & Jacobson, 1973).

Demonstrations of the contribution of similarity to the build-up of PI have been made through applying the PI release technique of Wickens, Born, and Allen (1963). In their demonstration, the first four trials presented items from the same class, leading to PI build-up. A switch to a different class on the next trial improved performance through diminishing PI. This PI release technique, combined with the Brown-Peterson task, has shown that the build-up of PI is a consequence of increased exposure to similar items: when this similarity is reduced through switching away from the similar items, performance benefits.

PI build-up and release have also been shown with semantic categories (Whimbey & Fischhof, 1968) and with shifts from more typical to less typical items from the same category (Keller & Kellas, 1978). Physical characteristics of words, such as word length (Lachar & Goggin, 1969) and phonological similarity (Coltheart & Geffen, 1970) can also give rise to PI build-up and release. Coltheart and Geffen (1970) described a memory trace to consist of a bundle of different classes of features, and that the class that participants pay most attention to will depend on the material presented. The stimuli they presented were nonsense syllables, and they supposed that this encouraged participants to attend most to the phonemic structure of the items. PI then built up at the phonemic level, the level to which participants were attending to the most. Notably, such interference effects do not only operate at the level of singular items: King and Forrester (1970), for example, have shown the negative impact of increased acoustic and semantic similarity on retention of short sentences.

In another simple demonstration of the contribution of similarity to PI, Loess (1967) presented word triads consisting of items from one category along with other triads of the same category, or with triads from a different category. The recency-based intrusion effect was specific to items from the same category, showing that similarity was necessary to give rise to this measure of PI. Turvey, Cremins, and Lombardo (1969) additionally showed that PI failed to build up if items from different taxonomic classes were chosen on every trial. The majority of such demonstrations applied serial recall as the dependent variable; however, Gorfein and Jacobson (1972) showed that release manipulations such as semantic shifts had the same effect on recognition memory as on recall.

In addition to PI being generated through inter-trial similarity, intra-trial similarity has also been shown to contribute to PI. For example, Delaney and Logan (1979) demonstrated that the build-up of PI across trials was further compounded by increased inter-item similarity within trials in the presence of across-trial similarity. Allen and Fisk (1986) refined this finding through showing that within-trial similarity, in the absence of across-trial similarity, actually lead to better recall, whilst the opposite finding arose when across-trial similarity was also present.

Bird (1976; 1977) proposed a classification system for describing different manipulations of content-related PI. Following PI build-up, a task-switch improves performance, but this improvement is curtailed if the upcoming stimuli are still from the same category. Bird suggested that interference is most acute in the feature dimension to which either the task or a participant's encoding strategy is orienting more attention towards. When the category to which the task is related fails to change, participants are attending to the same feature; hence, the reduction in PI-release. Through crossing different tasks and stimulus materials with PI build-up and release, a three-way classification was revealed, including semantic, auditory, and structural categories.

1.1.2 Working memory

May, Hasher, and Kane (1999) looked at PI in a complex-span task. Complex-span tasks differ from simple-span tasks in that they require concurrent storage and processing of different units of information—one of the first examples being Daneman and Carpenter's (1980) reading-span task. In the reading-span task, sets of sentences are presented for comprehension, and the final words of each sentence have to be retained for recall after the processing of the set. The number of sentences for processing per set typically increases incrementally and there are individual differences in the number of words that can be recalled, where a decrease in performance indicates an individual's memory-span. Complex-span tasks may be considered successful because they tap both processing and storage. Traditional views of WM (e.g., Baddeley & Hitch, 1974) suggest that WM is a system where resources are divided between two functions, processing (e.g., involving the executive component of WM) and storage (e.g., involving maintenance buffers). Consequently, tasks tapping both storage (of each final word in a sentence) and processing (the comprehension of each sentence) may be considered to load WM ability. Low- and high-WM performers have often been identified through a median split in complex-span data (e.g. Conway & Engle).

May et al. (1999) contrasted the presentation of incrementally increasing set-sizes with the presentation of decreasing set-sizes in the reading-span task. They suspected that PI builds up during the task, and that increases in set-size as trials continued would mean that greatest set-sizes are presented when PI is already at a maximum. They also reasoned that susceptibility to PI would decrease the span of low WM performers to a greater degree than that of high performers. Indeed the data revealed that span in low performers was greatly increased in the descending presentation condition. Similar results were obtained when ascending and descending digit presentations were contrasted in the backward digit span from the WAIS-R.

May et al.'s findings suggest an inverse relationship between susceptibility to PI and WM performance, since participants with low WM capacity were more affected by the ascending lists in which PI was at a maximum when higher loads were being presented. The data also challenge the view of what constitutes a successful WM task. Descending and ascending set sizes were matched on the degree of storage and processing required, yet span measures increased in the descending conditions relative to the typical presentation format. The type of interference that the reading-span task induces could be described as content-related, as participants were exposed to numerous similar sentences.

Further examples of content-related interference include a study by Atkins and Reuter-Lorenz (2008), in which participants were asked to retain four semantically similar words for either a recall or recognition test after both filled and unfilled delays. Regardless of the type of delay, semantically related lures in the recognition test gave rise to false-alarms and delayed reaction times, and the ratio of recall errors was tipped in favour of semantic intrusions over unrelated intrusions. Additionally, in the auditory domain, Visscher, Kahana, and Sekular (2009) manipulated the contents of an item on trial n – 1 and an item on trial n in a probed recognition task to be more or less similar. When both items were more similar, the trial n – 1 item often elicited a false-alarm when presented as a lure in trial n.

A small number of WM studies have systematically focused on the features that make up items in WM in order to assess how interference comes about. Oberauer and Kleigl (2006) refined an interference model of the amount of information that can be stored in WM. The main assumption of the model is that the features of items in memory can interact, and through doing so degrade one-another. One interference mechanism they considered was feature overwriting: if items compete for the same feature, only one item is able to integrate that feature into its representation. Their key manipulation involved varying the degree to which features were shared between different items in memory. In one experiment, phonological similarity was varied. Phonologically similar letters yielded a larger interference parameter in their model, and feature overwriting was suggested as one potential mechanism that could mediate this effect.

In a further study, Oberauer and Lange (2008) compared feature overwriting as a mechanism for mediating interference to two other potential mechanisms: similarity-based confusion and feature migration. In their Experiment 1, feature overwriting and similarity-based confusion were compared. Participants encoded lists of words (the memory lists). During encoding and recall of each memory list, participants read a list of different words (the reading lists). One of the words in the reading list had a high degree of phonological similarity to one of the words in the memory list—their manipulation of similarity-based confusion. To allow for the possibility of feature overwriting while controlling for the overall similarity between items on the memory list and items on the reading list, one of the reading list items shared its phonemes with different items in the memory list. If similarity-based confusion is the exclusive mechanism through which interference builds up, then interference should be absent when the features of items in the reading lists are shared across items in the memory list; thus controlling for item similarity between the memory and reading lists. The results showed that both manipulations gave rise to decreased recall of the memory item(s) that shared features with the item(s) in the reading list. Since the feature overwriting account, but not the similarity-based account, predicts the presence of both effects, parsimony favours feature overwriting.

In a second experiment, feature overwriting was contrasted with feature migration within memory lists. Letters of a word were shared across other target words within a list in order to induce feature overwriting. In their manipulation of feature migration, words were chosen that, upon one of their letters being exchanged, could provide a phonological neighbour. If feature migration were to potentiate interference, then having a letter in the reading list that was associated with a phonological neighbour of a target should decrease recall for that target. Results showed that recall was in fact better for targets that were phonological neighbours. This result may have arose from the uniqueness of encoding neighbours in the same list; the neighbours may have been represented more distinctly in memory than the other items. Regardless of the interpretation for the feature migration result, feature overwriting lead to poorer memory, showing its role in potentiating interference build-up.

1.2. Context-related manipulations of interference

1.2.1 Short term memory

One of the first studies to induce context-related interference concurrently induced content-related interference. Turvey and Egan (1970) presented consonant trigrams on every trial of a Brown-Peterson task in one of two arrangements, vertical or horizontal. When the phonemic class of the items was held constant, a significant release from PI was evident after a switch in the presentation arrangement, demonstrated through better recall of the consonants. The reverse effect was also found when the stimulus arrangement was held constant and phonemic class was changed. Interestingly, the effects of PI release brought on by both manipulations were independent of one another, at least suggesting the possibility that the build-up of PI related to context may be independent of the PI related to content. Further manipulations of context that have led to a release from PI include alterations to the learning environment (memory drum versus box, Dallett & Wilcox, 1968); changes to the display size (Turvey & Egan, 1969) or physical size of the stimuli (Elliott, 1974); changing the voice associated with item presentation (Gardiner & Cameron, 1974); manipulating the spatial location of the speaker through which the items are presented (Weeks, 1975).

In the animal literature, manipulations of context-related interference have dominated, particularly in the temporal domain. Wright, Urcuioli, and Sands (1986) reviewed a number of studies that showed poor memory in animals on simple delayed-matching-to-sample (DMTS) and probe recognition tasks. In these studies, repeating items within and/or across sessions was key to causing the animals' poor performance; if animals were shown novel stimuli on every trial, even with long delays, then performance was far better. This finding is illuminating when considering that previous literature supposed that effects of PI were confined to the influence of the 'just previous' trials. A key study by Sands and Wright (1980) detailed the manipulation of the number or items shown between a particular item and its repetition in a probe recognition task. If a smaller number of items separated a particular item and its repetition, the effect of PI was stronger. Even when item repetitions varied between 51 and 60 intervening items, an effect of PI was still evident. Wright et al. argued that recognition performance was poor because of the interference caused through presenting items in different temporal contexts within the same experiment—the effect was purely context-based, not content-based.

1.2.2 Working memory

Cantor and Engle (1993) manipulated 'concept fan' (following Anderson, 1974; 1983). On every trial, a set of sentences was presented, with each sentence stating the relationship between a subject (concept), which remained the same for each sentence in the set, and a location that was different in each sentence of the set; for example, the teacher is in the classroom, the teacher is in the lunch-hall and so forth. Locations were shared across sentence sets. After learning the sets, participants completed a sentence verification task. Similar to Anderson's findings, the larger the fan of a concept, in this case the greater the number of locations associated with a single subject, the less accurate were the verification judgements of associations made with the concept. The effect is arguably related to context (see e.g.

Diana, Reder, Arndt, & Park, 2006), as locations are shared across sentence sets, and participants must verify the context in which the location was seen (i.e. the subject associated with the particular location).

Cantor and Engle compared the performance of individuals with low and high WM span and showed that increasing fan-size reduced the recognition speed of low performers to a greater degree than the recognition speed of high performers. These findings were initially interpreted through the LTM framework provided by Anderson, which suggests that the fan effect reflects a capacity limit on the amount of LTM available; Cantor and Engle suggested that low WM performers have a reduced storage capacity in LTM. However, Bunting, Conway, and Heitz (2004) showed that the decrement in recognition speed for low performers only occurred when locations or subjects appeared in more than one set. The interference of having concepts shared across contexts (sentence sets) affected low performers more than high performers.

Conway and Engle (1994) looked at the memory-set-size-effect in low- and high-WM performers. The signature of the memory-set-size-effect is a linear relationship between set-size and the response time to match a target in memory (Sternberg, 1966). Conway and Engle asked performers to learn sets of letters or numbers of set-sizes 2, 4, 6, and 8. Each set was indexed by a specific number. During testing, the presentation of this number cued participants to recall the associated set in question in order to compare its contents with a probe. In two experiments each item appeared in two stimulus sets, and in the remaining two experiments there was no item overlap across stimulus sets. With item overlap across sets, i.e. when items were shared across different contexts, the time to compare the probe to a memory set increased at a greater rate for low than for high performers as the set-size increased: the interaction between group and set-size was absent when there was no overlap across lists.

Lustig and Hasher (2002) showed that general environmental factors can mediate PI build-up. They presented a complex-span task to participants who were either naïve or who had prior experience of testing in their laboratory. Participants had to encode and store a number of items in memory whilst concurrently meeting the demands of a secondary task designed to prevent rehearsal. The naïve group achieved higher span scores than the experienced group, suggesting a negative effect of repeated environmental context on cognitive performance.

Makovski and Jiang (2008) demonstrated the generality of these interference effects in a change detection paradigm. Arrays of colours were presented for encoding. During testing, temporal interference lures were shown in trial n in the same location as they were presented in trial n – 1. Such lures led to failures in noticing that a change had taken place. Spatial context-based interference was also demonstrated through exchanging the colours of nearby probes, which led to a deteriorated ability to detect change relative to when colours from more distant items were exchanged.

2. Theories of the relationship between proactive interference and immediate memory

2.1. Short term memory and working memory are argued to differ

Although the storage buffers that are perceived to support STM (e.g., Baddeley & Hitch, 1974) are considered part of the WM system (Baddeley, 1986), the WM system can not be reduced to STM. Consequently, stipulating the processes and mechanisms that influence the action of PI on memory may differ as a function of whether STM is sufficient to support task performance, or whether WM is required.

The argument for a distinction between STM and WM comes from a variety of sources. Factor analytic and structural equation modelling studies of STM and WM tasks consistently lead to the derivation of two factors, one related to STM, the other to WM; thus, the constructs are related to differences in cognitive variation (e.g., Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Hambrick, Tuholski, et al., 2004). Indeed the primary source of variability in STM tasks has been related to rehearsal processes that are specific to the modality in which information is presented (Unsworth & Engle, 2007), while the primary source of variability in WM tasks has been attributed to a central executive component that supervises the distribution of attentional resources within and across the storage buffers (Baddeley, 1996; Engle, 2002).

The first theories of PI in STM primarily related PI to the processes of encoding (e.g. Dillon, 1973) or retrieval (e.g. Underwood & Ekstrand, 1966; 1967). These studies revealed that it is possible to influence the magnitude of PI through manipulations included at either encoding (through better learning of items, for e.g.; see Knight & Gray, 1967) or retrieval (through presentation of cues during testing, for e.g.; see Gardiner, Craik, & Birtwistle, 1972; Watkins & Watkins, 1975). Later studies pointed out that the non-specificity of these findings suggests that another mechanism or process must mediate the build-up of PI independent of the processes of encoding and retrieval (e.g. Radke & Grove, 1977—see Appendix 1 for further information).

Despite a separation between WM and STM, there is an overlap in the approaches that have been taken in accounting for PI effects. The majority of theories in both domains seek a modality-independent process or mechanism that accounts for a large proportion of intra- and inter-participant variability in the PI-memory relationship. One approach that is common across both STM and WM studies is to relate PI to the capacity of memory, essentially the maximum amount of information that is represented distinctly over the short-term. A second approach relates PI to the ability to represent contextual aspects of encoded information. A final approach considers the role that distinct feature dimensions play in interference build-up.

2.2. Common approaches to explaining proactive interference in short term memory and working memory

2.2.1 *A role for capacity*

In their description of PI, Frost and Jahnke (1968) considered two approaches. One approach suggested that PI builds up independently in different dimensions; thus, PI is uniquely related to the features of a particular dimension. A second approach suggested that there is something common to situations within which PI builds up. To incorporate these two approaches in the one model, Frost and Jahnke proposed that PI effects could build up independently, but that all such effects would lead to a reduction in capacity, and it was this reduction in capacity that linked all PI effects. In other words, capacity limitations mediate PI, independent of its source.

Congruent with what would be expected on the basis of such a capacity-related account, Wickens, Moody, and Dow (1981) only found an effect of PI when they altered their task to test secondary memory rather than primary memory. They employed a probed recognition task, and recognition was tested immediately after encoding –primary memory– and after a distracter filled delay—secondary memory. Wickens et al. had equated the encoding account of PI with a perceptual account, and a retrieval account with a memorial one. They stated that retrieval is a process confined to secondary memory, and that if PI was only found in secondary memory, then it must be related to the retrieval process. They found an exclusive build-up of

PI following distracter filled delays and from this they concluded that PI emerges at the level of retrieval. Although they interpreted their data in relation to the distinction between primary and secondary memory, secondary memory is theoretically associated with a limited STM capacity, and further evidence suggests that PI arises when this capacity has been surpassed. For example, Halford, Mayberry, and Bain (1988) studied PI in relation to set-sizes, and failed to find effects of PI at set-sizes at or smaller than 4.

Capacity limitations in WM are spoken of in the context of the WMC construct. From the perspective of Engle and colleagues (Bunting et al., 2004; Engle, 2002; Kane & Engle, 2000), WMC is intrinsic to the function of executive control: with more precise control over attention, a greater amount of information can be stored in WM. Engle and colleagues (see e.g., Bunting et al., 2004) propose that executive control is responsible for preventing competition between items learned on different trials during retrieval. They thus attribute poor WM performance to weak executive control in the presence of PI.

Cowan (e.g., 2001) presents an alternative view of WMC to that of Engle and colleagues whereby attention itself is proposed to be quantifiable, and it is this attentional capacity that is measured in tasks purported to measure WMC. PI is then considered as a function of a capacity limit in attention. Cowan, Johnson, and Saults (2005) looked at the relationship between increasing levels of memory load and PI. They found that PI only influenced performance at loads greater than 4—loads greater than the proposed capacity limit for WM (Cowan, 2001).

2.2.2 A role for context

Anderson and Bower (1974) proposed that PI build-up was related to a reduction in the specificity with which participants could recognise the context associated with particular events. They presented participants with overlapping lists of items, and tested discrimination on the lists in which particular items were presented. PI effects grew larger the more lists that an item was presented in. The PI effect was described in terms of item-specific associative interference. Participants were proposed to associate each item with a list-tag. List differentiation became harder the more list-tags tied to an item.

If trial intervals are interjected with longer inter-stimulus-intervals (ITIs) following the build-up of PI, recognition memory is improved for the items encoded in proceeding trials (Gorfein & Jacobson, 1972). In investigating the locus behind this improvement, Gorfein and Schulze (1975) suggested that it was a fluctuation in temporal context that accounted for the benefit. When trials are further apart in time, memories are accompanied by a greater temporal distinctiveness as to which trial an item was presented in. The logic of this proposal is consistent with the evidence that contextual change can facilitate PI release. As described previously, Bird's evidence that a task-switch reduces PI is also consistent with a role for contextual change in reducing PI when it is considered that rules describe what a particular context means in terms of participants' actions.

Work with animals that has focused on the temporal context in which stimuli appear provides the background to the temporal discrimination hypothesis of PI proposed by D'Amato (1973). He noted that, in memory studies, items are regularly repeated across trials; thus judgments are based on the ability to discriminate the particular time points in which an item was presented. With increased repetition, this process of temporal discrimination is made more difficult.

In Sternberg-type tasks purported to measure WM, the use of PET and fMRI have highlighted a role for the inferior frontal gyrus (IFG) in the resolution of interference generated by recent negatives (n – 1 lures) (e.g., D'Esposito, Aguirre, Zarahn & Ballard, et al. 1998; Jonides, Marshuetz, Smith, et al., 1998). Jonides Marshuetz, Smith et al. (2000) compared a sample of elderly participants to a younger sample. In addition to showing an increased propensity to make false-alarms to lures, the older sample showed reduced activation in the IFG, leading to the suggestion that this region played a functional role in reducing PI. A link between the IFG and the resolution of interference has been further supported by experiments measuring ERPs (Du, Xiao, Song, et al., 2008) and using TMS (Feredoes, Tononi, and Postle, 2008).

Postle, Berger, Goldstein et al. (2001) tested for the purity of an association between activity in the IFG and interference. Bunge, Ochsner, Desmond, et al. (2001) had likened the increased activation of IFG in response to interference to an effect of load. Postle et al. tested whether PI was distinct from general load effects using a running-span paradigm. Participants were to remember the final four items presented in a sequence for a probe recognition task. The length of the list presented during encoding was varied to alter the load. PI was manipulated within trials: a high interference lure was presented earlier in the trial, before the final four items that were to be remembered.

FMRI data showed that the load and the PI effects differed qualitatively. Responding to PI was associated with increased activation in IFG, whilst increased load was associated with increased activation in dorsolateral prefrontal cortex (dlPFC) among other areas. Past research implicates the increased recruitment of dlPFC in cases where WMC is tested through increasing load, and these studies attribute increased dlPFC activity to executive function (Callicott, Mattay, Bertolino et al., 1999; Ranganath, DeGutis, and D'Esposito, 2004). The dissociation between activation in dlPFC and IFG suggests that the impact of interference on memory need not be dictated by variability in executive control, assuming that executive control and dlPFC function are closely related.

Jonides and Nee (2006) proposed a biased competition model of the functional relationship between the IFG and interference resulting from recent negatives. They described the initial response to recent negatives in recognition memory tasks in terms of a bias towards affirming that the item was present on the trial because of its high level of activation. The interference generated by this initial bias is resolved when participants differentiate between the present trial's context, and the context of the previous trial within which the lure was actually presented. Problems in using contextual information lead to PI, and the recruitment of IFG mediates the use of contextual information.

A link between the IFG and the ability to represent context was also suggested in a study by Caplan McIntosh, and DeRosa (2007). This study followed up on a line of animal research that found a relationship between acetylcholine and interference resolution (DeRosa & Hasslemo, 2000; Hasslemo & Bower, 1993). Medial septum (MS) nuclei and nuclei in the diagonal band of Broca (DB) are key players in the regulation of acetylcholine. Caplan et al. revealed a functional network of areas connected to MS/DB nuclei that was active during the build-up and successful resolution of PI. In the initial part of the task in this study, participants learned to respond to color paired associates. Later, additional pairs were learned that conflicted with the associations made in earlier learning. In-line with the work of Jonides, Postle, and colleagues, activity within IFG contributed to the network that resolved the interference bought about when the later pairs were presented.

Also of particular note is that a second functional network that did not engage MS/DB was also related to the presence of PI. This network included the parahippocampal gyrus and the orbito-frontal cortex. In a comparison between an alcoholic sample with impaired MS/DB function and a control sample, the alcoholic sample was shown to rely on this second network in their attempts to resolve PI. Caplan et al. described this result in terms of compensation: when the former network is compromised, the latter network is recruited. They concluded that although the goal of each network was the same –to resolve interference– the networks obviously differed in terms of the regions recruited and the degree with which they could resolve the type of PI generated—only the former network was capable of dealing with the context-related interference generated in the task.

2.2.3 A role for individual features

An alternative to linking interference to a mechanism or process that is detached from memory content is to examine whether individual features that are similar can interfere with one another as they are encoded across different items. Although content-related PI is typically measured in terms of cumulative build-up across trials in STM tasks, *intra-unit interference* was introduced to describe deterioration in memory when only one trial is administered. Fuchs and Melton (1974) manipulated the number of words encoded on one trial, and found that the number of items recalled from a trial in which more words were presented was proportionately lower than on a trial in which fewer words were presented. They suggested that the source behind this difference was greater intra-unit interference when an increased number of items were presented; for example, there may be difficulty in binding together the elements making up each item as more items are presented and overlapping elements occur. Repeating trials improved recall, and Fuchs and Melton speculated that the benefit of repetition was the reduction of intra-unit interference.

There is similarity between the approach of Bird, and the approach of Oberauer and colleagues in their study of interference at the microscopic level of individual features. A key question to ask, then, is whether the relationship between memory and content-related manipulations of interference is dependent on the specific featural dimensions for which memory is being tested, or whether there is a process or mechanism that operates similarly in all featural dimensions, and it is then the workings of this process or mechanism that mediates the relationship between content-related interference and memory. Despite the categorical nature of Bird's manipulations of interference, he favoured the view that featural processing is more continuum based, and attention can be biased in favour of processing one type of feature to varying degrees without taking attention fully away from processing other features. It then follows that attention influences PI build-up, independent of the dimension, which then fits with the accounts of Engle, Cowan, and colleagues.

The concept of feature overwriting introduced by Oberauer and colleagues offers an alternative means of describing the PI-WM relationship. Oberauer and Lange suggested that PI may arise when features of the current target to be represented are already bound to a previous task item in memory. Memory for the current item is degraded, as its representation fails to include the feature bound to the previous item. This suggests that a lack of integrity in the way features are bound together underpins PI; thus, a process or mechanism that operates to bind features together may underlie the relationship between content-related manipulations of interference and memory.

On the other hand, dimension-specific processing might create unique relationships between interference in different dimensions and memory. This alternative account fits with STM findings that show that while variability in rehearsal processes within dimensions is similar, variability across dimensions is dissimilar (Unsworth & Engle). However, this alternative account fails to support the findings of key studies that have demonstrated differences between high and low WM performers in interference tasks that include different kinds of features; thus there must be some common underlying processes or mechanisms that mediate the PI-WM relationship. Dimension-specific rehearsal processes may influence performance, but these processes would act outside the boundaries of other more dimension-generic processes and mechanisms.

2.3. Inhibition and an interference-specific mechanism

A final account of how interference might be mediated in memory is distinct from STM approaches. Postle et al. (2001) proposed the existence of an inhibition-based mechanism to resolve interference in memory, which they link to the inhibition account of WM performance put forward by Hasher and Zacks (1988). In this account, inhibitory processes are responsible for suppressing the influence of irrelevant information on WM (see Lustig, May, & Hasher, 2001; May et al., 1999, for similar proposals).

Postle and colleagues (2004ab) reviewed the diversity of manipulations that have given rise to PI. In their categorisation of the source of PI, item-non-specific PI was described as interference that accumulates due to having encoded multiple stimuli across a block, and their item-specific definition was confined to describing the impact of n-1 lures on recognition performance. Postle and Brush looked at item-non-specific PI through collapsing across a number of fMRI studies and looking at fluctuation in RT and fMRI signal emitted over time. They found increased RTs to items presented later within blocks, presumably indicative of item-non-specific PI. A positive effect of interference on IFG activity was found during both probe and delay periods (when PI should be present).

Postle et al. (2004) examined item-specific and non-specific PI concurrently in a probe recognition task. Recent negatives were shown on two consecutive trials before they were presented as lures, with the lure data acting as a measure of item-specific interference. There were 16 trials within each block which allowed for the measurement of item-non-specific PI, with the primary focus being on the first 5 trials, as demonstrations of PI using the Brown-Peterson task have shown that PI builds up most during these initial trials. The highest number of items in a stimulus-set was 21; thus items did repeat across trials. The IFG showed an increase in signal from the first to the second trial, implicating the region in responding to the build-up of item-non-specific interference. Responding to the item-specific manipulation also revealed IFG activation. It was concluded that a common mechanism, located in IFG, mediates both item-specific and non-specific PI.

3. In relation to the aims of the current thesis

The literature presents situations in which content- and context-related PI have been induced. Few studies have investigated the relationship between both sources of interference. Do both sources give rise to interference effects that are independent from one another? Alternatively, is there a common mechanism or process mediating the interference generated by both content- and context-related manipulations?

As noted above, theories typically attribute PI to a common process or mechanism. Postle and colleagues neither mapped item-non-specific onto a content-related effect, nor item-specific onto a context-related effect. Subsequent evidence discussed in the following Chapter supports the view that item-non-specific PI may share a unique relation to the ability to represent content, and item-specific PI a unique relation to the ability to represent context. In light of this subsequent evidence, the primary empirical aims of this thesis are to readdress whether the relationship between WM, and item-non-specific and item-specific PI can be described by a unitary mechanism or process.

Chapter 5 introduces a methodological approach that allows for the separate measurement of content- and context-related interference. An overview of this approach is presented in Figure 1. As is typical in IM tasks, a number of stimuli are encoded on every trial, and these stimuli are then presented with distracter items not present during encoding. Participants' task is to indicate each test item's perceived status—target or distracter. Non-words are the chosen stimuli in order to control for the number of dimensions being encoded along with each stimulus that could be involved in the build-up of PI (given that these stimuli are likely to be represented in orthographic and phonological forms, but not semantically). In the condition that measured content-related interference, different non-words are presented in every trial. In the condition that measured context-related interference, items repeated across trials. In the absence of item repetition, a decrease in performance across trials would be related to the ability to represent the featural content of the items; item repetition was expected to stress participants' ability to represent context, as it was necessary to distinguish whether memory for an item was associated with the current trial or a previous one. In Chapter 5 and subsequent Chapters, efforts are made to test whether the two interference effects are independent.

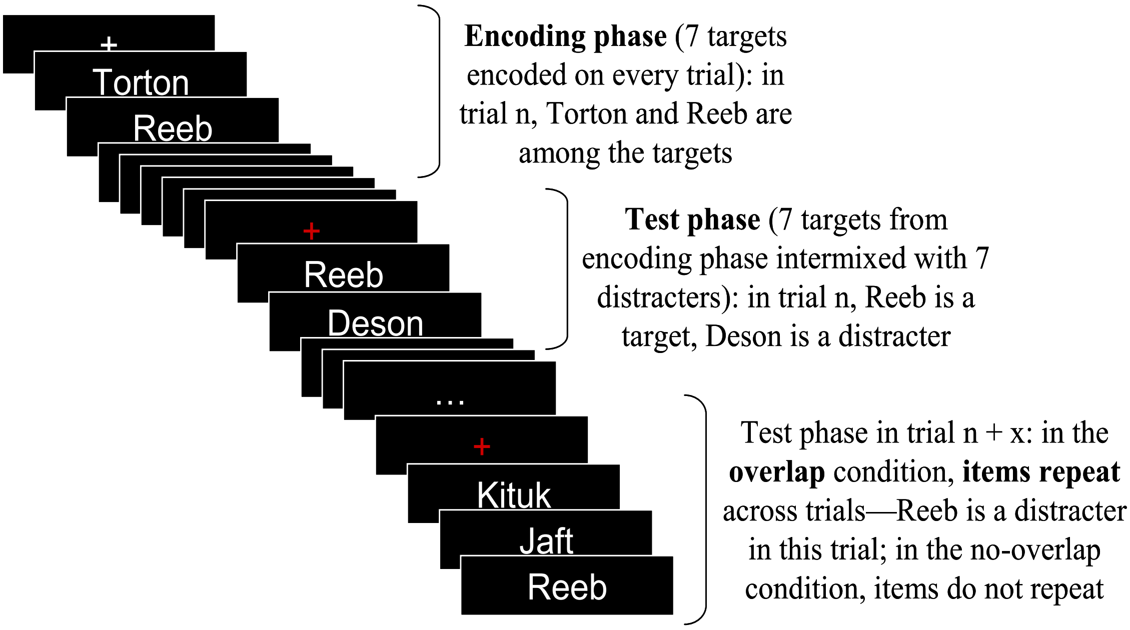

Figure 1: The paradigm developed in the thesis contrasts two conditions in which non-words are presented for encoding, followed by recognition judgements to old and new items. In one condition, different non-words are presented on every trial; in the other condition, a small number of non-words repeat across trials (light fixation indicates encoding phase; dark indicates test phase)

Chapter 3

Content and context are independent domains of representation

In the previous Chapter, evidence was considered that suggested that there might be two independent interference-related effects in memory. Earlier STM research instigated content- and context-based manipulations of interference, and there were suggestions that these manipulations lead to independent effects. In studies of LTM, a distinction is made between the processes of recollection and familiarity. A link is commonly made between recollection and holding a distinct representation of the contextual aspects of an event in memory, and between familiarity and the fluent processing of content related to an event (Yonelinas, 2002). In considering the evidence for a separation between content- and context-related interference as discussed in the previous Chapter, it is conceivable that these two types of interference may share distinct relationships with recollection and familiarity.

Familiarity effects in memory can be modelled in terms of signal-detection-theory (SDT). Familiarity for old and new test items in a recognition memory task can be described in terms of overlapping Gaussian distributions of signal strength elicited by an item presented during test, see Figures 2 and 3. Sensitivity reflects the ability to distinguish between old and new items; in the sensitivity measure d’ for example, normalised false alarm rate is subtracted from normalised hit rate in order to give a more accurate measure of participants’ memory. A criterion, C, arises at a decision level, whereby participants instantiate an activation point above which they accept items as being old, and below which they reject items as being new. In the shaded areas of Figure 2, items activated to the right of C are judged as old; items activated to the left of C are incorrectly rejected. In the shaded areas of Figure 3, items activated to the left of C are judged as new; items activated to the right of C are false-alarms (see Appendix 2 for a brief history regarding theories of recollection and familiarity).

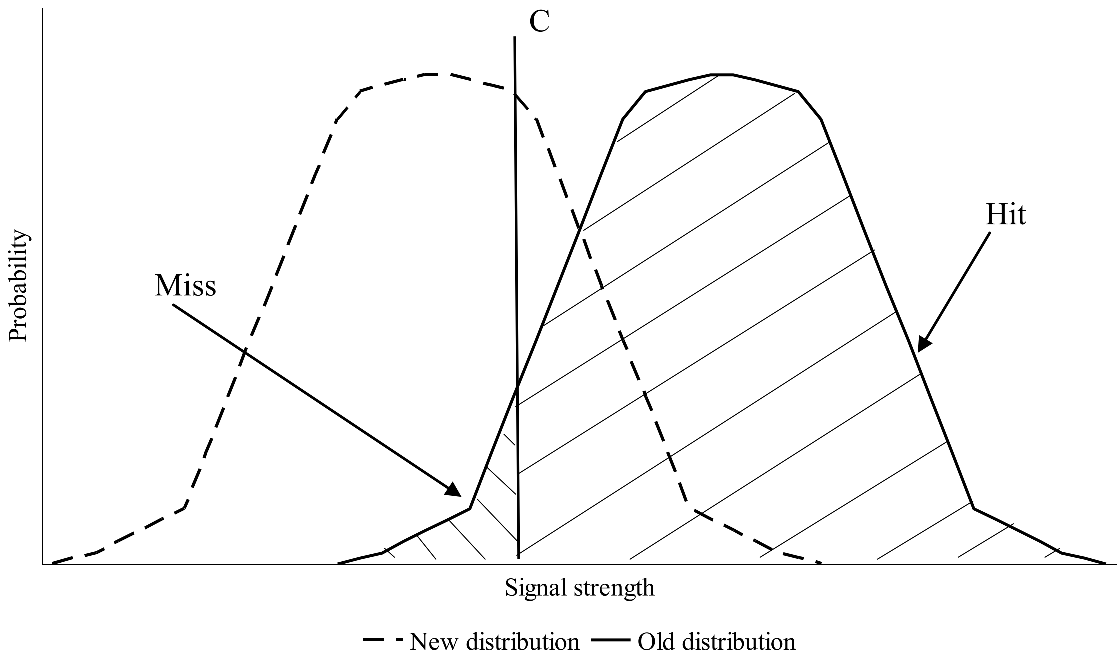

Figure 2: The old distribution consists of hits and misses

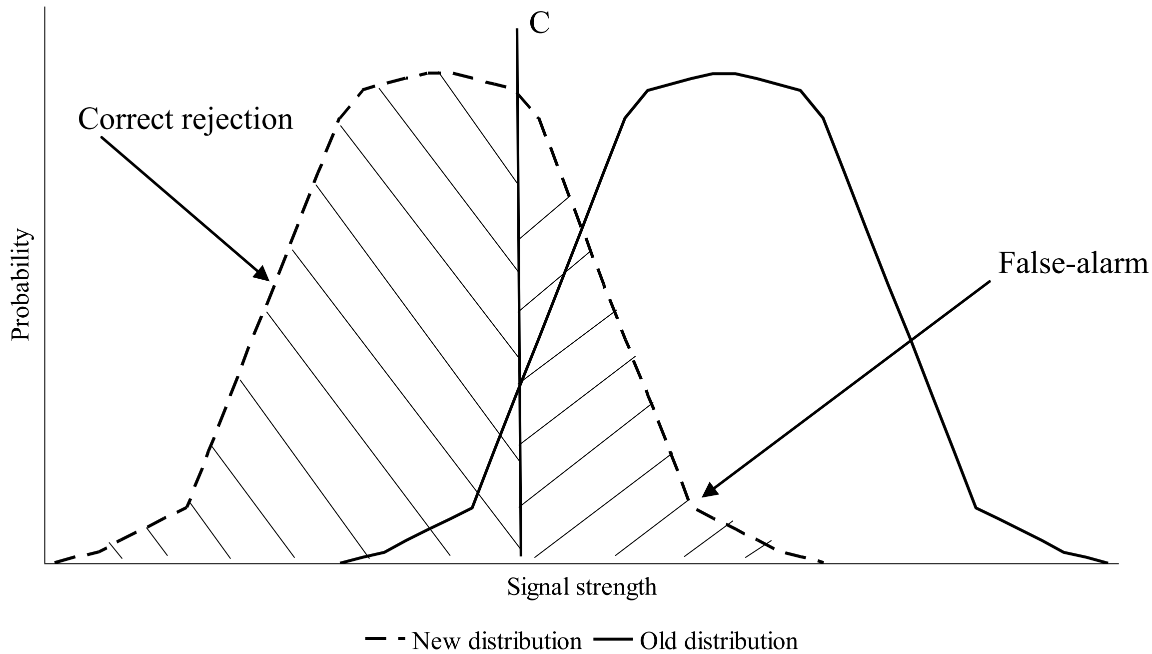

Figure 3: The new distribution consists of correct rejections and false-alarms

1. Separating content- and context-related interference

Jacoby, Debner, and Hay (2001) demonstrated that PI could act as a form of bias operating at the level of familiarity, without influencing the ability to recollect items. They pitted a manipulation known to reduce recollection against a manipulation known to increase the influence of bias. Participants learnt to associate items in different study lists under full or divided attention. Divided attention reduces the ability to recollect. Bias was manipulated through pairing some items with one strong associate, and one weak associate. Strong associates were presented 75% of the time during encoding with one item, whereas the same item was presented with a weaker associate 25% of the time during encoding. Interference was associated with a bias to incorrectly recall the strong associate over the weak associate. This recall bias effect was unrelated to the divided attention manipulation (divided attention reduced recollection), suggesting that the effect was isolatable to familiarity.

Öztekin and McElree (2007) showed that the negative impact of PI could lead participants to be more reliant on recollection in order to respond to a recognition probe. They combined a release from PI design, in which the semantic category that items belonged to could be altered after 3 trials, with a speed-accuracy trade-off variant of a probe recognition task. Participants encoded 6 items, and during testing, they were cued when to respond to the probe, which they had to do within a short time-frame. PI build-up was signaled by decreased accuracy, with recognition failure being particularly pronounced when shorter response intervals followed the probe. As familiarity-based judgments are often argued to allow faster responses, the decrease in accuracy that was particularly prevalent following shorter intervals suggests that participants were unable to rely on familiarity when PI built up. They suggested that the slowing of the speed with which participants could retrieve items showed a need to apply recollection when judging the probes status.

In an acknowledgment of the primary routes through which interference is induced, Brown and Gorfein (2004) returned to the earlier claim of Gorfein (1987) that performance in the Brown-Peterson paradigm was influenced by two types of similarity, environmental and semantic. Brown and Gorfein implicate environmental similarity in mediating the ability to temporally discriminate between items presented on current and previous trials. Environmental/temporal context is assumed to fluctuate across trials; thus the longer the lag between the presentation of an item as a probe and the re-presentation of that item as a foil, the less likely that both presentations of the item will be tagged to the same temporal context, decreasing the likelihood of a false-alarm on the current trial. Controlling for semantic similarity, Brown and Gorfein related higher levels of temporal discriminability with decreased interference. Given that it was possible to show the build-up of context-related interference while controlling for content-related interference, it suggests that there is some level of independence between the two types of interference.

Amundson and Miller (2008) have carried out a study with rodents that distinguished between content and context. Their tasks employed first-order Pavlovian conditioning, training rodents to press a lever in response to a target cue, and to refrain from pressing in response to an interference cue. In their content manipulation, the target and interference cue were either made up of the same number of elements, or a different number. In their context manipulation, the target and interference cue were either trained in the same context, or a different context. When the number of elements was equal, and the target and interference cue were trained in the same context, interference was more pronounced.

Key to the distinction between content- and context-related interference is the necessary separation between processes and mechanisms that support the representation of content, and different processes and mechanisms that support the representation of context. The above four examples represent the limited amount of work that separates content- and context-related interference. It is noteworthy that the distinction between recollection and familiarity was conceived in studies testing LTM. With some exceptions (e.g., Baddeley, 2000; Ecker, Zimmer, & Groh-Bordin, 2007; Oberauer, 2005), WM is not typically classified as upholding this separation.

One approach that can be invoked to assess content- and context-related effects in memory is to accompany memory decisions with remember-know judgements. Remembering can be related to the conscious experience of recollecting, and knowing can be related to the conscious experience of familiarity (see Tulving, 1985; Gardiner, 1988). Participants respond remember if they recollect that an item was presented in the context of the current trial, and they respond know if the item generates a strong sense of familiarity which is taken to indicate that it was present, even though recollection of its presentation is absent. In Chapter 6, remember and know judgements are assessed in relation to the measures of content- and context-related PI to see if a differential relationship is present. If the measure of context-related interference is more related to the ability to represent context than the ability to represent content, then remember responses should hold a unique relationship to this type of interference. If the measure of content-related interference is more related to the ability to represent content than the ability to represent context, then know responses should hold a unique relationship to this type of interference.

However, remember-know judgements are typically prescribed in LTM tasks; thus the assessment of whether these judgements could be made using a WM procedure is novel. To link the current effects to the literature on effects in LTM, a standard finding was evaluated—the word frequency mirror effect (WFME). It was reasoned that if the WFME could be replicated in the WM tasks here, and if the resultant remember-know pattern matched that found in LTM studies, then the remember-know judgements could be accepted here as valid measures of recollection and familiarity.

2. The word frequency mirror effect

In recognition memory tests in which a mixture of high- and low-frequency items are employed as stimuli, high-frequency items yield fewer hits and increased false-alarms, while low-frequency items yield the opposite pattern, a result that is called the WFME. Dual process theorists have applied the principles of recollection and familiarity to describing the source of both the hit and false-alarm portions of the effect. An earlier finding suggested that that the frequency effect in hits was related to recollection. Gardiner and Java (1990) showed that low-frequency items elicited a greater number of remember responses during recognition than high-frequency items.

Jacoby (1991) introduced experimental conditions in which both processes either worked in concert or antagonistically with the goals of the task. In a typical example of a memory condition in which both processes support correct recognition, participants encoded two lists, and during testing they were asked to confirm items they previously saw, regardless of which list they were presented in. In a second condition, in which familiarity must be ignored in favour of recollection, participants had to respond only to targets that appeared in list 2 (or 1). Performance on the first 'inclusion' condition is assumed to reflect a mixture of recollection and familiarity. In contrast, performance in the second 'exclusion' condition is assumed to rely on recollection. Through performing both inclusion and exclusion conditions, estimates of recollection and familiarity are then made. The calculation of these estimates of recollection and familiarity under conditions of inclusion and exclusion instructions is typically referred to as the dual-process procedure. Guttentag and Carroll (1994) manipulated word frequency as part of this procedure, and found the frequency effect in hit rate to be related to recollection. In a later study (Guttentag & Carroll, 1997), distracters in a recognition memory task had been presented in a previous task, and these distracters were manipulated on word frequency. Low-frequency distracters were rejected more easily than high-frequency distracters, showing that these items were better recollected as having been presented in the previous test. In their Experiments 2 and 3, participants were better able to indicate the processing operations that had been carried out with low-frequency words, suggesting that source information is particularly associated with low-frequency items, consistent with a greater role for recollection in low-frequency recognition.

Reder, Nhouyvanisvong, Schunn, et al. (2000) took advantage of what is called the remember-know mirror effect (RKME) in order to test whether their Source of Activation Confusion (SAC) model could explain the WFME. Hits typically elicit more remember than know judgments, whilst false alarms generate the opposing pattern—a mirror effect in remember and know judgments across hits and false alarms. According to the SAC account, high-frequency items have a raised base-level activation state, and they are associated with a greater number of contexts. During encoding, a fresh link is built between each word and a node representing the context. During recognition, the level of activation that spreads from a word to a particular context will be a function of the number of contexts already associated with that word. Due to a greater number of word-context associations, high-frequency items will have reduced activation to any one associated context. Reder et al. showed that differences between low- and high-frequency items in the strength of item-context associations accounted for the hit-portion of the WFME. The false-alarm portion was attributed to the increased baseline activation associated with high-frequency items; in other words, to increased familiarity.

In the SAC model, remember judgements are presumed to be reliant on the strength with which context nodes are active, and know judgements are presumed to rely on word activation strength. The strength of association between each low-frequency item and its corresponding context node is stronger than the alternative association with each high-frequency item; hence low-frequency items generate a greater number of remember responses. Although past studies failed to report differences in know responses as a function of frequency (e.g., Gardiner & Java, 1990; Gardiner, Richardson-Klavehn, & Ramponi, 1997; Kinoshita, 1995; Strack & Forster, 1995), Reder et al. (2000) reasoned that, given the higher levels of familiarity inherent in high-frequency items, high-frequency hits must be associated with more know responses. They went further, and additionally confirmed a novel prediction that high-frequency false-alarms would also be associated with more know that remember judgements, due to the higher baseline of activation with which these items were associated. Within the context of the thesis, the acronym RKWFME refers to the distinct pattern of remember and know judgements elicited as a consequence of word-frequency.

Joordens and Hockley (2000) provided similar findings to those of Reder et al. (2000), and they also found a remember-know dissociation in the hit rate that showed a similar relationship to frequency to that in Reder et al. (2000). The false-alarm portion of the ME was rarely more likely to be mediated by know responses, however.

They proposed that the hit portion of the ME stems from recollection opposing the underlying effects of familiarity. From this they proposed that the hit portion of the ME should be less consistently present than the false-alarm component—a result consistent with the review of Glanzer and Adam (1985). Joordens and Hockley went on to reduce recollection through delivering the stimuli to be encoded in a lexical decision task, and testing memory with a surprise test. Only the false-alarm portion of the ME was present under these conditions. In a final experiment, recollection was reduced through the introduction of speeded responding during encoding, recognition, or both. Speeded responding during encoding reversed the frequency effect in hits, while the typical effect of frequency on false-alarms remained.

Through manipulating frequency in non-words, Reder, Angstadt, Cary, et al. (2002) were able to study the growth of the WFME over time. Participants completed a number of training sessions that introduced the non-words to be learnt. Three levels of frequency of repetition were used: low, mid, and high. Exposure rates for items varied between 10 and 360 throughout the entire training phase. In the earlier sessions, high-frequency items elicited more hits and false-alarms. In the final session, the hit pattern reversed and a standard WFME in remember-know also arose.

Reder et al. (2002) argued that familiarity played a greater role in the initial sessions whilst recollection became increasingly involved as sessions went on; hence familiarity benefitted high-frequency items in earlier sessions. The framework behind SAC suggests that a selection of features must be linked together with sufficient strength in order to form a concept/chunk, and it may be difficult to form a link between a fragmented set of related features and a context node. It may have been more difficult to form concept nodes for low-frequency items as they were encountered less often. Following the formation of these nodes, recollection was engaged more than familiarity, as supported by an increase in both overall sensitivity and remember responses. Further support that familiarity can benefit the representation of non-words is shown in the finding that non-words elicit more know responses than real words (Gardiner & Java, 1990). The WFME provides a systematic effect within which to explore remember and know responses. If the experiments here replicated the WFME, and the remember-know pattern in the data fitted previous studies, then it would ensure that the measures of remember and know were valid measures of recollection and familiarity.

3. The contribution of the remember-know procedure to an understanding of recollection and familiarity

3.1. Evidence that remember and know underlie distinct factors

Remember and know judgments are commonly perceived to reflect independent memory sources or processes (see Appendix 3). Remember judgments are more likely following deep levels of processing and self-generation of the stimuli to be recognized (Gardiner, 1988). Remember judgments are less likely following divided attention during encoding, whereas know judgments are equally likely following full or divided attention (Gardiner & Parkin, 1990). Remember judgments have also been associated with a better memory for context. In many experiments (e.g., Dewhurst & Conway, 1994; Dewhurst & Hitch, 1999; Perfect, Mayes, Downes, & Van Eijk, 1996; Reder, Nhouyvanisvong, Schunn et al. 2000) participants are asked to make source judgments to each test item; for example, which list they saw an item in. Better source discriminations are more likely to be associated with a remember rather than a know response. Combined, these studies suggest that greater levels of attention during encoding promote recollection, and recollection is associated with memory for context.

Know responses are sensitive to manipulations of what may be termed the 'content' of memory representations. Rajaram (1993) found that know judgments were increased when test items were primed just prior to being presented during testing. Gregg and Gardiner (1994) manipulated the degree to which participants were oriented towards the perceptual features of stimuli through using different tasks during encoding. If the modality of stimulus presentation was altered between study and test under conditions of high attentional demand to perceptual features, know judgments were far less likely. The reduction in know responses suggests a link between the process reflected by know judgments and the featural content of the information being encoded.

A number of studies have succeeded in making different manipulations to the same variable in order to differentially influence remember and know responses; for example, remember-know judgments are influenced by different kinds of rehearsal. Gardiner, Gawlick, and Richardson-Klavehn (1994) used a directed-forgetting paradigm in which they manipulated the length of the delay between the presentation of each word to be encoded and the instruction to forget or learn for later recognition. They reasoned that lengthier delays would encourage maintenance rehearsal, but that only items that were given a learn instruction would undergo elaborative rehearsal. In a later recognition test that required participants to signal all items that were seen earlier, the potential for elaborative rehearsal affected remember judgments only. In addition, remember judgments were more likely with short delays following each encoded item; know judgments were facilitated through maintenance rehearsal. This suggests that familiarity is affected by the degree to which attention is directed towards content during encoding (supported by maintenance rather than elaborative rehearsal) with more attention to content boosting familiarity.

Parkin, Gardiner, and Rosser (1995) manipulated the lag at which an item repeated, lag 0 for immediate recognition, and lag 6 for spaced repetition. Know judgments increased following immediate repetitions; thus immediate repetition had a similar impact to that of maintenance rehearsal in boosting familiarity. Remember judgments increased following spaced repetitions; thus spaced repetition had a similar impact to that of elaborate rehearsal in boosting recollection. Parkin et al. also suggested that while familiarity was being boosted, participants were unable to engage in elaborative processing. However, an alternative explanation of the spacing effect is that spaced repetition creates two distinct episodes within the task which relate an item to the task, whereas an immediate repetition fits within the envelope of one episodic. Recollection would then benefit from two rather than one event being associated with the same item.

A recent study by Skinner and Fernandes (2008) consolidated a link between, on the one hand, remember and recollection, and, on the other, know and the representation of content. In earlier studies (Fernandes & Moscovitch, 2000, 2002, 2003), recognition memory was negatively affected by introducing a distracter task during retrieval that required processing of the same stimulus-type as was involved in the memory task. This effect of similarity may be thought of as content-related interference, based on an overlap between the distracter content and the content of the memory representation. Skinner and Fernandes investigated whether this content-related interference effect might be related to familiarity, and not recollection. Verbal recognition memory was tested while participants engaged in a distracter task with material that interfered with the memory task (other words), or did not (digits). The type of distracter task did have an influence on know responses: know responses were reduced when content-related interference was possible. The type of distracter task was also crossed with full or divided attention conditions. Both type of distracter and full versus divided attention were shown to have independent effects on recognition. An older and younger sample were additionally compared, and divided attention increased the likelihood of remember false-alarms, particularly in the older sample. Although the older sample showed slower responses times in the presence of content-related interference, there were no know differences between the groups.

Skinner and Fernandes concluded that there must be a distinct link between knowing and the representation of content: remember responses were unaltered by content-related interference. They also pointed to the important role that attention plays in monitoring and/or forming item-context associations, and that it is these latter abilities that are impaired in older samples.

Remember and know responses have also being qualitatively dissociated in terms of how participants describe their responses. Gardiner, Ramponi, and Richardson-Klavehn (1998) analyzed a large number of subjective reports and found that remember responses were far more likely to be accompanied by recollective experiences than know responses. Remember responses were associated with elaborative encoding, and contextual effects such as relating a stimulus to the self. Examples of elaborate encoding included forming within-list associations between items, forming associations between an item and something external to the list, generating specific images of the item presented and the physical features of the item. Participants connected know responses with feelings of familiarity. They typically found it harder to give descriptions for these judgments.

3.2. Know responses can be influenced by decision making strategies

Although there is evidence to suggest that remember and know responses may reflect different types of information encoded in memory, an alternative conception relates the responses to decision based factors rather than to memory related processes or substrates. Strack and Forster (1995) questioned whether know judgments could be taken to reflect a memorial substrate, as opposed to a judgment that was called upon when a participant was aware that they could not recollect an item. They showed that know judgments could be manipulated by other decisions that participants undertook in the task that were not based directly on the items stored in memory. In an attempt to check for a relationship between non-memorial forces and the know response, participants were told the proportion of test trials in which old items would be presented, either 50 or 30%. There was an effect of base-rate instruction in the know responses, such that know judgments were more likely if participants believed that 50 rather than 30% or encoded items were present, showing that, on the basis of the instruction, participants decided to use the know response more often in this condition.

In a second experiment, Strack and Forster manipulated the number of items that participants were asked to identify. Participants were more accurate when fewer items were to be identified, and this had opposing effects on remember and know judgments. Know judgments were more likely when a greater number of targets were to be identified, whereas remember judgments were more likely when a reduced number of targets were to be identified. Confidence judgments were additionally collected. While the number of targets to be selected influenced confidence in know responses, there was no effect on remember responses. Strack and Forster concluded that judgmental strategies come in to play when the memory for an event is weak, and when participants must decide as to whether the response criteria needs to be lowered. This raises a question about the validity of the know response as a source of information about the content of memory representations.

Evidence of the impact of decisional factors on remember as well as know responses has given rise to models that present remember and know judgments as indexes of memory strength along a signal detection-based continuum, with one criterion differentiating between old and new, and a further criterion distinguishing between remember and the first criterion (e.g., Dunn, 2004). Items that fall between both criteria are given a know response. Two criterion models of remember-know judgments were proposed by Donaldson (1996) and Hirshman and Master (1998; see also Hirshman, 1998). Hirshman and Master cited findings that know responses are less consistent within individuals than remember responses, when different variables are varied. They argued that know responses are sensitive to the placement of two criteria, and that this accounts for the increase in variability. For example, in Strack and Forster, participants were sensitive to the baseline instruction (the lower of the two criteria), and the criteria separating remember from know responses (upper criteria). Donaldson additionally showed a correlation between the old/new criterion and know responses, suggesting that know responses may simply reflect decisional factors involved in criterion placement.

Hirshman and Henzler (1998) manipulated an instruction to participants that described the proportion of old items that were going to be shown with new items during testing: 30 or 70%. When participants were instructed that old items were more likely, they ascribed a greater number of both remember and know responses to test items, the argument being that both criteria were adjusted downward. Hirshman and Henzler argued that if remembering is associated with a qualitatively different experience than knowing, then it should not be open to influence from decision processes. In addition to this manipulation, item-strength was varied through presenting items to be encoded for shorter or longer durations. There was an increase in know responses with longer durations when participants were instructed that a decreased proportion of test items were old. The result implies that the use of familiarity in memory is affected by decision processes.

Gardiner and Gregg (1997) argued against two decision-based models of remember-know judgments. Decision-based models suggest that remember and know only differ in criteria; thus, if criteria are matched across remember and know, then sensitivity to remember responses (calculated from remember hits and remember false alarms) should be similar to know responses (calculated from know hits and know false alarms). Gardiner and Gregg controlled for the criteria difference between remember and know, but still found that remember sensitivity was higher than know sensitivity. This result is consistent with recollection providing more qualitatively distinct memories than familiarity. It suggests that although decision processes may be able to influence remember and know responses, differences in memory must also contribute.

Gardiner, Richardson-Klavehn, and Ramponi (1997) re-ran the experiment of Strack and Forster and included the option of a guess response in addition to remember and know. Strack and Forster had found a response bias in know judgments in response to the baseline instruction: know responses were more likely when participants expected a greater number of targets to be present during testing. With the inclusion of a guess response, Gardiner et al. (1997) found that this response bias failed to emerge in know responses, and only arose in guess responses. The implication is that remember-know responses are not reducible to the influence of decisional factors.

In a meta-analysis, Gardiner, Ramponi, and Richardson-Klavehn (2002) reported that guessing correlated more strongly with the response criteria than either remember or know responses. They concluded that Donaldson's (1996) finding of a correlation between criteria and knows was simply a function of the know measure including guess responses. They also showed that when guess responses were combined with an index of memory strength (measured as A′), memory strength was actually lower than when remember and know memory strengths were combined together. The negative impact of guess responses on memory strength suggests that the guess response is more tightly tied to decisional factors than memorial factors. Guess responses also failed to consistently differ between targets and lures, whereas both remember and know responses did. Again, this shows that guess responses are not made on the basis of memorial information, but instead, decisional information.

In a final study, Gregg, Gardiner, Karayianni, and Konstantinou (2006) looked at remember, know, and guess responses in relation to the WFME. A frequency effect failed to arise in guess hit responses while it was present in both remember and know hit responses. Memorial effects underlie the effects of frequency in remember and know responses. The absence of a frequency effect in guess responses supports the association between guess responses and decision-based factors. In the experiments of this thesis, a guess response was not included, as remember and know responses were being collected in the context of the WFME. Through demonstrating a frequency effect in know responses to hits in addition to remember responses to hits, the ability of know judgements to capture memorial-related processing in relation to familiarity would be validated.

3.3. Is remembering dependent on control; is automaticity sufficient for knowing?

When making recognition decisions, Atkinson and Juola (1974) suggested the need for a process that would engage in a controlled search of memory if the signal strength of a test item was such that it could not be clearly accepted or rejected. This distinction between memories that are activated automatically, and those that require controlled access, was capitalised upon by Jacoby when he related recollection and familiarity to Shiffrin and Shiffrin's (1977) control and automaticity framework. Jacoby proposed that bottom-up automatic processes, which re-activate representations in memory, generate a sense of familiarity, while recollection allows for the controlled recovery of contextual details associated with an event during encoding. Yonelinas and Jacoby (1995) applied similar reasoning to their description of remember and know judgements: remember judgements were perceived to reflect control, and know judgements were perceived to reflect familiarity.

Gardiner and colleagues have questioned whether knowing truly reflects automaticity, and in so doing, they have created the suggestion that recollection and familiarity, and control and automaticity, are orthogonal sets of variables. This is an issue of importance to the current thesis, as WM-related theories of PI suggest that participants can exert some degree of control over interference build-up. If control is only related to the experience of recollection, and not familiarity, and aspects of control are related to both types of interference, then a relationship between content-related interference and know responses may be absent (as know responses would then be assumed to reflect automaticity).

It is generally assumed that recollection, because of its suggested controlled nature, is hampered under short response deadline procedures. As response deadline increases, participants can exert more control over their responses; thus, recollection is assumed to increase with lengthier response deadlines. Recognition under short response deadlines is assumed to be more reliant on familiarity, given that automaticity is assumed to be more capable of influencing responding under short deadlines than control (e.g., McElree, Dolan, & Jacoby, 1999).

Gardiner, Ramponi, and Richardson-Klavehn (1999) tested the idea that familiarity should strongly influence performance at short response deadlines, and that recollection should increase as deadline increases. In other words, they tested whether familiarity was directly dependent on the availability of automatic processes, and whether recollection was directly dependent on the availability of control. A response deadline manipulation was crossed with a manipulation of depth of processing at encoding (Experiment 1), and with conditions that required either word generation or reading during encoding (Experiment 2). Significantly, the positive effects of deeper encoding and self-generation on remember responses were independent of the response deadline, and know responses were not more likely under the shorter deadline; instead, both types of judgment increased with the longer deadline. Given that it is generally accepted that the level of control exerted over the information being retrieved can be increased with longer delays, Gardiner et al. suggested that cognitive control can influence both the experience of remembering and the experience of knowing. In addition the data suggest that both recollection and familiarity responses can be triggered automatically, as the same proportion of responses arose under short deadlines as under longer deadlines. The findings are inconsistent with the suggestion that recollection and familiarity are independent processes that reflect control and automaticity, respectively.

Gardiner and colleagues have presented further evidence that recollection and familiarity are orthogonal processes relative to control and automaticity. The link between control and recollection is believed to be attentional in nature; information that is processed automatically, and that is thus assumed to influence familiarity, does not require attention. Gardiner and colleagues reasoned that if attention is diverted away from encoding, it should not affect know responses if these responses are reflective of automaticity. Gardiner, Gregg, Mashru, and Thaman (2001) first investigated this reasoning in relation to the size-congruency effect. Rajaram (1996) had earlier demonstrated that changing the size and orientation of encoded pictorial stimuli reduced the number of remember responses ascribed to targets during testing.

Gardiner et al. (2001) assessed the size-congruency effect under conditions where, during encoding, there was either full or divided attention, or deep or shallow encoding. When attention was employed more during encoding (full attention and deep encoding), the size-congruency effect occurred in remember responses. However, under conditions of divided attention, and following shallow encoding, effects of size-congruency occurred in knowing. These results were accounted for in the framework of Rajaram (1996; 1998). This framework holds that optimal encoding conditions allow for distinctive aspects of encoded items to be represented. Altering the size of stimuli between study and test reduces the impact that these distinct features have on recollection; hence the reduction in remember responses. Under less optimal encoding conditions, items will be represented less distinctly; thus the potential for remembering is reduced. Recognition will now be more dependent on familiarity-based processing. Since familiarity will be reduced when items change size, know judgments are now affected under divided attention conditions during encoding.

Similar results to these were reported in follow-up work by Gardiner, Gregg, and Karayianni (2006) who examined picture-size and voice-congruence under full or divided attention conditions using a response deadline procedure. Effects of congruency occurred in remembering under full attention conditions, and in knowing under divided attention conditions. Both of these effects were independent of the response deadline. These results converge with the previous work on the effects of perceptual change on remember and know judgments under optimal and sub-optimal encoding conditions. The extension using the response deadline technique adds to this, by showing that a manipulation of control and automaticity, that is, the response deadline procedure, does not influence effects involving remember and know—in order words, the two sets of variables are orthogonal.

The findings of Gardiner and colleagues are consistent with the suggestion that remember and know reflect independent processes, but these independent processes are not control and automaticity. In an effort to map control and automaticity on to remember and know, Yonelinas and Jacoby had introduced a correction to know judgments (familiarity = know hits / (1 – remember hits)). Gardiner, Gregg, and Karayianni (2006) showed that automaticity measurements based on corrected know responses need not match standard know responses in their relation to experimental findings. Perceptual effects did occur in corrected measures of familiarity even when know responses did not show such effects (e.g., in the full attention conditions).

Finally, it has also been suggested that decisional factors may influence the relationship between control and automaticity, and remember and know responses. A number of studies have shown that remember response times are faster than know response times (Dewhurst & Conway, 1994; Dewhurst, Holmes, Brandt, & Dean, 2006; Henson, Rugg, Shallice, et al. 1999). This suggests that the information provided through recollection reaches awareness faster than the information provided through familiarity. However, know decisions may be more complex because participants have to consider whether contextual information is available to them, and if not, whether the strength of the familiarity signal coming from the item is enough to indicate its having been presented. As Knott and Dewhurst (2007) point out, however, the RT findings are enough to suggest that know responses do invoke cognitive control, and thus question the validity with which know responses can be directly mapped onto automaticity.

4. Associative and unitization mechanisms mediate recollection and familiarity respectively

Mandler (1980) argued that familiarity judgements are based on representations of integrated perceptual features that form an event, which he described as *intra-item* integration. In contrast, recollection was proposed to allow for features extrinsic to the current event of focus to become associated with that event, which he described as *inter-item* information. Starting with this distinction from Mandler, and following on with a distinction between grouping and unitization by Graf and Schacter (1989), which is similar to the distinction between recollection and familiarity, Yonelinas (2002) distinguished between the linking of features within an event/item, and the association between an event/item and its context. This work suggests than an associative mechanism that associates an item/event to its context supports the process of recollection, while a unitization mechanism binds the features that belong to a distinct item/event, supporting familiarity.

Strong evidence for a link between recollection and the ability to make associations has been presented at multiple levels, and at the core of this evidence is a link between recollection, associating, and the hippocampus (see Rugg & Yonelinas, 2003, for a review regarding the link between recollection and the hippocampus, and Norman & O'Reilly, 2001, for a link between associating and the hippocampus).

Importantly, a specific link between remember responses and the hippocampus was shown by Eldridge, Knowlton, Furmanski et al. (2000). Additionally, amnesic patients (Aggleton & Brown, 1999; Aggleton, Vann, Denby, et al., 2005; Yonelinas, Kroll, Dobbins, et al., 1998; and Verfaellie & Trendwell, 1993) and Alzheimer's patients (Balota, Burgess, Cortese, and Adams, 2002) with hippocampal damage show recollection deficits.

Distinct ERP components are related to recollection and familiarity (Curran, 2004; Düzel, Yonelinas, Mangun, et al., 1997; Rugg, Cox, Doyle, & Wells, 1995); however, familiarity has been less consistently linked to a distinct anatomical area(s). Ranganath, Yonelinas, Cohen, et al. (2004) highlighted one reason why familiarity-related fMRI findings are not as consistently found as recollection-related findings: familiarity is based on a continuum of strength, not an all-or-none sense of whether an item is familiar or not. To assess the continuum of familiarity, they had participants rate confidence in familiarity along a scale from little to very familiar. Activation during encoding within the rhinal cortex was positively related to the level of confidence with which participants responded to old items, while encoding activity within the hippocampus was related to correct source judgments (see Appendix 4 for further information).

The rhinal cortex has also been linked to unitization (Staresina & Davachi, 2006), and damage specific to this region has been shown to explicitly impair familiarity (Bowles, Crupi, Mirsattari et al., 2007). In addition to the evidence that unitization and familiarity overlap in a key anatomical region, unitization has also been shown to be related to the familiarity ERP component (Jager, Mecklinger, & Kipp, 2006; Rhodes & Donaldson, 2007). Amnesic participants also show better learning of unitized items than items that need to be associated, which suggests that unitized items are less dependent on the associative mechanism (Quamme, Yonelinas, & Normal, 2007). Finally, receiver-operating-characteristic-curves (ROCs) that relate hits and false alarms are more curvilinear than linear under conditions of unitization, which suggests a role for familiarity in task performance (Diana, Yonelinas, & Ranganath, 2008; Yonelinas, Kroll, Dobbins, & Soltani, 1999; see Appendix 5 for further information).

<u>5. Interference degrades working memory, but what is/are the mediating mechanism/s?</u>

From the perspective of a dual-route account, content-related interference should be related to familiarity, and context-related interference should be related to recollection. This approach evokes the need for separate mechanisms to explain the relationship between PI and WM. Given the relationship between recollection and an associative mechanism, it is conceivable that the same associative mechanism mediates the build-up of context-related interference: reduced susceptibility to context-related interference would then be related to a more proficient associative mechanism. Given the relationship between familiarity and a unitization mechanism, it is conceivable that the same unitization mechanism mediates the build-up of content-related interference: reduced susceptibility to content-related interference would then be related to a more proficient unitization mechanism.

Four points stand in the way of a dual-route account. Firstly, despite the evidence discussed hitherto for a distinction between recollection and familiarity, and thus a distinction between the ability to represent context and content, this evidence was generated in studies looking at LTM, not WM. Secondly, current accounts of the relationship between PI and WM hold that it is unitary, and independent of source. Thirdly, the only study that addressed differences in the source of interference found that the different measures of interference were reliant on the same underlying process/mechanism. Fourthly, PI is believed to be malleable to effects of control, and one perspective of the division between recollection and familiarity is that only recollection is related to control. From this perspective, a unique relationship between content-related interference and familiarity (know responses) seems unlikely; instead, both measures of interference should be related to control.

One caveat in relation to the studies of Postle and colleagues (2004ab) is that items repeated across trials in measurements of item-non-specific interference (one exception being a face study that was included in the fMRI meta-analysis, but separate imaging data for this study were not provided), which, from the dual-route approach, is a measure of content-related interference. Repetition has a cumulative negative impact on performance (e.g. Anderson & Bower, 1974; D'Amato, 1973). Although Postle and colleagues defined item-specific PI as interference stemming from item repetition across consecutive trials, it is worth considering that their measurement of item-non-specific PI may have been confounded by the cumulative build-up of item-specific PI. In addition to this caveat, there is also evidence to suggest that a distinction between an associative and a unitization mechanism may also be evident in WM in the form of a distinction between associating and binding.

5.1. To associate versus to bind

Ecker et al. (2007) introduced a distinction between the coding of content and context in IM based on the notion of object and episodic tokens. A distinction was made between the binding of intrinsic features to form the content of an item, and the association between a set of features and the extrinsic context. Using ERP, they showed that the binding of intrinsic features influenced both the familiarity and recollection ERP components, but when participants were required to recollect the extrinsic features associated with the bound content, the recollection component was specifically influenced.

Ecker et al. likened object tokens to object files, a concept introduced by Kahneman and Treisman (1984; see also Kahneman, Treisman, & Gibbs, 1992). An object file is an online representation of an object that is currently being processed. The term was introduced to facilitate understanding of how features can be bound together at a rapid pace to allow for the perception of objects with novel feature combinations. As evidence for the existence of object files, Kahneman et al. (1992) compared response times of features that had been previewed as part of an attended object relative to features that were part of another object. Faster response times were recorded for the former type feature, suggesting that this feature was activated as part of an object file currently in use. Although earlier work emphasised the role that location played in the coding of object files, Treisman and Zhang (2006) showed that, at least at the level of object memory, extrinsic spatial locations did not need to be part of a particular object file in order for that object to be recognised. This latter finding suggests that an assimilated set of features that make up an object can be stored separately from extrinsic features that are related to that object. The sense of familiarity for stored items can thus be processed independently of extrinsic details associated with items (i.e. object tokens are separate to episodic tokens).

While familiarity operates at the level of object tokens, Ecker et al. demonstrated further evidence that recollection operates on episodic tokens. They manipulated participants' goals through applying Jacoby's process dissociation procedure. In one recognition condition, participants were to verify all objects that they had seen during encoding, regardless of potential changes made to extrinsic contextual details presented with the items during encoding. In another recognition condition, participants were to exclusively verify all objects presenting during encoding that were now been shown with the same extrinsic features. While the former condition emphasised the representation of object tokens, the latter condition relied upon the representation of episodic tokens. Recollection was employed to a greater degree in the exclusion condition, consistent with the use of episodic tokens.

In contrast to Treisman and Zhang's finding of location non-specific recognition of object files stored in memory, Ecker et al. found location-specific effects on the recognition of episodic tokens: participants were better able to recollect which features were presented as part of the same object during encoding when objects were presented at the same location during testing. Both findings are consistent with the representation of extrinsic details such as location in episodic tokens—not object tokens, as there was no cost to the recognition of object tokens following a location change. A final finding by Treisman and Zhang that testified the ease with which object features are encoded as part of the same object file was that there was a cost to feature recognition when other features that were part of the same object during encoding changed at testing, which is of course consistent with the description of object tokens in memory.

Further support that the representation of extrinsic details in memory is not part of an item's object token can be taken from a study by Xu and Nakayama (2007). They tested memory for features that were presented on 1- or 2-planar 2-D surfaces. When participants were required to recognise which coloured objects had been presented in particular locations during testing, they observed a benefit of having the items presented on different planes during encoding. However, when participants were only required to remember the coloured features presented, memory failed to differ between 1- and 2-planar presentations. While memory in the latter condition was guided by the representation of object tokens, the additional representation of episodic tokens boosted the impact of having a 2-planar surface during encoding. Here, the second surface provided a further level on which to differentiate which colours were associated with which locations.

Ecker and colleagues applied similar principles to the characterisation of object and episodic tokens as are applied to the distinction between recollection and familiarity. Of primary interest to the current study is the suggestion that recollection is a controlled process, whilst familiarity is automatically elicited. This implies that episodic tokens require attention in order to be represented; on the other hand object tokens may be formed in the absence of attention. Congruent with this, Luck and colleagues (Luck & Vogel, 1997; Vogel, Woodman, & Luck, 2001) failed to find a cost to the recognition of feature bindings relative to feature recognition when the features were bound to the same object (e.g., a little square tucked inside a bigger square, or a coloured bar). Additionally, Brockmole, Parra, Sala, & Logie (2008) failed to find a difference in binding between older and younger adults but did find a difference in WMC. WMC has been associated with recollection (Oberauer, 2005), and older individuals are also reported to have poorer recollection; intrinsic binding is reliant on familiarity, and both older and younger participants are reported to rely equally on this process—hence accounting for Brockmole et al.'s pattern.

5.2. Is control necessary for associating; is automaticity sufficient for binding?

Not all LTM research is consistent with a necessary role for attention in relation to recollection, and the concurrent absence of a need for attention in bringing about familiarity. Indeed, there is evidence in WM to suggest that extrinsic details can be represented in memory in the absence of attention, and that attention may be able to strengthen the binding of intrinsic features. This WM-related evidence is of interest, as it suggests that control and automaticity may be orthogonal to the representation of extrinsic and intrinsic features in WM. These issues are particularly relevant when it comes to elucidating the relationship between PI and WM. Some theories of this relationship posit that the relationship is mediated through controlled processing (be this in relation to attention [Engle, 2002] or inhibition [Postle & Brush, 2004]). If, however, there are separate processes or mechanisms that facilitate the representation of intrinsic and extrinsic details independently of control, then PI may be more related to these processes/mechanisms than to an executive component that may influence these process/mechanisms in a task independent manner.

Van Asselen, van der Lubbe, and Postma (2006) presented evidence that the coding of extrinsic features may not always be reliant on control. They compared memory for the spatial and temporal location of objects. In some blocks, memory for only one feature was tested. In other blocks, memory for both features was tested, but a greater proportion of trials tested memory for one of the features. Although memory for the prioritised extrinsic feature was superior to that of the extrinsic feature tested less often in mixed blocks, memory for the less tested feature was still above chance, suggested that the less prioritised feature was coded automatically.

Wheeler and Treisman (2002) presented the argument that attention might also be required in the binding of intrinsic features. They found poorer performance on the binding of intrinsic features relative to feature memory. Notably some of the manipulations that gave rise to this thesis have been challenged, particularly the relocation of encoded objects between encoding and test. Johnson, Hollingworth, and Luck (2008) showed that when location was left unchanged, the cost to binding memory was reduced, and as mentioned above, Treisman and Zhang also showed the cost of location changes to binding memory.

Despite these criticisms, the thesis of Wheeler and Treisman fits with what would be predicted if control and automaticity are orthogonal to the representation of content and context: if extrinsic features can be coded automatically, attention may still influence the strength with which intrinsic features are bound. Johnston et al. did indeed demonstrate that attention could influence intrinsic binding memory. Between study and test in a change detection paradigm, they distracted attention from the encoded set through requiring participants to engage in a visual search task. Memory for the bindings between features was better when attention was not withdrawn; however, feature memory itself was also shown to be equally affected by the withdrawal of attention. They rejected Wheeler and Treisman's claim that attention was of greater need during the binding of features relative to the encoding of features in general; however, this evidence does suggest that attention can be employed in binding.

As highlighted in the interference literature, one situation in which greater attention is called to the processing of stimuli is when the potential for interference is present. Allen, Baddeley, and Hitch (2006) demonstrated the impact of interference on the binding of intrinsic features. Coloured shapes were either presented together in a spatial array during encoding, or separately, one at a time. There was only a cost to binding relative to single-feature memory with sequential presentation during encoding. Allen et al. proposed that there was bottom-up disruption to feature binding due to overwriting of each stimulus by the consecutive stimulus; however, it is worth considering that a greater amount of attention to the intrinsic features being bound during encoding might have offset overwriting.

5.3. Anatomical evidence for separation between control and automaticity on the one hand, and associating and binding on the other

At an anatomical level, executive control is consistently linked with DLPFC function. Although some research suggests that DLPFC may play a specific role in representing context (e.g. Blumenfeld & Ranganath, 2006; Henson, Shallice, & Dolan, 1999; Tsujimoto & Sawaguchi, 2005; Wagner, Desmond, Glover, & Gabrieli, 1998), and there is evidence to suggest that it monitors responding during testing in an effort to prevent false-alarms (e.g. Gerrie & Garry, 2007), its role in cognition is most consistently described in relation to monitoring and directing attentional resources so that behaviour remains congruent with the goals of a task (Duncan, Emslie, Willams, et al., 1996; Duncan, Parr, Woolgar, et al., 2008), and there is evidence to suggest that it plays a role in familiarity in addition to recollection (Turriziani, Oliveri, Salerno, et al., 2008). Automaticity as a construct has stimulated less research than executive control to date, but a recent review and synthesis of current perspectives suggested that the basal ganglia play a key role in mediating bottom-up driven behaviour (Saling and Phillips, 2007).

In LTM research, the hippocampus is most commonly tied to recollection, and regions linked to familiarity include the ento- and perirhinal cortices, and the parahippocampal gyrus. A separation between areas involved in monitoring goal-directed behaviour and facilitating bottom-up driven behaviour on the one hand, and areas that mediate the representation of context (e.g., the hippocampus) and content (e.g., the entorhinal cortex) on the other, is consistent with a need to acknowledge the separateness between control and automaticity, and processes/mechanisms that support memory for extrinsic and intrinsic features. While functional evidence for the role that DLPFC and basal ganglia, particularly the caudate region, play in WM is abundant (e.g., Gazzaley, Rissman, & D’Esposito, 2004; Lewis, Dove, Robbins, et al., 2004; White, 2009), there is also evidence that key areas involved in recollection and familiarity contribute to WM.

Ranganath, Cohen, and Brozinsky (2005) found hippocampal activation during encoding and in the early stages of maintenance in a DMTS task, and in addition to being correlated with better matching performance over the short term, the activation was also related to better LTM. When consolidation of an encoded item was interrupted through presenting a distracter task, LTM suffered. Amnesic patients have also demonstrated poorer memory over short delays (Hannula, Tranel, & Cohen, 2006; Nichols, Kao, Verfaellie, & Gabrieli, 2006). There is also evidence to suggest that the hippocampus plays a key role in representing extrinsic features in WM. Mitchell, Johnson, Raye, and Greene (2004) found poorer performance in a task that required participants to recognise associations between objects and locations in elderly individuals, consistent with ageing giving rise to less efficient recollection. They went on to show that decreased hippocampal activation separated the poorer performing elderly from a younger sample. Olson, Page, Moore, et al. (2006), Hannula and Ranganath (2008), and van Asselen, Kessels, Kappelle, and Postma (2008) also found greater hippocampal activation when objects and locations were associated relative to when either object or location memory was tested. This is consistent with a greater recruitment of the hippocampus in response to the requirement to associate a set of intrinsic features with an extrinsic feature.

Binding and unitization are similar, if not equivalent concepts. In support of this link, regions evoked in unitization have been shown to support binding in WM. Egorov, Hamam, Fransen et al. (2002) suggested that activity within the entorhinal cortex may be linked to WM maintenance. They showed that neurons within this region adapted to different but similar stimuli with graded changes in firing rate, and that the sustaining of specific firing rates could match the demands of WM maintenance. The perirhinal cortex has also been linked to WM. Lee, Buckley, Gaffan et al. (2006) compared the performance of Alzheimer's and semantic dementia patients in order to contrast memory involvement of the hippocampus (linked to Alzheimer's) and the perirhinal cortex (linked to semantic dementia). Recognition of scenes is hippocampally dependent, whereas face recognition can be successfully mediated by familiarity. Lee et al. found a specific scene recognition deficit in the Alzheimer's patients, and a specific face recognition deficit in the semantic dementia patients. The findings replicate the link between the hippocampus and recollection, and further support a link between binding, or unitization over the short-term, and the perirhinal cortex. Finally, while the IFG activation that defined the first interference network found by Caplan et al., is consistent with a link to recollection (e.g. Daselaar et al., 2006; Ranganath et al., 2003), activation of the second network in the parahippocampal gyrus (Daselaar et al., 2006; Gonslaves et al., 2005) and orbito-fronal cortex (Ranganath et al., 2003) is consistent with a role for familiarity in resolving interference.

The distinction between episodic and object coding in WM fits with the distinction between recollection and familiarity in LTM. Anatomical evidence suggests that similar regions play a role in recollection and episodic coding on the one hand, and familiarity and object coding on the other. Although some have argued that control is inherent to recollection and episodic coding, and automaticity is inherent to familiarity and object coding, other evidence, both behavioural and anatomical, suggests that such relationships are task dependent. Specifically, it will be argued that if there is potential for content-related interference, then the WM system will devote attentional resources to the binding of intrinsic features; if there is potential for context-related interference, then the WM system will devote attentional resource to associating intrinsic features to an extrinsic feature. It follows that there is a mechanism in the WM system that supports binding, and another mechanism that supports associating. The degree to which each mechanism is engaged will depend on the task, and while executive control will push attentional resources towards the mechanism that is needed, automaticity will facilitate processing of less relevant features.

6. In relation to the aims of the current thesis

A key aim was to replicate two LTM findings in IM, the WFME and the remember-know frequency ME, see Chapter 6. Replicating these effects would strengthen the validity of the remember-know measurements, insuring their fitness for an assessment of their relation to both types of interference. Context-related interference would be expected to be related to remember responses and the hit portion of the ME, while content-related interference would be expected to be related to know responses and the false-alarm portion of the ME.

It is interesting to note that Daniels (in preparation) has shown that measures of control as collected in relation to recollection are similar to measures of control taken in WM tasks. As interference is argued to be related to control in WM tasks, it seemed possible that measures of PI would only be related to measure of recollection. However, recollection and familiarity may be orthogonal to control and automaticity. The methods here provided a means of addressing this hypothesis. If the key separation between recollection and familiarity is the distinction between context and content, then it seemed likely that both types of interference would be differentially related to recollection and familiarity. If, however, the key separation between recollection and familiarity is the distinction between control and automaticity, then it seemed likely that both types of interference would be related to recollection only.

Extrinsic features are related to recollection and context, and intrinsic features are related to familiarity and content. The distinction between associating and unitization in LTM studies is strikingly similar to the evidence provided for a distinction between associating and binding in WM. Content-related interference, or item-non-specific interference, would be expected to be related to a binding mechanism in WM, and context-related interference, or item-specific interference, would be expected to be related to an associative mechanism in WM. Figure 4 displays the theoretical distinctions that act as a framework for this position.

Abiding by a framework that suggests a strong relationship between control and representing episodic codes, and automaticity and representing object codes, item-specific PI should share a stronger relationship to WM than item-non-specific PI. Consistent with this suggestion, Oberauer (2005) has claimed that recollection and WMC are related, whilst familiarity does not pick up on the same variance as WMC. WMC has been related to interference build-up in past studies through measurements of complex-span; thus, it is conceivable that recollection, WMC, and item-specific PI are related. From this perspective, if item-non-specific PI is an independent measure of interference, then it is more likely to be linked to STM variability rather than WM variability (e.g., variability in phonological coding). However, Oberauer and Lange (2009) have gone on to suggest that associating an item to its context, and binding lower level features together relies on the same underlying mechanism. Additionally, Raffone and Wolters (2001) have suggested that binding is related to WMC. If binding and associating are simply different labels that refer to the same process, then it might be possible to show that both types of interference are equally related to WM (i.e. the two manipulations of interference are not independent).

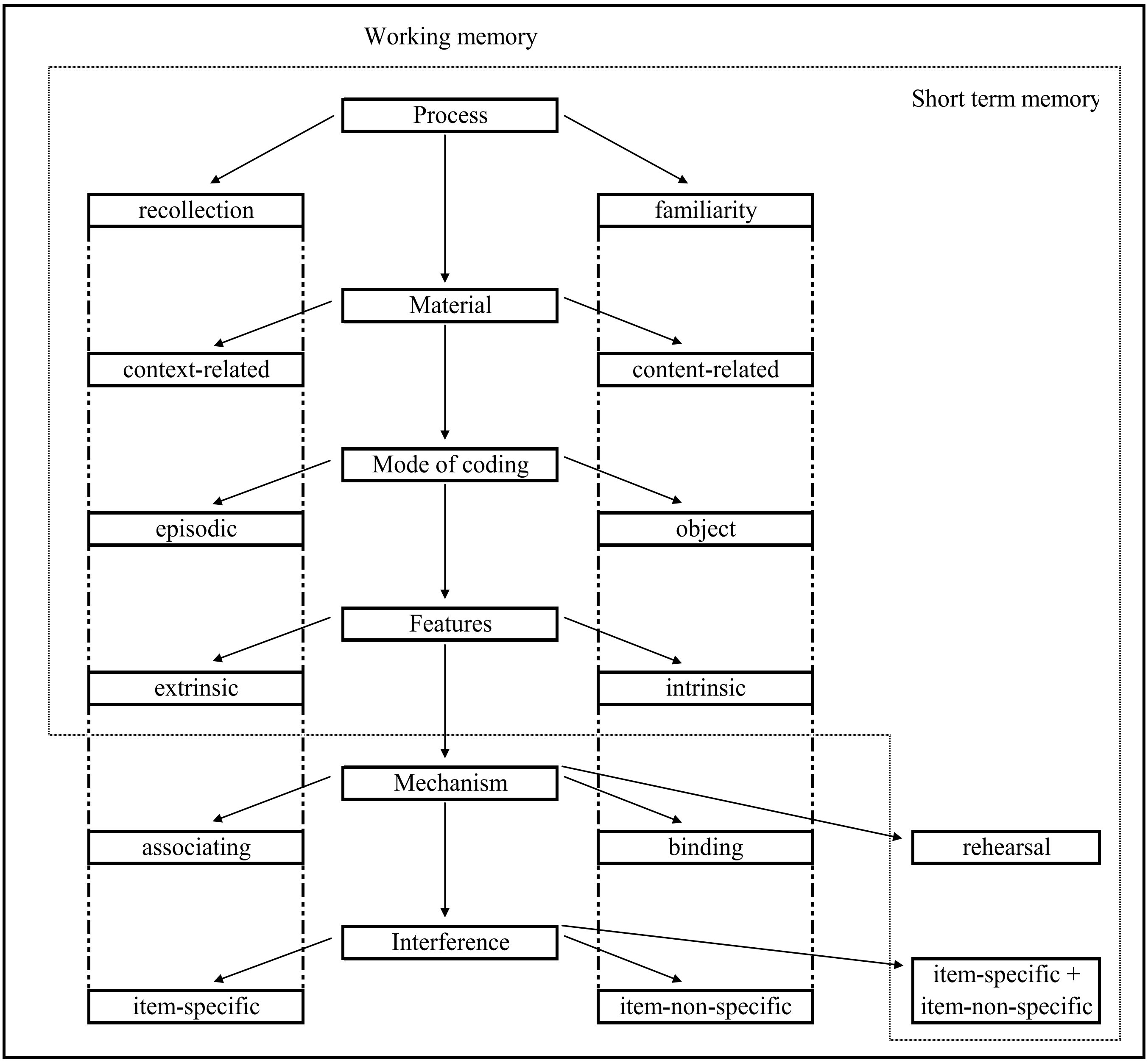

Figure 4: A dual-route framework of the two WM networks that influence PI in WM

Alternatively, there is a mechanism within the WM system that mediates the formation of associations that support episodic coding, and a mechanism that mediates the binding of intrinsic features for object coding. Each of these mechanisms can be actively engaged in accordance with the goals of a task, and the type of interference that a task generates. The associative mechanism is recruited if the goal of a task is to associate different features (e.g., non-objects and non-words). This mechanism is also recruited to mediate the build up of item-specific interference. The binding mechanism is recruited if the goal of a task is to link features into a unitized representation. This mechanism is also recruited to mediate the build up of item-non-specific interference. In accordance with past factor analytic studies, STM may be separated from WM. It is logical to assume that participants are restricted in the amount of processing that they can carry out on task information. If STM is engaged more in a task than WM, then performance should be more open to interference generally, as both WM mechanisms are less likely to be engaged in processing the stimuli in the task. Chapter 7 investigates how both types of interference are related to WM. A measure of episodic-coding is collected, and a measure of WMC, in addition to the two measures of interference, and measures of STM. If the framework formed here is correct, then episodic coding and WMC might be differentially related to both interference measures, independent of STM measures.

Chapter 4

The study of cognition in schizophrenia and schizotypy

In Chapter 2, the outlined literature supports a distinction between interference related to the content of encoded information, and interference related to the context of encoded information. In Chapter 3, a distinction between recollection and familiarity in LTM was described, and the suggestion was made that content-related interference might share a distinct relationship to familiarity, and context-related interference might share a distinct relationship to recollection. Additional outlined research supports a distinction between a mechanism in the WM system that binds the intrinsic features of an item together, and another mechanism that associates intrinsic features to an extrinsic, contextual feature. A separation between binding and associating in WM is a novel claim of this thesis. The WM system itself has been investigated extensively, and in relation to other variables such as personality traits. If a distinction between associating and binding is to carry some weight as a useful means of classifying information processing in WM, then it should be possible to relate measures of associating and binding to other variables. The aim was thus to look at associating and binding in relation to schizotypy traits.

Schizotypy is a multi-dimensional construct that is an amalgamation of personality traits related to the symptoms of schizophrenia in terms of their behavioural characteristics (Bentall, Claridge, & Slade, 1989; Raine, 1991). Positive schizotypy traits encompass increased levels of hallucination proneness, and delusional beliefs that are characterised as positive symptoms in schizophrenia—excessive levels of normal tendencies. Negative schizotypy traits include a decreased ability to engage in social functioning, and a decreased ability to experience positive emotions, and these traits are reflective of negative symptoms in schizophrenia—decreased levels of normal tendencies. Factor analytic studies have given rise to multi-factored questionnaires that include separate positive and negative factors (e.g. Schizotypy Personality Questionnaire (SPQ), Raine; Oxford-Liverpool-inventory-of-feelings-and-experiences (O-Life), Mason, Claridge, & Jackson, 1995).

The study of schizotypy provides an insight into schizophrenia, particularly in the domain of cognitive processing. Atypical patterns in cognition are prominent in schizophrenia. The study of cognition in schizophrenia provides an avenue through which a better understanding of symptoms may be achieved. A search for better understanding is particularly pertinent in research that looks at the transition to schizophrenia in individuals who are at a high-risk of developing the disorder. If a better understanding of schizophrenia symptoms could be achieved, then it might allow clinicians to intervene and either prevent or modify the transition from high-risk to schizophrenia. Given the common basis between schizotypy traits and symptoms in schizophrenia, the area of schizotypy research is ripe to provide a means of establishing how different aspects of cognition are related to symptoms/traits.

1. Establishing representations in working memory

Initial WM research in schizophrenia proposed a role for executive dysfunction in mediating poorer WM performance (e.g. Gooding and Tallent, see Appendix 6 for further information). Other research has questioned whether the emphasis should be on executive control when it comes to understanding WM function in schizophrenia. Glahn, Therman, Manninen, et al. (2003), among others, point out that very often, as was the case in their experiments using the spatial-delayed-response-task, schizophrenia patients perform more poorly than controls on easier –low levels of load, e.g. small set-sizes– in addition to harder –high levels of load e.g. large set-sizes– WM conditions. Problems with WM in schizophrenia do not just arise at high levels of WM load, when the central executive is recruited more. Instead, several recent findings report encoding and maintenance deficits which may best be described in terms of a difficulty in generating internal representations of items to be stored in memory, and a difficulty in initiating maintenance of these items.

Two perspectives of how internal representations may be compromised in schizophrenia can be separated. One perspective suggests that the ability to represent featural characteristics of stimuli at early sensory areas is impaired. Haenschel, Bittner, Haertling, et al. (2007) looked at performance in a parametric visual DMTS task. In controls, P1 amplitude (an index of early sensory processing) increased with increasing load, and this increase was a predictor of better memory for the encoded stimuli. In contrast, this load dependent increase in amplitude was absent in schizophrenia patients, in addition to an overall reduction in P1 amplitude. Haenschel et al. suggested that early sensory processing may be deficient, and that this could lead to featurally degraded stimuli being stored in WM. Congruent with this, the amplitude of the P300 (reflecting stimulus evaluation and consolidation) was reduced. Performance in schizophrenia samples can be impaired when test items are shown immediately following encoded items, and this is further evidence that there is a deficiency in generating featurally distinct items (Lee & Park, 2005; Mathes, Wood, Proffitt, et al., 2005).

Another perspective on how internally generated representations may be compromised in schizophrenia was presented by Fuller, Luck, McMahon, and Gold (2005). In addition to acknowledging evidence that there may be a deficit in generating a distinct representation of an item, they pointed out that performance is also deficient when encoded material is highly distinguishable, as were the coloured squares in their task. They distinguished between two stages of encoding: perceptual analysis and short-term consolidation. While the former transforms sensory input into a perceptual representation, the latter makes the representation more durable so that it will withstand delays. They regard the second stage as necessary in order to prevent the overwriting of the current perceptual representation by successively presented items. The rate of consolidation was examined through displaying a mask at varying delays post the formation of perceptual representations in a change detection task. Patients with schizophrenia required a longer delay between stimulus display and mask in order to consolidate the display, indicating deficient consolidation.

EEG has been employed in studying the build-up of representations in WM, and there is evidence to suggest that perceptual analysis and consolidation are impaired in schizophrenia. Cameron, Geffen, Kavanagh, et al. (2003) compared slow wave potentials between individuals with schizophrenia and controls. An increase in these potentials signals an effort to maintain stimuli in memory. In contrast to controls, slow wave potentials failed to develop during maintenance in the schizophrenia patients. The presentation of distracter stimuli during the delay of some trials encouraged an enhancement of slow wave potentials in controls that was also absent in schizophrenia patients. While Cameron et al. failed to find differences between the groups with there was no delay, thus failing to find evidence for differences in perceptual analysis, Kayser, Tenke, Gates, et al. (2006) found a slightly smaller N1 in patients during delays. In addition, Kayser et al. found that a stepwise growing negative wave that marked both the encoding and maintenance of each additional item was absent in patients, and the P300 was also reduced.

While these studies suggest that there is a deficit in building up stable representations in WM (with potential causes including a deficit in perceptual analysis, consolidation, or both), an alternative account was presented by Hartman, Steketee, Silva, et al. (2003). Hartman et al. equated the duration of stimulus presentation required for each participant to achieve an 80% recognition rate in the absence of a delay in a DMTS task on recognition memory for colour. Schizophrenia patients required a much longer duration to achieve the specified level of accuracy; however, the addition of a distraction-filled delay had no further impact on their performance. In equating the groups on the amount of time needed for encoding, no additional maintenance deficit arose, leading Hartman and colleagues to suggest that cognition may simply be slowed in schizophrenia. Badcock, Badcock, Read, and Jablensky (2008) also suggested a relationship between the increased time taken to encode information in schizophrenia, and general slowing in information processing. They asked participants to store a set of locations in memory, and recall these locations immediately, or following a 4 second delay. Patients required a longer duration to encode the locations, but there was no difference between patients and controls when testing was immediate. In contrast to Hartman et al., however, patients were poorer in the presence of a delay even with the additional time provided for encoding. This suggests that, even if slowed information processing is an alternative account of deficit to a perceptual analysis account, slowed information processing does not account for all WM deficits.

2. Could binding and associating play a role in atypical working memory function?

In light of the framework that guides the current thesis (Figure 4), there are two mechanisms involved in creating durable WM representations. One mechanism binds the intrinsic features of an item together, and the other associates an item to some extrinsic feature. Evidence for both mechanisms has been suggested in relation to two types of PI. Content-related interference is suggested to be related to the efficiency of a binding mechanism. Context-related interference is suggested to be related to the efficiency of an associative mechanism. From the perspective of this framework, consolidation would be unlikely to operate independently of the two proposed mechanisms; thus it might be possible to relate a deficit in consolidation to either binding or associating. In addition, it is at least plausible that perceptual analysis in schizophrenia may be hampered by inefficient binding.

Representations in WM in relation to schizophrenia may be degraded because this theorized binding mechanism is less able to create unitized representations of singular items. Consistent with this way of thinking, Gold, Wilk, McMahon, et al., (2003) attempted to measure binding in WM, but failed to find evidence of a binding deficit in the schizophrenia sample. The tasks in this study looked at memory for the locations of colored squares in a change detection paradigm. This type of task may not be an accurate measure of what others have described as binding. Unitization, as described in LTM studies, occurs when intrinsic features form part of a greater whole. Although a spatial array of colored squares could also be argued to give rise to a greater whole in terms of the spatial pattern they form on the screen, this manipulation may simply be too subtle to pick up on a binding deficit. In addition to that, spatial locations could be conceived of as an extrinsic feature, which would again make this task an insufficient measure of binding.

A key anatomical region reported to play a role in binding, the entorhinal cortex, has recently been shown to have a reduced volume in schizophrenia (Baiano, Perlini, Rambaldelli, et al. 2008). This area is linked to semantic memory generally (e.g. Trautner, Dietl, Staedtgen, et al., 2004; and as inferred from its role in semantic dementia, for example; Davies, Graham, Xuereb et al. 2004), and through its association with binding, it is suggested to support the familiarity process (see Chapters 3). Although there is evidence for semantic memory impairment in schizophrenia (e.g. McKay, Mckenna, Bentham, et al., 1996), there is little evidence to suggest that the familiarity process itself is impaired (a notable exception includes Weiss, Goff, Duff, et al., 2008). However, this is an area of ongoing investigation. In addition to that, studies often follow the conception that context representation is dependent on control, and familiarity is related to automaticity; thus it is possible that familiarity is not being adequately measured.

A key anatomical region reported to play a role in associating, the hippocampus, has been reported to show both structural and functional differences in schizophrenia samples relative to controls (see Boyer, Phillips, Rousseau, et al. 2007, for a review). Associative recognition tends to be more impaired that item recognition in schizophrenia samples (see Achim & Lepage, 2003, for a review), and in addition to further evidence for episodic memory impairment in schizophrenia samples (see Danion, Huron, Vidailhet, & Berna, 2007, for a review), there is cumulative evidence that an associative mechanism in WM could be impaired.

3. Evidence of atypical cognition in schizotypy

Different aspects of cognition are not systematically related to positive and negative traits. There is some evidence that negative traits are more related to non-contextual aspects of WM (Gooding & Braun, 2004; Tsakanikos & Reed, 2003), and positive traits are more associated with context-related deficits (Steel, Hemsley, & Pickering, 2002). WM acts as an interface through which we engage with our environment; thus, its association to negative symptoms that centre on a lack of engagement with the environment seems plausible. Context-related deficits have in particular been associated with hallucination proneness, as such experiences may stem from perceived content that is dissociated from its context (e.g., perceiving internally generated speech as external). However, studies are not consistent, as is described below.

Further research is needed to clarify symptom/trait relationships to memory. Schizotypy acts as a useful frame within which to test hypothesis regarding cognition in schizophrenia given the similarity between schizophrenia symptoms and schizotypy traits. In addition, the study of cognition in schizophrenia may be thwarted by extraneous variables including antipsychotics, hospitalisation, amotivation, and distractibility. Given the absence of such variables when looking at schizotypy in the normal population, it may be easier to identify symptom/trait specific relationships to cognition. There is some evidence that this may indeed by the case.

3.1. Positive traits

Differences in how semantic information is activated have been reported in schizotypy, particularly in relation to positive traits. Evidence includes enhanced semantic priming (e.g., Beech, McManus, Baylis, et al. 1991), and a reduced N400 component (e.g., Kimble, Lyons, O’Donnell, et al. 2000). Mohr, Graves, Gianotti, et al. (2001) found an association between magical ideation (MI), a positive trait, and the perception of reduced semantic distance between pairs of words, or an item and a word-pair. They suggested that an increased spreading of activation within the semantic network could lead to the activation of associates with high levels of MI that are not activated with low MI levels, leading to the perception of reduced semantic distance. Tsakanikos and Claridge (2005) found that positive traits were related to increased verbal fluency, also suggestive of an association between positive traits and more fluid processing in semantic memory.

Linscott and Knight (2004) suggested that a broader interpretation of findings related to semantic memory is that automaticity is potentiated. Using the process dissociation procedure, they made estimates of recollection and familiarity. They looked at these measures in relation to a factor that they elucidated from a questionnaire formed as part of the study. Items loading on this factor called aberrant information processing referred to hallucination, thought disorder, and perceptual illusion; thus to some extent, it reflected positive schizotypy traits. High scores on this factor were related to an increase in automatic memory measures, and to some extent, decreased recollection.

The proposal of potentiated automaticity in relation to positive traits may be related to findings of increased levels of incidental learning. In a study by Jones, Gray, and Hemsley (1992), participants completed two incidental learning tasks. In one task, words were presented in different quadrants of the screen, with the participants' task being to later recall the words. An additional test looked at whether participants had incidentally encoded the position in which words were presented. In a second task, participants were presented with a list of words, with their task being to learn the words beginning with a particular letter. An incidental recall test asked participants to recall the words on the list not beginning with that letter. In the first incidental task, participants high on positive traits had a greater tendency to code the positions in which words were shown at a cost to their overall levels of recall, and in the second task, positive traits were associated with a bias to recall the other words from the list without a cost to recall for the target words. Burch, Hemsley, Corr, and

Gwyer (2006) replicated the link between positive traits and higher levels of incidental recall.

As described in previous Chapters, there is evidence to suggest that control and automaticity are orthogonal to recollection and familiarity. In acknowledging a distinction between automaticity and familiarity, it is suggested that familiarity is more related to measures of content representation and binding. An alternative explanation of differences in semantic memory and incidental learning would suggest that positive traits are related to a more active binding mechanism that is over-inclusive when it comes to the consideration of semantic associates, and is more likely to encode less relevant features of a task. Here, binding has been described as a mechanism that focuses on processing intrinsic features. Consistent with this proposal that positive traits may be related to an overactive binding mechanism, Rawlings and Claridge (1984) reported a relationship between positive traits and better identification of local features in Navon stimuli, and Goodarzi, Wykes, and Hemsley (2000) have found increased local-to-global interference in these stimuli in relation to positive traits. Goodarzi et al. suggested that processing of the local elements of stimuli may proceed more automatically with higher levels of positive traits. Thus, although these findings are consistent with a role for binding, potentially changes in automaticity could also account for them.

An alternative account of findings that have been attributed to automaticity suggests that they are related to cognitive inhibition. Through the lens of this account, positive traits are associated with a reduced ability to actively prevent task-irrelevant information from intruding on task-relevant processing. Investigations of negative priming are purported by some to suggest of role for cognitive inhibition in accounting for cognitive effects seen in schizophrenia related populations as negative priming is reduced in schizotypy (Beech & Claridge, 1987). However, the specificity of a relationship between cognitive inhibition and positive traits is questionable. Some studies find a stronger relationship between negative priming and positive traits (e.g., Steel, Hemsley, & Jones, 1996); however, reduced negative priming is related to several schizotypy traits with short stimulus-onset-asynchronies (SOAs), and with positive traits with longer SOAs (Moritz, Andresen, Probsthein, et al. 2000).

If tasks purported to measure automaticity and cognitive inhibition are related, then increased automaticity should be directly related to decreased cognition inhibition. Moritz et al. followed this line of reasoning, and attempted to relate semantic and negative priming. A correlation was only found in short SOAs, and the direction of the relationship was inconsistent with the two tasks being directly linked: spreading activation was actually positively related to increased negative priming. Moritz et al. pointed out that the understanding of NP is complicated by competing and equally valid suggestions that attempt to account for the effect. For example, Neill, Valdes, Terry, and Gorfein (1992) proposed an episodic retrieval account of NP. From this perspective, participants who fail to create an accurate memory episodic that prioritises the target at the cost of the distracter will show reduced NP to that distracter when it is later shown as a target. Further, Moritz, Mass, and Junk (1998) claimed that inaccurate perception of the prime could also give rise to reduced NP, but that this would be unrelated to inhibition.

Beech et al. (1991) suggested that cognitive disinhibition and potentiated automaticity may not be mutually exclusive; thus the suggestion that more than one mechanism may be involved in mediating cognitive effects in relation to positive traits. Steel et al. (2002) also considered that more than one cognitive mechanism may be involved in mediated differences in cognition. They considered a distinct role for reduced associative learning in addition to an influence from cognitive disinhibition. They tested a selective attention task in which participants must respond to the identity of a centrally presented letter that is flanked by other letters. The flanking letters are associated with the same target on a high proportion of trials, and with a different target on a small number of trials. Reduced cognition inhibition would anticipate increased distraction from the flankers in such a paradigm, particularly in low probability trials. Findings did show increased RTs to low probability trials; however this effect was smaller in individuals with higher levels of positive traits. Steel et al. reasoned that in order for the effect to emerge, participants must acquire the predictive value of high probability flankers through associating each target with its high probability flanker. If this association fails to be made, then the resultant consequence would be a reduced negative impact of low probability trials; thus the link between positive traits and reduced associative learning.

Steel, Hemsley, and Pickering (2007) presented further evidence of a relationship between associative learning and positive traits. They examined memory for associations between cues and potential targets. Cue-target probability was varied to create different levels of cue-target expectancy. A violation of cue-target expectancy increases RTs only if the system is capable of representing the regularities between stimuli. Positive traits were associated with a reduced cost when expectancy was violated, suggesting that cue-target associations were less strongly represented.

On the one hand there is evidence for a relationship between automaticity and positive traits that may or may not be better described in terms of an overactive binding mechanism. On the other hand there is evidence for a relationship between context representation and positive traits. Although there are suggestions that there may be an additional need to invoke the contribution of cognitive disinhibition in describing cognitive performance in schizophrenia, parsimony would favour an account that focuses on fewer cognitive processes/mechanisms; thus in the context of the framework for this thesis, the focus is on binding and associating.

Binding and associating may be linked to recent findings of heightened levels of false-alarms in relation to positive traits. Tsakanikos and Reed (2005; 2006) presented participants with a rapid steam of words mixed with non-words. Two report conditions of this task have been compared, one in which participants simply respond whether a word is present of absent, and the other in which they report the perceived identity of words. False-alarms in the detection condition, and false perceptions in the report condition were related to positive traits. The probability of a word being present was manipulated in a further study (Reed, Wakefield, Harris, et al. 2008), and when real words were presented with high probability, higher proportions of false-alarms were associated with positive traits. Tsakanikos and colleagues suggested that, on the basis of similarity, non-words may have activated real words in memory, and that positive traits were then linked to a tendency to accept such internally generated representations as having been externally presented. This interpretation suggests a source monitoring/context representation deficit. An alternative suggestion is that a greater number of similar real words were activated by non-words, leading to the increased false-alarm rate, or that an overactive binding mechanism was more likely to create real words from the features in non-words.

3.2. Negative traits

To some extent, it has been difficult to find separate relations between negative traits and cognition. In schizotypy, measures of executive control, for example, are often related to negative traits in addition to positive traits. Eye-movements are perceived as providing an insight into cognitive influences on task performance, and even reflexive eye movements are suspected to be open to influence from high level cognition (Hutton, 2008). Smooth pursuit has been related to both positive (Lenzenweger & Korfine, 1994; Gooding, Miller, & Kwapil, 2000; Holahan & O'Driscoll, 2005) and negative (Gooding et al. 2000; Holahan & O'Driscoll) traits. Positive traits have additionally been related to antisaccade errors (O'Driscoll, Lenzenweger, & Holzman, 1998; Holahan & O'Driscoll). Poor performance in the Wisconsin-Card-Sorting-Task has being related to positive traits (Lenzenweger & Korfine, 1994; Park, Holzman, & Lenzenweger, 1995), spatial WM deficit being related to both positive (Park et al., 1995) and negative (Park & McTigue, 1997) traits, and impaired switching attention across modalities has being related to negative traits and high schizotypy scores (Wilkins & Venables, 1992). Finally, poor performance in the Continuous-Performance-Test has been found in relation to both positive (Lenzenweger, Cornblatt, & Putnick, 1991; Obiols, Garcia-Domingo, Trincheria, and Domenech, 1993; Gooding, Matts, & Rollman, 2006) and negative (Chen, Hsiao, & Lin, 1997; Gooding et al., 2006) schizotypy traits.

Although recognition memory is not often looked at in relation to schizotypy, some findings suggest that it is also hard to distinguish between individuals high on positive traits and individuals high on negative traits. Dagnall and Parker (2009) looked at positive and negative traits in a version of the Deese-Roediger-McDermott (DRM) paradigm. In this paradigm, participants study list items that share an association to a lure that is presented during testing. Increased spreading of activation in memory is argued to activate the lure, which may lead to a false-alarm during testing. Positive traits were related to both increased false-alarms and poorer recognition of targets. Negative traits were also related to poorer recognition of targets, but not increased false-alarms.

Finally, other findings in relation to negative traits suggest that they are linked with the converse cognitive pattern to which positive traits are linked. In addition to finding the relationship between positive traits an increased verbal fluency, Tsakanikos and Claridge found the opposite relationship with negative traits. Also, Mohr, Landis, Bracha, et al. (2005) have found evidence to suggest that while positive traits are related to increased reliance on dopamine, negative traits may be related to reduced reliance on dopamine.

Despite these difficulties, there is evidence to suggest that negative traits may be related to WM tasks that have a strong perceptual element. For example, negative traits have been related to impaired performance in the Embedded-Figures-Test (Tsakanikos & Reed, 2003) and the Rey-Osterrieth-Complex-Figure-Test (Gooding & Braun, 2004). These findings are consistent with the suggestion that schizotypy traits are related to deficiencies in creating accurate templates of information to be stored.

4. In relation to the aims of the current thesis

Positive traits may be related to an overactive binding mechanism, and compromised associative learning. There is evidence that negative traits may mimic positive traits in their relation to cognition. In stark contrast, however, opposing relationships between negative traits and cognition have also been found. Finally, there is some evidence that negative traits may be related to WM deficit at the level of perceptual analysis. In the context of the framework that has guides this thesis, deficits at the level of perceptual analysis in WM may confer a deficit in binding. Although it is difficult to fully anticipate how positive and negative traits would be related to measures in the current thesis, given that a search for more precise relations between symptoms/traits and cognition is ongoing, establishing such relations would justify the framework that guides the interpretation of the findings in this thesis.

Chapter 5

Manipulating item-non-specific and item-specific interference

Chapter 2 described literature related to two primary manipulations of interference. In content-related manipulations (e.g., Coltheart & Geffen; Visscher et al.), features intrinsic to the items that are encoded on every trial interfere with one-another, with higher levels of similarity yielding higher levels of interference. In context-related manipulations, a feature extrinsic to the content being encoded is either shared across several items (e.g., Gardiner & Cameron), making memory less distinctive, or an item is shared across several contexts (e.g., Anderson & Bower), making it difficult to distinguish a particular context in which the item was presented.

Single process/mechanism views of the relationship between PI and IM were considered, and of particular interest was the work of Postle and colleagues (2004ab). Postle and colleagues distinguished between item-non-specific and item-specific PI. Item-non-specific PI was described as a content-related effect: increased exposure to items during a memory tasks breeds interference. Item-specific PI was described as a context-related effect: viewing a distracter item that was presented in the previous trials (n-1/2) can lead to false-alarms in the current trial. The activation of the same brain region in response to both types of interference was interpreted to support a single PI mechanism. It was considered that measurements of item-non-specific PI may be confounded with measures of item-specific PI if both are measured in the same condition. With this consideration in mind, two conditions were introduced in Experiment 1 with the aim of making independent measurements of both types of interference. Experiments 2 and 3 investigated whether evidence could be found to support independent effects of both types of interference.

1. Experiment 1: Cumulative effects of item-specific and non-specific interference

Memory for non-words was tested across two conditions, designed such that one of the conditions induced item-non-specific PI, and the other item-specific PI. For brevity, the former condition is called *no-overlap*, and the latter *overlap*. Participants encoded a set of non-words, and, in a recognition memory task, they had to distinguish encoded items from distracter non-words. In the no-overlap condition, non-words were selected from a stimulus-set, and each item was only presented on one trial. In the overlap condition, the non-words presented formed a much smaller stimulus-set; thus, all items were repeated across trials.

The dependent variable was target sensitivity, as measured through d' (see Wilken & Ma, 2004, for a discussion regarding the advantages of SDT over percentage correct). It was hypothesised that sensitivity would decrease cumulatively with increased item-specific and item-non-specific PI. Although the majority of earlier studies focus on interference build-up in the first five or so trials, the lead of Postle and colleagues (2004ab) was followed here, allowing for the measurement of interference over a greater number of trials.

1.1. Method

Participants: 12 students –age range: 18-24– completed the experiment, and were ascribed course credit in return.

Stimuli: Non-words, taken from a computer generated database created by Müeller (2005), were all pronounceable and were 4, 5, or 6 letters in length.

Design: A 2 × 2 repeated-measures design was used with the factors being overlap –no-overlap and overlap– and trial—15. The overlap list consisted of 21 non-words, each of which was presented 15 times: 5 times as a target during encoding, thus another 5 times as a target during testing, and 5 times as a distracter. Item selection in each trial was then random, given these provisions. In the no-overlap list, each item acted as either a target or a distracter only once.

Procedure: Both conditions were completed in random order in one session. There were 15 trials per condition. Following a 2 second fixation, each trial took the following form. Seven non-words appeared sequentially at a rate of 2 seconds. These stimuli were followed by a 2 second gap prior to the recognition test. In the recognition test, the targets from the trial were presented in a random sequence among an equal number of distracters. Test items remained on the screen until the participant made a recognition judgement indicative of the item's perceived status—target or distracter.

1.2. Results

Hit and false-alarm data for each trial were transformed into sensitivity. A 2 x 2 repeated-measures ANOVA with overlap and trial as factors revealed that both manipulations had lead to a cumulative build-up of PI, see Figure 5, as an effect of trial was significant, F (14, 154) = 3.32, p < .001. Sensitivity scores in the overlap condition tended to be lower than those in the no-overlap condition, p = .104 (Eta Sq = .222; type x trial, p = .241).

The next analysis assessed whether the build-up of PI could be confined to the first 5 trials, or whether it extended beyond that. In the first 5 trials, an effect of trial was significant, F (4, 44) = 4.71, p = .003. In the remaining trials, the effect of trial in the overlap condition began to diverge from the effect of trial in the no-overlap condition. This was confirmed by a marginal interaction between overlap and trial, F (9, 99) = 1.88, p = .063 (Eta Sq = .146), with an effect of trial only approaching significance in the overlap condition, $F(9, 99) = 1.88$, $p = .076$ (Eta Sq = .146; no-overlap, $p = .745$). Thus, although PI build-up was more pronounced in the first 5 trials, it showed a tendency to extend beyond that boundary, at least in the overlap condition.

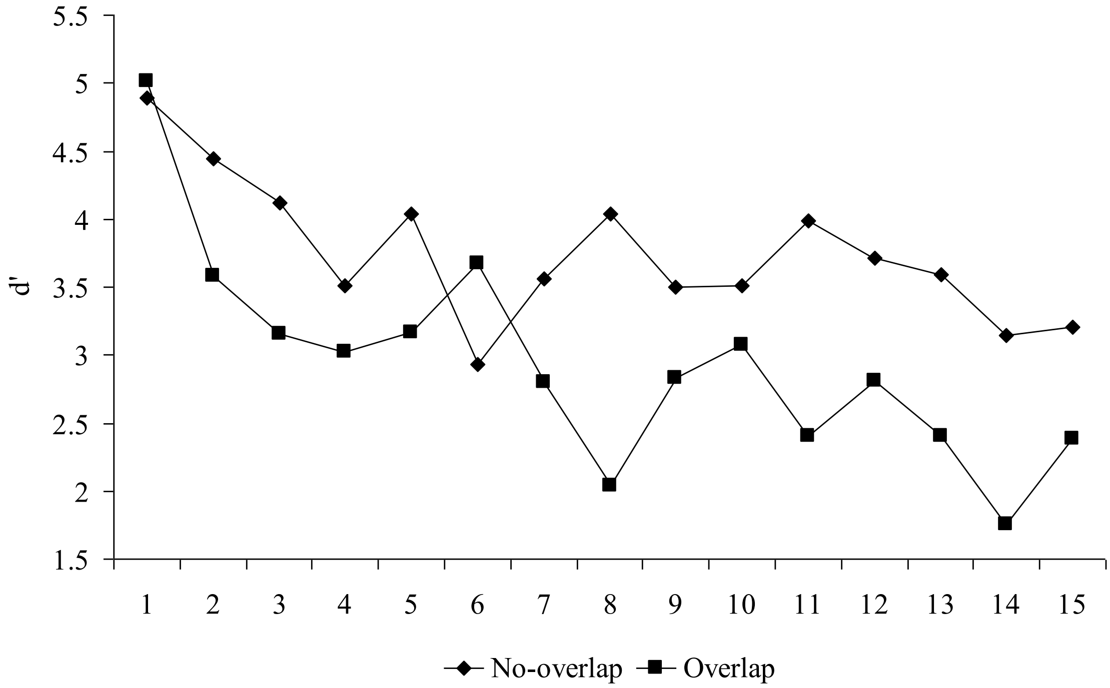

Figure 5: The effect of trial in both the no-overlap and overlap condition

1.3. Discussion

Both manipulations successfully led to PI build-up, as demonstrated in the drop in sensitivity across trials, with the majority of PI build-up already present in the first five trials. However, there was a tendency for the cumulative decrease in overlap sensitivity to persist beyond the five trial boundary, as demonstrated by the marginal effect of overlap trials relative to no-overlap in later trials. The following experiment addressed whether it would be possible to differentially control the build-up of each type of interference. If each type of interference can be independently manipulated, then there would be evidence to suggest that item-non-specific and item-specific PI are not wholly mediated through the same process/mechanism.

2. Experiments 2a and 2b: Separate manipulations of item-non-specific and specific interference

Research on short-term recall has shown that memory may be improved through vocalising verbal material to be encoded; for example, Tell and Voss (1970) asked participants to vocalise items as they were being encoded in the Brown-Peterson procedure, and this led to improved recall relative to when the items were not vocalised. Tell (1971) suggested that vocalized material is temporarily stored in an echoic memory system, and that participants' recall can benefit from the availability of echoic memory, particularly in short delays between study and test. In short-term cued recall tasks, Tolan and Tehan (1999) showed a most dramatic reduction in PI if target memory sets were vocalised during encoding, whilst distracter memory sets were encoded silently, particularly if distracter-filled delays required non-vocal rather than vocal responses.

The above results suggest that vocalising stimuli may improve the distinctiveness of the content of their representations in memory. If item-non-specific PI (in the no-overlap condition) reflects interference based on the content of memory representations, then increasing item distinctiveness through pronouncing each item aloud during encoding should reduce this PI effect. In contrast, if item-specific PI reflects contextual interference operating independently of the content of the memory representations, then item-specific PI should be unaffected by vocalising items during encoding. These proposals were tested in Experiment 2a by having participants vocalise items during encoding.

In Experiment 2b, the frequency with which items were repeated in the overlap condition was manipulated. When items are exposed repeatedly, recognition memory accuracy may depend on the success of associating items with their appropriate context. These item-context associations can be expected to be less distinct the more frequently repeating the item. Wright (1967) employed a similar manipulation, repeating specific consonants across sets. PI was demonstrated in the difficulty of recalling later-encoded sets in their correct order. Additionally, such repetitions elicited intrusions in recall that were found with test delays up to at least 18 seconds. In this experiment, three levels of repetition frequency were delivered: high, mid, and low. Item-specific PI should be less for items repeating with a lower frequency since the contexts of their occurrence should be more distinct relative to those of high-frequency items.

2.1. Experiment 2a: The manipulation of vocalisation

2.1.1 Method

Participants: 20 students –age range: 18-24– completed the experiment in exchange for course credit.

Design: The design of Experiment 2a included three factors: (1) overlap (no-overlap or overlap), (2) vocalisation (vocalise or silent), where participants named each item aloud once, or silently processed the items as in Experiment 1, and (3) trial. The no-overlap condition matched that of Experiment 1, with new items being presented on every trial. The overlap list consisted of 17 items, with each being presented approximately 18 times.

Procedure: A total of four non-word tasks were completed across two sessions. Tasks of the same level of overlap were presented in separate sessions, and one condition in each session was a vocal condition, whilst the other one was a silent condition. This gave rise to two combinations of the conditions (no-overlap vocal and overlap silent; no-overlap silent and overlap vocal). Half of the participants completed the combinations in one order, and the other half completed them in the alternative order. The order of the conditions within each session was then randomised. There were 15 trials in each condition, and the trial procedure matched that of Experiment 1, except for the introduction of verbalisation in Experiment 2a.

2.1.2 Results

A 3-way ANOVA contained the factors overlap, vocalisation, and trial. There were significant main effects for all variables: overlap, $F(1, 19) = 66.18$, $p < .001$; vocalisation, $F(1, 19) = 16.98$, $p = .001$; trial, $F(14, 266) = 7.83$, $p < .001$. Figure 6 presents the mean trial time-lines for each condition. A 2-way interaction between overlap and vocalisation was marginal, $F(1, 19) = 3.24$, $p = .088$ (Eta Sq = .146), whilst a 2-way interaction between vocalisation and trial was significant, $F(14, 266) = 2.48$, $p = .003$. Vocalisation tended to increase sensitivity to a greater degree in the no-overlap relative to the overlap condition; the benefit from vocalisation was reliable for the no-overlap trials but marginal for the overlap trials: no-overlap, $t(19) = 5.59$, $p < .001$; overlap, $t(19) = 1.90$, $p = .072$.

To facilitate the analysis of the interaction between vocalisation and trial, each consecutive series of five trials were averaged, thus creating cycles of trials, with three cycles of trials in each level of vocalisation. An effect of vocalisation was present in the first and second cycles, $t(19) = 4.89$, $p < .001$ and $t(19) = 4.24$, $p < .001$, but not in the final cycle, $p = .283$.

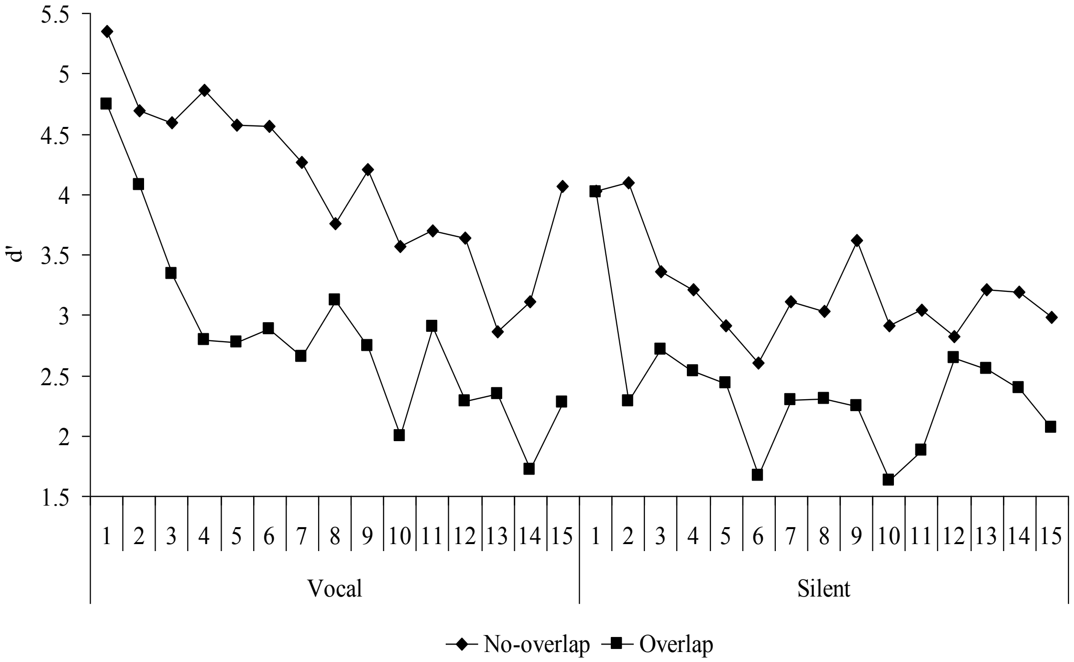

Figure 6: Sensitivity levels in each trial in both vocal and silent no-overlap and overlap conditions

Similar to Experiment 1, the majority of PI build-up took place in the first five trials. The data within these trials were then assessed to test for the effects of vocalisation and overlap. A 3-way ANOVA (factors: overlap, vocalisation, and trial [5 levels]) revealed a 3-way interaction, F (4, 76) = 3.42, p = .013. As Figure 6 shows, vocalising the items had a differential impact on sensitivity in no-overlap relative to overlap trials: vocalisation only reduced the drop in sensitivity in no-overlap trials. Without vocalisation, sensitivity dropped in both conditions.

To demonstrate this more simply, and to increase the power of the result, the first and second, and fourth and fifth trials were averaged in each condition. This then supported a substantial three-way interaction between overlap, vocalisation and trial, F (1, 19) = 11.11, p = .003. Overlap and trial interacted when items were vocalised, F (1, 19) = 9.33, p = .007. An effect of trial was only present in the overlap but not the no-overlap condition, t (19) = 4.61, p < .001 (no-overlap, p = .381). In the silent condition, the interaction between overlap and trial did not approach significance (*p* = .383), though there was a reliable main effect of trial, $F(1, 19) = 8.98$, $p = .007$.

In line with previous findings, vocalisation had a beneficial effect on performance, but only in the no-overlap condition. Vocalisation reduced the build-up of interference in the first five trials of the no-overlap condition whilst an interference effect in the overlap condition was independent of vocalisation. Vocalisation increases the activation of the content being encoded; thus, it is possible to surmise that the exclusiveness of the vocalisation benefit to the no-overlap condition suggests that the interference in this condition is related to the clarity with which item-content is being represented.

2.2. Experiment 2b: The manipulation of frequency

2.2.1 Method

Participants: 26 students, age range 18-24, completed the experiment in exchange for credit.

Design and procedure: the overlap design included two factors, frequency and trial. Frequency was made up of three levels: low, mid, and high. There were 7 items in each frequency list. Low-frequency items were seen 9 times during the experiment, 6 times as a target (3 during encoding followed by a further 3 during recognition) and 3 as a distracter; mid-frequency items were seen 15 times, 10 times as a target and 5 times as a distracter; high-frequency items were seen 21 times during the condition, 14 times as a target and 7 times as a distracter.

2.2.2 Results

To simplify the analysis, cycles of trials were created to allow a comparative measure of the amount of PI as a function of frequency. The first cycle of trials was an average of sensitivity levels in the first five trials at each frequency, while the final cycle was an average of the final five trials at each frequency (for low-frequency items, the final cycle variable was calculated on the final 5 trials in which each participant saw low-frequency items, as these were not present on every trial). Overall effects of frequency and cycle were present: F (2, 50) = 12.14, $p < .001$ and F (1, 25) = 5.95, $p = .022$ respectively. High-frequency items generated poorest recognition, followed by mid-frequency items, while low-frequency items produced the best recognition, with LSD confirming all comparisons as significant ($p < .05$). The interaction between frequency and cycle was significant, F (2, 50) = 3.39, p = .042, see Figure 7. A significant build-up of PI was exclusive to high-frequency items, t (25) = 3.94, $p = .001$ (mid-frequency, $p = .267$; low-frequency, $p = .433$).

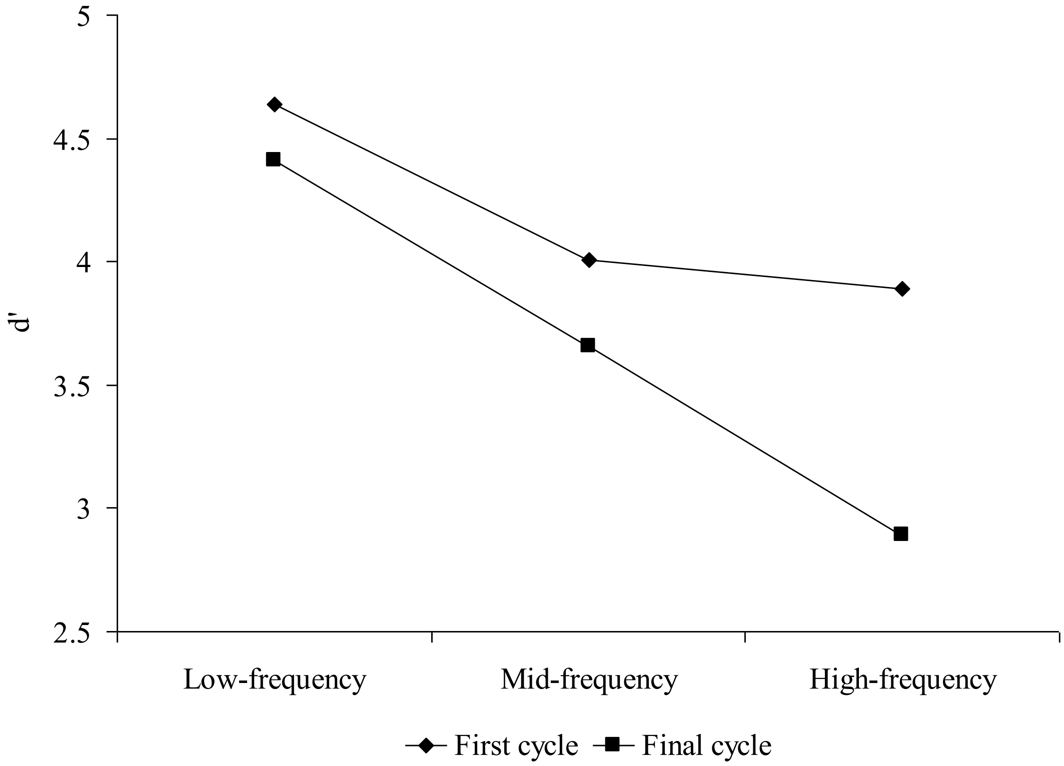

Figure 7: Sensitivity data in each cycle at each level of frequency

2.3. Discussion

The primary aim of Experiment 2 was to assess whether item-specific and non-specific PI could be differentiated and linked to separate causal processes. It was proposed that vocalisation may make the memory representation of each item more distinct, and this might help reduce item-non-specific PI if that reflects decreasing distinctiveness in the content of an item's representation across trials. In contrast, it was hypothesised that item-specific PI is due to the reduced distinctiveness of the associations between each item and its temporal context. This was then tested by manipulating the frequency of item repetition in the overlap condition to assess whether item-specific PI would increase for items repeated with high relative to low-frequency.

2.3.1 Overall performance and effects of verbalisation

Similar to Experiment 1, sensitivity was higher with non-overlapping items than with overlapping items, though the effect of trial was significant in both cases. Although performance in both conditions benefited from having items vocalised during encoding, the benefit to no-overlap performance was larger. The interaction between vocalisation and trial showed that the benefit of vocalisation diminished in later trials. Similar to Experiment 1, the drop across trials (the build-up of interference) was most severe in the first 5 trials. Perhaps not surprisingly then, the benefit of vocalisation was most pronounced in these first 5 trials, and this was particularly the case in the no-overlap condition. Item-non-specific PI was alleviated in the first 5 trials of the vocal condition, while an effect of item-specific PI remained significant. This suggests that the mechanism mediating the build-up of item-non-specific PI is a reduction in the distinctiveness with which the content of items is being represented. Vocalisation increased the distinctiveness of each item's phonological code, and this curtailed item-non-specific PI.

The introduction of vocalisation failed to completely dispel the build-up of item-non-specific PI, however, and a 3-way interaction between overlap, vocalisation, and trial could only be shown after excluding from the analysis trials after the five trial boundary. It is possible that vocalising the items protected against item-non-specific PI to a certain degree, but this protection saturated as the trials continued and item-non-specific PI then build up.

<u>2.3.2 Effects of repetition frequency</u>

When items overlapped across lists, sensitivity levels were lower for items that repeated with higher frequencies. The interaction between frequency and cycle showed that item-specific PI was exclusive to high-frequency items. The effects of frequency and cycle likely reflect a greater reduction in temporal distinctiveness for items repeated at higher frequencies. High-frequency items were associated with a greater number of temporal contexts than mid- and low-frequency items. With each additional repetition of an item, performance may become increasingly dependent on the degree to which the item's context is encoded; thus the mechanism mediating item-specific interference reflects the specificity of item-context associations.

The results indicate a separation between two mechanisms mediating PI. The mechanism mediating item-non-specific build-up is a reduction in the distinctiveness with which item content is being represented. The mechanism mediating item-specific build-up is a reduction in the distinctiveness with which item-context associations are being represented. Vocalisation reduced the amount of item-non-specific PI through allowing more distinct representations of item-content to be stored in memory. Decreased frequency of repetition reduced the build-up of item-specific PI through allowing more distinct representations of the associations between an item and the temporal context within which it was presented to be stored.

However, a single process account of the PI effects may be proposed from these results, based on the idea that performance reflects variations in the strength of activation in representations of stimulus content in WM. As before, vocalisation may reduce the build-up of item-non-specific PI by allowing for more distinct content representations to be phonologically encoded. Now, on a single mechanism view, item repetition may also make the content of items more distinct, but the consequence is that the content activation associated with repeated items will remain closer to the criterion, making it harder to distinguish whether they were presented on the trial or not. Vocalisation may initially benefit performance with overlapping items by the same mechanism; however, given that the content of the representations for overlapping stimuli will also increase due to their repeated presentations, the benefit of vocalisation is far less. The net result will be that vocalisation will reduce item-non-specific interference (in the no-overlap condition) more than item-specific interference (in the overlap condition), while frequency will particularly affect item-specific interference. The one- and two-process accounts were further contrasted in Experiment 3.

3. Experiment 3: Serial position curves differ in no-overlap and overlap

One way that the single and dual accounts can be teased apart is by examining whether PI build-up in each condition has a differential impact on item and order information in memory. Conrad (1960) first showed that item and order information may be distinguished in memory. He noted that participants sometimes falsely recall items from previous lists in positions that are approximately the same as the positions the items were presented in, in the previous list. Conrad showed that these across-list substitution errors were greatly reduced when the interval between lists increased, whereas within-list substitutions (between items in the same list) were less affected by varying the inter-list interval. Conrad suggested that across-list substitutions can arise if the content of an item in the current list was lost, but the temporal context of a prior item was preserved. This suggests that content and temporal context are represented separately in memory.

One argument for a separation between the content and context of memory representations comes from the study of serial position functions. Healy (1974) studied serial position functions when participants were required to only remember the content of the items they had encoded, or when item order also had to be maintained. Performance was generally poorer when participants had to attend to serial order. More critically, the serial position curve was U-shaped when participants needed to recall serial order, whereas it was typically flat when only content information needed to be recalled. Healy concluded the U-shaped function reflects temporal distinctiveness, which contributed to performance separately from effects of item content.

Interestingly, Houston (1976) proposed that PI could have its main impact on order information. He contrasted (1) recall of a list that, during encoding, had been preceded by a list made up of the same items in a different order, and (2) recall of a list that, during encoding, was preceded by a list of different items. Whilst the report of both order and item information was reduced when items differed across lists, only order report was reduced when the items were the same across lists. This suggests that, if item strength is particularly high through stimulus repetition, then PI may be exclusive to memory for order. If the same items are associated to different order positions in different lists, PI arises at the level of order memory.

Data on serial position effects in recall have been simulated in models that explicitly distinguish between the representation of item and order information. Burgess and Hitch (1992), for example, introduced a model that uses temporal oscillators to signal changes in temporal context, while separate representations code the content of memory (e.g., phonological representations of letters). These oscillators can be reset at the beginning of a memory trial, but can present similar contexts across trials leading to across-list errors. Burgess and Hitch (2006) further found that there were independent serial position effects of phonological similarity and temporal grouping. If phonological similarity affects the distinctiveness of the content of memory representations, then the evidence for independence suggests that memory content can be distinguished from the temporal context signals.

Other evidence for the separate representation of item and order information in memory comes from the study of temporal grouping. Ryan (1969ab) inserted short intervals between subsets of items in STM lists and found, specifically, that the formation of these temporal sub-groups reduced the number of transposition errors within sub-groups. Ryan suggested that temporal grouping allowed for the recoding of items within each subset, with fewer serial position markers then being needed because there were then a smaller number of items in each subset relative to the overall list.

Postle (2003) extended these prior experiments by exploring temporal grouping using an IM recognition procedure. He assessed whether stimulus grouping influenced performance even when it was incidental to task demands. Grouping was manipulated using a running-span paradigm in which the participants' task was to maintain the last four items in a trial of unpredictable length. Grouping was manipulated through presenting the items to be encoded in sets of one, two, or three: group integrity was thus violated on trials where some items must be maintained, and some items must be dropped from a set to meet task requirements. Performance was negatively affected when group integrity was violated, showing that contextual detail unrelated to task demands is nonetheless encoded. This result indicates that temporal context effects should be possible in recognition memory paradigms such as the one employed here.

3.1. Why serial position curves may differ between no-overlap and overlap

Item-specific build-up in the overlap condition arises when an item becomes associated with an increasing number of contexts (trials), making it difficult to recognise whether an item was presented on the current trial or a previous one. Performance becomes reliant on the ability to represent the temporal context in which an item is being presented. Experiment 3 assessed whether the temporal context of stimuli, reflected in item order during encoding, could selectively affect performance when item-specific PI was occurring but not item-non-specific PI, as item-non-specific PI reflects content-related interference.

In the context of the recognition memory experiments of this thesis, it must be recognised that serial position models are simulated on recall data: they make no set provisions on how, or even whether, content and context are encoded through separate mechanisms or processes. Although evidence of u-shaped serial position curves is often assumed to indicate difficulties in *retrieving* items from mid-list positions, it is also possible that temporal distinctiveness during *encoding* may influence the shape of serial position functions. From an encoding perspective, items at the beginning and ends of lists are in temporally distinctive positions; thus recognition memory for these items might be better than that for mid-list items, particularly when performance is dependent on representing temporal context (the start-end model formulated by Henson [1998; 1999], presents a similar logic, though the effects on performance are described in terms of retrieval difficulties). It is also worth noting that the temporal context effects demonstrated by Postle (2003) were in IM tasks. It was thus predicted that on later trials when item-specific PI builds-up, a u-shaped serial position curve should arise in the overlap condition.

In order to compare the shape of the serial position curve before performance was overcome by interference, relative to the shape of the curve when interference was highest, the first and final 5 trials were collapsed across. This created two levels of the factor cycle. This reduced the number of trials that measured primacy and recency, but the loss of power was recovered through employing a large sample. A u-shaped serial position curve was anticipated in the final cycle of the overlap condition only. A further bonus of compiling a large data base like this is that it allows a detailed assessment of the cumulative build-up of both types of interference. Although the largest build-up of interference is in the first five trials, both Experiments 1 and 2 suggested that a slower build-up of interference takes place across later trials, but this slow effect requires sufficient power to be investigated fully. Experiment 1 had also suggested a divergence between the two types of interference for later trials, with the build-up of interference being more pronounced in the overlap condition. A stronger test of this was provided here. In addition to testing a greater number of participants, overlap items were now repeated at the ‘high’ sample frequency used in Experiment 2 (18 rather than 15), and three additional trials were added to each condition.

3.2. Method

Participants: 120 participants completed both conditions in one session in exchange for course credit (half of these participants completed the PI tasks as part of Experiment 5, 56 completed them as part of Experiment 6, and the final 4 were recruited specifically).

Design and procedure: Two primary factors fed into the first analysis, overlap and trial. The overlap list consisted of 21 non-words. Each overlapping item was presented 18 times: 6 times as a target during encoding, thus another 6 times as a target during testing, and 6 times as a distracter (no-overlap condition same as previous). Three factors fed into the analysis on serial position data: overlap, cycle, and position. The first and final five trials were averaged to generate both levels of the factor cycle. Effects of PI were then reflected in the degree of sensitivity drop from the first to the final cycle. 18 trials measured performance in each non-word condition, and both conditions were completed in one session, with the order being counterbalanced.

3.3. Results

A 2-way ANOVA of factors overlap and trial returned main effects of both variables: overlap, F (1, 119) = 131.01, $p < .001$; trial, F (17, 2023) = 22.18, $p < .001$. The interaction between the two was significant, F (17, 2023) = 1.69, $p = .037$, see Figure 8; however, this was due to the similar levels of performance in both conditions in the first trial, as when the first trial scores were removed from the analysis, the interaction was no longer significant ($p = .292$). Even if the first five trials were excluded from each level of overlap, an overall effect of trial was significant, F (12, 1428) = 4.78, $p < .001$.

In the analysis of serial position data, the three-way interaction between overlap, cycle, and position was significant, F (6, 708) = 2.38, $p = .031$, see Figure 9. In the no-overlap condition, cycle and position failed to interact ($p = .450$), while an overall effect of position was significant, F (6, 708) = 5.29, $p < .001$. When items were overlapping, there was an interaction between cycle and serial position, F (6, 708) = 3.01, $p = .007$. The build up of item-specific interference had the largest impact on positions 2-4. To simplify the interaction between cycle and position, accuracy in positions 2-4 at each level of cycle was averaged to represent the early portion of the serial position curve, and accuracy in positions 5-7 at each level of cycle was averaged to represent the late portion of the serial position curve. The subsequent interaction between cycle and position (early versus late), F (1, 119) = 14.41, $p < .001$, was decomposed into an effect of position in the final cycle, t (119) = 5.08, $p < .001$ (first cycle, $p = .516$).

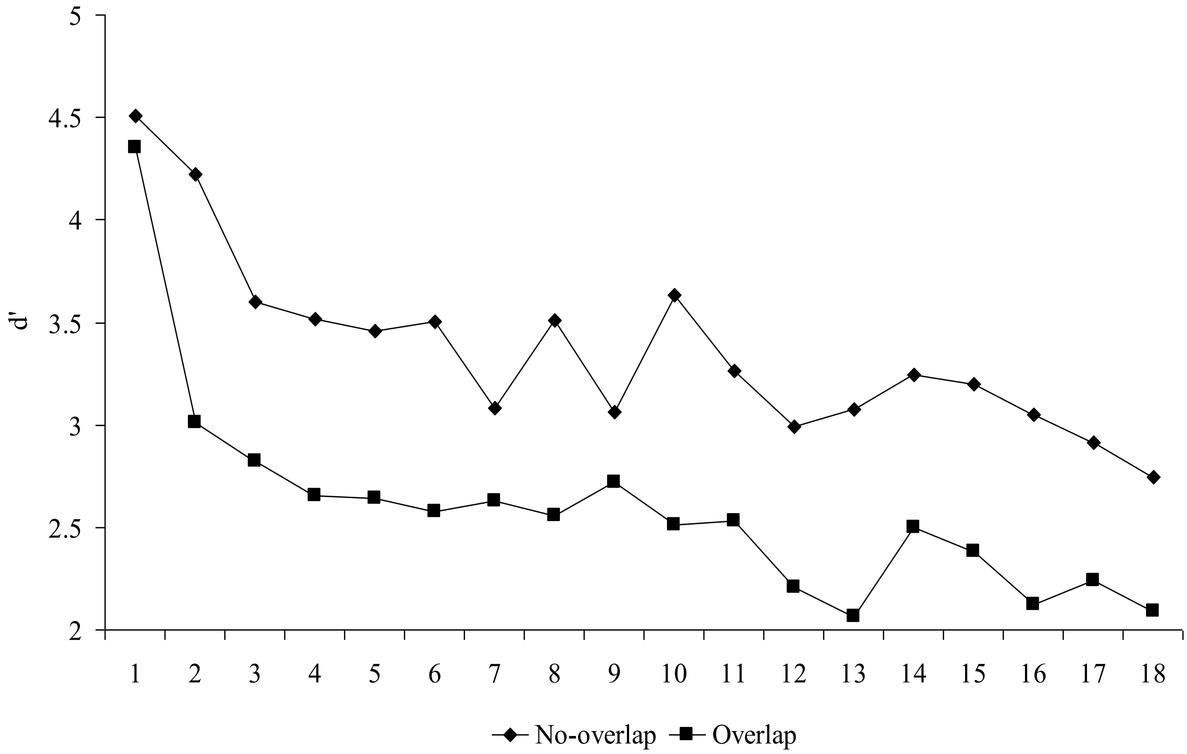

Figure 8: Sensitivity data for each trial at each level of overlap

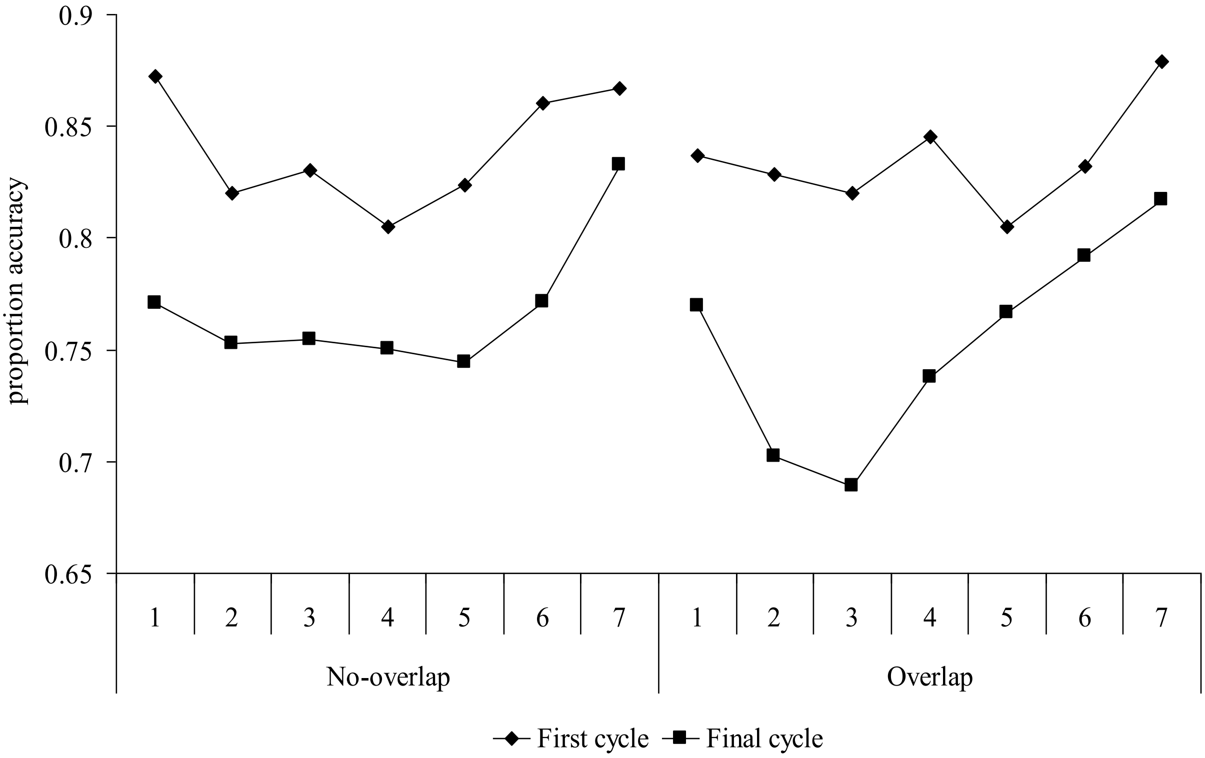

Figure 9: Proportion correct as a function of serial position during encoding in each cycle in each level of overlap

3.4. Discussion

The primary aim of Experiment 3 was to assess whether accuracy varied as a function of serial position during the first and final coding cycles (with the effect of cycle reflecting the build-up of either item-specific or item-non-specific PI in the overlap and no-overlap conditions). Recognition in the overlap condition was proposed to be more reliant on the encoding of order information in addition to item information, as the representation of temporal context was necessary in facilitating better performance when item-specific PI was most pronounced (final cycle). A larger reduction in recognition accuracy from the first to the final overlap cycle for items in earlier serial positions (2-4) relative to later serial positions (5-7) is supportive of this hypothesis.

These data in the overlap condition contrast with those obtained in the no-overlap condition. In the no-overlap condition, there was an overall detriment in performance in the final relative to the first cycle, but this did no change across the serial positions. This suggests that the effect of PI with non-overlapping items does not reflect the loss of temporal context (affecting earlier serial positions more than late), but rather a more general loss of item information. If the recognition of item information occurs equally across the serial positions, an additive effect of interference build-up will result.

One other point to note from these data is that, when the cumulative drops in performance for sensitivity were examined, these clearly extended beyond the first 5 trials in the sequence. Thus, although interference build-up is most acute in the first 5 trials, the effects of interference extend beyond this boundary.

4. General discussion

Similar amounts of PI, reflected in performance drops from the beginning of a memory condition to its end, were generated through two different manipulations. One manipulation involved the continued presentation of new items from the same category throughout the memory task (the no-overlap condition); the other involved repetition of the same small set of items (the overlap condition). There should be item-non-specific PI in the no-overlap condition, and item-specific PI when there is overlap (Postle et al., 2004; Postle and Brush, 2004). Previous accounts of PI assume that interference on memory across trials is mediated by a cognitive component that operates independently of the source of interference (a single process/mechanism account). An alternative possibility is that there are separate factors contributing to item-non-specific and item-specific PI, and that there may be source specific relationships between PI and WM performance (a dual process/mechanism account). The present data favour a dual account. There are four critical findings:

a. Effects of both item-non-specific and item-specific PI were shown to accumulate to similar degrees in separate conditions;
b. Vocalisation reduced the initial build-up of item-non-specific PI through allowing for more distinct content representations to be encoded. This finding suggests that the mechanism mediating item-non-specific build-up is a reduction in the distinctiveness of item-content;
c. Repetition frequency affected the magnitude of item-specific PI in the overlap condition, with high-frequency items showing the largest detriment in performance across cycles. High-frequency items were associated with a greater number of temporal contexts; thus this finding suggests that the

mechanism mediating the build-up of item-specific PI is a reduction in the distinctiveness of item-context associations;

d. When performance was broken down as a function of the serial position of the items during encoding, there was a differential effect of cycle across the serial positions in the no-overlap and overlap conditions. In particular, there was a selective drop in the early-middle serial positions in the final cycle in the overlap condition. In the no-overlap condition, the effect of cycle was additive across the serial positions. This suggests that cycle degraded the temporal context in the overlap condition, affecting serial positions where the context signal was weakest. In contrast, cycle affected item knowledge in the no-overlap condition, and item information was lost equally across the different serial positions.

4.1. Item-specific and non-specific: two different types of interference

Earlier studies that explored PI showed that there are several dimensions associated with the representation of a stimulus. These can be broadly characterised as content-related and context-related. Features that are inherent to the physical detail of the items being encoded can be classified as content-related features; for example, values on phonological and semantic dimensions. Extrinsic features of the content to be encoded, such as the voice associated with item presentation, or the spatial and temporal characteristics of item presentation, can be classified as context-related features. In addition to binding the physical features of a stimulus together in order to enable a stable memory trace of the bound item to be represented, bound items are also associated with contextual features present at their time of encoding.

Congruent with what would be expected on the basis of earlier studies, Experiments 2 and 3 suggest that these two forms of information, item content and item context, may be represented separately in memory; thus lost selectively from memory. The loss of information from each source is related to different types of interference. Item-non-specific PI reflects the loss of content for items in memory, while item-specific PI stems from the loss of contextual information. Both types of PI were modulated by different variables –vocalisation (Experiment 2a, affecting item-non-specific PI), repetition frequency (Experiment 2b, affecting item-specific PI), and serial position (Experiment 3, differentially affecting item-specific PI)– supporting the distinction between content and context representation.

Although the separation between content and position information has been interpreted to reflect the ability to retrieve item content independently of item context at retrieval (Burgess & Hitch 1992, 1999, 2005; Henson, 1998, 1999), the evidence here suggests that different mechanisms/processes operate on both domains during encoding. In the overlap condition, it was necessary to encode temporal context (position information) in order to recognise when an item was associated with the current trial. It was reasoned that it would be more difficult to represent mid-list positions relative to first and final positions, as mid-list positions are less temporally distinctive. Results showed that this difficulty in representing mid-list positions was greatest in the second and third serial positions. As performance became more reliant on temporal context (overlap final cycle), this difficulty in representing items in these particular serial positions was demonstrated in the drop in recognition accuracy for items presented in there positions.

These conclusions diverge from those drawn by Postle and colleagues (2004ab). Postle and colleagues reported that there was recruitment of a common brain area, IFG, under conditions of both item-specific and non-specific PI, and they suggested that the two forms of PI are mediated by a common mechanism. One explanation of the difference between these conclusions and those of Postle and colleagues is that PI is being examined on different levels. Oberauer and Lange (2009) linked differences in activation strength to rehearsal processes in STM. In order to recognise no-overlap items, the activation of item content needed to be high, whereas in the overlap condition, performance was reliant on item-context associations. It seems possible that the item-non-specific measure here is picking up on variability more tuned to STM rather than WM. In their studies, Postle and colleagues repeated items across trials; thus differences in activation strength may have been less determinant of participants' responses.

An alternative proposal, however, is that the measurement of item-non-specific PI is confounded through repeating items across trials. Recognition of items that repeat across trials calls for the representation of context; thus item repetition may confound measurements of item-non-specific PI with the build-up of item-specific PI. The confounding of both measures of PI may be most pronounced when both are being measured in the same experiment. Postle et al. defined item-specific PI solely in relation to lures presented on the previous trial; however, the results here show that there is a slow cumulative build-up of item-specific PI across trials (see Experiment 3). Given that all the items repeated in the majority of their experiments (even if they were not lures on the immediately preceding trials), it seems possible that their measurement of item-non-specific PI was in fact a measurement of item-specific PI. Following this proposal, it is yet inconclusive as to whether both types of interference reflect the same or different mechanisms within WM.

These initial experiments provided a basis within which to investigate whether item-non-specific interference and item-specific interference are independent of one another. Each type of interference is measured separately in these experiments, excluding the possibility of the measurement of either type of interference being confounded by the other. Now that it is possible to take separate measures of both types of interference, it is possible to test how both measures will relate to other variables. Item-non-specific PI should show a positive relationship to variables that commonly measure the ability to represent memory content. Item-specific PI should show a positive relationship to variables that commonly measure the ability to represent contextual aspects of memory.

Chapter 6

Relating item-non-specific to familiarity, and item-specific to recollection

In the previous Chapter, there was evidence to suggest that item-non-specific and item-specific PI are dissociable effects. Item-non-specific PI was related to a manipulation of content (vocalisation), and item-specific PI was related to manipulations of context (frequency and serial position). In the experiments described in the current Chapter, remember-know judgements were collected in conjunction with measures of both types of interference. Remember judgments are reflective of recollection, inter-item associative information, and the representation of context (e.g., Dewhurst & Hitch, 1999; Eldridge et al.; Skinner & Fernandes). Know judgements are reflective of familiarity, intra-item information or unitization, and the representation of content (e.g., Giovanello et al.; Rajaram, 1993). One account specifically holds that remember judgments are linked with control, and know judgments are linked with automaticity (Yonelinas & Jacoby, 1995).

Following-on from the findings of the previous Chapter, a logical prediction is that item-specific PI will be related to remember judgements (both being linked by contextual representations), and item-non-specific PI will be related to know judgements (both being linked through the representation of content). However, this prediction clashes with assumptions from the previous literature relating PI with control (Engle, 2002), and control with recollection (Jacoby, 1991). Based on these latter assumptions, both types of interference would be anticipated to be exclusively related to remember judgements. Thus, in addition to remember-know judgements being useful for dissociating the two different types of interfere, the current experiments additionally shed light on whether recollection and familiarity on the one hand, and control and automaticity on the other, are equivalent, or orthogonal, sets of variables.

1. Experiment 4: Mirror effects in immediate memory

Remember-know judgements are regularly collected in LTM studies, not IM studies; thus, there was a need to ensure that the measures of remembering and knowing were actually reflective of recollection and familiarity. This confirmation was achieved through replicating a remember-know ME in relation to the WFME—RKWFME. In the hit portion of the WFME, the sequence of highest to lowest hit rate is LF > MF > HF. Past research relates this portion to recollection: low-frequency items are easiest to remember as they have been linked with fewer contexts. In the false-alarm portion, the sequence of lowest to highest false-alarm rate is LF < MF < HF. Past research relates this portion to familiarity: high-frequency items are hardest to reject because of their higher levels of familiarity. The proportion of remember judgements to low-frequency items is typically higher than the proportion to high-frequency items, demonstrating the relationship between remember responses and context representation. The pattern in know judgements mirrors the remember pattern –know judgments to high-frequency items are more frequent– demonstrating the relationship between know responses and content representation. On occasion (e.g. Reder et al. 2000), know false alarms are more common than remember false alarms, with this pattern being greater for high-frequency items.

To the best of the author's knowledge, this is also the first attempt made to replicate these effects in an IM experiment. Although a previous study by Reder and colleagues (2002) had replicated the ME with non-words through varying the frequency of item repetition, this procedure was carried out over a number of sessions. Considering the evidence on frequency effects in Experiment 2 here, it seemed likely that the build-up of the WFME could be studied in one short experiment. Based on the work of Joordens and Hockley, and Reder et al. (2000; 2002), subtle changes in familiarity are believed to influence the false-alarm rate, leaving the hit rate unaffected. The hit rate becomes affected as high-frequency items become associated with an increasing number of contexts; thus, it was predicted that, as a function of increasing trials, the false-alarm portion of the WFME would emerge first in the data, followed by the hit portion.

1.1. Method

Participants: 28 participants completed a 45 minute session, and were ascribed course credit in return: age range, 18-24.

Design: The primary design consisted of three factors: frequency, block, and cycle. Levels of frequency were low, mid, and high. There were 10 mid- and high-frequency items. Mid-frequency items were repeated 18 times during the session (12 times target, 6 times distracter). High-frequency items were repeated 45 times during the session (30 times target, 15 times distracter). Low-frequency items were only present on a single trial (70 targets, 70 distracters). The forty trials were divided into three blocks, with breaks of individually determined duration between them. Each cycle was an average of either the first or final four trials within each block. Remember-know judgements were included as a factor in the examination of their relationship to the other variables.

Procedure: Participants completed 40 recognition memory trials. Following a two second fixation, seven non-words were presented sequentially for encoding at a rate of one every two seconds. During the recognition phase, the seven non-word targets were then randomly presented with seven distracter items, with each item being presented sequentially, and participants categorised each as either a target or distracter. Participants made remember-know judgements on items assigned the status of target.

1.2. Results

The analysis was divided into four sections:

1. The first analysis tested for the presence of the WFME in the relationship between hit and false-alarms and frequency, and examined this relationship as a function of block;
2. The second analysis focused on the WFME within each block;
3. The third analysis tested for a ME in the relationship between frequency and remember-know judgements;
4. The forth analysis investigated the remember-know ME as a function of frequency, block, and cycle.

1. Testing for a ME in terms of hit and false-alarm rates

A repeated-measures ANOVA with the factors hit and false-alarm rate, frequency, block, and cycle, revealed two-way interactions between hit and false-alarm rate and frequency, F (2, 54) = 39.04, $p < .001$, and hit and false-alarm rate and block, F (2, 54) = 4.45, $p = .025$. The three-way interaction between hit and false-alarm rate, frequency, and block was also significant, F (4, 108) = 4.76, $p = .003$—see Figure 10. The four-way interaction was marginal, however, F (4, 108) = 2.01, $p = .100$ (Eta Sq = .069).

To examine the ME as a function of block, the relationship between hit and false-alarm rates and frequency was assessed in each block. The interaction between hit and false-alarm rate and frequency was reliable in each block: first, F (2, 54) = 12.30, $p < .001$; second, F (2, 54) = 13.97, $p < .001$; third, F (2, 54) = 29.26, $p < .001$. For hit rate, an effect of frequency was absent in the first block, $p = .604$, but it emerged in both the second and third blocks, F (2, 54) = 3.66, $p = .032$ and F (2, 54) = 8.39, $p = .001$, respectively. While in the second block, the hit rate for mid-frequency items tended to be highest (mid versus high, $p = .008$; mid versus low, $p = .100$), the low-frequency hit rate was highest in the third block—low versus mid, $p = .021$, low versus high, $p = .001$, mid versus high, $p = .057$.

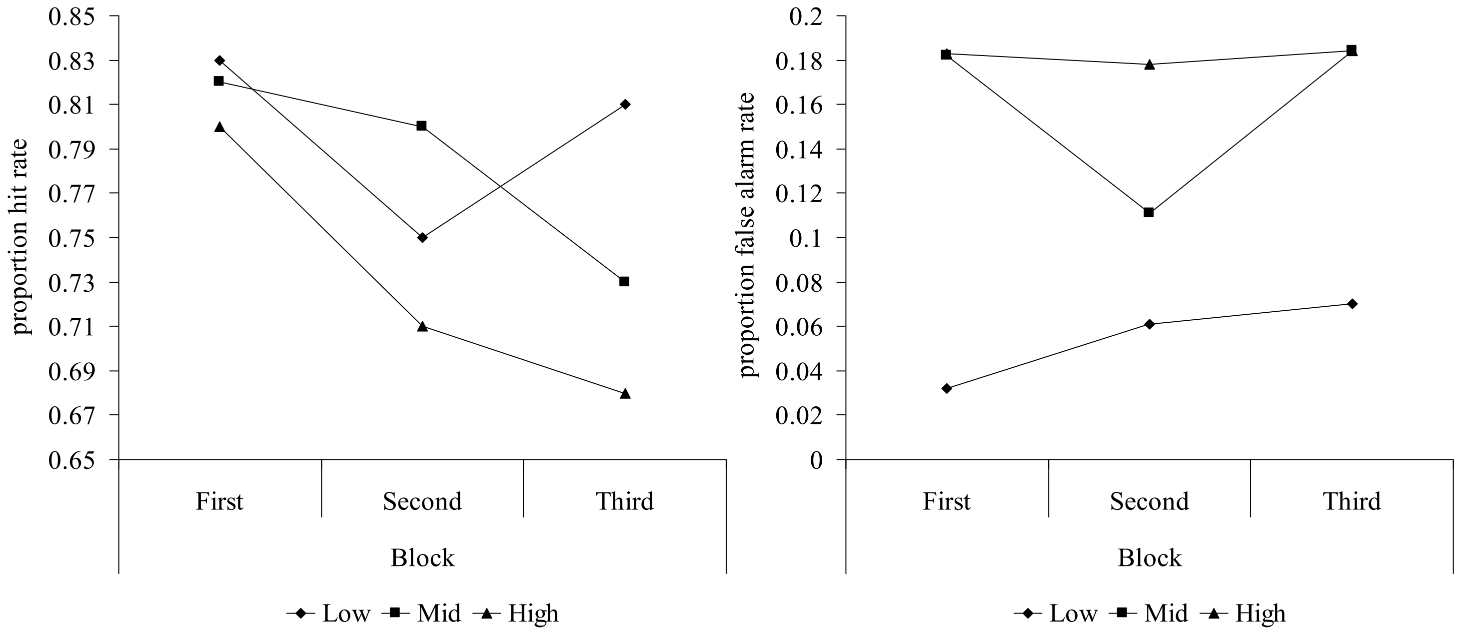

Figure 10: The impact of frequency on hit (left) and false-alarm (right) rates as a function of block

For false-alarms, an effect of frequency was present in each block: first, F (2, 54) = 27.91, $p < .001$; second, F (2, 54) = 15.49, $p < .001$; third, F (2, 54) = 14.02, $p < .001$. In both the first and third block, both mid- and high-frequency false-alarms differed from low-frequency false-alarms ($p < .01$), while in the second block, mid-and high-frequency false-alarms additionally differed from one another (mid versus high, $p = .001$; mid versus low, $p = .026$; low versus high, $p < .001$).

As predicted, the false-alarm portion of the ME developed first. A standard ME pattern was obtained in the third block (hits: L < M < H; false-alarms: L < M = H). However, this was preceded in the second block by overall higher hits for mid-frequency items relative to both low- and high-frequency, and a reduced false-alarm rate for mid-frequency items relative to high. Low-frequency hit rate dipped in the second block relative to the first block, matching the degree to which mid-frequency hit rate increased, but low-frequency recognition recovered in the third block.

2. The frequency effects within each block

Although the four-way interaction was marginal, further probing of the data was necessary in order to establish the cycle in the second block where differences between low- and mid-frequency items developed. Remember-know judgements would then provide additional insight as to whether these differences were differentially being mediated by recollection or familiarity. The relationship between frequency, block, and cycle was assessed separately for both hit and false-alarm rates. In the hit rate data, effects of frequency and block were significant, $F(2, 54) = 3.97$, $p = .026$ and $F(2, 54) = 8.86$, $p = .001$ respectively, and an effect of cycle was marginal, $F(1, 27) = 3.91$, $p = .058$ (Eta Sq = .127). The hit rate for high-frequency items was significantly lower than that for low- ($p = .027$) and mid-frequency items ($p = .016$; low versus mid, $p = .619$). Target accuracy was significantly higher in the first block relative to the second ($p = .003$) and the third ($p = .002$; second versus third, $p = .375$). Target accuracy tended to drop in the second cycle relative to the first.

Two-way interactions between frequency and block, and frequency and cycle were significant, F (4, 108) = 3.41, p = .014 and F (2, 54) = 3.78, p = .030 respectively, and the interaction between block and cycle was marginal, F (2, 54) = 3.42, p = .055 (Eta Sq = .112). The three-way interaction between frequency, block, and cycle was significant, F (4, 108) = 2.76, p = .036—see Figure 11. Frequency and cycle interacted in both the first and second blocks (third block, p = .643): first, F (2, 54) = 5.94, p = .005; second, F (2, 54) = 3.56, p = .046. In the first block, an effect of cycle was only present in high-frequency items, t (27) = 5.63, p < .001, and there was no overall effect of frequency (p = .604). In the second block, an effect of frequency was significant in the second cycle, F (2, 54) = 5.63, p = .008 (first cycle, p = .451): mid-frequency hit rate was significantly higher than that for low- and high-frequency items (mid versus low, p = .027; mid versus high, p < .001; high versus low, p = .689). In the third block, an effect of frequency remained, F (2, 54) = 8.39, p = .001 (cycle, p = .441) in which comparisons were significant or marginally so (low versus mid, p = .021; low versus high, p = .001; mid versus high, p = .057).

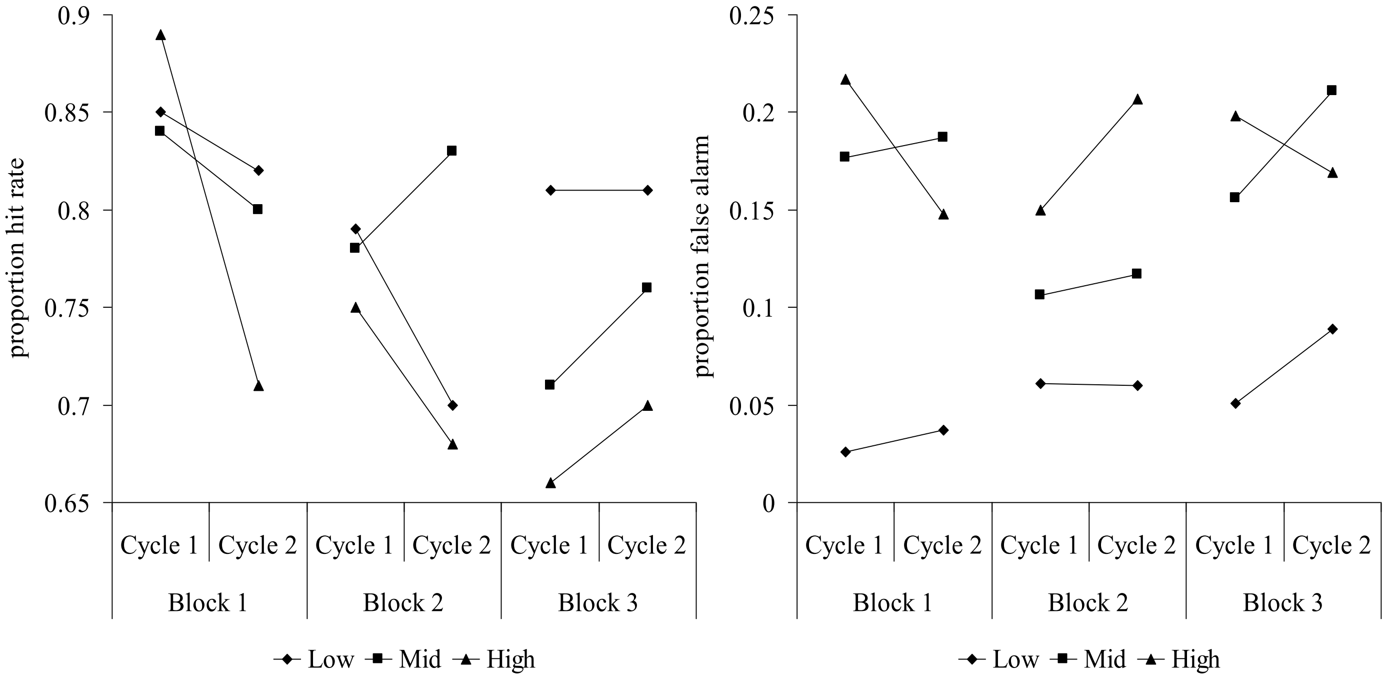

Figure 11: The relationship between frequency and cycle as a function of increasing block—left = hits; right = false-alarms

In the false-alarm data, an overall effect of frequency was significant, F (2, 54) = 32.32, $p < .001$ (high versus mid, $p < .001$; high versus low, $p < .001$; high versus mid, $p = .106$), frequency interacted with block, F (4, 108) = 3.95, $p = .007$, and the three-way interaction between frequency, block, and cycle was marginal, F (4, 108) = 2.36, $p = .079$ (Eta Sq = .081). In high-frequency items, both block and cycle interacted, F (2, 54) = 4.50, $p = .016$. While the high-frequency false-alarm rate dropped in the first block from the first to the second cycle, t (27) = 1.91, $p = .067$, it increased again in the second block, though not significantly so ($p = .117$), and it tended to remain at this rate in the third block.

The expected WFME (hit rate, LF > MF > HF; false-alarm rate, LF < MF < HF) emerged in the third block, whereas the mid-frequency hit rate was highest in the second cycle of the second block. A more typical frequency effect dominated all three blocks in the false-alarm data: the low-frequency false-alarm rate was always lower than that of the other two frequencies. The false-alarm rate for mid-frequency fell below that for high-frequency items in the second block; however, the overall direction of the frequency effect was not altered as it was in the hit data. The dissociable pattern of frequency effect across hits and false-alarms –a typical effect of frequency emerged quicker in false-alarms– is consistent with two process models in which subtle changes in familiarity alter the false-alarm rate, but are not enough to interfere with the recollection process governing the hit rate. The fact that firstly, the mid-frequency improvement in the second block spanned both hit and false-alarms rates, and that secondly, this was coupled with a drop in the hit rate for low-frequency items suggests that familiarity was driving the mid-frequency benefit in the second block.

3. Testing for a ME in remember-know judgements

The repeated-measures ANOVA included five factors: hit and false-alarm rate, frequency, block, cycle, and remember-know judgements. An overall effect of remember-know, F (1, 27) = 21.85, p < .001, revealed a stronger tendency to respond remember. Two-way interactions between hit and false-alarm rate and remember-know, and frequency and remember-know were significant, F (1, 27) = 37.17, p < .001 and F (2, 54) = 12.68, p < .001 respectively, as was the three-way interaction between hit and false-alarm, frequency, and remember-know, F (2, 54) = 26.15, p < .001. Other interactions included remember-know x cycle, F (1, 27) = 3.19, p = .085 (Eta Sq = .106), remember-know x frequency x cycle, F (2, 54) = 2.53, p = .089 (Eta Sq = .086), and the four-way interaction including these latter variables and block, F (4, 108) = 2.95, p = .026. The five-way interaction was marginal, F (4, 108) = 2.59, p = .058 (Eta Sq = .088).

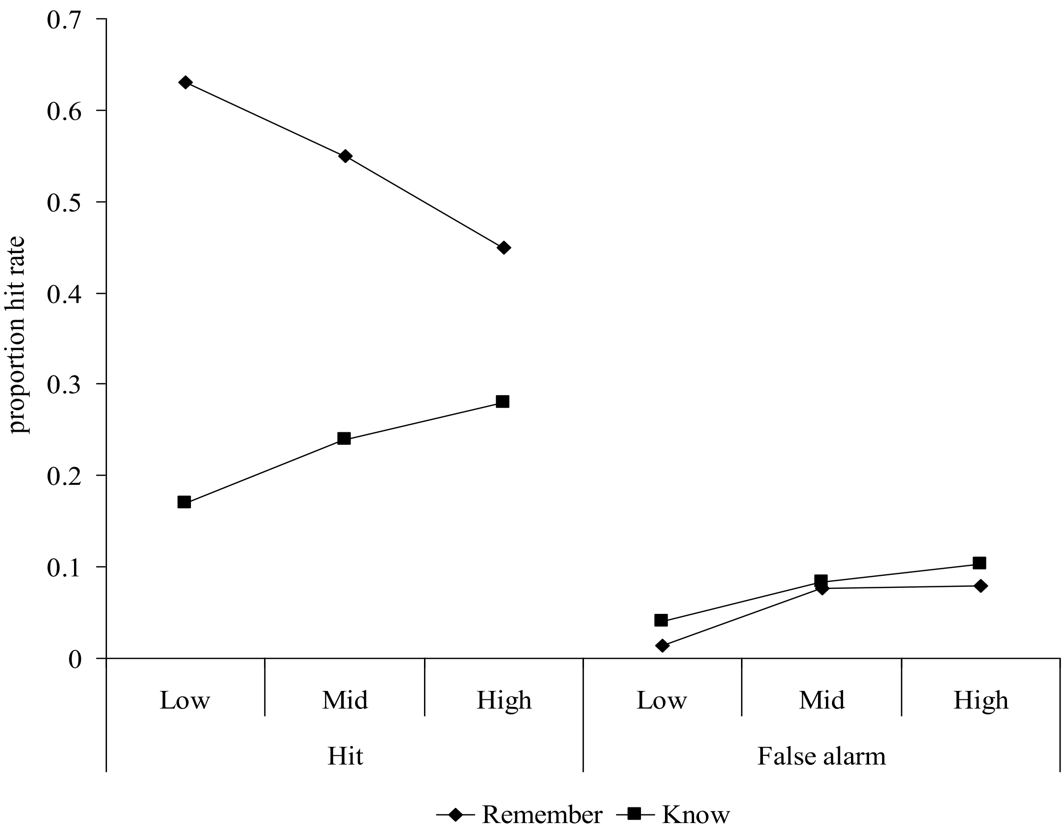

Figure 12: The relationship between frequency and remember-know in terms of both hits and false-alarms

The first subsidiary analysis tested for the overall presence of the RKWFME. An interaction between frequency and remember-know was present for hit rate, F (2, 54) = 26.20, $p < .001$, and absent for the false-alarm rate. An overall effect of frequency was present for remember judgements, F (2, 54) = 25.94, $p < .001$, and know judgements, F (2, 54) = 19.11, $p < .001$, and all comparisons were significant ($p < .05$)—see Figure 12.

4. The RKWFME as a function of block and cycle

The influence of block and cycle on the relationship between frequency, and remember-know was assessed separately for hit and false-alarm rates. In the hit data, an overall effect of remember-know was significant, F (1, 27) = 29.63, $p < .001$, with the following interactions: frequency x remember-know, F (2, 54) = 19.59, $p < .001$; cycle x remember-know, F (1, 27) = 2.94, $p = .098$ (Eta Sq = .098); frequency x cycle x remember-know, F (2, 54) = 2.47, $p < .094$ (Eta Sq = .084); frequency x block x cycle x remember-know, F (4, 108) = 2.84, $p = .039$—see Figure 13. The interaction between frequency, cycle, and remember-know was only present in the first block, F (2, 54) = 4.79, $p < .017$ (second, $p = .434$; third, $p = .261$). Frequency and cycle interacted in both remember and know responses: remember, F (2, 54) = 6.46, $p < .004$; know, F (2, 54) = 2.63, $p = .089$ (Eta Sq = .089). Subjective differences in reports as a function of frequency were only evident in the second cycle: remember, F (2, 54) = 11.08, $p < .001$; know, F (2, 54) = 6.53, $p < .005$. Remember judgements differed between all frequencies (1 versus 2, $p = .051$; 1 versus 3, $p < .001$; 2 versus 3, $p = .018$), while know judgements differed between high and low ($p < .001$) and mid and low ($p = .023$) frequencies (high versus mid, $p = .687$).

In the second block, frequency interacted with remember-know, F (2, 54) = 15.89, $p < .001$. There was an overall effect of frequency in terms of remembers, F (2, 54) = 12.87, $p < .001$. High-frequency remember hit rate was significantly lower than that of the other two frequencies ($p < .001$), but there was no difference between mid- and low-frequency stimuli ($p = .317$). In terms of knows, and in addition to an overall effect of frequency, F (2, 54) = 13.88, $p < .001$, frequency interacted with cycle, F (2, 54) = 3.67, $p = .034$ (remembers: frequency x cycle, $p = .953$). In the first cycle, the overall effect of frequency, F (2, 54) = 5.25, $p = .010$ constituted of a significant difference between high-frequency know hits and hits for low- and mid-frequency items ($p < .05$; mid versus low, $p = .572$). In the second cycle, the overall effect of frequency, F (2, 54) = 18.40, $p < .001$, constituted of a significant difference between low-frequency know hits and mid and high frequencies ($p < .001$; mid versus high, $p = .683$).

In the third block, frequency interacted with remember-know, F (2, 54) = 10.81, $p < .001$. There was an effect of frequency on remember responses, F (2, 54) = 13.66, $p < .001$, with all comparisons being significant ($p < .05$). There was also an effect of frequency on know responses, F (2, 54) = 4.80, $p = .017$. There was a significant difference between high-frequency items and both other frequencies ($p < .05$; low versus mid, $p = .182$; remembers, frequency x within-cycle, $p = .267$; knows, frequency x within-cycle, $p = .427$).

A remember-know ME in the hit data emerged in the first cycle and was then sustained throughout. The typical pattern for remember responses was low-frequency > mid-frequency > high-frequency, with the opposite pattern defining know responses. The position of mid-frequency know hits relative to the other two frequencies differed across cycles in the second block. While know hits to mid-frequency items matched those of low-frequency items in the initial cycle of the second block, they increased within the block to match those of high-frequency items. Meanwhile, the absence of a difference between low- and mid-frequency remember judgements remained constant during the second block. This pattern is consistent with the idea that recollection was equally employed in the detection of both low- and mid-frequency targets in the second block, but the higher familiarity signal associated with mid-frequency items lead to their detection as targets at a cost to low-frequency items.

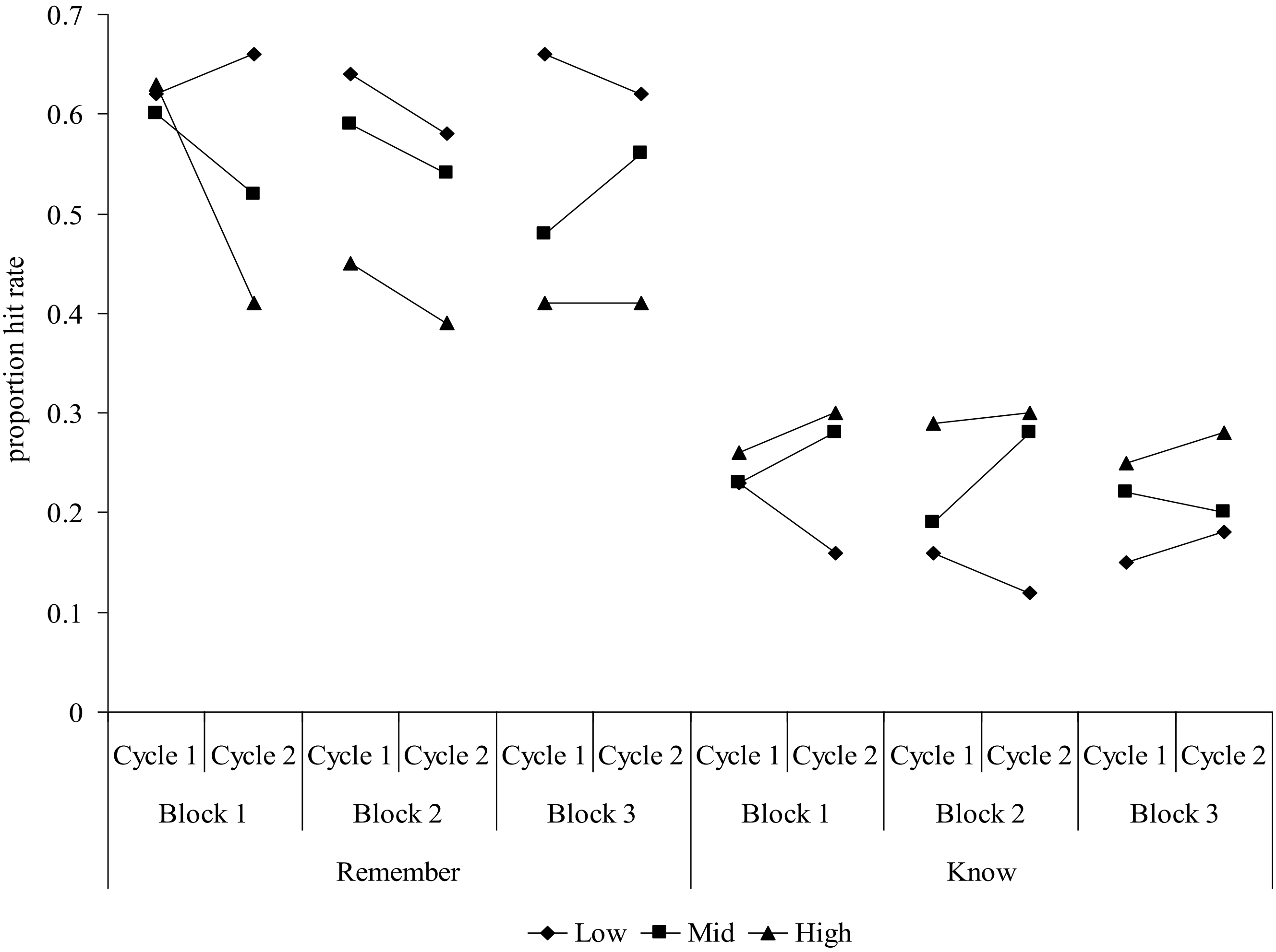

Figure 13: The four-way interaction between frequency, block, cycle, and remember know in the hit data

The four-way interaction between frequency, block, cycle, and remember-know was marginal in the false-alarm data, F (4, 108) = 2.25, p = .079 (Eta Sq =

.077)—see Figure 14. In a separate analysis of remember responses, only an effect of frequency was significant: there were significantly fewer low-frequency remember false-alarms relative to the other two frequencies ($p < .001$), while there was no difference between mid- and high-frequency responses ($p = .733$). In know responses, the three-way interaction between frequency, cycle, and block was significant, F (4, 108) = 3.63, $p = .017$ (remembers, $p = .687$). Frequency and cycle interacted in the second and third block: second, F (2, 54) = 3.35, $p = .042$; third, F (2, 54) = 4.80, $p = .012$ (first, $p = .378$). In the second block, the increase in know false-alarms for high-frequency items from the first to the second cycle was marginal, t (27) = 1.99, $p = .056$, and in the third block, the increase from the first to the second cycle in know false-alarms for low- and mid-frequency stimuli was significant: low, t (27) = 2.09, $p = .046$; mid, t (27) = 2.13, $p = .042$.

For remember false-alarms, low-frequency false-alarms were fewer than both mid- and high-frequency false-alarms. For know false-alarms, the data began to diverse from the remember false-alarm data as blocks progressed. In the final block, high-frequency know false-alarms were numerous, and both mid- and low-frequency items showed a significant increase in know false-alarms. Although increases in know false-alarms would be expected in both high- and mid-frequency data due to these items repeating, the increase in low-frequency know false-alarms in the third block was not predicted on the bases of any current theory. Below it will be argued that this increase is a consequence of item-non-specific interference.

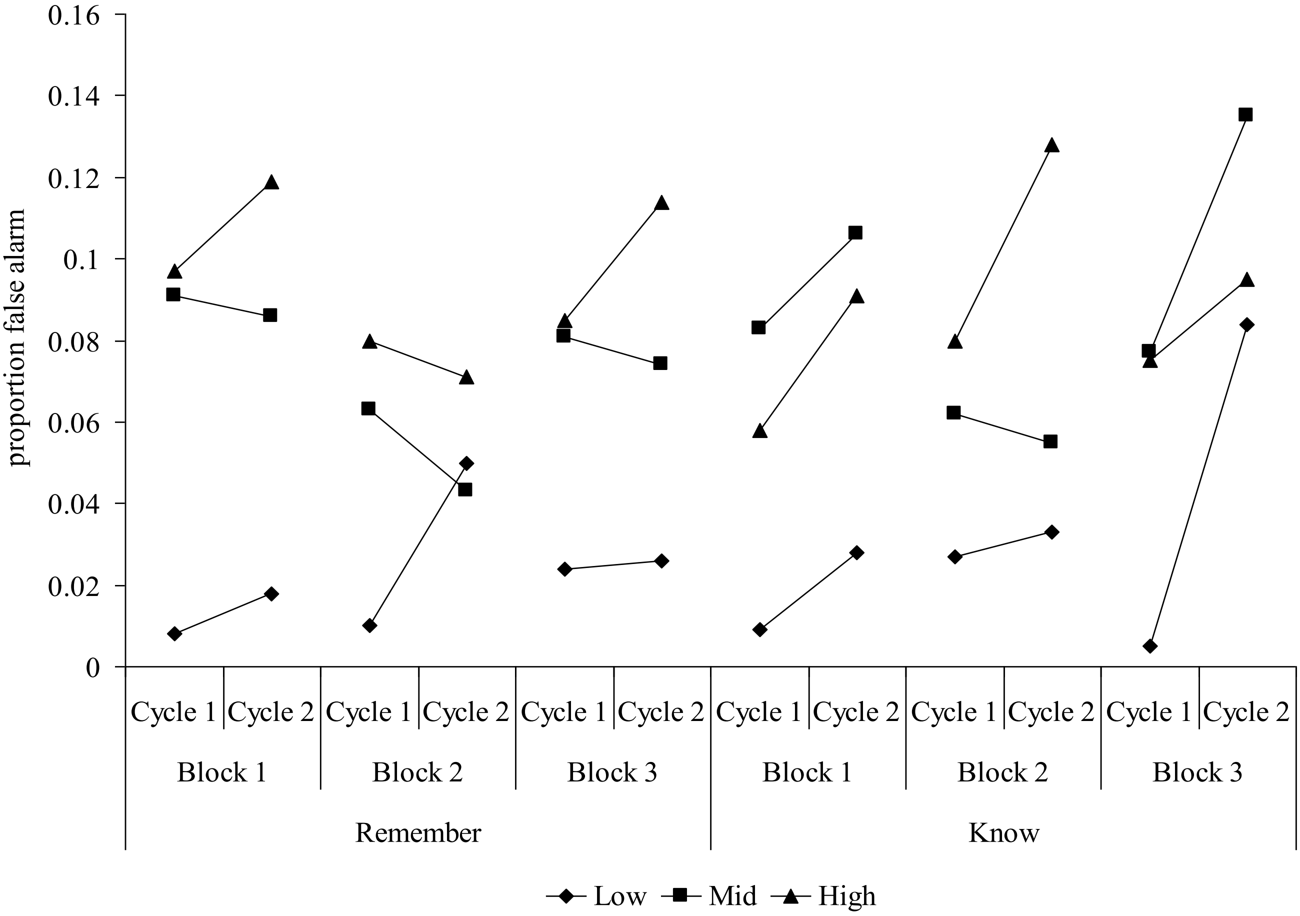

Figure 14: The four-way interaction between frequency, block, cycle, and remember know in the false-alarm data

1.3. Discussion

Consistent with the results from studies of LTM, a ME developed in the relationship between hit and false-alarms and frequency, with hit rate decreasing as a function of increasing item frequency and false-alarms increasing. Also consistent with previous studies, the false-alarm portion of the effect emerged first (in the first block), while a typical frequency effect in the hit data was only present in the third cycle. Unexpectedly, the hit rate for mid-frequency stimuli surpassed that for low-frequency items in the second cycle of the second block, and the false-alarm rate for mid-frequency items dropped in the second block.

The effect of frequency also induced a ME in the relationship between remember-know, and frequency, but only in the hit data. Remember hits decreased as a function of frequency, while know hits increased. The increase in mid-frequency hits in the second block was related to an increase in the proportion of mid-frequency know responses. Generally, the increase in know responses across trails reflects the increased difficulty with which mid- and high-frequency items are distinguished as having been presented on the current trial. Consistent with this, high-frequency items showed an increase in know false-alarms in the second block, while mid-frequency items showed an increase in know false-alarms in the third block. However, there was also an increase in low-frequency false-alarms in the third block. Low-frequency distracters were only presented once; thus this increase in low-frequency know false-alarm rate cannot be attributed to familiarity for specific items. Instead, it is likely that the task bought about a certain level of item-non-specific interference, due to the increase in familiarity for the non-word category as a whole, and that this non-specific level of familiarity lead to low-frequency false-alarms.

2. Experiment 5: The relationship between interference, recollection, and familiarity

The data from Experiment 4 are consistent with the need to distinguish between content and context representation in memory. From the perspective of a dual-route framework of the relationship between PI and memory, item-non-specific interference affects the content of memory representations while item-specific interference affects the quality of contextual links. In this experiment, measures of both types of interference are collected in addition to measuring the WFME and collecting remember-know judgements. A dual-route model predicts that item-non-specific interference will be positively related to know responses, and item-specific interference will be positively related to remember responses. Should these predictions be met, it would be additional evidence in favour of the dual-route approach.

Experiment 5 had two primary goals. Firstly, it sought to test how the interference measures were related to the hit and false-alarm portions of the WFME. Item-specific PI should be positively related to the hit portion of the WFME, if both effects are being mediated by recollection. In contrast, item-non-specific PI should be positively related to the false-alarm portion of the WFME, if both effects are being mediated by familiarity. Secondly, it sought to look at the relationship between remember and know responses, and the measures of PI. In addition to this, an attempt was made to extract out any STM rehearsal-related contributions to the effects of overlap and remember-know differences by collecting data on forward and backward digit span (FS and BS), and then removing variance associated with span performance. Removing variability due to FS and BS scores from the data should remove more basic vocal memory differences, but not variability along the domains of recollection and familiarity.

2.1. Method

Participants: 60 participants, age-range 18-30, registered to take part in the study, and were ascribed either course credit or £8 in return.

Design: The study consisted of two primary tasks, one that measured each type of PI, and the other that measured the RKWFME. The PI measurement task was made up of two levels of overlap, no-overlap and overlap. Another factor, cycle, had two levels: an average of performance on the first five trials, and the final five trials.

Two PI factors, each specific to one form of interference, were calculated: sensitivity for the first cycle of trials in each level of overlap was separately subtracted from sensitivity levels for the final cycle in each level of overlap. This subtraction lead to negative values representing the magnitude of interference build-up; hence, in the subsequent analyses, if a PI slope is positively correlated with another continuous variable, this other variable is then related to reduced interference build-up.

The remember-know task had the factor frequency as a primary variable—low- mid- and high-frequency. Remember-know judgements were included as a factor when needed. The factor cycle consisted of three levels: an average of the first five trials, an average of the middle five trials, and an average of the final five trials. The number of trials administered to participants was reduced relative to the first experiment for the purpose of efficiency, given that the emergence of both MEs had previously been observed.

In the PI measurement task, overlap items were presented 18 times during testing, 12 times as a target and six as a distracter, and no-overlap items were novel on every trial. The high- and mid-frequency lists in the remember-know task consisted of 10 items each. High-frequency items were seen thirty times during the session, 20 times as a target, 10 as a distracter. Mid-frequency items were seen fifteen times during the session, 10 times as a target, and 5 as a distracter. Each low-frequency item was only presented on one trial.

Participants also completed visual versions of the forward and backward span tasks in the same session as the PI measurement task. FS trials went from 3 to 9 digits, with two trials measuring span at each number of digits. The number of digits increased linearly, and the task ended when participants either failed to input the correct digits or their serial order on two consecutive trials, or completed all 14 trials. BS trials went from 2-8, while other task parameters were similar.

Procedure: Participants performed the two primary tasks on separate days, with each session lasting forty minutes, and the order being counterbalanced across participants. The levels of overlap in the PI measurement task were completed in random order, with one of the digit-span tasks being completed in-between the two, and the other being completed at the beginning or end of the session, the order being random. Participants were given a practice trial before the PI measurement task to ensure they understood the procedure. In the remember-know task, participants were given a minimum of two practice trials to ensure that they were comfortable making remember-know judgements. The instructions matched those of the previous experiment.

The trial procedure was similar in both tasks. Each trial began with a two second presentation of a fixation cross. Seven non-word targets were presented sequentially at the rate of one every two seconds following fixation. After the presentation of the final target to be encoded, the presentation of another two second fixation cross signalled the onset of testing. Test items were presented sequentially and remained on the screen until participants responded. Responding in both tasks required participants to categorise each item as either a target or distracter. In the remember-know task, participants judged whether each item categorized as a target was remembered as having been presented, or whether participants sensed (knew) that the stimulus had appeared but could not recollect the episode. The PI measurement task consisted of 18 trials, and the remember-know task 21.

2.2. Results

The analysis is divided into five sections:

1. PI variables were computed in the PI measurement task;
2. A ME in the relationship between hit and false-alarms was tested for;
3. A remember-know ME was assessed;
4. The PI measurement variables, and the span tasks were included as covariates to investigate the relationship between PI susceptibility, and the WFME;
5. The PI measurement variables and the span tasks were included as covariates to investigate the relationship between PI susceptibility, recollection, and familiarity.

1. PI measurement

A 2-way ANOVA revealed main effects of overlap and cycle: F (1, 59) = 52.73, $p < .001$ and F (1, 27) = 43.42, $p < .001$ respectively (overlap x cycle, p = .321). No-overlap performance was better than overlap performance, and there was interference build-up in both conditions—see Table 1. As described in the method, PI effects were calculated for each level of overlap.

Table 1: Sensitivity as a function of overlap and cycle

	First cycle		Final cycle		PI build-up	
	M	*SD*	*M*	*SD*	*M*	*SD*
No-overlap	4.00	1.23	3.09	1.29	-0.91	1.13
Overlap	3.20	1.10	2.45	1.34	-0.75	1.20

2. WFME

A repeated-measures ANOVA including the factors hit and false-alarm rate, frequency, and cycle revealed main effects of each: F (1, 59) = 665.01, $p < .001$, F (2,

118) = 14.78, $p < .001$, and F (2, 118) = 3.45, $p = .035$ respectively. All two-way interactions were significant: hit and false-alarm rates x frequency, F (2, 118) = 35.01, $p < .001$; hit and false alarm rates x cycle, F (2, 118) = 3.98, $p = .023$; frequency x cycle, F (4, 236) = 2.97, $p = .029$. The three-way interaction between hit and false-alarm rate, frequency, and cycle was also significant, F (4, 236) = 5.41, $p = .001$. For hits, an overall effect of frequency was not significant ($p = .168$), while an overall effect of cycle was significant, F (2, 118) = 6.24, $p = .003$, and frequency interacted with cycle, F (4, 236) = 5.60, $p = .001$—see Figure 15. In the false-alarm data, there was an overall effect of frequency, F (2, 118) = 40.26, $p < .001$, but no effect of cycle ($p = .994$), and frequency only showed a marginal interaction with cycle, F (4, 236) = 2.21, $p = .070$ (Eta Sq = .036).

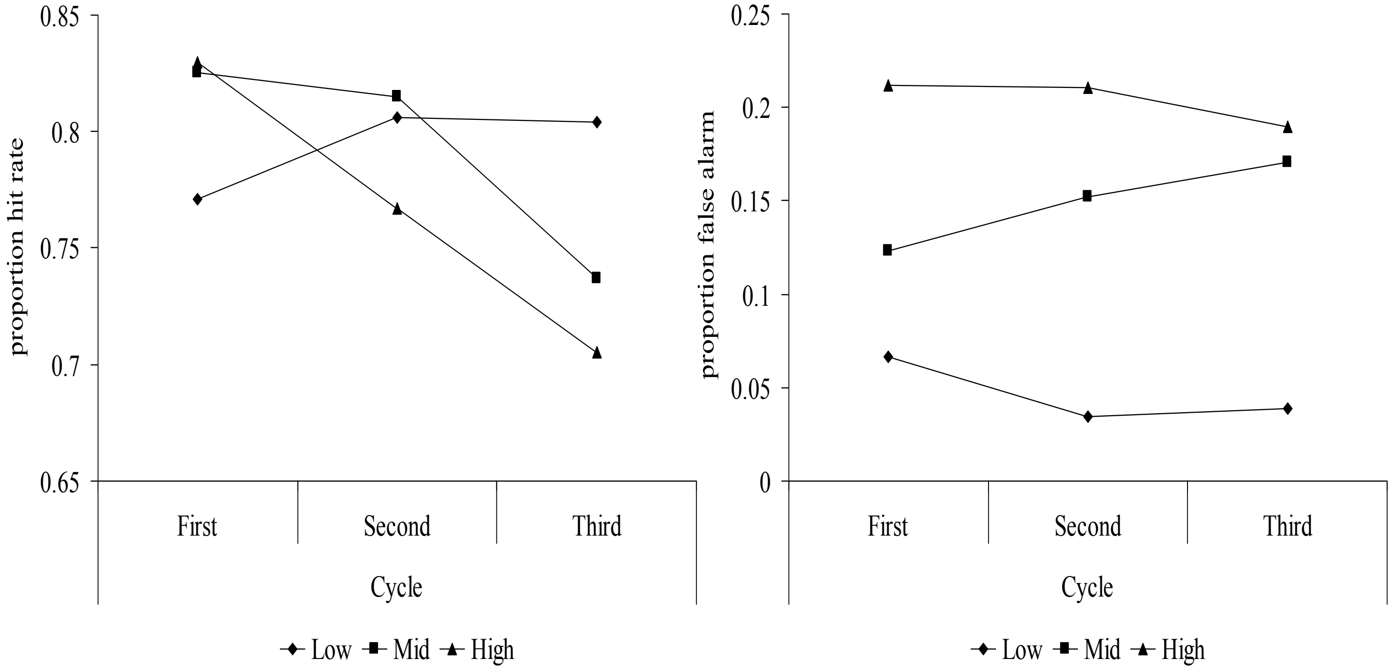

Figure 15: The effect of frequency and cycle on hit (left) and false-alarm (right) rates

The frequency x cycle interaction on hits was decomposed as follows. An effect of cycle was significant in the high-frequency hit data, F (2, 118) = 14.97, $p < .001$, with all comparisons reaching significance ($p < .05$). An effect of cycle was marginal in the mid-frequency hit data, F (2, 118) = 3.98, p = .025 (Eta Sq = .063), with the third cycle showing reduced accuracy relative to the other two cycles (first vs. third, p = .009; second vs. third, p = .056). In the low-frequency hit data, an effect of cycle failed to reach significance (p = .255). Overall effects of frequency were significant in the first and final cycles: first, F (2, 118) = 4.47, p = .015; final, F (2, 118) = 6.29, p = .004 (second, p = .175). The hit rate for low-frequency items was significantly lower than that for high-frequency items (p = .003) and mid-frequency items (p = .032) in the first cycle (mid vs. high, p = .839). The opposite pattern in low- and high-frequency hits was present in the final cycle (p < .001). The hit rate for mid-frequency items also differed from that for low-frequency items in the final cycle (p = .050), but not from that of high-frequency items (p = .223).

In the false alarm data, an effect of frequency was significant in each cycle: first, F (2, 118) = 21.24, p < .001; second, F (2, 118) = 24.74, p < .001; third, F (2, 118) = 18.77, p < .001. However, while all comparisons were significant in the first and second cycles (p < .05), mid-frequency false-alarm rate no longer differed from high-frequency false alarm rate in the third cycle (p = .435).

3. A ME in remembers and knows

A repeated-measures ANOVA was conducted, including the factors hit and false-alarm rates, frequency, cycle, and remember-know. An overall effect of remember-know was significant, F (1, 59) = 72.43, p < .001, as were the two-way interactions between hit and false rate and remember-know, and frequency and remember-know, F (1, 59) = 124.29, p < .001 and F (2, 118) = 4.92, p = .015 respectively. The following three-way interactions were significant: hit and false-alarm rate x frequency x remember-know, F (2, 118) = 7.54, p = .001; hit and false-alarm rate x cycle x remember-know, *F* (2, 118) = 4.14, *p* = .018; and frequency x cycle x remember-know, *F* (4, 236) = 4.10, *p* = .004.

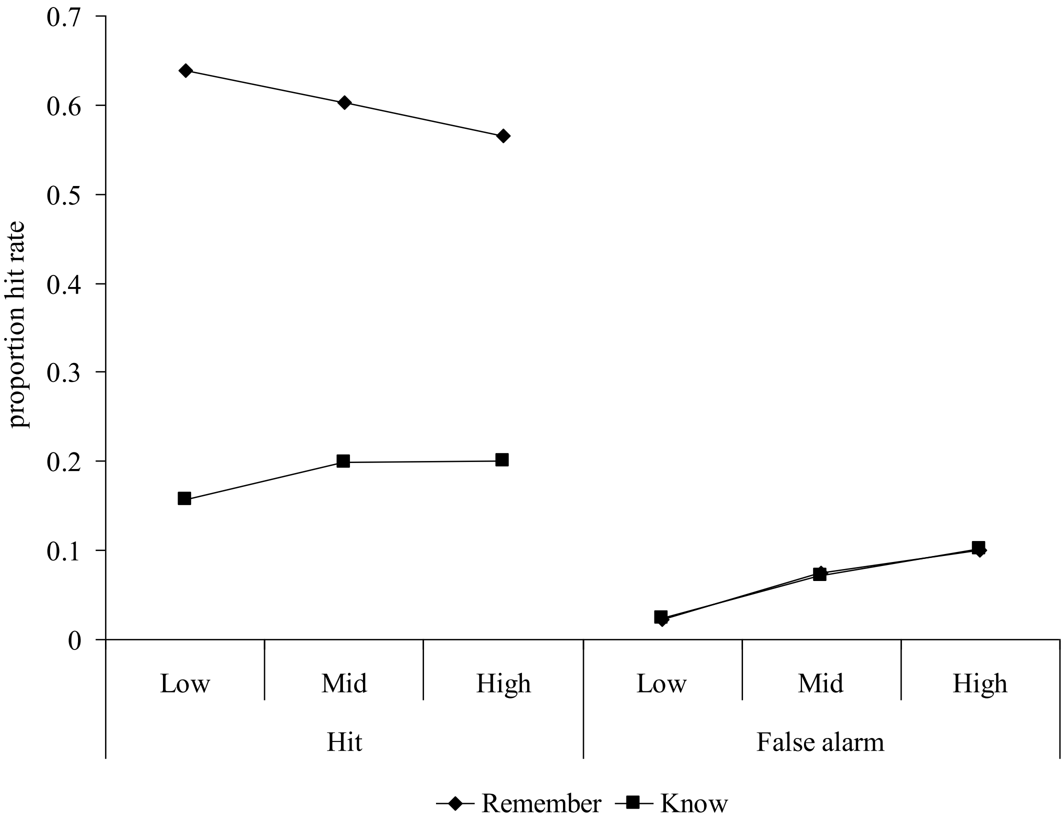

Figure 16: The relationship between remember-know and frequency as a function of both hits and false-alarms

Figure 16 shows the relevant interaction between hit and false-alarm rate, frequency, and remember-know. Effects of both remember-know and frequency were significant in the hit data, *F* (1, 59) = 106.31, *p* < .001 and *F* (2, 118) = 3.07, *p* = .051 respectively, and the interaction between them was significant, *F* (2, 118) = 7.71, *p* = .001. An effect of frequency on remember judgements, *F* (2, 118) = 7.46, *p* = .001, revealed significant simple effects between high-frequency items and the other two frequencies (*p* < .05), while the difference between low- and mid-frequency items was marginal (*p* = .098). The effect of frequency in terms of knows, *F* (2, 118) = 5.46, *p* = .008, revealed significant simple effects between low-frequency items and the other two frequencies (*p* < .05), with no difference between mid- and high-frequency items

(p = .907). In the false alarm data, only an effect of frequency was significant, F (2, 118) = 48.78, p < .001 (other effects, p > .9), with differences between all comparisons (p < .001)

In order to look at the build-up of the ME in closer detail, the relationship between frequency, cycle, and remember-know was analysed separately for hits and false-alarms. The three-way interaction was only significant in the hit data, F (4, 236) = 3.59, p = .009 (false-alarms, p = .626)—see Figure 17. An interaction between frequency and cycle was specific to the remember data, F (4, 236) = 7.26, p < .001 (knows, p = .775). An effect of frequency was significant in both the second and third cycles in the remember data: second, F (2, 118) = 5.09, p = .008; third, F (2, 118) = 12.92, p < .001 (first, p = .367). In the second cycle, the remember hit rate for high-frequency items was lower than that for low-frequency items (p = .001) and (marginally) lower than that for mid-frequency item (p = .097), while there was no difference between low- and mid-frequency items (p = .156). In the final cycle, all comparisons were significant (p < .05). An overall effect of cycle was significant in both high- and mid-frequency remember hits, F (2, 118) = 12.85, p < .001 and F (2, 118) = 3.85, p = .026 respectively (low, p = .413). All comparisons were significant in high-frequency remember hits (p < .05), while mid-frequency remember hits were lower in the third cycle compared to the other two cycles (first vs. third, p = .007; second vs. third, p = .105).

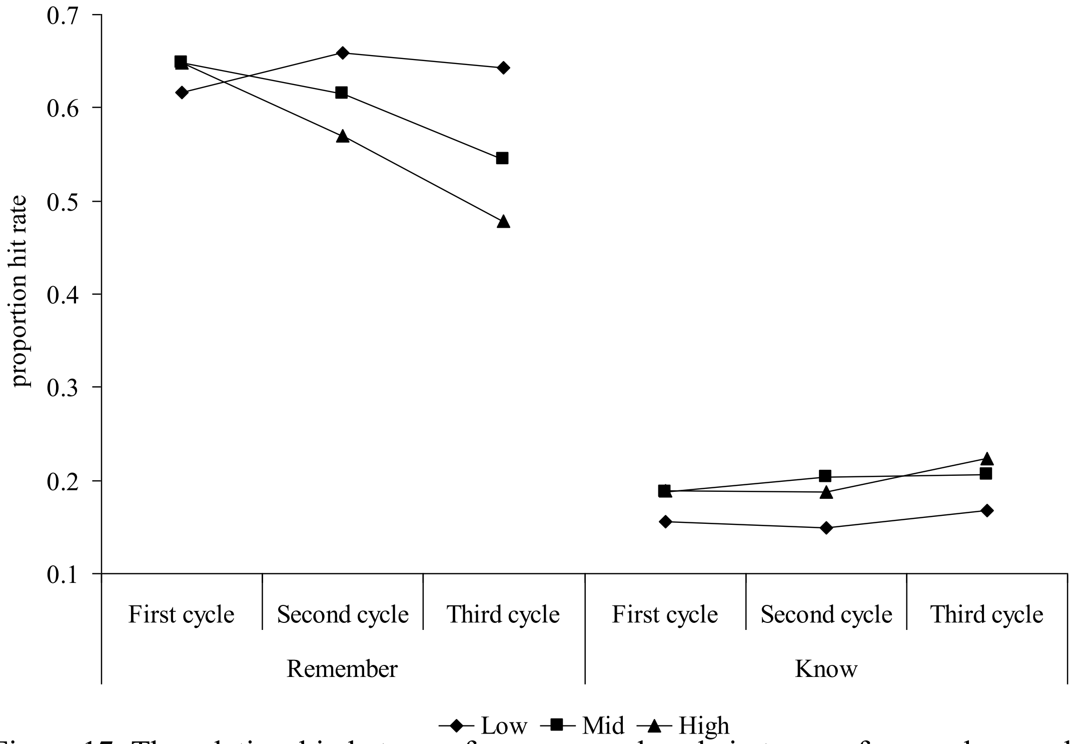

Figure 17: The relationship between frequency and cycle in terms of remembers and knows

4. The relationship between PI susceptibility, and the WFME

The PI effects (no-overlap/overlap: final cycle – first cycle) were included as covariates, along with the span tasks, in a repeated-measures ANOVA with the factors hit and false-alarm rate, frequency, and cycle. Evidence suggests that the hit portion of the ME is mediated by recollection, and the false-alarm portion is mediated by familiarity. A dual-route approach to interference suggests that item-specific interference reflects difficulties in recollection, and item-non-specific interference reflects difficulty in familiarity discrimination. It follows that the measure of item-specific build-up should be the best predictor of the hit portion of the ME, and the measure of item-non-specific interference should be the best predictor of the false-alarm portion. In the ANCOVA, the interaction between hit and false-alarm rate and frequency was no longer reliable (p = .164), while the three-way interaction between the hit and false-alarm rates, frequency, and cycle was also not reliable (p = .489). Remaining effects in the ANCOVA are shown in Table 2.

Table 2: Effects in the ANCOVA analysis with variables hit and false-alarm, frequency, and cycle, and covariates item-non-specific, item-specific, FS, and BS, and the partial correlations supporting these effects.

ANCOVA			Partial correlation		
Covariates: item-non-specific, item-specific, FS, BS	*F*	*p*		*r*	*p*
Hit and false alarm	9.69	0.003			
Hit and false alarm x item-non-specific	11.41	0.001	Hits	-0.420	0.001
			False alarms	0.206	0.125
Hit and false alarm x item-specific	7.23	0.009	Hits	0.241	0.071
			False alarms	-0.281	0.034
Hit and false alarm x cycle x BS	2.90	0.059			
Hits: cycle x BS	3.18	0.045	Third cycle	0.195	0.147
False alarms: BS covariate	4.35	0.042		(-)	

The WFME was no longer significant upon inclusion of the covariates. The measures of both types of interference and the build-up of the WFME shared a high degree of common variability. The interaction between hit and false-alarm rate and both types of interference confirmed positive associations between item-non-specific PI and false-alarms, and item-specific PI and hits. The alternate correlations were also present, however. BS was positively related to hit rate in the third cycle, suggesting that processes related to BS become more engaged in determining hit rate as the task progresses. BS was negatively related to false-alarm rate, suggesting that higher levels of BS were linked with reduced false-alarms.

5. The relationship between PI susceptibility, and remember-know

Multiple regression (backward method) was employed to investigate the relationship between the two types of interference and remember-know judgements. Remember and know judgements (averaged across the hit rate data) were entered separately as dependent variables, along with the following predictors: item-non-specific (no-overlap final cycle - first), item-specific (overlap final cycle - first), FS, and BS. In the remember data, the regression was significant, F (2, 57) = 10.13, p < .001 (R = .512). Item-non-specific PI was a negative predictor (t = 4.49, p < .001) and item-specific PI was a positive predictor (t = 2.05, p = .045; FS and BS, p > .7). The regression in the know data was also significant, F (1, 58) = 7.38, p = .009. Item-non-specific PI was the only significant predictor (t = 2.72, p = .009; remaining variables, p > .2), and its relationship to knows was positive.

Remember and know judgements attributed to false-alarms obviously do not reflect true memory. Memory can be distorted through interference; thus it was of interest to see whether the interference measures might be related to participants' false-alarm judgements. The regression predicting remember false-alarms was significant, F (1, 58) = 6.04, p = .017. The only significant predictor was BS. BS was negatively related to the remember false-alarm rate (t = -2.46, p = .017; remaining variables, p = .2). The regression predicting know false-alarms was also significant, F (2, 57) = 3.56, p = .035. Item-non-specific PI was positively related to the number of know false-alarms (t = 1.87, p = .067), whereas item-specific PI was negatively related to the number of know false-alarms (t = 2.50, p = .015).

Two potential causes might contribute to the oppositional pattern that arose in the relationship between remember-know judgements and item-non-specific PI. On a trial-by-trial basis, remember and know responses are mutually exclusive: as know responses increase, remember responses decrease; hence, the oppositional pattern may be a consequence of this exclusivity. Alternatively, the pattern might have more meaningful consequences for understanding the relationship between recollection, familiarity, and PI. As item-non-specific PI increases in the no-overlap condition, processes/mechanisms better able to represent memory content should become more involved in memory, and processes/mechanisms better able to represent contextual aspects of memory are less required. The negative relationship between item-non-specific and remember may reflect the disengagement of processes and mechanisms related to context as content-related interference builds up. Correlation confirmed that the item-non-specific pattern might hold more meaning than a simple exclusivity explanation: while remember responses were positively related to sensitivity in the initial no-overlap cycle, $r\ (56) = .480, p < .001$, a relationship was absent in the final no-overlap cycle ($p = .593$). From the perspective of interference, the finding suggests that a reduced susceptibility to item-non-specific interference is related to reduced recollection.

2.3. Discussion

Consistent with Experiment 4, a WFME built up across cycles, and the false-alarm component on the WFME arose first. A remember-know ME in relation to frequency also arose. Novel findings included the following:

a. The hit rate in the WFME was positively related to item-specific PI, and the false-alarm rate in the effect was positively related to item-non-specific PI. The opposing relationships between item-non-specific and hits, and item-specific and false-alarms were also present;
b. BS showed some tendency to covary with the hit rate as the task progressed (third cycle), and false-alarms were negatively related to BS;
c. In the hit data, the positive relationship between item-specific PI and hits was exclusive to remember responses, and despite the overall negative relationship between item-non-specific PI and hits, item-non-specific PI was positively

related to know hits. Item-non-specific PI showed an additional negative relationship to remember hits;

d. In the false-alarm data, the negative relationship between BS and false-alarms was exclusive to remember false-alarms. The positive relationship between item-non-specific PI and false-alarms was exclusive to know false-alarms, whilst the negative relationship between item-specific PI and false-alarms was also exclusive to know false-alarms.

Experiment 5 suggests a link between item-non-specific PI and the representation of memory content, and a link between item-specific PI and contextual representations in memory. Remember judgements were positively related to item-specific PI, and know judgements were positively related to item-non-specific PI. Remember judgements measure recollection, the ability to remember the associations between item and context information; thus, it can be argued that item-specific PI and remember judgements overlap in context-related processing. Know judgements measure familiarity for the content of the information encoded; thus, it can be argued that item-non-specific PI and know judgments overlap in content-related processing. The positive relationship between item-non-specific PI and know judgements can also be described in terms of unitization. Unitization is believed to reflect the degree to which the intrinsic features of an item are bound together. Item-non-specific PI may then reflect variability in unitization, and the know response may reflect an individual's awareness of whether there has been recent binding of the features being presented to them.

An unexpected finding was the negative relationship between remember responses and item-non-specific PI. It was reasoned that this finding may simply be a reflection of the mutual exclusivity shared between remember and know responses. However, subsequent correlations between no-overlap sensitivity and remember responses suggested that processes/mechanisms engaged in representing context may become less engaged in influencing task performance when content-interference builds up. An initial positive relationship between no-overlap sensitivity and remember responses (final cycle) disappeared when content-related interference had built up (final cycle). This suggests that when the primary aim of the task is to deal with content-related interference, recollection provides no additional bonus. The finding additionally suggests than a reduced susceptibility to item-non-specific PI has a negative impact on recollection.

Interestingly, the false-alarm data also revealed relationships between remember and know on the one hand, and the covariates on the other. BS was negatively related to remember false alarms. With the additional need to reverse encoded digit strings, BS is more difficult than FS; hence the reduction in the number of items that can be reported backwards. BS may be a more accurate measure of the accuracy with which phonological codes are being stored in memory, particularly as rehearsal is also made more difficult through the need to reverse the digit string. The negative relationship between BS and remember false-alarms may reflect a decreased tendency to accept items of lower activation strength as having appeared during encoding with higher BS. The positive relationship between item-non-specific PI and know false-alarms is consistent with a link to familiarity. The familiarity process works to reduce item-non-specific interference, but it also contributes to false-alarm rate. In contrast, the negative relationship between item-specific PI and know false-alarms suggests that a better ability to recollect reduces the likelihood that a test item will be falsely recognised as a target on the basis of familiarity.

Theories of LTM have presented varying notions concerning the relationship between remember and know responses and memory. One extreme viewpoint suggests that both remember and know responses reflect variability in response confidence (Donaldson, 1996; Dunn, 2004). Given the intricate pattern of interactions between remember and know judgements and both measures of interference here, this view seems unable to adequately describe the relationship between remember and know judgements.

The present findings are more consistent with remember and know reflecting independent processes. Supportive of this stance, remember and know judgements shared distinct relationships with the covariates included in ANCOVA, both in terms of hits and false-alarms. The positive relationship between remember hits and item-specific PI can be accounted for through the common role of context representation. Remember hits will increase if there is a strong contextual signal linked to items held in memory, and strong contextual links also make performance less susceptible to item-specific interference. The negative relationship between remember false-alarms and BS can be accounted for in terms of high BS being related to a reduced tendency to endorse items of reduced activation strength as having been presented. On the other hand, the positive relationship between both know hits and false-alarms, and item-non-specific PI can be accounted for through the common role of content representation. High activation of memory content will lead to know hits (when targets are activated) and false-alarms (when distracters are activated), but to reduced levels of item-non-specific PI (as the content of encoded items is represented distinctly, and is thus easy to distinguish from novel distracters).

3. General discussion

The present experiments demonstrate evidence for a WFME in IM. On later parts of both experiments, participants were less accurate in responding to items that repeated across trials with higher frequencies, and were relatively more accurate at responding to low-frequency items. High-frequency items were associated with both a lower hit rate and higher false-alarm rate than low-frequency items. Scores for items that repeated at a mid-frequency fell in-between the scores for low and high-frequency items. In LTM research, the hit portion of the effect is mainly attributed to the action of recollection, whilst the false-alarm portion is attributed to the action of familiarity. Similar to past studies, the false-alarm portion of the effect emerged first in both experiments of this study. Small changes in the familiarity for different items can influence the false-alarm rate in the absence of an effect on hit rate. A typical frequency effect in the hit data arose later in both experiments.

In addition to this, a remember-know ME was demonstrated. In the hit data for both experiments, remember responses were more frequent than know responses. Although overall effects of remember-know in the false-alarm data failed to reach significance in both experiments, know false-alarms for all three frequencies increased in later blocks in Experiment 4, whereas the remember false-alarm rate remained unchanged: this is consistent with know responses being more likely with misidentified targets. Remember hit responses were more prevalent than know hit responses when recollection was strongly weighted. False-alarms are typically perceived to stem from high levels of familiarity being falsely mistaken as evidence for an item's presentation.

Remember-know responses fit the WFME shown in previous studies (Joordens and Hockley; Reder et al.). High-frequency items registered fewer remember hits relative to low-frequency items as the WFME built up, and the opposite pattern arose for know responses. High-frequency items are associated with a greater number of list contexts (trials) compared with low-frequency items, and this broader contextual fan decreases their recollection relative to low-frequency items. A decreased ability to recollect high-frequency items is concurrently linked with an increase in recognising high-frequency items on the basis of familiarity—the increase in know hits relative to low-frequency items. The pattern in the false-alarm data differed somewhat between experiments, and this is likely due to the extended length of the first experiment. In later blocks of the first experiment, know false-alarms increased in all frequencies. The increase in high- and mid-frequency false-alarms is likely related to the increased familiarity for these items. It is surmised that the increase in low-frequency know false-alarms might be related to a build-up of item-non-specific interference during the condition. Supportive of this supposition, item-non-specific PI was positively related to know false-alarms in the second experiment.

The build-up of the WFME can be directly described in relation to both measures of interference. This is supported by evidence that the interactions involving hit and false-alarm rate and frequency diminished when the analysis accounted for variability in susceptibility to PI. Hit rate in the hit portion of the WFME was positively related to item-specific interference. As the hit portion is believed to be mediated by recollection, this link suggests that item-specific PI and recollection are related. The false-alarm rate in the false-alarm portion of the WFME was positively related to item-non-specific PI. As the false-alarm portion is believed to be mediated by familiarity, this link suggests that item-non-specific PI and familiarity are related.

The relationship between the WFME and both types of interference was even clearer when remember-know judgments were considered. Item-specific interference showed an exclusive positive relationship with remember hits, supporting a common link to context representation. Item-non-specific PI showed an exclusive positive relationship with both know hits and false-alarms, supporting a common link to content representation. Unitization, the binding of intrinsic features into a single whole, has recently being related to familiarity, and the link between unitization and the representation of non-words that has been found in previous studies is present here.

Some of the present results suggest that recollection and familiarity may interact under a small number of circumstances. While the positive relationship between item-non-specific PI and know responses was consistent with both being related to the strength of individual memory representations, item-non-specific PI was negatively related to remember hits. From the perspective of item-non-specific build-up, this finding suggests that a propensity to focus on representing memory content can come at a cost to representing contextual information in memory (reduced ability to remember). From the perspective of the recollection process, correlation revealed that while remember was positively related to no-overlap sensitivity when item-non-specific PI was low, this relationship diminished when item-non-specific PI was high. This suggests that the recollection process can become disengaged from a task when familiarity in connection with unitization is most useful to performance (no-overlap final cycle).

A second finding that suggested a trade-off between recollection and familiarity was the negative relationship between item-specific PI and know false-alarms. The finding suggests that a strong weighting of recollection (linked with reduced susceptibility to item-specific PI) can shield performance from false-alarms based on familiarity. It is noteworthy that these latter suggestions of an interaction between recollection and familiarity may only arise in STM tasks; they are yet to be reported or explored in tasks of LTM. Despite this, however, there was enough evidence to show that both recollection- and familiarity-based processes can have independent effects on memory.

3.1. Implications for the relationship between recollection, familiarity, and control

One particular approach to dual process theory in LTM links recollection to control processes, and familiarity to automatic processes (Jacoby, 1991). If this view is accepted, then item-specific PI can provide an index of control processes, while item-non-specific PI may index automatic processes in memory. In WM research, PI has been related to control (e.g. Bunting, 2006). One possibility here is that only the item-specific measure here is truly related to variability in WM. Perhaps item-non-specific interference is related to variability in verbally-related processing in STM. Such a pattern would preserve the link between control and recollection, and automaticity and familiarity.

Experiment 5 attempted to control for variability in STM through inclusion of the span tasks. Even when these tasks were included as covariates, a positive relationship between knowing and item-non-specific PI remained. This finding would not be expected if variability in item-non-specific PI could be attributed to STM. If further evidence is found to suggest that item-non-specific PI is not related to STM, but instead to WM, then it will question whether recollection and familiarity, and control and automaticity, reflect common processes. Instead it would favour the thoughts of some in LTM research (Gardener and colleagues; e.g. 2006) who suggest that both sets of variables are orthogonal.

Experiments 4 and 5 were successful in replicating the RKME and the WFME in an IM task. The findings were congruent with studies of both effects in LTM. The false-alarm portion of the WFME, reflecting familiarity, developed quickly, whereas the hit portion, reflecting recollection, fully developed in later trials. The remember-know ME was influenced by frequency, giving rise to the RKWFME, demonstrating the validity of both effects. Additional weight that both effects reflect recollection and familiarity came from their predicted relationship with both types of interference: item-specific PI was positively related to remember hits, and to the hit rate in the WFME generally, and item-non-specific PI was positively related to know hits and false-alarms, and to the false-alarm rate in the WFME generally. There was evidence of interaction between both interference effects, in that item-non-specific interference was negatively related to remember hits, and item-specific interference was negatively related to know false-alarms.

Chapter 7

Separating a binding mechanism from an associative mechanism in working memory

Experiments 1-3 suggested that it is possible to dissociate item-non-specific and item-specific interference. It is possible to induce each type of interference separately (Experiments 1-3). Item-non-specific interference is related to manipulations of the content in memory (verbalisation result in Experiment 2a), and reduced susceptibility to item-non-specific PI is related to familiarity (the positive correlation between item-non-specific and know hits and false-alarms in Experiment 5), though the association between item-non-specific and familiarity can have a negative impact on recollection (the negative correlation between item-non-specific and remember hits in Experiment 5). Item-specific interference is related to manipulations of contextual aspects of memory (frequency result in Experiment 2a, and quadratic serial positive curve in Experiment 3), and reduced susceptibility to item-specific interference is related to recollection (the positive correlation between item-specific PI and remember hits), though the association between item-specific and recollection can have an impact on familiarity (the negative correlation between item-specific and know false-alarms in Experiment 5).

This Chapter aimed to test whether the findings in the previous experiments had implications for understanding the relationship between PI and WM. The majority of WM theories suggest that the relationship between PI and WM is mediated by some aspect of controlled processing (e.g. executive control, inhibition). Controlled processing has been argued to be necessary for recollection, not familiarity (stemming from Jacoby's dual process account). Along this line of reasoning, item-specific PI may have a selective association with WM—not item-non-specific PI.

However, it was reasoned that unitization may explain the link between item-non-specific PI and familiarity. Unitization, as described in studies of LTM, is a mechanism responsible for binding intrinsic features into a coherent whole. Binding has also been related to WM, with similar descriptions to those that are ascribed to unitization. More specifically, binding has been related to WMC—which has also been related to PI. Following this latter line of reasoning, it may be item-non-specific PI that is related to WM. However, it was previously shown that item-non-specific PI is related to familiarity, not recollection. This latter line of reasoning goes against the supposed role that control plays in bringing about the WM-PI relationship.

An alternative perspective is presented in the dual-route framework outlined in the current thesis. In this framework, a mechanism within WM operates to bind intrinsic features together, and a further mechanism operates to associate an extrinsic feature with a set of intrinsic features. Both of these mechanisms operate within the WM system; thus both types of interference have the potential to be linked to WM performance. From this perspective, item-specific PI will be associated with a WM task that relies upon the representation of context. In contrast, item-non-specific PI will be related to a task that relies upon the representation of content. At the mechanistic level, the relationship between WM and item-non-specific PI will be mediated by binding, and the relationship between WM and item-specific PI will be mediated by associating.

1. Experiment 6: Item-non-specific is related to binding, and item-specific is related to associating

As in the previous Chapters, both types of interference were measured. In addition to this, four tasks were undertaken:

(1) the operation-span task (OPSPAN), in which participants answered math problems while keeping a set of letters in mind. This task was included in order to assess WMC.

(2) an associative task that required participants to make associations between non-objects and non-words on every trial. This was included in order to provide a direct measure of episodic coding.

(3) FS and BS tasks from Experiment 5 were included as measures of STM.

Several predictions can be outlined. Predictions A and B are based on the assumption that the two types of interference (item-specific and item-non-specific PI) reflect common underlying factors. In contrast, predictions C and D are based on the assumptions of the dual coding model, that the two types of interference reflect distinct underlying processes and mechanisms.

Prediction A: If the two manipulations of interference operate on STM, and are related to variability in the phonological store and loop for example, then both interference measures will be related to FS and BS (see Table 3, A). The interference measures will be less related to OSPAN and the associative task, as these have been claimed to be better measures of WM.

Prediction B: If the manipulations of interference are mediated by WMC, and there is no distinction in the cognitive processing related to binding and associating, then the two types of interference should each be related to both OSPAN and associative memory (Table 3, B). Interference should then be less related to STM.

Prediction C: If item-non-specific is truly related to object coding, and OSPAN is more related to variability in episodic rather than object coding, then item-specific will share a relationship with both OSPAN and the associative task, and item-non-specific may be more related to STM (Table 3, C).

Prediction D: If item-non-specific is more related to variability in binding rather than activation strength in STM, and WMC is more related to object rather than episodic coding, then item-non-specific and WMC may share a distinct relationship mediated through object coding and binding. In contrast, item-specific and the associative task may share a distinct relationship mediated through episodic coding and associating (Table 3, D).

Table 3: Potential formulations of the relationship between interference, STM, associative memory, and WMC

		Complex span	Associative task	Forward span	Backward span
Item-non-specific	A			+ +	+ +
	B	+ +	+ +		
	C			+ +	+ +
	D	+ +			
Item-specific	A			+ +	+ +
	B	+ +	+ +		
	C	+ +	+ +		
	D		+ +		

1.1. Method

Participants: 56 participants, age-range 17-31, took part in the experiment in exchange for course credit.

Design: 6 tasks were completed in two sessions: two PI tasks (same procedure as in previous experiments), the OSPAN task, an associative task, and FS and BS.

Detailed instructions on the OSPAN are available from Conway, Kane, Bunting, et al. (2005). Briefly, participants carry out simple mathematical operations, (e.g., 18 + 11) and in-between each operation, a letter is presented that has to be encoded. At the end of the trial, participants have to select, from an array, the letters they had seen during the trial. Trials show between 3 and 7 operations; thus letter span varies between 3 and 7. Three trials test letter span at each load, and the various loads are intermixed. Three primary measures are calculated. The first measure is the proportion of math problems solved correctly. It is suggested that only participants who achieve a score of 85% or above on the math problems should be included in further analyses in order to insure a valid measure of complex-span. The second measure is the total number of letters correctly recalled, independent of position recall. The third measure is the total number of letters recalled in their correct position. Prior work has found little differential effect of which measure of letter span is taken with regard to how OSPAN is related to other tasks. As a consequence, the total number of letters recalled correctly independent of position was used here (including the other measure had little effect on the analysis).

In the associative task, participants were presented with three pairings of non-objects and non-word pairs on every trial (see Figure 18). The items in each pair were presented concurrently, the non-word just below the non-object. Each pair appeared for 3 seconds, with a gap of 1.5 seconds between each pair to allow for better consolidation in memory. In the recognition memory test, 6 pairings were shown sequentially. Some were intact pairs that had been presented during the initial encoding phase and some pairs were distracter pairs. There were two types of distracter pair. One type consisted of new items not presented at the encoding phase (novel pair). The second type was created by recombining items from pairs that were shown during encoding (recombined pair).

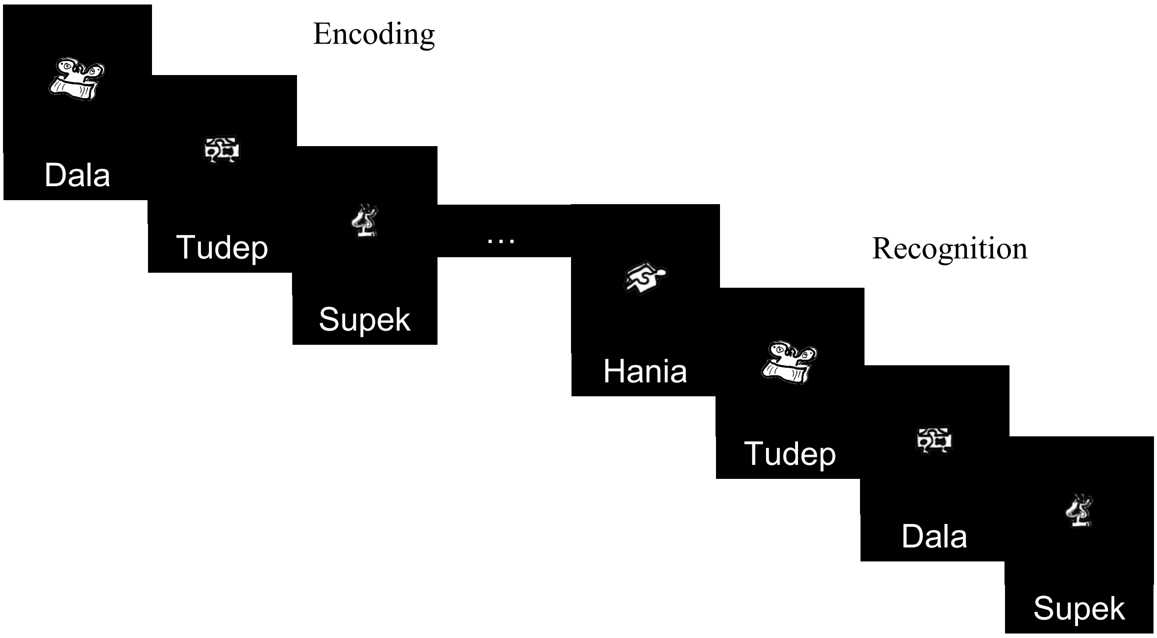

Figure 18: The procedure of the associative memory task

Procedure: The two non-word tasks were completed in one session, with FS and BS being completed in-between. OSPAN and the associative task were completed in the other session. The order in which participants completed both sessions was counterbalanced, as was the order of tasks within each session. For FS and BS, participants were instructed to type in the digits seen during a trial in the same order for FS, and in reverse order for BS. For the OSPAN task, emphasis was placed upon reporting the letters in the same order as presented. In the associative task, participants had three keys to select from. One key was specifically for those pairs that participants perceived as intact. Recombined pairs were ascribed to a further key. The final key represented novel pairs.

1.2. Results

Six participants failed to reach the 85% criterion on the math operations in the OSPAN. As the focus of the analysis was on the relations between tasks, the data sets of these participants were excluded from all analyses. The analysis was divided into three parts:

1. The first analysis summarised the standard effects of each task;
2. The second analysis was a factor analysis that tested the relationship between item-non-specific and item-specific PI, and the other four covariates;
3. The first part of the third analysis applied ANCOVAs to investigate the relationship between the covariates (FS, BS, OSPAN, and the associative task), and the variables overlap and cycle in the non-word tasks. The second part of the third analysis looked directly at the relationship between the build-up of item non-specific PI, the build-up of item-specific PI, and the four covariates.

1. Standard analysis

Non-words: Table 4 shows the sensitivity scores in the overlap and no-overlap presentation conditions at each level of cycle. Main effects of both overlap and cycle were present, F (1, 49) = 33.81, $p < .001$ and F (1, 49) = 49.94, $p < .001$ respectively, but there was no interaction ($p > .8$).

Table 4: Sensitivity as a function of overlap and cycle

	First cycle		Final cycle		PI build-up	
	M	*SD*	*M*	*SD*	*M*	*SD*
No-overlap	3.94	1.04	3.26	1.17	-0.68	1.14
Overlap	3.22	1.05	2.53	1.43	-0.69	0.90

Associative task, OSPAN, FS and BS: The literature connects the ability to reject recombined pairs as having not been presented during encoding with recollection (e.g. Kirwan & Stark, 2004) since both parts of the recombined pair will elicit familiarity; participants must recollect that both parts were presented with other items during encoding. Increased sensitivity to intact pairs is also reliant on recollection; however, intact pairs may also be signalled from their familiarity alone. To reflect the variability in recollection from these data, recombined hits were amalgamated with recombined false-alarms to intact items to provide a measure of recombined sensitivity. The descriptive statistics for the tasks are shown in Table 5. For FS and BS, the total score (14) represented the number of trials that participants could potentially complete (forward, 3-9 x 2; backward, 2-8 x 2). In the OSPAN task, the score represents the total number of letters recalled in the correct order, while the total represents the number of letters recalled.

Table 5: Total scores for each task in brackets. OSPAN Score = number of letters recalled in the correct order; Total = number of letters recalled independent of order

		M	*SD*
OSPAN	Score (80)	37.64	17.57
	Total (80)	54.90	14.06
Forward	Score (14)	8.50	2.71
Backward	Score (14)	8.14	2.84
Recombined	Sensitivity	1.53	0.94

2. Factor analysis

Table 6 shows the relationship between the covariates. D-recombined was not significantly related to either FS or BS, but the other correlations were significant. A factor analysis was undertaken to assess the underlying structure of processes contributing to item-specific and item-non-specific PI. The variables considered were the effects of cycle in the overlap and no-overlap conditions (the measures of item-specific and item-non-specific PI), FS and BS, and OSPAN and d-recombined. In line with the predictions set forth in Table 3, four underlying factor structures were possible. If both measures of interference were related to STM, not WM, then a two factor solution was likely (the STM measures and the interference measures aligned with one factor, d-recombined and OSPAN aligned to the other). A two factor solution would also be anticipated if the interference measures shared an equal relationship to WM, or if only item-specific PI was related to WM. The final alternative is that item-non-specific and item-specific are differentially related to binding and associating, in which circumstance it seemed possible that WMC might align with item-non-specific, and d-recombined with item-specific.

Table 6: The pattern of correlation between the four covariates

		BS	OSPAN	D-recombined
FS	*r*	**0.426**	**0.289**	0.120
	p	0.002	0.042	0.405
BS	*r*		**0.304**	0.178
	p		0.032	0.216
OSPAN	*r*			**0.315**
	p			0.026

A principle component analysis was conducted that relied on factors having an Eigenvalue above 1, and a varimax rotation was applied. The final solution yielded three factors that each accounted for a similar percentage of variability in the data: factor 1, 26.08%; factor 2, 23.56%; factor 3, 22.69%—the three factors overall accounting for 72.33% of the variability in the data. Table 7 shows the rotated component matrix. Given that both F- and BS exclusively loaded on the first factor, this factor can be said to be a measure of STM. Item non-specific PI and OSPAN loaded on the second factor; item-specific PI and d-recombined loaded on the third factor.

Table 7: The three factors in the rotated component matrix (INS = item-non-specific; IS = item-specific)

	Factor 1	Factor 2	Factor 3
FS	**0.755**	-0.009	0.231
BS	**0.860**	0.140	-0.134
INS	-0.115	**0.889**	-0.241
IS	-0.140	-0.048	**0.809**
OSPAN	0.375	**0.776**	0.257
D-recombined	0.285	0.002	**0.714**

3. Covariate analysis

As expected, FS and BS were included in the same factor, signalling their association with STM variation. The resultant factor scores of their association (factor 1) were included as a covariate along with OSPAN and d-recombined in the analysis for the non-word tasks. With the addition of the three covariates, an overall effect of overlap was no longer reliable (p = .450). An effect of cycle remained however—F (1, 46) = 24.85, p < .001. Cycle interacted with OSPAN and STM, F (1, 46) = 12.77, p = .001 and F (1, 46) = 6.02, p = .018 respectively. Three-way interactions between OSPAN, d-recombined, and overlap and cycle were also present: OSPAN, F (1, 46) = 12.99, p = .001; d-recombined, F (1, 46) = 12.43, p < .001. However, an interaction between overlap and cycle arose, F (1, 46) = 4.56, p = .038.

The three-way interactions were decomposed into two one-ways ANOVAs assessing the effect of cycle at each level of overlap. In the no-overlap condition, both OSPAN and d-recombined interacted with cycle: OSPAN x cycle, F (1, 46) = 24.75, p < .001, d-recombined x cycle, F (1, 46) = 9.33, p = .004. In the overlap condition, cycle only interacted with d-recombined, F (1, 46) = 4.23, p = .045 (OSPAN x cycle, p = .862). The correlations underlying these interactions are shown in Table 8. While OSPAN became more related to no-overlap when interference had developed (in the final cycle), d-recombined had become less related to performance. The degree of shared variability between overlap and d-recombined increased after interference had built up (in the final cycle).

Curiously, the covariates were better able to account for variability in the overlap cycle: no-overlap, F (1, 46) = 23.80, p < .001 (without covariates, F = 17.80); overlap, F (1, 46) = 3.63, p = .063 (without covariates, F = 29.74). This pattern is reflected in the overlap x cycle interaction that became significant upon the addition of the covariates. The STM x cycle interactions were based on small effects. The direction of the relationship changed between cycles 1 and 2 (positive to negative), but the magnitude of relationship was small (p = .546 to p = .269).

Table 8: The relationship between OSPAN, d-recombined, and the levels of cycle in no-overlap and overlap

		No-overlap		Overlap	
		First cycle	Final cycle	First cycle	Final cycle
OSPAN	r	-0.073	0.538	0.157	0.100
	p	0.622	< .001	0.285	0.497
D-recombined	r	0.587	0.191	0.406	0.476
	p	< .001	0.194	0.004	0.001

Given that the factor analysis had demonstrated the validity of the slope measures collected through subtracting the first from the final cycle in each level of overlap, it was of interest to see how these measures would also relate to the covariates, see Table 9. As was evident in the Factor analysis, OSPAN was positively related to item-non-specific PI, and d-recombined was positively related to item-specific PI. The previous interaction between cycle and STM showed up as a negative relationship between STM and the magnitude of interference build-up.

Table 9: The relationship between the slope measures of PI, and the covariates

		Item-non-specific	Item-specific
STM	*r*	-0.340	
	p	0.018	
OSPAN	*r*	0.592	-0.026
	p	< .001	0.863
D-recombined	*r*	-0.411	0.290
	p	0.004	0.046

1.3. Discussion

The present study revealed several novel findings:

a. Build-up in item-non-specific and item-specific interference (as measured by the drop from the first to the final cycle in no-overlap and overlap respectively) were associated with distinct patterns in the data that suggested dissociation between two WM-related mechanisms;

b. The factor analysis and the covariate analysis provided evidence for a positive relationship between OSPAN and measures related to item-non-specific PI (the final cycle in the no-overlap condition, and the item-non-specific slope [final cycle – first cycle]);

c. The factor analysis and the covariate analysis indicated a positive relationship between d-recombined and measures related to item-specific PI (the final cycle in the overlap condition, and the item-specific slope [final cycle – first cycle]);

d. The factor analysis also indicated that STM was not directly related to interference. Nevertheless, the STM factor was negatively related to the degree of build-up of interference (the drop from the initial to the final cycle);

e. There were distinct patterns of association between item-non-specific interference and OSPAN, and between item-specific interference and d-recombined. These associations support the argument that separate processes and mechanisms are linked to the two types of interference. Moreover, d-recombined showed a negative relationship to item-non-specific PI. It would therefore seem that the processes and mechanisms that underlie OSPAN and d-recombined can interact, and negativity influence one another.

1.3.1 Factor analysis

The analysis revealed a three factor structure linking (i) FS and BS, (ii) OSPAN and item-non-specific PI, and (iii) d-recombined and item-specific PI. The link between the first set of variables is likely to be related to STM. FS is argued to reflect processing within the phonological store and loop (Baddeley, 2000; 2003), and while it has been suggested that BS is more related to processing in executive control than in the phonological store and loop (e.g., Groeger, Field, & Hammond, 1999), the current measures confirmed a closer association to STM than WM. The factor analysis confirmed a separation between STM and WM in extracting a distinct factor for STM.

The second factor revealed by the analysis pulled together the OSPAN measure and item-non-specific PI. The link between these two variables is likely to be related to binding. Item-non-specific PI was linked to unitization in the previous Chapter through its association with familiarity. OSPAN has been taken to as an index of WMC (e.g. Engle, 2002), and one interpretation of WMC suggests that it is related to the ability to bind items in WM. In the dual-route framework proposed in this thesis, WM is endowed a specific mechanism for binding intrinsic features to form a coherent whole, and this mechanism can account for the relationship between item-non-specific PI and OSPAN.

The third factor revealed by the analysis encompassed item-specific PI and d-recombined, and this factor is likely to be related to the coding of context. Item-specific PI was linked to context in the previous Chapter through its correlation with recollection. Sensitivity to recombined pairs reflects the ability to distinguish between the contexts in which items were initially presented during encoding. Although participants are familiar with the items that make up recombined pairs, they are sensitive to the fact that each part of the part was presented with a different extrinsic feature during encoding. This sensitivity relies heavily on the coding of context. In the dual-route framework, WM possesses a specific mechanism for binding an extrinsic feature to a set of intrinsic features, and this mechanism can account for the relationship between item-specific and d-recombined.

1.3.2 Covariance analysis

OSPAN and d-recombined interacted with overlap and cycle. These results were consistent with the picture emerging from the factor analysis. The factor analysis pointed to OSPAN and item-non-specific PI sharing a common mechanism. Matching this, OSPAN showed a stronger relationship with performance when item-non-specific PI was strong (final cycle > first cycle, no-overlap condition). The factor analysis also showed that the d-recombined measure and item-specific PI share a common mechanism: d-recombined showed a stronger relationship with performance when item-specific PI was strong (relation to d-recombined in final cycle > first cycle). The factor analysis also indicated that STM reflected a factor independent of the PI effects. STM measures (span tasks) were weakly related to sensitivity in the non-word conditions. In fact, STM was negatively related to the magnitude of PI. This contrasts to the pattern between PI and the two WM tasks. Apparently the recruitment of STM can lead to a build-up in interference generally, when the influence of WM is controlled for. The finding nicely showed that processing with STM cannot offset the build-up of interference: only mechanisms within WM can fulfil this function.

There is a similarity in the relationship between d-recombined and measures related to item-non-specific PI in this experiment, and the relationship between remember and measures related to item-non-specific PI in the previous experiment. The first no-overlap cycle was positively related to both remembers and d-recombined, the final no-overlap cycle showed less of a relationship to both variables, and the item-non-specific slope was negatively related to both variables. This pattern is consistent with the proposal that the recollection process can disengage from a task when the primary requirement of that task is to bind intrinsic features together.

Finally, it is worth noting that the covariates (OSPAN, d-recombined, STM) were better able to account for variability in PI in the overlap condition compared with the no-overlap condition. An effect of cycle was no longer reliable upon the addition of the covariates in the overlap condition while an effect of cycle was highly significant in the no-overlap condition. These differences between the two levels of overlap suggest that although a process indexed by OSPAN influences the magnitude of item-non-specific build-up, there is another source of variability that also contributes to the magnitude of item-non-specific build-up.

1.3.4 Proactive interference is not unitary

The findings fail to fit with what would be expected on the basis of current theories of the relationship between PI and WM. These accounts (Engle, 2002; Postle et al., 2004ab; Jonides & Nee, 2006; May et al., 1999; Cowan et al., 2005) fail to distinguish between interference related to content and context. Instead they describe the relationship between interference and WM in terms of a third variable.

Ecker et al. have argued that WM involves the coding of the intrinsic features of stimuli in memory, the letters in a non-word, for example, along with coding the associations between items and an extrinsic feature; for example, temporal context, or forming an association between a picture and a word. Furthermore, they argue that the coding of intrinsic features is related to familiarity, and the coding of extrinsic features to recollection. In the light of their approach, the relationship found here between item-non-specific interference and familiarity suggests that item-non-specific PI reflects variability in the binding of intrinsic features. In contrast, the relationship between item-specific interference and recollection connects this type of interference to variability in the association of intrinsic to extrinsic features.

It follows that the relevant processes engaged in mediating PI are recollection and familiarity; and the relevant mechanisms that support these processes are associating and binding. Item-non-specific interference is mediated through the familiarity process: as more items from the same category are presented, performance becomes increasingly reliant on the degree to which participants bind the intrinsic features of each item to form unique representations in memory—the degree to which the familiarity process and the binding mechanism are engaged. Item-specific interference is mediated through the recollection process: as the same items become linked to an increasing number of similar temporal context, performance becomes increasingly reliant on the degree to which participants associate each non-word with the list context—the degree to which the recollection process and the associative mechanism are engaged.

1.3.5 Implications for working memory theory

Much current WM research focuses on the topic of binding, and questions how some features are bound to the same object in memory, yet objects are still represented separately from one another. For example, Allen et al. (2009) failed to find a greater requirement of attention for binding relative to feature coding, and suggested that feature binding might be automatic. This concerned them, as it suggested the potential for perceptual chaos, if all features are bound automatically. The difficulty here might be solved, however, if there is a division between two mechanisms responsible for forming integrated representations, one that focuses on binding intrinsic features into a coherent whole, and the other that focuses on relating a related set of intrinsic features to an extrinsic feature with which a specific relationship is shared.

This reasoning is in part integrated in a model of binding by Raffone and Wolters (2001). Like others (e.g., Engle & Singer, 2001), they attribute the binding of features to synchronization in neural firing. Raffone and Wolters suggest that as features synchronize to become part of the same object, the underlying signals that correspond to each feature begin to oscillate at the same frequency. Features oscillating at one frequency fall out of phase with other features oscillating at different frequencies, a process that they describe as desynchronization. They argue that a combination of both processes will prevent perceptual chaos, and that the balance of both processes might account for the capacity limit in WM; hence the implication that binding is directly related to WMC. However, this account describes synchronisation and desynchronization as flip sides of the same coin. From the perspective of a dual-route approach, dessynchronization may be realised when the association between an intrinsic set of features and an extrinsic feature begin to take on a different pattern of oscillation to an alternative intrinsic-extrinsic association.

If indeed there are two mechanisms within the WM system that alleviate perceptual chaos, then future research on capacity limitations in WM will need to focus on both. A further implication of such a change in focus would be the acknowledgment that variability captured in OSPAN may not necessarily cover all aspects of the limitations placed on WM. The suggestion that recollection also plays a role in WMC has already been made (Oberauer, 2005); thus future research will likely focus on the independent contributions of both recollection and familiarity to WMC.

Beyond the implications for understanding the construct of WMC, the findings also imply that our current understanding of how executive control and attention operate in WM is limited by the fact that a separation in how content and context are represented is not yet integrated with these constructs. In line with the arguments of Asseln and colleagues (2006), control and automaticity should be perceived as dichotomous variables. A strict association between controlled attention and recollection on the one hand, and automaticity and familiarity on the other, does not however fit the current data. Controlled attention, as measured by complex-span, was related to item-non-specific PI, which was previously shown to be related to familiarity (in know judgements). Controlled attention (OSPAN) failed to show a positive relationship with item-specific PI, and item-specific PI was previously shown to be related to recollection (in remember judgements). Treisman and Zhang did however suggest that attention could influence the binding of intrinsic features in memory, implying, in the current context, a link between executive control and familiarity. In LTM, proponents of the remember-know procedure have shown links between recollection and automaticity (as described in Chapter 3), and they in fact argue that control and automaticity are orthogonal to recollection and familiarity. Their arguments fit with the findings of the current data, as the current data also suggest that control and automaticity may be orthogonal to mechanisms that are involved in associating and binding.

An unanswered puzzle relates to the covariates being better predictors of variability in the effect of cycle in the overlap condition rather than in the no-overlap condition. Some other variable must be contributing to the effect of cycle in the no-overlap condition. The measurements taken here attempted to account for (i) variability in recollection and familiarity, which, it is argued, are directly related to associating and binding, and (ii) variability in controlled attention (OSPAN). The only variable which was not independently measured was automaticity. It is interesting to speculate that bottom up differences in the perceptual system, operating outside the arm of executive control, may be a further source of variation in item-non-specific interference.

Current theories of the relationship between PI and WM suggest that this relationship is mediated by a common process or mechanism. The findings here of distinct causal pathways mediating the relationship between item-non-specific PI, item-specific PI, and performance favour a dual route account of the PI-WM relationship. The relationship between item-non-specific PI and WM may be mediated by a mechanism responsible for binding intrinsic features that contributes to the process of familiarity. The relationship between item-specific PI and WM may be mediated by a mechanism responsible for associating a bound set of intrinsic features to an extrinsic feature that contributes to the process of recollection. The findings support the distinction between episodic and object codes, and the implications this distinction has for understanding how both intrinsic and extrinsic features are represented in memory. Within the WM system, PI has been related to WMC. Given a dual route account, there is now some uncertainty as to the cause(s) of WMC. Possibly WMC, and the variables often shown to be correlated with it –for example, intelligence (Bunting, 2006)– should be looked at in relation to both binding and associative mechanisms.

Chapter 8

Binding and associating in relation to schizotypy traits

In Chapters 5 and 6, evidence suggested that content-related interference and context-related interference are independent effects. Content-related interference was related to the strength of activation of items in memory (vocalising the items increased item strength, delaying the build-up of content-related interference), and to know responses (which represent a measure of familiarity for content). Context-related interference was related to the frequency with which items repeated across trials (high-frequency items are associated with a greater number of trials/ contexts; thus are harder to recognise), to remember responses (which represent a measure of recollection for context), and the serial position curve in the overlap condition in which this type of interference was measured was quadratic in nature (interference build-up was highest in those positions for which it is harder to code temporal position).

Chapter 7 tested the hypothesis that content-related interference is related to a mechanism in WM that is responsible for binding intrinsic features into a coherent whole, and that context-related interference is related to a mechanism in WM that is responsible for associating a bound set of features to an extrinsic feature. This hypothesis was confirmed. Content-related interference loaded on the same factor as a measure of complex-span, a task that has been related to WMC, and that has been suggested to be related to binding. Context-related interference loaded on the same factor as a measure of associative memory, and associative tasks are related to recollection, and therefore to the proposed associative mechanism. Covariation between complex-span and no-overlap (in which content-related interference was measured) increased when PI was highest (final cycle > first cycle). Conversely, covariation between associative memory and overlap (in which context-related interference was measured) increased when PI was highest. Importantly, the two factors that related to binding and associating were separate from a third factor that described variability in ST verbal related processing, reinforcing the association between PI and WM specifically.

In this Chapter, an attempt was made to relate schizotypy traits to the two mechanisms proposed to exist in WM: a binding mechanism and an associative mechanism. As reviewed in Chapter 4, there is some suggestion that positive traits are related to a more active binding mechanism (Rawlings & Claridge; Goodarzi et al.). Coupled with this, however, there is additional evidence that relates positive traits to a reduced tendency to make associations (Steel et al., 2002; 2007). Based on the findings in this thesis, it would be predicted that positive traits will be related to better performance when performance is more dependent on the binding mechanism, and poorer performance when performance is more reliant on the associative mechanism. Chapter 4 also reviewed some evidence that suggested that negative traits are often linked to oppositional patterns in cognitive data to positive traits (Tsakanikos & Claridge, 2005; Mohr et al., 2005), and that, specifically, negative traits might be related to reduced reliance on binding (Tsakanikos & Reed, 2003; Gooding & Braun). In accordance with the data here, if negative traits do show an oppositional pattern in cognitive data to positive traits, then negative traits will be related to increased reliance on the associative mechanism and reduced reliance on the binding mechanism. Alternatively, they may simply differ from positive traits in measures of the binding mechanism.

Participants completed the O-Life, which generates four traits: *unusual experiences*, *introvertive ahedonia*, *cognitive disorganisation*, and *impulsive non-conformity*. The former two traits measure patterns in behaviour that are consistent with positive and negative symptoms in schizophrenia; for example, the former picks up on hallucination proneness, and the latter picks up on a lack of social engagement. For ease of reading, these will be referred to as positive and negative traits in the text. Although there were no expectations of how the latter two traits would relate to the memory measures, it was considered prudent to include them in some form of analysis to ascertain whether any relationships were present.

1. Experiment 7: The relationship between interference and schizotypy

The initial experiments (1-3) that suggested a distinction between the two mechanisms in WM looked at PI susceptibility. Reduced susceptibility to content-related interference, as indicated in a reduced drop in performance from the first cycle in the no-overlap condition to the final cycle, and higher levels of performance in the final cycle, became related to binding. Reduced susceptibility to context-related interference, as indicated in a reduced drop in performance from the first to the final cycle in the overlap condition, and higher levels of performance in the final cycle, became related to associating. If positive traits are related to a more active binding mechanism, then these traits should be positively related to a reduced build-up of content-related interference (a reduced drop from the first to the final cycle), and better performance in the final no-overlap cycle. If a negative relationship between positive traits and associating exists, then these traits should be related to an increased build-up of context-related interference (an increased drop from the first to the final cycle), and poorer performance in the final overlap cycle. If negative traits are reversely related to the two mechanisms, then the opposite patterns in the data would arise. Alternatively, negative traits may simply be related to an increased build-up of content-related interference, and poorer performance in the final no-overlap cycle.

A large sample completed the O-Life, and two approaches were taken in relating schizotypy traits to the memory measures. One approach was group-based. A positive group was formed through splitting the data collected on the unusual experiences measure at the median, and only including participants above the median in this group. A negative group was formed through splitting the data collected on the introvertive ahedonia measure at the median, and only including participants above the median in this group. In the group analysis that compared the positive and negative groups, the data collected in two of the previous Chapters in the same experiment (Chapters 6 and 7) was included in the form of a control group. Mason and colleagues have shown that the traits measured by the O-Life are normally distributed in the population; thus a random sample of participants would be expected to have scores converging on mean levels of positive and negative traits. The inclusion of the control group is useful, as it provides a baseline against which to compare the positive and negative groups.

The second approach to the analysis was regression-based. All four traits of the O-Life were included as predictors of memory-related variables. There were no pre-ordained hypotheses on how cognitive disorganisation and impulsive non-conformity might be related to the memory measures, but their inclusion in the analysis was worth-while in an effort to test whether such relationships might exist, and in an effort to ensure the specificity in the relationships between positive and negative traits and the memory measures.

1.1. Method

Participants: 80 participants took part in this experiment in exchange for course credit, age-range 18-28. 20 participants were selected to form the positive group, as they had above median scores on positive traits and below median scores on negative traits. 20 further participants were selected to form the negative group, as they had above median scores on negative traits and below median scores on positive traits. The final 40 participants that were not included in the group analysis were included in the regression analyses along with the participants in the two groups.

Table 10 shows the means and standard deviations on unusual experiences and introvertive ahedonia in the positive and negative groups. Z-scores are provided to allow for a comparison across measures: an effort was made to have the positive and negative groups differing to the same degree, but in opposite directions, on positive and negative traits. Table 11 shows the normative O-Life data on unusual experiences and introvertive ahedonia. The means in the positive group fell in the 75th percentile with regard to unusual experiences, and in the 25th percentile with regard to introvertive ahedonia. The means in the negative group fell in the 75th percentile with regard to introvertive ahedonia, and in the 25th percentile with regard to unusual experiences.

Table 10: Descriptive data on unusual experiences (UE) and introvertive ahedonia (IA) in the positive and negative groups

	M		*SD*		*zM*		*zSD*	
	UE	IA	UE	IA	UE	IA	UE	IA
Positive group	15.00	2.20	3.45	1.58	0.77	-0.84	0.55	0.39
Negative group	4.40	7.40	2.56	1.70	-0.91	0.47	0.41	0.43

Table 11: Normative data on UE and IA scores (collapsed across gender) as described by Mason and Claridge (2006)

	UE		IA	
25th percentile	4		2	
M (*SD*)	10.14	(6.28)	5.54	(3.99)
75th percentile	15		7.5	

Design and procedure: Identical versions of the no-overlap and overlap conditions as described in previous Chapters were completed in a single session. The first five trials in each condition were averaged to form the first level of the factor cycle, and the final five trials in each condition were averaged to form the final level of cycle. In the group analysis, overlap and cycle were included in a split-plot design with the factor group. Group had three levels: positive, negative, and control. In the regression analysis, one set of regressions was run in which the four O-Life traits were included. In another set of regressions, STM measures of verbal-related processing (BS and FS) were included in addition to the O-Life traits in order to account for variability in verbal related processing, and to ensure the effects were specific to the WM system[1]. Here, the analyses in which STM scores are included (data on 64 participants) are reported.

1.2. Results

The first part of the analysis was group focused, and looked at the relationship between overlap, cycle, and group. The second part of the analysis was regression based, and included all four variables of the O-Life in addition to the STM measures. Main effects were similar to those reported previously: overlap, F (1, 147) = 40.28, p

[1] The studies in this Chapter were run in the same time frame as the experiments in the previous Chapters. When the benefit of controlling for STM was realised, an effort was made to have participants return to complete to span tasks. 80% of participants in this experiment completed the span tasks.

< .001; cycle, F (1, 147) = 92.19, p < .001 (overlap x cycle, p = .752). The three-way interaction between overlap, cycle, and group was significant, F (2, 147) = 4.45, p = .013, see Figure 19. Overlap and cycle interacted in the positive and negative groups: positive, F (1, 19) = 5.78, p = .027; negative, F (1, 19) = 4.23, p = .054 (control, p = .536). In the positive group, the effect of cycle was smaller in the no-overlap condition, t (19) = 3.27, p = .004 (overlap, t (19) = 6.80, p < .001). In the negative group, the effect of cycle was smaller in the overlap condition, t (19) = 2.54, p = .020 (no-overlap, t (19) = 8.34, p < .001).

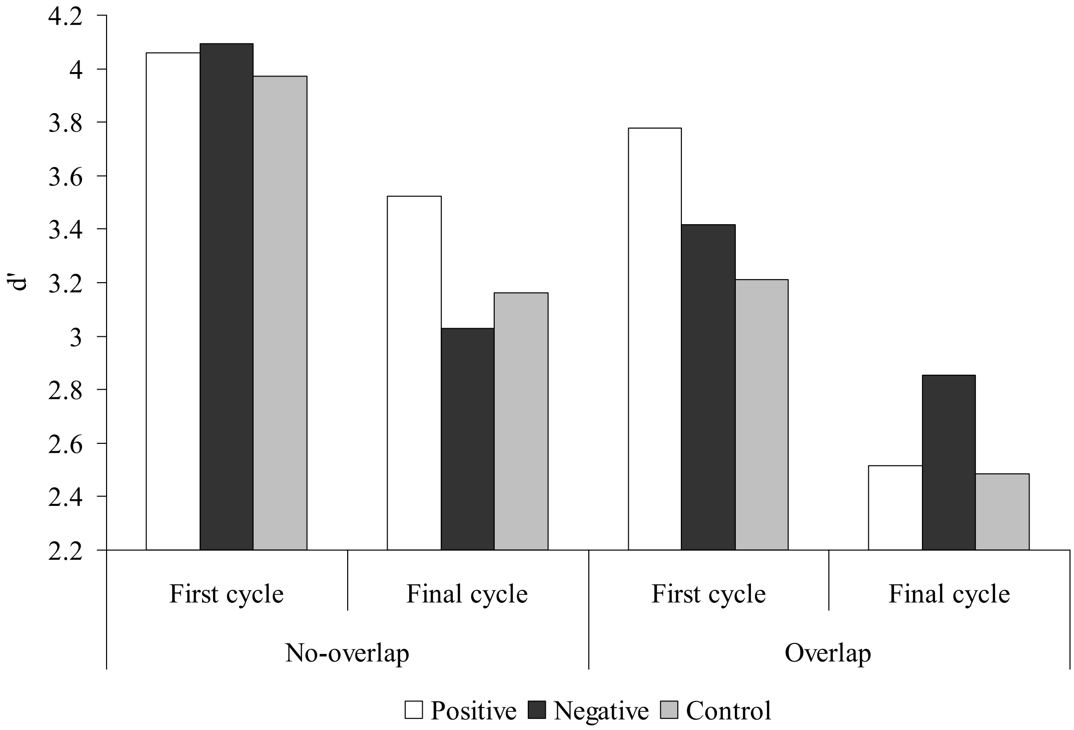

Figure 19: Sensitivity in the no-overlap and overlap conditions in each group

The decreased drop in the no-overlap condition in the positive group seemed to be related to a group difference in the final no-overlap cycle. Conversely, the decreased drop in the overlap condition in the negative group seemed to be related to a group difference in the final overlap cycle. These effects were tested for through analysing the data from each final cycle separately. In order to ensure that the group effects in each cycle were independent of one another, the final overlap cycle was included as a covariate in the analysis of the final no-overlap cycle and vice versa. In the final cycle of the no-overlap condition, the positive group was compared to the negative and control group combined, and there was a tendency for the positive group to show higher levels of sensitivity in the final cycle relative to the negative and control groups, F (1, 147) = 2.68, p = .104. In the final cycle of the overlap condition, the negative group was compared to the positive and control group combined, and there was a tendency for the negative group to show higher levels of sensitivity in the final cycle relative to the positive and control groups, F (1, 147) = 3.36, p = .069.

In summary, the positive group showed a reduced effect of cycle in the no-overlap condition. In the final cycle of the no-overlap condition, they tended to perform better than the other groups. They performed similarly to the control group in the overlap condition. The negative group showed a reduced effect of cycle in the overlap condition. In the final cycle of the overlap condition, they tended to perform better than the other groups. They performed similar to the control group in the no-overlap condition. In all these aspects, the positive and negative groups were showing reversed patterns in performance.

Regression analysis

The group analysis suggested that positive traits are related to better sensitivity in the final no-overlap cycle, and that negative traits are related to better sensitivity in the final overlap cycle. It would therefore be expected that positive traits will be related to higher levels of sensitivity in the final no-overlap cycle. Conversely, negative traits would be expected to be related to higher levels of sensitivity in the final overlap cycle. Two regressions were run (backward method), separately for no-overlap final cycle and overlap final cycle, with the predictors of interest being the four traits.

In order to ensure that the relationships between traits and each level of overlap could not be accounted for by the other level of overlap, no-overlap final cycle was added as a predictor of overlap final cycle and vice versa. Through doing this, it was more certain that the relationships being observed between traits and each level of cycle were specific to that level. To control for variability in STM, the span tasks were additionally included.

With no-overlap final cycle as the dependent variable, the regression analysis excluded all but two variables from the final model: positive traits and the final overlap cycle—$R = .497$; $F(2, 66) = 10.82$, $p < .001$. Positive traits showed a positive relationship with the final no-overlap cycle, $t = 1.90$, $p = .061$ (as did the overlap final cycle, $t = 4.19$, $p < .001$). With overlap final cycle as the dependent variable, the regression analysis yielded three predictors: negative traits, forward span, and the final no-overlap cycle—$R = .539$; $F(3, 65) = 8.86$, $p < .001$. Negative traits showed a positive relationship to the final overlap cycle, $t = 1.93$, $p = .058$ (as did the no-overlap final cycle, $t = 4.19$, $p < .001$, and forward span, $t = 1.86$, $p = .067$). The patterns in the data provided direct support for the findings in the group analysis. Positive traits were related to higher sensitivity levels in the final no-overlap cycle, and negative traits were related to higher sensitivity levels in the final overlap cycle.

1.3. Discussion

Positive traits were related to better sensitivity in the no-overlap condition. The positive group endured a smaller build-up of interference in the no-overlap condition relative to the overlap condition (the drop from the first cycle to the final cycle). Their sensitivity in the final cycle of the no-overlap condition tended to be better than the sensitivity in the other groups. In the regression analysis, positive traits were positively related to sensitivity in the final no-overlap cycle. In the overlap condition, their performance matched that of the control group.

Negative traits were related to better sensitivity in the overlap condition. The negative group endured a smaller build-up of interference in the overlap condition relative to the no-overlap condition. Their sensitivity in the final cycle of the overlap condition tended to be better than the sensitivity in the other groups. In the regression analysis, negative traits were positively related to sensitivity in the final overlap cycle. In the no-overlap condition, their performance matched that of the control group.

Positive and negative traits showed a reversed pattern in their relationship to the no-overlap and overlap conditions when interference was highest (final cycle). In previous Chapters, the drop from the first to the final cycle in no-overlap, and performance in the final no-overlap cycle was described in relation to binding. A more exact binding of the intrinsic features of each non-word is related to a reduced build-up of content-related interference (as is shown in a decreased drop from first to final cycle), and better performance when the potential for content-related interference is high (no-overlap final cycle). Using this interpretation as a framework, it would seem that positive traits are related to a more active binding mechanism, as was expected. There was no evidence of a relationship between positive traits and a less active associative mechanism.

The drop in the overlap condition from the first to the final cycle, and performance in the final overlap cycle was related to associating in previous Chapters. More exact associations between each non-word and the temporal context in which each non-word is presented is related to a reduced build-up of context-related interference (as shown in a decreased drop from first to final cycle), and better performance when the potential for context-related interference is high (overlap final cycle). Using this interpretation as a framework, it would seem that negative traits are related to a more active associative mechanism. Based on past findings, this result was not anticipated, although it is in keeping with some cognitive patterns that have been found in relation to positive and negative traits, in that it is a finding opposite to that found in relation to positive traits. A relationship between negative traits and a less active binding mechanism was absent. Neither cognitive disorganisation, nor impulsive non-conformity was related to the memory measures.

2. Experiment 8: The relationship between remember-know and schizotypy

The findings of Experiment 7 were not altogether predictable on the basis of previous studies. While the link between positive traits and a more active binding mechanism was anticipated, a link between positive traits and a less active associative mechanism was absent. The link between negative traits and a more active associative mechanism is linked with previous findings in that it is another example of negative traits being related to an oppositional effect to positive traits; however, as a finding in itself, it was not predicted. Finally, there was no link between negative traits and a less active binding mechanism.

In the current experiment, the aim was to see whether positive traits could be related to a less active associative mechanism through the inclusion of remember-know responses. If positive traits are related to a less active associative mechanism, then the positive group should respond with fewer remember responses than the control group and negative group. In addition, regression analysis might show that positive traits were negatively related to remembering, and positively related to knowing. Based on the previous experiment in which negative traits were related to a more active associative mechanism, the negative group might respond with more remembers. In addition, regression analysis might show that negative traits were positively related to remember. At the group level, the expected effects included a three-way interaction between hit and false-alarm rate, remember-know, and group. In the regression analysis, the O-Life traits were related to the proportion of remember and know responses provided to both targets and distracters.

2.1. Method

Participants: 72 participants completed the experiment in exchange for course credit. Through the same procedure as in Experiment 7, a positive and a negative group were formed. 18 participants were in each of these groups. The scores on unusual experiences and introvertive ahedonia in each of the groups are shown in Table 12.

Table 12: Descriptive data on unusual experiences (UE) and introvertive ahedonia (IA) in the positive and negative groups

	M		*SD*		*zM*		*zSD*	
	UE	IA	UE	IA	UE	IA	UE	IA
Positive group	15.17	2.28	3.50	1.56	0.80	-0.82	0.56	0.39
Negative group	4.61	7.89	2.75	1.45	-0.88	0.59	0.44	0.36

Design and procedure: Participants completed the remember-know experiment described in Chapter 5, Experiment 4. This included three within-subject factors: frequency (low, mid, and high), block (first, second, and third), and cycle (first and final). Hit and false-alarm and remember-know were also included as within-subjects factors, and group was included as a between subjects factor. The regression analysis focused on the relationship between the O-Life traits and averaged remember and know hits. 69 participants were finally included in the regression analysis (along with STM scores).

2.2. Results

Remember-know data

Hit and false-alarm rate, frequency, block, cycle, and remember-know were included in a mixed-measures design along with the between-factor group. Similar findings involving the factor remember-know to those described in Experiment 4 were found here: hit and false-alarm x remember-know, F (1, 61) = 104.20, p < .001; hit and false-alarm x frequency x remember-know, F (2, 122) = 34.62, p < .001; hit and false-alarm x frequency x block x remember-know, F (4, 244) = 2.84, p = .030; hit and false-alarm x frequency x cycle x remember-know, F (2, 122) = 5.81, p = .004; hit and false-alarm x frequency x block x cycle x remember-know, F (4, 244) = 3.76, p = .008. Group failed to interact with remember-know at any level (p > .25).

Sensitivity data

Frequency, block, and cycle were included in a split-plot analysis along with group. An effect of frequency was significant, F (2, 122) = 186.86, p < .001, and frequency interacted with block, F (4, 244) = 3.60, p = .008. Frequency tended to interact with group, F (2, 122) = 2.17, p = .077, and the three-way interaction between frequency, block, and group was significant, F (4, 244) = 4.28, p < .001, see Figure 20. To simply the analysis of the three-way interaction, the first and final blocks were taken for each frequency, and were analysed along with group. In each block, frequency and group interacted: first, F (4, 122) = 5.48, p = .001; final, F (4, 122) =

4.56, $p = .002$. In the first block of trials, low-frequency sensitivity levels in the negative group were lower than those in the positive and control groups combined, t (62) = 2.10, $p = .04$, but mid- and high-frequency sensitivity levels were lowest in the control group relative to the negative and positive groups combined: mid, t (62) = 3.33, $p = .001$; high, t (62) = 2.33, $p = .023$. In the final block, the low- and mid-frequency sensitivity levels were lowest in the control group related to the other two groups combined: low, t (62) = 2.20, $p = .032$; mid, t (62) = 4.37, $p < .001$, and the high-frequency sensitivity levels tended to be higher in the negative group relative to the positive and control group combined, t (62) = 1.75, $p = .085$.

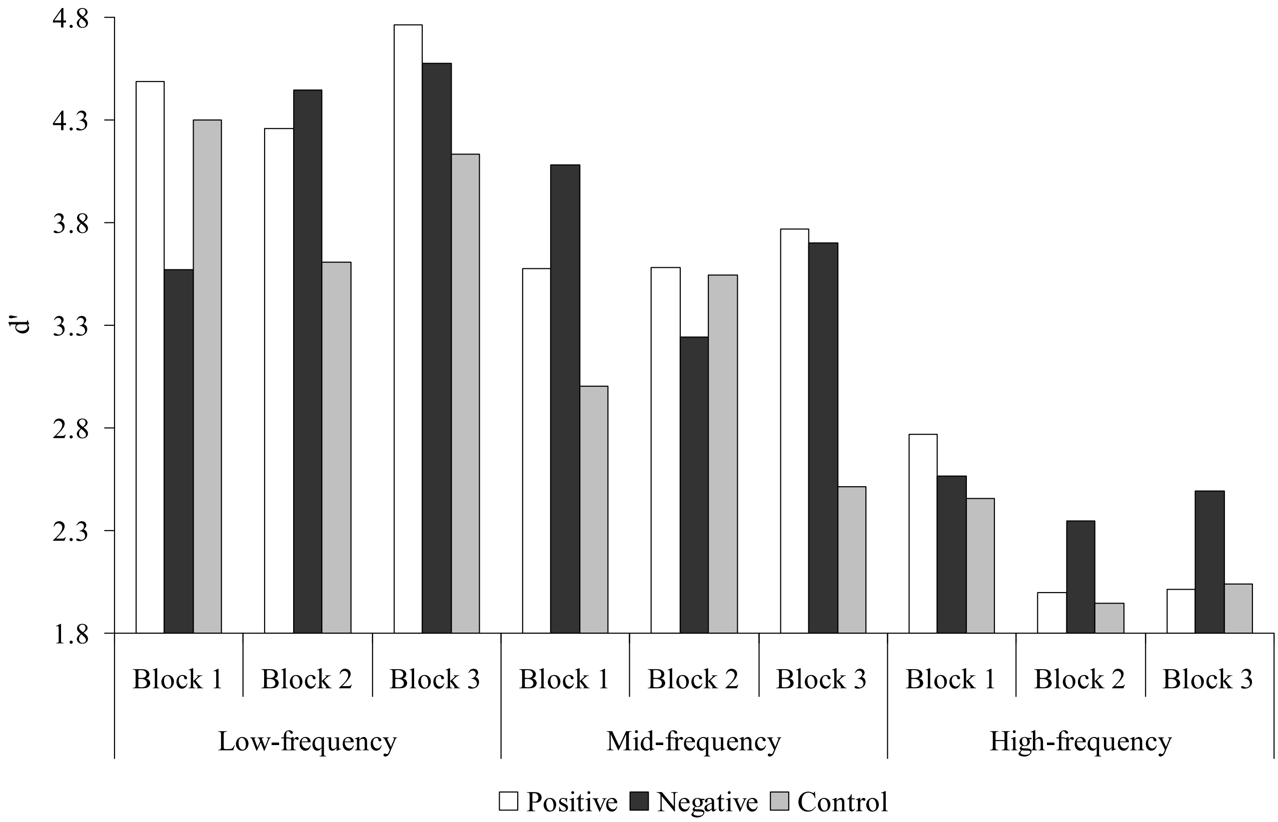

Figure 20: The interaction between frequency, block, and group in the sensitivity data

Regression analysis

The regression analysis investigated whether the O-Life traits were related to remember and know responses in the hit data. Having failed to find a difference between positive and negative traits in the group analysis, a difference between them in their relationship to remember and know responses was not expected. More importantly, the regression analysis would address whether positive and negative traits were related to remember and know responses overall. Based on the previous experiment, it was predicted that negative traits would be positively related to remember responses, and that positive traits might be positively related to know responses; based on the group analysis, however, this now seemed unlikely. Remember hits and know hits were included as dependent variables in separate regressions with the predictors of interest being the four O-Life traits. The span tasks were also included. Table 13 shows the results.

Table 13: Regression analysis predicting remember and know from the four O-Life factors. The span tasks controlled for STM variability

		R	*F*	*p*	*t*	*p*
DV	Remember	0.366	3.34	0.025		
	(span tasks)					
Predictors	positive				2.58	0.012
	negative				2.34	0.023
	cognitive disorganisation				-2.22	0.030
DV	Know	0.398	4.08	0.010		
	(span tasks)					
Predictors	positive				-2.99	0.004
	negative				-2.35	0.022
	cognitive disorganisation				2.51	0.015

Positive in addition to negative traits were positively related to remember responses. In contrast, cognitive disorganisation was negatively related to remember responses. The analysis on the know data returned the opposite findings. However, given that remember and know are binary choices, it is possible that the pattern in the know data does not reflect relationships between these traits and familiarity. This interpretation seems unlikely however, as when the same analysis was run with the corrected measure of know responses (K / (1-R)), the findings were similar (UE, $t = -2.15$, $p = .035$; IA, $t = -1.61$, $p = .112$; CD, $t = 1.94$, $p = .057$).

2.3. Discussion

The sensitivity analysis provided findings that were relatable to Experiment 7, as described below. This analysis failed to reveal a differential relationship between remember and know, and positive and negative traits. In the regression analysis, both positive and negative traits were positively related to remember responses and negatively related to know responses. Cognitive disorganisation showed the opposite pattern to positive and negative traits in its relationship to remember and know responses.

Sensitivity data

The low-frequency items here are similar to the items shown in the no-overlap condition of Experiment 7. In the no-overlap condition, emphasis is on binding the intrinsic features of each item together so that items are less susceptible to content-related interference; thus, in addition to being easier to recognise due to being associated with fewer temporal contexts, the low-frequency items are nevertheless dependent on the binding mechanism. The high-frequency items here are similar to the items shown in the overlap condition of Experiment 7. In the overlap condition, emphasis is on the need to associate an intrinsic set of features to an extrinsic feature so that items are less susceptible to context-related interference; thus the high-frequency items are reliant on representing context in order to be recognised.

The negative group performed similarly to the control group in Experiment 7, yet the negative group were less sensitive to low-frequency items in the first block of trials: why do the negative group perform more poorly on low-frequency items in this experiment, and yet, only in the first block? An additional finding in the negative group in this experiment was their greater sensitivity to high-frequency items compared to the positive group and the control group in the final block of this experiment. They were also less susceptible to context-related interference in the previous experiment. It is possible to relate the high- and low-frequency findings in the negative group as follows. The high-frequency finding in the negative group can be related to their reduced susceptibility to context-related interference in Experiment 7, and both findings suggest a greater reliance on associative processing. This greater reliance on associative processing may come at a cost to performance when better performance is more dependent on the processing of content. In other words, despite the fact that content and context are independently represented, a trade-off in processing may favour the representation of one at a cost to the other. The recovery of low-frequency sensitivity in the final block may then be a consequence of increased bottom-up exposure.

The drop in high-frequency recognition in the positive and control groups can be related to increased difficulty in associating high-frequency items to temporal context. These groups do not differ in high-frequency sensitivity; thus, failing to suggest a less active associative mechanism in the positive group. Both positive and negative groups outperform the control group in low- and-mid-frequency sensitivity in the final block. Although the positive and negative groups are performing similarity at mid- and low- levels of frequency in these instances, it could be argued that their performance is being differentially supported by binding and associating. The negative group seem to be more reliant on associating (reduced context-related interference, better high-frequency sensitivity), with a potential cost to performance when performance is more reliant on binding (low-frequency items, first block). The positive group seem to be more reliant on binding (reduced content-related interference, consistently high low and mid-frequency sensitivity).

Regression analysis

Improved high-frequency sensitivity for the negative group in the final block suggests an improved ability to associate high-frequency items with their temporal context, which is consistent with their reduced susceptibility to item-specific PI. A group difference in remember responses, as was expected on the basis that the negative group was least susceptible to item-specific PI, failed to arise, however. Added to that, positive, in addition to negative traits were associated with increased remember responding, which was not expected as positive traits were not linked to reduced item-specific PI. The independent relationships between both traits and remember responses suggests that two separate factors played a role in bringing about these relationships—not just variability in recollection.

Variability in representing context is the logical source of the positive relationship between remember responses and negative traits, given than negative traits are related to reduced item-specific PI. Although the previous experiments (4 and 5) demonstrate that remember and know responses reflect independent processes, as is consistent with most theories on how remember and know responses are related (e.g. Yonelinas & Jacoby, 1995), another theory suggests that both responses are redundant (Knowlton): while the know response reflects familiarity for content, the remember response also reflects memory for content in addition to its association to context. In the previous experiment, positive traits were related to a reduced susceptibility to item-non-specific interference, which is consistent with an improved ability to represent content. In the current experiment, the positive group were more sensitive to low- and mid-frequency items relative to the control group—also consistent with an improved ability to represent content. In both this and the previous experiment, the positive group performed similarly to controls when performance was most reliant on the ability to represent context (in the overlap condition, and in recognising high-frequency items), suggesting the absence of a deficiency in recollection. Given that the accuracy with which content is represented may also influence remember responding, the relationship between positive traits and remembers may be facilitated by an increased ability to represent content in the absence of a deficiency in representing context.

Reduced sensitivity to low-frequency items for the negative group in the initial block suggests the potential for a trade-off in representing content and context. An increased propensity to rely on the associative mechanism more than the binding mechanism when it comes to encoding information to WM may have a negative impact on performance when the binding mechanism is required. The remaining experiment tested whether the reverse pattern could be demonstrated in the positive group; an increased emphasis on binding may lead to poorer performance when the associative mechanism is required more.

3. Experiment 9: Recollection and familiarity can be traded off against one another

Experiment 8 suggested that in the negative group, a more active associative mechanism may coincide with a less active binding mechanism. As the negative group were more likely to focus on temporal coding, they were less likely to bind the features of the novel low-frequency items. General levels of familiarity with non-words were heightened in a bottom-up manner over trials, presumably accounting for the increase in low-frequency sensitivity in the negative group. In this Experiment, a condition was tested that was reasoned would benefit more from associating and less from binding. Participants completed the non-object-non-word associative task that was described in Chapter 7. Sensitivity to recombined pairs was again the focus of attention. A greater emphasis on associating favours participants' ability to distinguish between intact and recombined pairs. Both non-objects and non-words are novel on every trial. An emphasis on representing content could lead to reduced sensitivity in distinguishing between intact and recombined pairs, as familiarity for the items in intact and recombined pairs is similar, and an emphasis on content may come at a cost to representing context. It was hoped that recombined sensitivity levels would be lower in the positive group due to a sacrifice of context in favour of content.

In order to increase the changes of finding group differences, the factor cycle was included. The negative group showed reduced sensitivity to low-frequency items in the previous experiment. As the non-words and non-objects here were novel on every trial, it was possible that the content-related effect might afflict sensitivity levels at the beginning of the condition. Low-frequency sensitivity had recovered by the final cycle; thus any content-related influence on recombined sensitivity should not be sustained across trials.

Additionally in the previous experiment, both positive and negative traits were predictive of remember responses. It was argued that an improved ability to represent content in relation to positive traits facilitated remember responses when there was no concurrent recollection deficit. The positive relationship between remember responses and negative traits was supposed to be reliant on recollection. The recollection component of this experiment, recognising recombined pairs, relies heavily on the associative mechanism. If only negative traits correlate with the recollective component in this experiment, then it will support the argument that remember responses were biased by an improved ability to represent content in relation to positive traits. If recombined sensitivity is poorer in the positive group, it will support the proposal that an emphasis on binding can come at a cost to associating.

3.1. Method

Participants: 96 participants took part in this experiment, and the recombined sensitivity data from the previous Chapter were included in the form of a control group. The unusual experiences and introvertive ahedonia scores for the positive and negative groups are shown in Table 14.

Table 14: Descriptive data on unusual experiences (UE) and introvertive ahedonia (IA) in the positive and negative groups

	M		*SD*		*zM*		*zSD*	
	UE	IA	UE	IA	UE	IA	UE	IA
Positive group	14.08	2.08	3.57	1.61	0.63	-0.87	0.57	0.40
Negative group	4.67	7.75	2.60	1.87	-0.87	0.55	0.41	0.47

Design and procedure: Participants completed this task under the same conditions as participants in the previous Chapter. Additionally here, in considering the group differences in the previous two experiments that arose as a function of cycle, two levels of cycle were computed to measure recombined sensitivity at the beginning and end of the task.

3.2. Results

The analysis followed two paths, similar to the previous experiments. The first looked for a difference between the groups in recombined sensitivity. The second included all four O-Life traits in a regression predicting recombined sensitivity.

Sensitivity data

The first analysis included two factors, group and cycle. Group interacted with cycle, F (2, 93) = 3.68, p = .029, see Figure 21. Recombined sensitivity dropped during the task in the positive group, t (23) = 1.98, p = .060. In contrast, in the negative group recombined sensitivity increased during the task, t (23) = 2.22, p = .037. In the final cycle, recombined sensitivity in the positive group was lower than the other two groups combined, t (94) = 1.90, p = .060.

Regression analysis

The dependent variable in the regression (backward method) was recombined sensitivity in the final cycle, and the predictors were the four O-Life traits. The regression was significant, R = 2.63, F (1, 94) = 6.97, p = .010. The only significant predictor was negative traits (positive, p > .4). Higher levels of negative traits were related to better recombined sensitivity. 68 of the 96 participants had completed the STM span tasks. When these were included in the regressions to control for variability in verbal-related processing, the regressions fell below significance, but negative traits remained the closest predictor (p = .202). The drop in prediction is likely to be related to a loss in power rather than to the possibility that verbal-related processing accounts for the results.

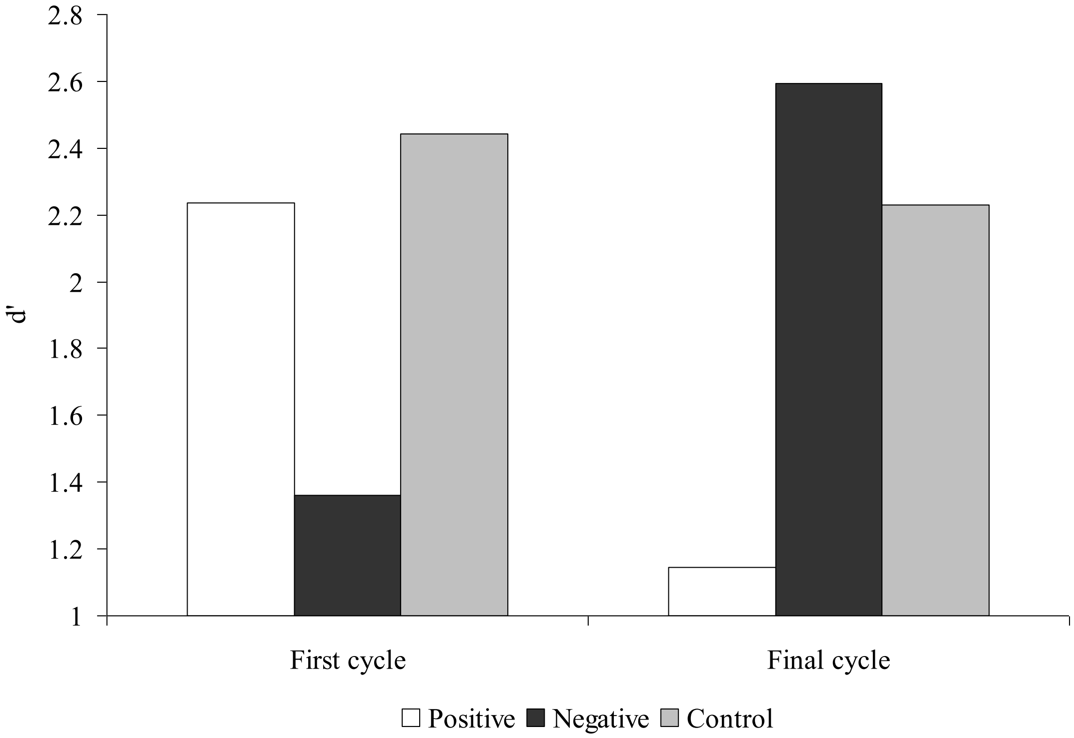

Figure 21: The interaction between recombined sensitivity and group

3.3. Discussion

The group analysis showed a contrasting pattern between the positive and negative groups. The negative group became more sensitive to the distinction between intact and recombined pairs (increase in sensitivity from the first to the final cycle), while the positive group became less sensitive to this distinction (decrease in sensitivity from the first to the final cycle). Sensitivity levels in the control group were similar throughout. Regression showed that only negative traits were related to recombined sensitivity in the final cycle.

Sensitivity data

The non-objects and non-words were novel on every trial, similar to the low-frequency stimuli in the previous experiment. Recombined sensitivity in the negative group was poor in the first cycle, as was low-frequency sensitivity in the previous experiment. In both cases, sensitivity recovered. The cause of both findings may be related to a trade-off between content- and context-related processing. The low-frequency items in the previous experiment were mixed with items that repeated across trials. The recruitment of a more active associative mechanism to deal with the repeating items in the negative group may have reduced the involvement of the binding mechanism, keeping low-frequency sensitivity low, until more exposure to the non-word category helped low-frequency sensitivity to improve in a bottom-up manner. Similarly with regard to recombined sensitivity, a more active associative mechanism may have lead to a cost in representing the novel stimuli until increased exposure to both categories helped the negative group to recover from this loss in content-coding.

Additional support that trade-offs between content- and context-related processing may be possible is seen in the data for the positive group. In the previous experiment, the positive group responded with a similar proportion of remember responses to the negative group. It was argued that remember responses were influenced by an improved ability to represent content in the positive group, in the absence of a concurrent effect on associating. Recombined sensitivity in this experiment reflected the recollection process, and the positive group became less sensitive to recombined pairs. Recombined sensitivity differs from remember responses, as familiarity is insufficient to distinguish between intact and recombined pairs. From the first to the final cycle in recognising recombined pairs, the positive group failed to regulate a more active binding mechanism in favour of recruiting the associative mechanism.

Curiously, recombined sensitivity in the positive group was similar to that of the control group in the first cycle. It is possible that the positive group were able to rely on activation differences between the two items in the recombined pair in order to distinguish whether they had been presented together (i.e. the two items in the recombined pair were shown at different time points, one more recent than the other). This strategy may then have failed following increased exposure to further items, as activation differences would be more subtle when the non-word and non-object categories are generally more active.

Regression analysis

Only negative traits were related to the measure of recollection in this experiment—recombined sensitivity. The stronger relationship between negative traits and recombined sensitivity is consistent with the reduced context-related interference in the negative group. The negative group intrinsically rely on a more active associative mechanism. Positive traits were predictive of remember responses, but they failed to predict recombined sensitivity. A tendency to rely more on binding facilitates the representation of individual items, but not the associations between items. A better representation of the content of individual items improved the ability to respond remember in relation to positive traits; however, this had a negative impact on performance when the task required the creation and recognition of associations.

4. General discussion

In Experiment 7, the negative group were less susceptible to context-related interference, and the positive group were less susceptible to content-related interference. This suggested that the negative group recruited a more active associative mechanism, and the positive group recruited a more active binding mechanism. Conceptually, at an intrinsic level, the negative group are more likely to engage the associative mechanism when information is encoded to WM, and the positive group are more likely to engage the binding mechanism. In Chapters 6 and 7, it was argued that binding is related to familiarity, and associating is related to recollection. Negative traits were exclusively related to recombined sensitivity, a measure of recollection, confirming an association between these traits and a more active associative mechanism. The positive group were more sensitive to low- and mid-frequency items relative to the control group, but a difference was absent in high-frequency items. As high-frequency sensitivity is more reliant on the ability to represent temporal context, improved low- and mid-frequency sensitivity in the positive group is most consistent with a more active binding mechanism.

Although both traits were positively related to remembering, sensitivity to recombined pairs decreased in the positive group, suggesting that while the binding mechanism could have a positive influence on remember responses through generating clearer representations of content, associative processing can be traded off in favour of a more active binding mechanism. In a similar vein in the negative group, the lower sensitivity levels to low-frequency items in the first block of trials suggested that binding can be traded off in favour of a more active associative mechanism.

4.1. Schizotypy, cognition, and schizophrenia

4.1.1 Positive traits and cognition

Evidence in the literature suggests that positive traits are related to increased fluency in semantic memory (Beech et al., 1991), potentiated automaticity (Linscott & Knight), a better ability to encode local features when presented in a global context (Goodarzi et al.), and increased incidental recall (Jones et al.). Semantic memory and automaticity have been related to familiarity (Yonelinas, 2002), and the binding mechanism was related to familiarity (see Chapters 6 and 7). In addition, binding may be related to a propensity to focus on local-level features, as is demonstrated in the relationship between binding and reduced content-related interference. The representation of features that are not relevant to the task may be more likely in the case of a more active binding mechanism. In essence, it is possible to relate these previous findings on positive traits under the umbrella of a more active binding mechanism.

Additional past research also suggested that positive traits are linked to a reduced tendency to make associations (Steel et al., 2002; 2007). In the context of the current experiment, a link was found between positive traits and a reduced tendency to make associations in their decreased recombined sensitivity. It is thus possible to suggest that positive traits are related to a more active binding mechanism; however, in tasks that allow for potential trade-offs between content- and context-related processing, positive traits may show themselves to be related to a reduced reliance on associating.

4.1.2 Negative traits and cognition

Evidence in the literature suggests that negative traits are related to poorer recognition of targets (Dagnall & Parker), reduced verbal fluency (Tsakanikos & Claridge), and a decreased ability to assimilate local details (Tsakanikos & Reed, 2003; Gooding & Braun). These findings could suggest a reduced reliance on familiarity and binding. In the first block of Experiment 8, and the first cycle of Experiment 9, performance in the negative group was poor with novel stimuli (low-frequency items). It was suggested that this finding stemmed from a trade-off in coding context information at the neglect of content. It is possible that other findings in the literature may relate to such a trade-off. While the evidence of a link between negative traits and associating has not been previously noted in the literature, it is worth pointing out that other studies have found oppositional patterns between cognitive performance and positive and negative traits. Such oppositional patterns may be related to trade-offs between content- and context-related processing; thus the absence of other studies that report an association between negative traits and associating may simply reflect the need to focus on WM to a greater degree in schizotypy.

4.1.3 Schizophrenia and cognition

In addition to being able to differentiate cognitive performance in relation to positive and negative traits through grouping, the regression analyses also supported greater links between positive traits and binding, and negative traits and associating. Positive traits were positively related to performance when the potential was content-related interference was high (no-overlap final cycle). Negative traits were positively related to performance when the potential for context-related interference was high (overlap final cycle), and when it was necessary to represent associations between stimuli (recombined sensitivity). Although relationships between the memory measures and the remaining O-Life traits were not predicted, cognitive disorganisation and impulsive non-conformity, a negative relationship between cognitive disorganisation and remembering was found, and a positive relationship between cognitive disorganisation and knowing. It is possible that cognitive disorganisation gives rise to reduced certainty in memory, and that this may account for the remember-know pattern.

The sample sizes in the current study were similar to those used in previous studies. At least three of the O-Life traits showed a tendency to covary with WM performance. The findings suggest that it should be possible to explore atypical WM function in relation to positive and negative schizotypy traits. WM research in schizophrenia has recently highlighted problems in perceptual analysis (e.g., Haenschel et al.) and consolidation (Fuller et al.). Perceptual analysis may be related to binding, and it is at least conceptually plausible that a reliance on either associating or binding may lead to a cost in consolidating content or context, respectively. Thus the approach here that separates associating from binding may prove useful in further explorations of cognition in schizotypy, and this could potentially lead to a better understanding of symptoms in schizophrenia.

Overall, the experiments supported a WM framework that distinguishes between an associative mechanism and a binding mechanism. Factor analyses have confirmed that positive and negative traits are separate sources of variability with regard to personality, and these two traits shown distinct patterns in their relationship to tasks that were differentially related to both mechanisms, as was shown in Chapters

5-7. The findings support efforts to distinguish the relationship between positive traits and cognition, and negative traits and cognition. Although the area of WM is researched intensely in schizophrenia samples, there is a much reduced focus on WM in schizotypy samples. The separation between associating and binding may prove useful if WM is to become a focus in schizotypy samples. Such a focus could prove enlightening with regard to understanding WM function in schizophrenia.

Chapter 9

General discussion

The studies focused on three goals. The first goal was to determine whether two types of PI, item-non-specific and item-specific, demonstrate independent effects in memory. Chapter 5 provided the first empirical evidence that the two types of interference are separable: it was possible to differentially manipulate each type of interference, and each type of interference was linked to a contrastingly-shaped serial position curve. The second goal was to better delineate the processes and mechanisms that mediate each interference effect. Chapter 6 provided evidence that item-specific PI is related to the recollection process, and item-non-specific PI to the familiarity process. Chapter 7 provided evidence that item-specific PI is related to what was described as an associative mechanism, and that item-non-specific PI is related to what was described as a binding mechanism. These findings amalgamated to support the framework that was set forth in Chapter 3: IM can be divided into a short-term component, and two WM-related networks, one related to associating, the other to binding. The final goal of the thesis was to proffer further support in favour of the dissociation between two WM-related networks by looking at the relationship between schizotypy and measures of the two mechanisms. Chapter 8 provided evidence that different aspects of schizotypy are differentially related to the two mechanisms; thus supporting the classification described in the framework.

1. A dual-route approach to proactive interference

In Experiment 2a, the build-up of content-related interference was modified through allowing participants to vocalise items during encoding. In Experiment 2b, reducing the frequency with which items repeated curtailed the build-up of item-specific interference. It was concluded that the data provided initial evidence for independent interference effects. Despite the validity of this claim, it is worth noting that vocalising the items only worked to reduce interference in the initial five trials; following this juncture, an effect of interference was incurred.

It was reasoned that vocalising the items during encoding increased the activation defining each item in memory. In light of Oberauer and Lange's (2009) recent dissociation between binding in WM, and activation strength in STM, it is possible that vocalising strengthened items' level of activation, but did not specifically function to strengthen the bindings between the intrinsic features within items. Within the conceptual framework of this thesis, it is possible for STM-related processing to influence recollection and familiarity, and information held in the WM system generally. A distinction is drawn at the level of mechanism: STM-related processing can influence activation strength, but it is the binding network that is related to strengthening the bonds between intrinsic features. This distinction at the level of mechanism may explain why vocalising the items did not have a more pronounced effect on item-non-specific interference. Increasing activation strength buffered familiarity, but it did not increase the strength of binding between the intrinsic features of items.

Experiment 3 provided further evidence that performance in the presence of item-specific interference was more reliant on representing temporal context than performance in the presence of item-non-specific interference. It was reasoned that position information is harder to represent for items that are not in the first or final list position. Item-specific PI was greatest in early serial positions (2-4). Given its association with a decreased ability to specify temporal context, it is logical that item-specific interference is greatest in serial positions that automatically incur context-processing difficulties.

2. The processes and mechanisms mediating the proactive interference – working memory relationship

2.1. Proactive interference and the processes of recollection and familiarity

2.1.1 Proactive interference and the word-frequency-mirror-effect

Although past literature failed to reveal an instance in which the WFME effect was created in an IM context, the replication of the effect in the current thesis fitted patterns reported in previous studies (e.g. Reder et al., 2000: hit rate: LF > HF; false-alarm-rate: LF < HF). As would be expected on the basis of past studies (e.g. Reder et al., 2002), the false-alarm portion of the effect, mediated by familiarity, developed first, followed by the hit portion, mediated by recollection. A remember-know ME as a function of frequency was systematically present in the hit data, and in the false-alarm data, know false-alarms increased for all frequencies during Experiment 4. A low-frequency increase in know false-alarms was reasoned to be related to a potential build-up of item-non-specific PI during the task. Of most importance to the purpose of the current thesis, measures of both types of interference accounted for the WFME created here, as the effect was no longer significant when the interference covariates were included.

Consistent with what would be expected on the basis of past studies, item-specific PI was positively related to hit rate, and item-non-specific PI was positively related to false-alarm-rate (positive linked with reduced interference). The ability to represent context links item-specific PI and hit rate, and the ability to represent content links item-non-specific PI and false-alarm-rate. In addition, item-non-specific PI was negatively related to hit rate (negative related to increased interference). This finding suggested the possibility that a reduced susceptibility to item-non-specific PI is related to poorer memory in general.

2.1.2 Proactive interference and remember-know judgements

Remember hits were positively related to reduced item-specific interference, and this is consistent with a link to the representation of context. It suggests that the recollection process is involved in curtailing item-specific interference. Know hits and false-alarms were positively related to increased item-non-specific interference, and this is consistent with a link to the representation of content. It suggests that the familiarity process is involved in curtailing item-non-specific interference. In addition to this finding, increased item-non-specific PI was negatively related to remember hits. This latter finding relates to the previously discussed negative relationship between item-non-specific PI and hit rate independent of remember-know: a reduced susceptibility to item-non-specific PI is related to a reduced engagement of recollection. In contrast to the positive relationship between item-non-specific and know false-alarms, reduced item-specific was negatively related to know false-alarms. This finding suggests that an increased ability to represent context is related to a reduced impact of familiarity on false-alarm rate.

2.1.3 Content and context are separate domains of representation in working memory

Studies of the WM system rarely make a distinction between the ability to represent content, and the ability to represent context. Some notable exceptions include the work of Jonides and Nee in their proposal of a relationship between interference and context representations, and the work of Oberauer (2005) in the demonstration of a relationship between measures of WMC and measures of recollection. The replication of the RKWFME in these IM experiments suggest that the processes of recollection and familiarity do play a role in memory that is measured over the short term—not just memory that is measured over the long term.

The positive relationships between item-specific and measures of recollection (the hit rate portion of the WFME, and remember hits) are consistent with item-specific PI being related to the representation of context. The positive relationships between item-non-specific and measures of familiarity (false-alarms and know hits) are consistent with item-non-specific PI being related to the representation of content. These relationships solidify the separation of both types of interference, and they support the framework created to interpret the findings here. While the experiments in Chapter 5 justify a link between item-non-specific PI and content, and item-specific PI, and context, the remember-know experiments in Chapter 6 justify the extension of a link between item-non-specific PI and familiarity, and item-specific PI and recollection. Importantly, the introduction of more STM measures failed to account for relationships between both types of interference and other measures. This failure suggests that STM related processing can be separated from the mechanisms that can curtail the build-up of both interference effects.

The findings generally add to evidence that remember and know underlie distinct processes. However, the negative relationships between item-non-specific and remember hits, and item-specific and know false-alarms suggest that, at least in WM tasks, a trade-off between the processing of content and context may occur. A reduced susceptibly to item-non-specific PI would seem to be related to a reduced deployment of recollection. A reduced susceptibility to item-specific PI would seem to be related to a decreased liability to know false-alarms. Given the levels of individual variability in item-specific PI, and the resultant correlations between item-specific PI and recollection, the recollection process may also be better described as a continuous process akin to familiarity, as favoured by Reder and colleagues (2000; 2002), rather than a process capped by a high criterion (e.g. Yonelinas, 1999)—at least in WM.

2.2. Proactive interference and the mechanisms of binding and associating

Three levels of analysis supported a distinction between binding and associating. The factor analysis deduced commonality between item-non-specific PI and complex-span, and item-specific PI and recombined sensitivity. This is consistent with a binding mechanism being engaged in controlling item-non-specific build-up, and this binding mechanism is picked up on by complex-span. An associative mechanism is engaged in controlling item-specific build-up, and this mechanism is picked up on in recombined sensitivity.

The covariance analysis showed that the variability shared between no-overlap and complex-span was highest when item-non-specific PI had built up. The binding mechanism would be expected to become more engaged in the no-overlap condition when item-non-specific PI is high. Likewise, the variability shared between overlap and recombined sensitivity was highest when item-specific PI had build-up. The associative mechanism would be expected to become more engaged in the overlap condition when item-specific PI is high. The exclusiveness of these associations was supported by (i) a drop in the amount of shared variability between recombined sensitivity and no-overlap performance when item-non-specific PI was high, and (ii) the failure to find significant associations between complex-span and overlap.

As would be predicted on the basis of the factor analysis, the slope measure of item-non-specific PI was positively related to complex-span, and the slope measure of item-specific was positively related to recombined sensitivity. The negative relationship between the STM factor and both PI slopes was novel. It was reasoned that STM rehearsal-related processes could contribute to measures related to both recollection and familiarity (content and context features can be rehearsed). The resultant negative correlations between STM and both PI slopes would suggest that a reliance on STM-related processing at a cost to WM-related processing negatively influences interference build-up generally.

Recombined sensitivity and remember judgements are related measures of the ability to represent context, as was shown in their similar relationship to item-specific PI. Further justification of there relatedness was shown in the no-overlap data. Both measures were positively related to no-overlap sensitivity when content-related interference was low (first cycle), but these relationships diminished when this type of interference was high (final cycle). Additionally, relationships with the item-non-specific slope were negative. This pattern of findings suggests that as a task becomes more reliant on the ability to represent content, the associative mechanism becomes less engaged in influencing performance; instead, performance is now reliant on the binding mechanism.

Finally, the covariates included here (OSPAN, d-recombined, FS, and BS) were better able to account for the build-up of item-specific interference than the build-up of item-non-specific interference. The inclusion of the covariates led to an interaction between overlap and cycle. This interaction was decomposed to show the absence of an effect of cycle in the overlap condition with the inclusion of the covariates, but an effect of cycle was still significant in the no-overlap condition.

It was reasoned that variability earlier in the information processing stream, specifically at the perceptual level, may contribute to item-non-specific PI. Although speculation at this point, saliency is one particular variable that could be considered for the role of additionally influencing item-non-specific PI. Saliency can be described as the boosted processing of some elements of a perceptual event relative to other elements in the same event. Mevorach, Humphreys, & Shalev (2006) has investigated effects of saliency in Navon stimuli. Global-to-local interference is high when participants must respond to the local target, but the global level is more salient. Local-to-global interference is high when participants must respond to the global target, but the local level is more salient. A bold suggestion in that increased local-to-global interference may be related to item-non-specific PI. If local features are perceived as more salient, particularly in the face of interference, then this may contribute to reduced item-non-specific PI—saliency may be that 'other' variable.

2.2.1 Instantiating binding and associating as mechanisms in working memory

Interference has recently become central in WM-related studies. One aspect of this centrality is with regard to PI. The findings of this thesis show that, contrary to current perceptions (Bunting et al.; Cowan et al.; May et al.; Postle & Brush, 2004; Postle et al., 2004), the relationship between PI and WM is not unitary. A separation needs to be made based on whether the type of interference in a task relates to the intrinsic features of items that are being represented, or whether it relates to the distinctiveness of associations between intrinsic and extrinsic features. A second aspect of this centrality is more fundamental. Recently, the debate has been re-opened between those who would suppose that decay of activation can account for the loss of information from memory (Barrouillet, Bernardin, & Camos, 2004; Barrouillet & Camos, 2009), and those that stand by an interference approach to memory loss (Lewandowsky, Geiger, & Oberauer, 2008; Oberauer & Lewandowsky, 2008; Lewandowsky, Oberauer, & Brown, 2009ab). PI simply represents a specific means of thinking about interference in general. This ongoing debate may benefit from investigations that separate content and context. For example, it is difficult to see how the abstract measure of context that was measured in the overlap condition would be related to the theoretical concept of decay; it is more likely that it is related to interference.

The dual-route framework presents an elaborate means of how interference can be conceptualised in memory. Starting from the bottom up, a binding mechanism that specifically operates at the level of WM strengthens the bonds between features that represent a coherent whole, and an associative mechanism that also operates specifically at the level of WM strengthens the associations between intrinsic and extrinsic features. The former mechanism mediates the build-up of item-non-specific PI, whilst the latter mechanism mediates the build-up of item-specific PI. Ecker and colleagues distinguished between two modes of coding that are directly related to binding and associating, object- and episodic-based coding, respectively. Episodic coding seeks to represent contextual aspects of an event, whereas object coding seeks to represent the content of an event. Episodic coding supports the recollection process, and object coding supports the familiarity process. STM rehearsal-relating processing can influence how content and contextual aspects of information are representing; however, the mechanism involved here can be set apart from the more specific WM mechanisms of binding and associating.

At this point, it is necessary to note that there is some conflict between the labels item-non-specific and item-specific and the findings of this thesis. Letters and digits repeated across trials in the complex-span task, yet this task was positively related to item-non-specific interference—not item-specific. This finding is easily interpreted from the perspective that the complex-span task is picking up on participants' ability to bind each additional letter into a coherent set of letters that can be reported at the end of the task, and item-non-specific PI is mediated by binding. It does suggest, however, that these labels may be better replaced by the more accurate labels of content-related interference and context-related interference.

The experiments here encourage theoretical reasoning as to how a binding and an associative mechanism can be related to concepts like attention and inhibition, and constructs such as WMC. Within the WM system, arguments are made to suggest that individuals have the ability to control what they attend to (Engle), and what they inhibit (Hasher & Zacks, 1988). Here it is claimed, as has similarly being claimed by remember-know theorists, that control is not central to recollection. Presumably attention can play a role in strengthening binding, as is suggested by the association between OSPAN and item-non-specific PI, and attention can play a role in strengthening associations, as is suggested by the association between d-recombined and item-specific PI. Perhaps there is now a need to look at these concepts in relation to this distinction between associating and binding. The label unitization and the label binding are addressed in LTM (e.g. Diana et al., 2008) and WM (e.g. Raffone & Wolters) respectively, but they do seem inherently synonymous. Functional studies suggest that surrounding regions of the hippocampus are necessary for binding (e.g. Staresina & Davachi). An anatomical offshoot of this thesis would suggest that functional connectivity between more frontal, attention related regions, and regions such as the entorhinal cortex may be strengthened when participants actively engage in binding.

A further interesting notion is that control may be involved in the trade-offs that were measured between associating and binding (item-non-specific PI negatively related to recombined sensitivity). Similar trade-offs were noted in the associations between remember-know responses and the two measures of interference (item-non-specific PI negatively related to remember; item-specific PI negatively related to know false-alarms). Perhaps control could play a role in the instantiation of individual differences in how the associative and binding mechanisms are applied. If an individual is more inclined to evoke the associative mechanism when representing information, could the binding mechanism perform that bit more poorly, simply due to a 'lack of practice'? Perhaps at a functional level, the degree of covariation between control and binding could be negatively related to the degree of covariation between control and associating? These questions obviously step on the bounders of suggesting that binding and associating, and their related concepts, are not wholly independent. However, it is worth considering that, at least in some samples, this may indeed be the case.

A final worthy aspect to note about the dual-route framework outlined here is that separations are maintained between STM-related processing and WM-related processing. Theoretically at least, this framework can be super-imposed onto notions of LTM that separate recollection and familiarity (see Diana et al. 2006, for a review). However, binding and associating, as mechanisms, could be claimed to remain part of WM proper. This would provide of fresh approach to relating WM to LTM. For example, could a measure of binding in WM be employed as a predictor of how well an individual can relate the specific aspects of an event stored in LTM?

3. Binding and associating in relation to positive and negative schizotypy traits

At several junctures of the analysis, positive traits were specifically related to binding. In the group analyses, the positive group was less susceptible to item-non-specific PI than item-specific PI (Experiment 7), and in the previous experiments, reduced susceptibly to item-non-specific PI was related to binding. In Experiment 8, the positive group was better at representing both low- and mid-frequency stimuli than the control group. The representation of low- and mid-frequency stimuli is buffered from familiarity in addition to recollection; hence the suggestion that the positive group were performing better due to their buffered use of familiarity. In the regression analyses, positive traits correlated positively with the sensitivity measure in the final no-overlap cycle when item-non-specific was high—also consistent with a positive link between these traits and binding.

In contrast, negative traits were specifically related to associating. In the group analysis, the negative group was less susceptible to item-specific PI than item-non-specific PI (Experiment 7), and in the previous experiments, reduced susceptibility to item-specific PI was related to associating. In Experiment 8, the negative group tended to be more sensitive to items of all frequencies than the control group, and in addition, more sensitive to high-frequency items than the positive group. The representation of high-frequency items must be supported by recollection in order to distinguish the particular context in which an item was presented; hence the suggestion that the negative group was performing better due to their buffered use of recollection. In the regression analyses, negative traits correlated positively with sensitivity in the final overlap cycle when item-specific PI was high—also consistent with a positive link between these traits and associating.

It was reasoned that familiarity in the positive group may adversely affect performance when participants are expected to ignore familiarity cues and focus on recollection. This finding was reflected in the deterioration of recombined sensitivity in the positive group as the task proceeded. A little surprising at first, the negative group showed reduced sensitivity to recombined pairs at the beginning of the task, but as the task went on, their sensitivity recovered. This finding was related to the poor performance on low-frequency items at the beginning of the WFME task. In contrast to positive traits, in which recollection can be traded off in favour of familiarity, it would seem that familiarity is traded off in favour of recollection in relation to negative traits. More importantly, negative traits correlated with recombined sensitivity towards the end of the task; hence re-stating the relationship between recollection and negative traits.

A final finding was the negative relationship between cognitive disorganisation and remember responses, and the positive relationship between this variable and know responses. Cognitive disorganisation is described in terms of a decreased ability to control ongoing behaviour, both covert and overt. It is this aspect of control that may bring about the pattern of correlation with remember-know responses. If high levels of cognitive disorganisation are linked with a decreased ability to focus attention on representing items, then this might show up in decreased remember responses, but increased know responses.

For the purpose of clarification, it is worth noting that what is described here as associative is distinct from what is often implied in work on semantic memory in schizophrenia. For example, Spitzer, Braun, Hermle, and Maier (1993) described evidence for indirect semantic priming in terms of dysfunction in how associations are made in semantic memory. The use of association in this context is related to increased spreading of activation which gives rise to enhanced semantic priming (for example, Gouzoulis-Mayfrank, Voss, Moerth et al. 2003; Moritz, Woodward, Kueppers et al., 2002; Wentura, Moritz, & Frings, 2008). The associative mechanism proposed in the thesis related a set of bound features to an extrinsic contextual feature. It is a matter for further research as to whether the concept of binding is related to what is described as spreading activation in these studies.

3.1. Understanding the relationship between cognition and symptoms

At an intuitive level, it is natural to consider that schizophrenia and schizotypy may arise as consequences of a differently functioning WM system. The delusions that underlie positive traits suggest a bias in binding novel information to the conceptual framework of the delusion instead of coding it as a distinct episodic event. The hallucinations that underlie positive traits suggest a failure to localise a particular perceptual event to its appropriate context. And therein the suggestion that positive traits are related to a propensity to over-engage (more than normal) the binding mechanism in WM, potentially at a cost to tasks that require the associative mechanism. The decreased levels of engagement that underlie negative symptoms and traits may arise from a fragmented representation of the environment due to an over-emphasis an representing context, at a cost the binding features into the same event to allow for more coherent interaction.

In essence, positive and negative traits may be related to a flux in the operation of the binding and associative mechanisms. Such a flux may lead to inherently unstable representations of information in memory. Recent schizophrenia research has looked at internal representation in relation to consolidation (Fuller et al.) and perceptual analysis (Haenschel et al.): perhaps an examination of binding and associating could be looked at in relation to these two concepts. In schizotypy, it is possible to re-interpret findings in the light of a separation between binding and associating. Further research could test as to whether this distinction might be more accurate in describing memory findings in schizotypy. Finally, the unexpected correlation between remember-know responses and cognitive disorganisation suggest that it may be worth while crossing levels of cognitive disorganisation with positive and negative traits in order to see how different schizotypy traits interact.

The three goals of this thesis were met. Firstly, content- and context-related interference led to independent memory effects. Secondly, content-related interference was related to the process of familiarity, and to a binding mechanism; context-related interference was related to the process of recollection, and to an associative mechanism. Finally, support for these distinctions was provided by the distinct relationships between positive and negative schizotypy traits on the one hand, and measures related to the two difference types of interference on the other.

Appendix 1

Earliest proactive interference theories

Retrieval

Initial accounts (e.g., Underwood & Ekstrand, 1966; 1967) proposed that items encoded in memory tasks compete with one another at the level of retrieval, and that this competition interferes with participants' ability to recall the correct items. Increasing the number of items in memory across trials increases competition, giving rise to cumulative PI. According to this account, items are equally represented in memory in both the presence and absence of interference. Competition at retrieval decreases access to the represented items.

Two findings interpreted to support competition based accounts were (i) the impact of cues provided during retrieval, and (ii) the presence of recency-based false alarms. Gardiner, Craik, and Birtwistle (1972) manipulated whether the items presented following the build-up of PI were from a sub-set of the same category associated with PI build-up, or whether they were just generally associated with the same category. PI was reduced when the items were from a sub-category, but only if a cue was present to indicate this to participants. Gardiner et al. suggested that the sub-category cue directed retrieval, which either increased accessibility to the relevant material, or facilitated the discrimination of the more from the less relevant items; thus reducing the impact of competition. Watkins and Watkins (1975) extended the findings of Gardiner et al., and formulated a retrieval based account of PI that attributed PI to an overload in the number of items associated with the same cue that decreased the ability to retrieve any one item.

Bennett and Kurzeja (1976) studied intrusion errors in relation to speed/accuracy trade-offs in memory, and showed that under conditions of speed, intrusion errors followed a gradient whereby it was more recently presented items that intruded on recall. They argued that this recency effect suggested that the increased activation of more recent items relative to more distant ones competed to a greater degree with the relevant set, decreasing the efficiency of retrieval.

In addition to competition, another concept that became associated with retrieval theories was that of differentiation. Underwood and Freund (1968) had earlier looked at the impact of temporally separating the presentation of lists for learning in LTM. Some of the members of associative pairs were shared across lists, with a small number of associative pairs being common to both lists. Two groups that learnt the two lists on different days showed better recall of the second list when it was tested a day later than two groups who learnt the lists on the same day. The repeating associative pairs were members of the second list in one of the groups from each procedure. With no separation between lists, recall in the group without temporal separation was very poor. Underwood and Freund connected their findings with the ability to differentiate between lists. This notion also featured in STM work; for example, Bennett (1975) described cumulative build-up in Brown-Peterson tasks in terms of a loss in the ability to temporally discriminate between items presented on different trials, and the ability to filter out irrelevant traces.

Encoding

Encoding accounts questioned whether competition is a viable characteristic of cognitive performance, and have scrutinised whether the above findings make PI exclusive to retrieval. Dillon (1973) considered that if PI arises as a consequence of competition at retrieval, then reducing this competition through displaying items from earlier trials during testing, and acknowledging that these items are not targets from the current trial, should reduce PI. This manipulation had no effect on PI build-up. Another possible prediction of the retrieval perspective that Dillon considered was recovery of items from earlier trials might increase as PI is increasing. This latter result was also unconfirmed.

Dillon and Thomas (1975) further investigated the relationship between current and just previous trials in order to assess to what degree intrusions from previous trials could determine recall on the current trial. They believed that if competition was a viable process in describing PI, then the number of intrusions should be negatively related to recall. In their study, participants were encouraged to guess during recall. Results showed intrusions to be unrelated to recall success. Given the independence of recall and intrusions, they suggested that measuring PI through decreases in recall across trials should not be described in terms of competition. A further manipulation claimed to increase the competition from just previous trials even more through requiring participants to simultaneously recall the items from both trials. Recall of items from the current trial was no worse in this manipulation compared to when participants were just to recall the items from the current trial. Dillon and Thomas concluded that the absence of signs of competition when competition should have been at its highest made it unlikely that this factor accounted for PI.

An earlier demonstration of the impact of learning on performance showed that the degree to which items are learnt during encoding might influence PI. Although Knight and Gray (1967) showed typical effects of PI even when they insured high levels of learning on each trial, they also showed that items that were not learnt to a high degree were more susceptible to PI. This suggests that if items are poorly encoded, then they will be more susceptible to PI; however, even if items are encoded to a high degree, PI may still arise.

Process non-specific

Incorporating the evidence in favour of both accounts, later work suggested that PI is unlikely to be process pure. O'Neill, Sutcliffe, and Tulving (1976) followed up Gardiner, Craik, and Birtwistle's (1972) retrieval cue experiments and suggested that the sub-category label that was presented on PI-release trials was likely to have been primed during encoding, and that this could influence the release from PI. In support of this, participants often failed to report that they noticed the shift-change, or treated that trial in a different way to previous ones.

Radtke and Grove (1977) described the encoding retrieval debate in terms of availability and accessibility. From an encoding standpoint, PI builds up as items become less available. From a retrieval standpoint, PI builds up as items become less accessible. When PI had already reached asymptote in a Brown-Peterson task, Radke and Grove repeated some of the items that had been presented in earlier sets. The trial number of the initial presentation of the item was manipulated, as was the lag between its first and second presentation. A facilitatory effect of repetition (better recall of repeated items) was dependent on the initial trial of presentation. Repeated items initially presented in trial 1 gave rise to a more pronounced repetition benefit than repeated items presented in trials 2-4. Radke and Grove argued that the more pronounced repetition benefit from items presented in trial 1 must have been mediated by the increased availability of items presented in the first trial. For this benefit to have arisen, items encoded in the first trial must have been either differentially encoded or stored. They introduced a distinction between two types of information associated with PI: general (e.g., features making up an item) and specific (e.g., novel contextual feature) occurrence information. First trial presentation acted as a specific information cue to items presented on the first trial; having specific in addition to general information available to them, first items generated better recall.

Appendix 2

Theories of recollection and familiarity

Before the terms of recollection and familiarity were introduced, a recognition model introduced by Atkinson and Juola (1974) described the need for a process that would engage in a controlled search of memory if the signal strength of a test item was such that it could not be clearly accepted or rejected. They suggested that this control process would only be recruited when the assessment of memory strength was equivocal about whether an item was studied or not. Mandler (1980) introduced the term recollection, and also described it as a search process; however, he made a further critical suggestion which is that recollection and familiarity can operate independently of one another. Mandler argued that familiarity judgements in memory were based on representations of integrated perceptual features that formed an event. This may be termed *intra-item* integration. In contrast to this process, Mandler proposed that recollection allows for features *extrinsic* to the current event of focus to become associated with that event—*inter-item* information.

This earlier work suggested that recollection was a controlled process through which memory was searched. In contrast, familiarity was related to content-based information that was automatically retrieved by the re-presentation of an encoded item during recognition, or by a cue in tests of recall. This distinction was capitalised upon by Jacoby (Jacoby & Dallas, 1981; Jacoby, 1991) when he related recollection and familiarity to Shiffrin and Shiffrin's (1977) control and automaticity framework. Jacoby proposed that bottom-up automatic processes, which re-activate representations in memory, generate a sense of familiarity, while recollection allows for the controlled recovery of contextual details associated with an event during encoding.

In Yonelinas' (2002) dual process theory, the role of recollection is elaborated on in relation to the strength of memory signals. If a signal falls above a certain threshold, then qualitative information, such as the context within which events were encoded, is retrievable through the recollection process. This process and a measure of familiarity, derived bottom-up from the stimulus, may differ in terms of the level of confidence that they generate in an individual's conscious perception of memory, with the recollection process yielding uniformly higher levels of confidence. Yonelinas also reintroduced the importance of Mandler's distinction between intra- and inter-item information, adopting the term, *unitization* to describe the binding of intra-unit information to form a coherent event/stimulus (Graf & Schacter, 1989). In this view, variability in unitization is believed to influence familiarity.

Parallel to the development of these models, a further conception of recollection and familiarity relates both processes to separate memory systems. Tulving (1985) proposed that memory relies on distinct systems that are responsible for processing and storing different types of information, two key systems being episodic and semantic memory. Although both of these systems are assumed to work sequentially during encoding, with the semantic system processing information before it proceeds to be processed by the episodic system, the two systems work independently and in parallel during retrieval. Tulving surmised that, at a conscious level, the qualitative experience of memories relating to each system differed. Remembering was linked to the awareness of memories represented in the episodic system; knowing was the type of awareness ascribed to memories represented in the semantic system. Participants have been shown to be capable of distinguishing between remember and know judgements when they identify items as having been presented in an earlier list (Gardiner, 1988). Remembering is recognised as being aware of elaborate details associated with the encoding of an event, such as contextual details, whereas knowing is linked with a strong feeling of familiarity in the absence of remembering (Gardiner, Ramponi, & Richardson-Klavehn, 1998).

A more recent model, the Source of Activation Confusing (SAC) model, by Reder and colleagues (e.g., Reder, Nhouyvanisvong, Schunn et al., 2000; Diana, Reder, Arndt, & Park, 2006) forges the approaches of these previous models into a more mechanistic account of how recollection and familiarity are instantiated. Each item presented for encoding is assumed to be reflected in a concept node. Following the first trial of a task, an experimental context node is formed that represents generic contextual details related to the task; for example, room settings. On particular trials, associations may be formed between a concept node, and a specific context node that represents a contextual detail that is more directly associated with the item being processed. In the processing of any one item, an episodic node can be created to hold the link between the other three nodes. During testing, activation of the episodic node gives rise to recollection, while activation of the concept node alone allows for a sense of familiarity. In contrast to the previous models, however, the ease of recollection itself is also conceived of as reflecting memory strength, although in this case this is related to the strength of the association between an item and its context.

<u>The nature of information retrieved through recollection and familiarity</u>

A number of distinctions between the nature of familiarity and recollection processes can be made. Firstly, most models suppose that recollection is associated with increased ‘quality’ of information (Diana et al., 2006; Mandler, 1980; Tulving, 1985; Yonelinas, 2002). The models proposed by Jacoby (1991) and Atkinson (1974) can be thought to differ in this respect. In Jacoby's account, it is not the quality of information that separates recollection from familiarity, but the degree to which information can either be passively available (through automaticity) or actively accessed (through control). In the Atkinson model, however, recollection is only employed when a stimulus cannot be identified through familiarly; thus recollection is linked with degraded, rather than embellished representation.

Secondly, four of the models (Diana et al., 2006; Mandler, 1980; Tulving, 1985; Yonelinas, 2002) profess a strong link between recollection and the ability to represent context, and also, though not always as directly, the models imply a link between familiarity and the ability to represent content. Recollection is required to consolidate inter-item associations, and familiarity is required to strengthen the connections between intra-item features (Mandler, 1980; Yonelinas, 2002).

Thirdly, most models assume that familiarity and recollection operate in a graded and all-or-none manner, respectively (Atkinson & Juola, 1974; Mandler, 1980; Jacoby, 1991; Yonelinas, 2002). The graded access to familiarity is subsumed in the use of signal detection theory in its description. The assumption that access to recollection is all-or-none stems from the description of recollection as a search process: search either succeeds in finding its target, or it does not, that is, it is all-or-none.

These assumptions were qualified by Yonelinas (1994; 1999) when the shapes of receiver-operating-curves (ROCs) were manipulated to be based more on recollection, or familiarity. ROCs can be derived through plotting hits against false alarms at different levels of response confidence. The shape of the relationship between hits and false alarms is more linear and symmetrical in probability space if participants primarily recruited familiarity in the service of memory. The linear shape of the familiarity-based ROC reflects linear sensitivity increases in perceiving familiarity. The shape of the relationship between hits and false alarms is more curvilinear and asymmetrical in probability space if participants rely more on recollection in the service of memory. The curvilinear shape of the recollection based ROC is taken to stem from the high criterion that separates memories that are recollected from those that are not. The intercept of the curve represents a measure of familiarity, and the slope represents a measure of recollection. Combined, an assessment of the shape of the ROC with the slope and intercept measures provides a means of measuring recollection and familiarity. Despite the greater likelihood that recollection is all-or-none, Reder and colleagues (Diana et al., 2006) favoured a graded description of recollection, as it fits situations in which some contextual details of an event can be recalled when others cannot.

Appendix 3

Describing the relationship between remember and know responses

According to Tulving (1985), information is first encoded into the semantic system before it is consolidated into the episodic system. Storage then operates in parallel in both systems, and retrieval operates independently in the systems. Based on this systemic perspective, Knowlton (1998) suggested that the relationship between remember and know is one of redundancy: remember responses reflect both familiarity and recollection, whereas know responses reflect familiarity in the absence of recollection. Knowlton and Squire (1995) had previously found that if memory is tested at two time points, shortly after encoding and then after a longer interval, a proportion of items that were earlier given a remember response are later converted to a know response. The dynamic conversion of remember responses into know responses was deemed to fit the redundancy view in which the loss of recollection could leave familiarity spared, but not vice versa.

Knowlton (1998) additionally argued that this one-way conversion went against the view that remember and know represent exclusive memorial substrates or independent processes. However, given that the instructions push participants to respond to better memories with remember, this result might be influenced by decisional factors. As Gardiner and colleagues acknowledge (e.g., Gardiner et al., 1998), remember and know assess an individual's subjective level of awareness. Remember and know may come to represent qualitatively independent experiences at the level of awareness if they do indeed reflect independent processes, despite the influence of decisional factors.

Rajaram (1996) presented an independence model of remember and know judgements, and described the two underlying processes in relation to distinctiveness and perceptual fluency. Remembering was taken to refer to distinct episodic memories for information, and knowing was described in terms of fluent processing of perceptual information (consistent with Jacoby, 1991) describing familiarity in terms of processing fluency rather than activation strength). When the congruence between study and test modality was manipulated (items presented as words at study might be shown as pictures at test), a switch in modality reduced remember responses. Effects on remember responses were also brought about by changing the size and orientation of encoded pictorial stimuli. Rajaram argued that such changes reduced the quality of contextually distinctive information that was being provided to participants during testing, and that this decrease in distinctiveness reduced the number of remember responses. As further support for a link between remember responses and contextual distinctiveness, Rajaram (1998) manipulated conceptual (homographs) and perceptual (orthography) aspects of encoded stimuli such that either a more or less distinct version of the stimulus was represented in memory. Remember responses benefited from more distinct representations.

Yonelinas and Jacoby (1995) introduced a novel means of calculating familiarity from know responses. In typical binary choice procedures, remember and know judgments are mutually exclusive: remember responses can reflect both recollection and familiarity, whereas know responses reflect familiarity in the absence of recollection. Know responses may thus be an underestimate of familiarity. Yonelinas and Jacoby suggested that know responses be divided by the number/proportion of opportunities participants have to make know responses ($F = K / (1-R)$). They compared dual-process measures of recollection and familiarity with original remember-know measures, and remember and adjusted know measures in recognition memory for random geometric shapes. When know responses were adjusted, then the remember know procedure produced similar effects to the dual process procedure: when the stimuli changed size between study and test, recollection and familiarity were reduced. Without adjusting the know response, only remember responses were reduced following size changes, consistent with the results of Rajaram. Given that the results obtained through using the remember-know procedure were similar to those obtained using the dual-process procedure, Kelley and Jacoby (1998) suggested that knowing is a measure of familiarity, and that knowing therefore reflects automaticity.

In their analysis of remember-know responses, Yonelinas (2001) further showed that, under divided attention conditions, recollection (remember responses) was reduced, as was familiarity (corrected know responses), though familiarity was affected to less of a degree. A further experiment introduced a levels of processing manipulation during encoding, and the data were examined using Jacoby's process dissociation procedure, ROCs, and remember-know. In all methods, deep encoding benefited recollection, whereas level of processing did not influence familiarity.

Appendix 4

Further evidence for dissociation between recollection and familiarity

Beyond the behavioural measures of remember-know and the WFME, the argument that recollection and familiarity make distinct contributions to memory has extensive support through a number of sources. As discussed below, EEG studies have related familiarity to a negative, frontal ERP component stimulated in the region of 300-500 ms called the FN400 old/new effect. Recollection, on the other hand, has been related to a parietal positivity in the 600-1000 ms range called the parietal old/new effect. While the medial temporal lobe (MTL) is related to recognition memory generally, fMRI and neurological studies have suggested a different distinction between recollection and familiarity, with the hippocampus being related to recollection, whilst other MTL regions are related to familiarity. Finally, pharmacological manipulations also support dissociation. This diversity of support encourages a closer look at how both recollection and familiarity influence the representation of information in memory at the microscopic level.

ERP and functional measures

Rugg, Cox, Doyle, and Wells (1995) related recollection to the magnitude of the old/new parietal-related ERP component through examining the word frequency effect on hit responses in recognition memory. Low-frequency items stimulated a far larger parietal old/new ERP effect than high-frequency items, and this was related to the better recollection of low-frequency stimuli. Remember-know judgments have also been dissociated based on their ERP components. Know judgements are related to a temporoparietal positivity in the N400 range, and a later frontocentral negativity

(600-1000 ms), whereas remember judgements are associated with a late bifrontal and left parietotemporal positivity (600-1000 ms; for example, Düzel, Yonelinas, Mangun, et al., 1997). The relationship between the parietal old/new effect and recollection was further demonstrated when the effect was reduced under divided attention whilst the FN400 old/new effect was unaffected (Curran, 2004).

FMRI studies support a link between recollection and the hippocampus (for a review, see Rugg & Yonelinas, 2003). Remember-know judgments have also supported an exclusive link between the hippocampus and recollection. Eldridge, Knowlton, Furmanski et al. (2000), for example, found greater hippocampal activation in an fMRI study in remember relative to know judgements. Hippocampal activation did not differ as a function of whether an item was judged as familiar (know) or unfamiliar (new), suggesting an exclusive role for the hippocampus in recollection. Know judgements failed to be related to a particular region, however.

Ranganath, Yonelinas, Cohen, et al. (2004) highlighted one reason why familiarity-related fMRI findings are not as consistently found as recollection-related findings. Based on behavioural data that shows the continuous basis of familiarity assessments, they had participants' rate familiarity along a scale from little to very familiar. They examined subsequent recollection- and familiarity-based activation during encoding. Participants carried out one of two tasks on each word presented during encoding, the task being signalled by the colour of the item. During recognition, participants first related their confidence on having seen a particular item, and then made a source judgment as to what colour it had been associated with. Activation during encoding within the rhinal cortex was positively related to the level of confidence with which participants responded to old items, while encoding activity within the hippocampus and posterior parahippocampal cortex was related to correct source judgments. Additionally, there were dissociations in frontal cortex with regard to which regions were associated with recollection and familiarity. Familiarity effects were related to activation in a region of the frontopolar cortex, and medial orbitofrontal cortex. In contrast, large parts of the inferior frontal gyrus (IFG) were related to recollection, although one posterior part was related to both processes.

A second reason why familiarity-related findings may be less consistent is that activation from regions associated with familiarity seems to differ between encoding and recognition. In contrast to the findings of Ranganath et al. (2004), Gonslaves, Kahn, Curran, et al. (2005) found that memory strength for old items, as reflected in confidence responses made during testing, was parametrically related to decreased activation in perirhinal/entorhinal, while activation in the parahippocampal cortices was linked to growing familiarity. Of additional interest, know false alarms were specifically associated with reduced activation in parahippocampal cortex relative to correct rejections. The difference in parahippocampal activation across increased confidence to hits, and know false alarms suggests a role for this area in facilitating content representation. The stimuli used in the study were faces, and a final reduction in signal strength was also found in the fusiform cortex, suggesting that these MTL areas may respond along with content-specific areas to item familiarity.

Other evidence for decreased activation in response to increased familiarity comes from Montaldi, Spencer, Roberts, and Mayes (2006). Participants made graded familiarity judgements to complex visual scenes. Decreased activation in response to increased familiarity was found in the perirhinal cortex, insula, and left superior temporal cortex. There was also evidence for increased activation in some areas: the left dorsomedial thalamus, left ventrolateral, and anteromedial frontal cortex, posterior cingulated cortex, and left parietal neocortex. Recollection exclusively activated the hippocampus, and a number of regions were more responsive to recollection than to strong familiarity, including left anterior and inferolateral frontal and parietal cortices. However, they failed to find areas receptive to familiarity strength that were uninfluenced by recollection.

In an effort to formulate these conflicting findings in an interpretable frame, Daselaar, Fleck, and Cabeza (2006) distinguished between two sources that could contribute to familiarity based judgements: familiarity assessment itself, and novelty detection (old > new). Confidence ratings were collected following old/new judgments. Within MTL itself, confidence in novelty detection was related to linear decreases in signal strength in the anterior half of the hippocampus and rhinal cortex. Confidence in familiarity was related to linear increases in signal strength in the parahippocampal gyrus, and confidence in recollection was related to a non-linear increase in signal strength in the posterior half of the hippocampus. The non-linear and linear fit to recollection and familiarity respectively matches the predictions of the Yonelinas model. This difference in how activation corresponded to both recollection and familiarity was also present in other regions of the brain. A retrosplenial/ventral posterior cingulate region, a parieto-temporal region, and ventrollateral PFC (including areas of IFG) were associated with recollection. A dorsal posterior cingulate region, the precuneous, and a parieto-occipital region were associated with familiarity. Notably, the right dorsolateral prefrontal cortex (DLPFC) was associated with novelty detection. This is consistent for a role in frontal related processes in monitoring distracters to prevent false recognition (e.g., Gerrie & Garry, 2007).

Daselaar et al. reasoned that activation in parieto-occipital regions supported a strong link between familiarity and the strength with which perceptual information is represented, as this region is interconnected with the parahippocampal gyrus which is itself implicated in object representation (Gonslaves et al., 2005). The parieto-temporal area shares connections with the hippocampus; hence the response of this area to recollection. Daselaar et al. reasoned that activation within rhinal cortex is responsive to the current goal. During encoding, novelty detection facilitates encoding, whereas during retrieval, better performance is facilitated through responding more to what is familiar rather than to what is novel.

At a behavioural level, in the measurement of familiarity, it is difficult to see whether novelty detection may also be contributing to performance. In addition to the activation pattern, Daselaar et al. ran multiple regressions to see if the regions associated with recollection, familiarity, and novelty detection could independently predict a significant amount of variability in the old/new data. The findings confirmed that each process was significantly and independently related to recognition memory.

Neurological samples

Both familiarity and recollection judgments are commonly examined in neurological patients, with a view to testing whether a patient group has a deficit in one but not the other process. Amnesic patients are proposed to have a pronounced deficit in recollection which has been related to damage inflicted on the hippocampus (Aggleton & Brown, 1999). Aggleton, Vann, Denby, et al. (2005) showed that if damage in amnesic patients was exclusive to the hippocampus, then familiarity was spared. Consistent with this, amnesic participants perform more poorly on measures on recollection as collected through the dual-process procedure compared to controls (Verfaellie & Treadwell, 1993; Yonelinas, Kroll, Dobbins, et al., 1998); they respond with fewer remembers relative to controls; and their ROCs tend to be more linear in probability space than controls (Yonelinas et al., 1998). Alzheimer's patients have also been shown to have a larger deficit in recollection than familiarity. In testing the WFME, Balota, Burgess, Cortese, and Adams (2002) failed to find a low frequency advantage in Alzheimer's patients, whilst their performance on high-frequency items matched that of controls. The typical advantage to low-frequency hit rate has been shown to be related to recollection in the WFME (Reder et al. 2000, 2002).

A recent study by Davidson, Anaki, Saint-Cyr et al. (2006) suggested that the opposite pattern could also occur. These authors compared Parkinson's patients with controls on the WFME, remember-know responses, and process-dissociation estimates of recollection and familiarity. Parkinson's patients showed a reduction in their estimates of familiarity (as calculated through remember and know responses, and process-dissociation) relative to controls, while the recollection estimates were similar, if not greater, for the patients than the controls. The hit-rate pattern as a function of frequency was matched across patients and controls; however, the patients were more likely to make high-frequency false alarms. This latter finding was attributed to an inability to regulate decisions based on familiarity. Davidson et al. reasoned that a familiarity deficit may arise from the impact that dopaminergic dysfunction has on regions within the basal ganglia, or on the interplay between the prefrontal cortex and the basal ganglia.

Further evidence that familiarity could be impaired in the absence of recollection was presented by Bowles, Crupi, Mirsattari et al. (2007). Recollection and familiarity were examined in a patient who had endured damage to the perirhinal cortex following epilepsy-related surgery. Remember-know responses, ROC curves, and a response-deadline procedure all confirmed that this patient was selectively impaired in the ability to recruit familiarity.

Pharmacological manipulations

Lorazepam and midazolam have both been shown to impair recollection while sparing familiarity. Curran, Gardiner, Java, and Allan (1993) showed that Lorazepam exclusively impaired remember relative to know responses. Curran, DeBuse, Woroch, and Hirshman (2006) further demonstrated that midazolam reduced the parietal old/new effect, but left the FN400 unchanged. They also showed that, while the recollection component correlated with memory performance in a drug placebo condition, the familiarity component correlated with performance under the influence of midazolam. This suggests that, if recollection is unavailable to dominate performance, familiarity fills this role.

A further manipulation that supports a dual process account is the impact of the administration of midazolam on the hit rate portion of the WFME. Hirshman, Fisher, Henthorn et al. (2002) showed that the negative impact that midazolam has on recollection reversed the typical pattern of the WFME on hit-rates, while leaving the false alarm portion unaffected. Remember-know judgements were also administered to items perceived as old. In the placebo condition, remember responses to low-frequency targets were increased relative to high frequency items; this was eliminated in the midazolem condition. Midazolem also eliminated the effect of increasing the stimulus exposure duration at encoding, while longer durations were associated with increased proportions of remember responses in the placebo condition.

Appendix 5

Evidence for unitization

Unitization has also been shown to possess a distinct relationship with the familiarity-related ERP component. Jager, Mecklinger, and Kipp (2006) manipulated unitization by pairing different profiles of the same face during encoding. During testing, participants first made old/new judgements to presented faces. For correct old responses, they were then presented with two profiles of the same encoded face, and had to choose which profile had been encoded. The profiles were similar, as they were of the same face; thus the degree to which participants had bound the features of the initial profiles they did see would determine their ability to distinguish between similar profiles. This unitization condition was contrasted with a different face condition, in which different faces were presented during encoding. This latter condition was less reliant on unitization, as the test items being compared were less similar. During the forced-choice decision in the different face condition, participants were to choose the face that was paired with the initial face to which they responded old.

The unitization and the non-unitization conditions differed in both the familiarity and the recollection ERP components. The parietal recollection component was absent in the unitization condition, which may reflect the hippocampus disengaging from the task when feature-overlap is too great (consistent with suggestions made by Norman & O'Reilly, 2003). The familiarity ERP component was more involved in the unitization condition than in the other condition, and this is consistent with the involvement of familiarity in binding. The recollection ERP component did arise in the different faces condition, while the negative frontal familiarity component was absent. The findings suggest that when recognition is more dependent on distinguishing between intrinsic features of an item/event, the familiarity component becomes more engaged in influencing memory. Alternatively, when memory relies more on distinguishing between separate items/events, recollection suffices.

The baseline relationship between encoded word pairs has also been shown to influence recognition performance through its links with unitization. Rhodes and Donaldson (2007) had participants encode three categories of word pairs. One category of pairs was made up of compound words having a strong association, and likely a pre-existing unitised representation in memory. Two other categories were made up of more weakly associated pairs. Compound words were better recognised during testing. The parietal recollection component of the ERP response was present equally across the categories. The negative frontal familiarity component was only present for the compound words with unitised representations.

Unitization also shows a distinct relationship to anatomical regions believed to be engaged in familiarity related processing. Staresina and Davachi (2006) made a three way comparison between item recognition, feature binding, and recall. During encoding, participants were presented words on color backgrounds. Participants were encouraged to imagine the noun in the particular background color, and to judge whether the combination was plausible in nature or not. After a recall test, participants completed a recognition task that first required old/new judgments, and then source judgments that required participants to indicate the color bound to the encoded word, if possible—a test of unitization in memory. A number of areas showed a linear increase in activation from item recognition to unitized recognition to recall. These included anterior left inferior frontal gyrus (aLIFG), the right hippocampus, and the lateral temporal and fusiform cortices. An additional posterior region of the LIFG showed equal activation for unitization and recall, greater than in response to item recognition. Consistent with a link between the rhinal cortex and unitization, the left perirhinal cortex responded equivalently during encoding regardless of whether later pairs were recalled or not recalled, as long as the colour of the word was remembered. Finally, free recall was exclusively supported by the involvement of left mid/DLPFC and bilateral PPC (including inferior parietal lobule, intraparietal sulcus, and retrosplenial cortex).

Giovanello, Keane, and Verfaeillie (2006) examined performance following the presentation of word pairs to be associated versus unitized compound words. Remember-know judgments were required during recognition. In control participants, familiarity (corrected know measure) boosted recognition for compound over associated words. In addition, a group of amnesic participants showed better memory for the compound pairs over the unrelated pairs (and this held particularly for patients with exclusive hippocampal damage). These findings are consistent with the hippocampus playing a role in recollection, not familiarity, and with unitization effects being mediated through familiarity. Similar data from amnesic patients have been reported by Quamme, Yonelinas, and Norman (2007).

In a tightly controlled study Diana, Yonelinas, and Ranganath (2008), conditions were manipulated that encouraged unitization or did not. Unitization was encouraged when participants rated the plausibility of the association between a named stimulus and the background color it was presented on. Unitization was not encouraged when participants made pleasantness or size judgments on encoded items, pending on the background color. In one experiment, participants gave confidence ratings to their source judgments on the subsequent recognition task. When items and sources were unitized, the resultant ROC curve was more curvilinear than without unitization, demonstrating a greater deployment of familiarity under conditions of unitization. A further experiment used yes-no responses under speeded or unspeeded recognition conditions under the same sets of instructions. Source memory was below chance for item-color associations that were not unitized, while it was above chance with unitization in speeded conditions. This fits with the speeded conditions promoting familiarity judgments.

Appendix 6

A focus on executive control in schizophrenia

WM is an area of extensive research in schizophrenia. The beginnings of WM-related research in schizophrenia can be traced back to the examination of oculomotor behaviour in monkeys following DLPFC cortex lesions (Goldman-Rakic, 1987), and the suggestion that this behaviour resembled cognitive deficit in schizophrenia. There is certainly enough research to suggest that the WM system operates atypically in schizophrenia. Differences in the WM system have been shown to be amodal, as such differences transcend the modality in which information is presented (e.g. evidence for spatial WM deficit: Park & Holzman, 1992, Carter, Robertson, Nordahl, et al., 1996; evidence for verbal WM deficit: Fleming, Goldberg, Gold, & Weinberger, 1995; Stevens, Goldman-Rakic, Gore, et al., 1998). A candidate that was proposed to account for this amodal pattern was the central executive (e.g. Gooding & Tallent, 2004). Functional activation differences between schizophrenia samples and controls have been shown to include the DLPFC, a suggested substrate of executive control, adding support to this hypothesis (Callicott, Ramsey, Tallent, et al. 1998; Callicott, Bertolino, Mattay, et al., 2000; Callicott, Egan, Mattay, et al, 2003; Carter, Perlstein, Ganguli, et al., 1998; Manoach, Gollub, Benson, et al. 2000; Manoach, 2003).

Initial accounts suggested that the central executive itself is dysfunctional, and fMRI studies that reported reduced activation in DLPFC (Callicott et al., 1998; Carter et al., 1998) seemed consistent with this. However, some studies have reported increased activation in DLPFC (Callicott et al., 2000; Manoach et al., 2000), and this seems less consistent with the dysfunctional executive account. More recent studies look at the response of the DLPFC to varying levels of cognitive load (Callicott et al., 2003; Manoach, 2003). These studies have shown that activation in the DLPFC shows a characteristic u-shaped pattern akin to that shown in controls (peak levels for loads that are just inside WMC), but the pattern is shifted to the left, suggesting that schizophrenia is related to the need to engage executive control at lower levels of load (Perlstein, Carter, Noll, & Cohen, 2001).

Jansma, Ramsey, van der Wee, and Kahn (2004) also questioned whether the differences found between patients and controls in DLPFC activation needed to be understood from the perspective of dysfunction. They pointed out that, in itself, the response of the DLPFC in patients was normal, although shifted to the left, and proposed that changes in DLPFC activation were simply a correlate of disturbed WM, not a cause. The amount of evidence against a pure executive account of atypical cognition in schizophrenia is mounting. In addition to the above evidence, meta-analyses of WM impairment report that average effect size in studies of executive function tends to be smaller (Heinrichs & Zakzanis, 1998) than the large effect sizes found for both global verbal memory (Heinrichs & Zakzanis) and spatial WM (Piskulic, Olver, Norman, & Maruff, 2007).

One question then is why are individuals with schizophrenia less capable of accommodating higher amounts of information in WM? In other words, why is their WMC decreased? Another approach to the study of a-modal WM deficit views it in terms of hierarchically related processes that move from encoding to maintenance to manipulation. One hypothesis is that it might be possible to localise atypical patterns in cognition to the operation of one of these processes, and to suggest that if one of these processes is operating less efficiently, then a reduced quantity of information will be supported in WM. Such an exclusive hypothesis is not supported, however, and studies have found evidence to suggest dysfunction at encoding (Glahn, Therman, Manninen, et al., 2003; Mathes, Wood, Proffitt, et al., 2005), maintenance (Cannon, Glahn, Kim, et al., 2005; Glahn et al., 2003), and manipulation/retrieval (Cannon et al., 2005; Tan, Choo, Fones, & Chee, 2005).

Setting DLPFC-related findings aside, several other regions have been shown to respond differentially across patients and controls, even when both groups are matched on performance. For example, in a study by Sneider, Habel, Reske, et al. (2007), patients showed reduced activation in ventrolateral prefrontal, thalamic, caudate, hippocampal, and superior temporal regions, and increased activation in the paracentral lobule, and the pre- and post central gyri. Structural abnormalities are often found in the hippocampus (see Boyer, Phillips, Rousseau, & Ilivitsky, 2007, for a review), and the basal ganglia (Ballmaier, Schlagenhauf, Toga, et al., 2008 [unmedicated]), but findings are not always consistent; for example, Baiano, Perlini, Rambaldelli, et al. (2008) found reduced volume in the entorhinal cortex, but failed to find reduced volume in the hippocampus. In effect, it is difficult to draft fMRI and structural findings in schizophrenia into a coherent hypothesis of cognitive deficit, as behavioural findings are yet to better specify the process(es) or mechanism(s) that is(are) most impaired in schizophrenia.

References

Achim, A.M. and Lepage, M. (2003). Is associative recognition more impaired than item recognition memory in schizophrenia? A meta-analysis. *Brain and Cognition*, 53, 121-124.

Aggleton, J. P. and Brown, W. M. (1999). Episodic memory, amnesia, and the hippocampal-anterior thalamic axis. *Behavioral and Brain Sciences*, 22, 425–486.

Aggleton, J.P, Vann, S.D., Denby, C., Dix, S., Mayes, A.R., Roberts, N., and Yonelinas, A.P. (2005). Sparing the of the familiarity component of recognition memory in a patient with hippocampal pathology. *Neuropsychologia*, 43, 1810–1823.

Allen, R. J., Baddeley, A. D., and Hitch, G. J. (2006). Is the binding of visual features in working memory resource-demanding? *Journal of Experimental Psychology: General*, 135, 298-313.

Amundson, J.C. and Miller, R.R. (2007). Associative interference in pavlovian conditioning: a function of similarity between the interfering and target associative structures. *The Quarterly Journal of Experimental Psychology*, 61, 1340-1355.

Anderson, J. R. (1974). Retrieval of propositional information from long-term memory. *Cognitive Psychology*, 6, 451-474.

Anderson, J. R. (1983). Retrieval of information from long-term memory. *Science*, 220, 25-30.

Anderson, J. R., & Bower, G. H. (1972). Recognition and retrieval processes in free recall. *Psychological Review*, 79, 97-124.

Atkins, A.S. and Reuter-Lorenz, P.A. (2008). False working memories? Semantic distortion in a mere 4 seconds. *Memory and Cognition*, 36, 74-81.

Atkinson, R. C., and Juola, J. F. (1974). Search and retrieval processes in recognition memory. In D. H. Krantz, R. C. Atkinson, R. D. Luce, and P. Suppes (Eds.), *Contemporary developments in mathematical psychology, Vol. 1, Learning, memory and thinking*. San Francisco, CA: Freeman, p.p. 243–293.

Baddeley, A. (1986). *Working memory*. New York: Oxford Press.

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology*, 49A, 5-28.

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

Baddeley, A. (2002). Is working memory still working? *European Psychologist*, 7, 85-97.

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Neuroscience Reviews*, 4, 829-839.

Baddeley, A. and Hitch, G. (1974). Working memory. In G.A. Bower (Ed.), *The Psychology of Learning and Motivation*, 8, 47-89. New York: Academic Press.

Baiano, M., Perlini, C., Rambaldelli, G., Cerini, R., Dusi, N., Bellani, M., Spezzapria, G., Versace, A., Balestrieri, M., Pozzi-Mucelli, R., Tansella, M., and Brambilla, P. (2008). Decreased entorhinal cortex volumes in schizophrenia. *Schizophrenia Research*, 102, 171-180.

Ballmaier, M., Schlagenhauf, F., Toga, A., Gallinat, J., Koslowski, M., Zoli, M., Hojatkashani, C., Narr, K., and Heinz, A. (2008). Regional patterns and clinical correlates of basal ganglia morphology in non-medicated schizophrenia. *Schizophrenia Research*, 106, 140-147.

Balota, D.A., Burgess, G.C., Cortese, M.J., and Adams, D.R. (2002). The word-frequency mirror effect in young, old, and early-stage Alzheimer's disease: evidence for two processes in episodic recognition performance. *Journal of Memory and Language*, 46, 199-226.

Barrouillet, P., Bernardin, S., and Camos, V. (2004). Time constraints and resource sharing in adults' working memory spans. *Journal of Experimental Psychology: General*, 133, 83-100.

Barrouillet, P. and Camos, V. (2009). Interference: unique source of forgetting in working memory? *Trends in Cognitive Sciences*, 13, 145-146.

Beech, A. and Claridge, G. (1987). Individual differences in negative priming: relations with schizotypy and personality traits. *British Journal of Psychology*, 78, 349-356.

Beech, A., McManus, D., Baylis, G., Tipper, S., and Agar, K. (1991). Individual differences in cognitive processes: towards an explanation of schizophrenic symptomatology. *British Journal of Psychology*, 82, 417-426.

Bennett, R. W. (1975). Proactive interference in short-term memory: Fundamental forgetting processes. *Journal of Verbal Learning & Verbal Behavio*r, 14, 123-144.

Bennett, R.W. and Kureja, P.L. (1976). Competition processes and proactive interference in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, 15, 703-711.

Bentall, R.P., Claridge, G.S., and Slade, P.D. (1989). The multidimensional nature of schizotypal traits: a factor analytic study with normal subjects. *British Journal of Clinical Psychology*, 28, 363-375.

Bird, C.P. (1976). On the role of processing requirements in short-term memory. *Journal of Experimental Psychology: Human Learning and Memory*, 2, 234-243.

Bird, C.P. (1977). Proactive inhibition as a function of orienting task characteristic. *Memory and Cognition*, 5, 27-31.

Blumenfeld, R.S. and Ranganath, C. (2006). Dorsolateral prefrontal cortex promotes long-term memory formation through its role in working memory organisation. *The Journal of Neuroscience*, 26, 916-925.

Boldini, A., Russo, R., and Avons, S.E. (2004). One process is not enough! A speed-accuracy tradeoff study of recognition memory. *Psychonomic Bulletin and Review*, 11, 353-361.

Bowles, B., Crupi, C., Mirsattari, S.M., Pigott, S.E., Parrent, A.G., Pruessner, J.C., Yonelinas, A.P., and Koehler, S. (2007). Impaired familiarity with preserved recollection after anterior temporal-lobe resection that spares the hippocampus. *Proceedings of the National Academy of Sciences*, 104, 16382-16387.

Boyer, P., Phillips, J.L., Rousseau, F.L., and Ilivitsky, S. (2007). Hippocampal abnormalities and memory deficits: new evidence of a strong pathophysiological link in schizophrenia. *Brain Research Reviews*, 54, 92-112.

Brockmole, J.R., Parra, M.A., Della-Sala, S., and Logie, R.H. (2008). Do binding deficits account for age-related decline in visual working memory? *Psychonomic Bulletin and Review*, 15, 543-547.

Brown, J. A. (1958). Some tests of the decay theory of immediate memory. *Quarterly Journal of Experimental Psychology*, 10, 12-21.

Brown, V.R. and Gorfein, D.S. (2004). A new look at recognition in the Brown-Peterson distracter paradigm: towards the application of new methodology to unsolved problems of recognition memory. *Memory and Cognition*, 32, 674-685.

Bunge, S. A., Ochsner, K. N., Desmond, J. E., Glover, G. H., and Gabrieli, J. D. E. (2001). Prefrontal regions involved in keeping information in and out of mind. *Brain*, 124, 2074-2086.

Bunting, M. (2006). Proactive interference and item similarity in working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 32, 183-196.

Bunting, M. F., Conway, A. R. A., and Heitz, R. P. (2004). Individual differences in the fan effect and working memory capacity. *Journal of Memory and Language*, 51, 604-622.

Burch, G.J., Hemsley, D.R., Corr, P.J., and Gwyer, P. (2006). The relationship between incidental learning and multi-dimensional schizotypy as measured by the oxford-liverpool inventory of feelings and experiences (O-Life). *Personality and Individual Differences*, 40, 385-394.

Burgess, N. and Hitch, G.J. (1992). Toward a network model of the articulatory loop. *Journal of Memory and Language*, 31, 429-460.

Burgess, N. and Hitch, G.J. (1999). Memory for serial order: a network model of the phonological loop and its timing. *Psychological Review*, 106, 551-581.

Burgess, N. and Hitch, G. (2005). Computational models of working memory: putting long-term memory into context. *Trends in Cognitive Sciences*, 9, 535-541.

Burgess, N. and Hitch, G.J. (2006). A revised model of short-term memory and long-term learning of verbal sequences. *Journal of Memory and Language*, 55, 627-652.

Callicott, J.H., Bertolino, A., Mattay, V.S., Langheim, F.J.P, Duyn, J., Coppola, R., Goldberg, T.E., and Weinberger, D.R. (2000). Physiological dysfunction of the dorsolateral prefrontal cortex in schizophrenia revisited. *Cerebral Cortex*, 10, 1078-1092.

Callicott, J.H., Egan, M.F., Mattay, V.S., Bertolino, A., Bone, A.D., Verchinksi, B., and Weinberger, D.R. (2003). Abnormal fMRI response of the dorsolateral prefrontal cortex in cognitively intact siblings of patients with schizophrenia. *American Journal of Psychiatry*, 160, 709-719.

Callicott, J. H., Mattay, V. S., Bertolino, A., Finn, K., Coppola, R., Frank, J. A., Goldberg, T. E., and Weinberger, D. R. (1999). Physiological characteristics of capacity constraints in working memory as revealed by functional MRI. *Cerebral Cortex*, 9, 20-26.

Callicott, J.H., Ramsey, N.F., Tallent, K., Bertolino, A., Knable, M.B., Coppola, R., Goldberg, T., van Gelderen, P., Mattay, V.S., Frank, J.A., Moonen, C.T.W., and Weinberger, D.R. (1998). Functional magnetic resonance imaging brain mapping in psychiatry: methodological issues illustrated in a study of working memory in schizophrenia. *Neuropsychopharmacology*, 18, 186-196.

Cameron, A.M., Geffen, G.M., Kavanagh, D.J., Wright, M.J., McGrath, J.J., and Geffen, L.B. (2003). Event-related potential correlates of impaired visuospatial working memory in schizophrenia. *Psychophysiology*, 40, 702-715.

Cannon, T.D., Glahn, D.C., Kim, J., Van Erp, T.G.M., Karlsgodt, K., Cohen, M.S., Nuechterlein, K.H., Bava, S., and Shirinyan, D. (2005). Dorsolateral prefrontal cortex activity during maintenance and manipulation of information in working memory in patients with schizophrenia. *Achieves of General Psychiatry*, 62, 1071-1080.

Cantor, J. and Engle, R. W. (1993). Working-memory capacity as long-term memory activation: an individual-differences approach. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 19, 1101-1114.

Caplan, J.B., McIntosh, A.R. and de Rosa, E. (2007). Two distinct functional networks for successful resolution of proactive interference. *Cerebral Cortex*, 17, 1650-1663.

Carter, C.S., Perlstein, W., Ganguli, R., Brar, J., Mintun, M., and Cohen, J.D. (2003). Functional hypofrontality and working memory dysfunction in schizophrenia. *American Journal of Psychiatry*, 155, 1285-1287.

Carter, C., Robertson, L., Nordahl, T., Chaderjian, M., Kraft, L., and O'Shora-Celaya, L. (1996). Spatial working memory deficits and their relationship to negative symptoms in unmedicated schizophrenia patients. *Biological Psychiatry*, 40, 930-932.

Chen, W.J., Hsiano, C.K., and Lin, C.C.H. (1997). Schizotypy in community samples: then three-factor structure and correlation with sustained attention. *Journal of Abnormal Psychology*, 106, 649-654.

Coltheart, M., & Geffen, G. (1970). Grammar and memory: I. Phonological similarity and proactive interference. *Cognitive Psychology*, 1, 215-224.

Conrad, R. (1960). Serial order intrusions in immediate memory. *British Journal of Psychology*, 51, 45-48.

Conway, A. R. A. and Engle, R. W. (1994). Working memory and retrieval: a resource-dependant inhibition model. *Journal of Experimental Psychology: General*, 123, 354-373.

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

Conway, A. R. A., Kane, M. J., and Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Sciences*, 7, 547-552.

Cowan, N. (2001). The magical number 4 in short-term memory: a reconsideration of mental storage capacity. *Behavioural and Brain Sciences*, 24, 87-114.

Cowan, N., Johnson, T. D., and Saults, J. S. (2005). Capacity limits in list item recognition: evidence from proactive interference. *Memory*, 13, 293-299.

Crowder, R. G. (1970). The role of one's own voice in immediate memory. *Cognitive Psychology*, 1, 157-178.

Curran, T. (2004). Effects of attention and confidence on the hypothesized ERP correlates of recollection and familiarity. *Neuropsychologia*, 42, 1088-1106.

Curran, T., and Cleary, A. M. (2003). Using ERPs to dissociate recollection from familiarity in picture recognition. *Cognitive Brain Research, 15,* 191-205.

Curran, T., DeBuse, C., Woroch, B., and Hirshman, E. (2006). Combined pharmacological and electrophysiological dissociation of familiarity and recollection. *The Journal of Neuroscience*, 26, 1979-1985.

Curran, H.V., Gardiner, J.M., Java, R.I., and Allen, D. (1993). Effects of lorazepam upon recollective experience in recognition memory. *Psychopharmacology*, 110, 374-378.

D'Amato, M.R. (1973). Delayed matching and short-term memory in monkeys. In G.H. Bower (Ed.), *The Psychology of Learning and Motivation*, Vol. 7. New York: Academic Press.

Dagnall, N. and Parker, A. (2009). Schizotypy and false memory. *Journal of Behaviour Therapy and Experimental Psychiatry*, 40, 179-188.

Dallett, K., & Wilcox, S.G. (1968). Contextual stimuli and proactive inhibition. *Journal of Experimental Psychology, 78,* 475–480.

Daneman, M. and Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behaviour*, 19, 450-466.

Daniel, K.A. (in press). Cognitive control, automaticity, and working memory: a dual process analysis.

Danion, J.M., Huron, C., Vidailhet, P., and Berna, F. (2007). Functional mechanisms of episodic memory impairment in schizophrenia. *Canadian Journal of Psychiatry*, 52, 693-701.

Daselaar, S.M., Fleck, M.S., and Cabeza, R. (2006). Triple dissociation in the medial temporal lobes: recollection, familiarity, and novelty. *Journal of Neurophysiology*, 96, 1902-1911.

Davidson, P.S.R., Anaki, D., Saint-Cyr, J.A., Chow, T.W., and Moscovitch, M. (2006). Exploring the recognition memory deficit in Parkinson's disease: estimates of recollection and familiarity. *Brain*, 129, 1768-1779.

Davies, R.R., Graham, K.S., Xuereb, J.H., Willams, G.B., and Hodges, J.R. (2004). The human perirhinal cortex and semantic memory. *European Journal of Neuroscience*, 20, 2441-2446.

Delaney, H.C., and Logan, F.A. (1979). Item similarity and proactive interference in short-term memory. *Bulletin of the Psychonomic Society*, 14, 288-290.

De Rosa, E. and Hasselmo, M.E. (2000). Muscarinic cholinergic neuromodulation reduces proactive interference between stored odor memories during associative learning in rats. *Behavioural Neuroscience*, 114, 32-41.

D'Esposito, M., Aguirre, G.K., Zarahn, E., Ballard, D., Shin, R.K., and Lease, J. (1998). Functional MRI studies of spatial and nonspatial working memory. *Cognitive Brain Research*, 7, 1-13.

Dewhurst, S. A. and Anderson, S. J. (1999). Effects of exact and category repetition in true and false recognition memory. *Memory & Cognition*, 27, 665–673.

Dewhurst, S. A. and Conway, M. A. (1994). Pictures, images, and recollective experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20, 1088–1098.

Dewhurst, S.A., Holmes, S.J., Brandt, K.R., and Dean, G.M. (2006). Measuring the speed of the conscious components of recognition memory: remembering is faster than knowing. *Consciousness and Cognition*, 147-162.

Diana, R.A., Reder, L.M., Arndt, J., and Park, H. (2006). Models of recognition: a review of arguments in favour of a dual-process account. *Psychonomic Bulletin and Review*, 13, 1-21.

Diana, R.A., Yonelinas, A.P., and Ranganath, C. (2008). The effects of unitization on familiarity-based source memory: testing a behavioural prediction derived from neuroimaging data. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 34, 730-740.

Dillon, R. F. (1973). Locus of proactive interference effects in short-term memory. *Journal of Experimental Psychology: General*, 99, 75-81.

Dillon, R. F., & Thomas, H. (1975). The role of response confusion in proactive interference. *Journal of Verbal Learning and Verbal Behaviour*, 14, 603-615.

Donaldson, W. (1996). The role of decision processes in remembering and knowing. *Memory and Cognition*, 24, 523-533.

Du, Y., Xiao, Z., Song, Y., Fan, S., Wu, R., and Zhang, J.X. (2008). An electrophysiological signature for proactive interference resolution in working memory. *International Journal of Psychophysiology*, 69, 107-111.

Duncan, J., Emslie, H., Willams, P., Johnson, R., and Freer, C. (1996). Intelligence and the frontal lobe: the organisation of goal-directed behaviour. *Cognitive Psychology*, 30, 257-303.

Duncan, J., Parr, A., Woolgar, A., Thompson, R., Bright, P., Cox, S., Bishop, S., and Nimmo-Smith, I. (2008). Goal Neglect and Spearman's *g*: competing parts of a complex task. *Journal of Experimental Psychology: General*, 137, 131-148.

Dunn, J. C. (2004). Remember-know: A matter of confidence. *Psychological Review*, 111, 524-542.

Düzel, E., Yonelinas, A. P., Mangun, G. R., Heinze, H.J., and Tulving, E. (1997). Event-related brain potential correlates of two states of conscious awareness in memory. *Proceedings of the National Academy of Science*, 94, 5973-5978.

Ecker, U.K.H., Zimmer, H.D., and Groh-Bordin, C. (2007). Colour and context: an ERP study on intrinsic and extrinsic feature binding in episodic memory. *Memory and Cognition*, 35, 1483-1501.

Egorov, A.V., Hamam, B.N., Fransen, E., Hasselmo, M.E., and Alonso, A.A. (2002). Graded persistent activity in entorhinal cortex neurons. *Nature*, 420, 173-178.

Eldridge, L.L., Knowlton, B.J., Furmanski, C.S., Bookheimer, S.Y., and Engel, S.A. (2000). Remembering episodes: a selective role for the hippocampus during retrieval. *Nature Neuroscience*, 3, 1149-1152.

Elfman, K.W., Parks, C.M. and Yonelinas, A.P. (2008). Testing a neurocomputational model of recollection, familiarity, and source recognition. *Journal of Experiment Psychology: Learning, Memory, and Cognition*, 34, 752-768.

Elliott, M.C. (1974). Physical size shift and release of proactive inhibition in short term memory. *Journal of Experimental Psychology*, 103, 1216-1217.

Engle, A.K. and Singer, W. (2001). Temporal binding and the neural correlates of sensory awareness. Trends in Cognitive Sciences, 5, 16-25.

Engle, R. W. (2002). Working memory capacity as executive memory. *Current Directions in Psychological Science*, 11, 19-23.

Engle, R.W., Tuholski, S.W., Laughlin, J.E., and Conway, A.R.A. (1999). Working memory, short-term memory, and general fluid intelligence: a latent-variable approach. *Journal of Experimental Psychology: General*, 128, 309-331.

Feredoes, E., Tononi, G., and Postle, B.R. (2008). Direct evidence for a prefrontal contribution to the control of proactive interference in verbal working memory. *Proceedings of the National Academic Society*, 103, 19530-19534.

Fernandes, M. A., & Moscovitch, M. (2000). Divided attention and memory: Evidence of substantial interference effects at retrieval and encoding. *Journal of Experimental Psychology: General*, 129, 155-176.

Fernandes, M. A., & Moscovitch, M. (2002). Factors modulating the effect of divided attention during retrieval of words. *Memory and Cognition*, 30, 731-744.

Fernandes, M. A., & Moscovitch, M. (2003). Interference effects from divided attention during retrieval in younger and older adults. *Psychology and Aging*, 18, 219–230.

Fleming, K., Goldberg, T.E., Gold, J.M. and Weinberger, D.R. (1995). Verbal working memory dysfunction in schizophrenia: use of a Brown-Peterson paradigm. *Psychiatry Research*, 56, 155-161.

Frost, R.R. and Jahnke, J.C. (1968). Proactive effects in short-term memory. *Journal of Verbal Learning and Verbal Behaviour*, 7, 785-789.

Fuchs, A.H. and Melton, A.W. (1974). Effects of frequency of presentation and stimulus length on retention in the Brown-Peterson paradigm. *Journal of Experimental Psychology*, 103, 629-637.

Fuller, R.L., Luck, S.J., McMahon, R.P., and Gold, J.M. (2005). Working memory consolidation in abnormally slow in schizophrenia. *Journal of Abnormal Psychology*, 114, 279-290.

Gardiner, J.M. (1988). Functional aspects of recollection experience. *Memory and Cognition*, 16, 309-313.

Gardiner, J.M. and Cameron, P.C. (1974). Change in speaker's voice and release from proactive inhibition. *Journal of Experimental Psychology*, 102, 863-867.

Gardiner, J. M., Craik, F. I. M., and Birtwistle, J. (1972). Retrieval cues and release from proactive inhibition. *Journal of Verbal Learning and Verbal Behaviour* 11, 778-783.

Gardiner, J.M., Gawlicj, B., and Richardson-Klavehn, A. (1994). Maintenance rehearsal affects knowing, not remembering; elaborative rehearsal affects remembering, not knowing. *Psychonomic Bulletin and Review*, 1, 107-110.

Gardiner, J.M. and Gregg, V.H. (1997). Recognition memory with little or no remembering: implications for a detection model. *Psychonomic Bulletin and Review*, 4, 474-479.

Gardiner, J. M., Gregg, V. H., & Karayianni, I. (2006). Recognition memory and awareness: Occurrence of perceptual effects in remembering or in knowing depends on conscious resources at encoding, but not at retrieval. *Memory and Cognition*, 34, 227–239.

Gardiner, J. M., Gregg, V. H., Mashru, R., & Thaman, M. (2001). Impact of encoding depth on awareness of perceptual effects in recognition memory. *Memory & Cognition*, *29,* 433-440.

Gardiner J.M, Java R.I. (1990). Recollective experience in word and non-word recognition. *Memory and Cognition*, 18, 23–30.

Gardiner, J. M., Java, R. I., & Richardson-Klavehn, A. (1996). How level of processing really influences awareness in recognition memory. *Canadian Journal of Experimental Psychology, 50,* 114-122.

Gardiner, J.M., Konstantinou, I., Karayianni, I., and Gregg, V.H. (2005). Memory awareness following speeded compared with unspeeded picture recognition. *Experimental Psychology*, 52, 140-149.

Gardiner, J. M., & Parkin, A. J. (1990). Attention and recollective experience in recognition memory. *Memory & Cognition*, 18, 579–583.

Gardiner, J.M., Ramponi, C., and Richardson-Klavehn, A. (1998). Experiences of remembering, knowing, and guessing. *Consciousness and Cognition*, 7, 1-26.

Gardiner, J.M., Ramponi, C., & Richardson-Klavehn, A. (1999). Response deadline and subjective awareness in recognition memory. *Consciousness and Cognition*, *8,* 484-496.

Gardiner, J.M., Ramponi, C., & Richardson-Klavehn, A. (2002). Recognition memory and decision processes: A meta-analysis of remember, know, and guess responses. *Memory*, 10, 83-98.

Gardiner, J.M., Richardson-Klavehn, A., and Ramponi, C. (1997). On reporting recollective experiences and direct access to memory systems. *Psychological Science*, 8, 391-394.

Gazzaley, A., Rissman, J., and D'Esposito, M. (2004). Functional connectivity during working memory maintenance. *Cognitive, Affective, and Behavioural Neuroscience*, 4, 580-599.

Gerrie, M.P. and Garry, M. (2007). Individual differences in working memory capacity affect false memories for missing aspects of events. *Memory*, 15, 561-571.

Glahn, D.C., Therman, S., Manninen, M., Huttunen, M., Kaprio, J., Lonnqvist, J., and Cannon, T.D. (2003). Spatial working memory as an endophenotype for schizophrenia. *Biological Psychiatry*, 53, 624-626.

Glanzer, M., & Adams, J. K. (1985). The mirror effect in recognition memory. *Memory & Cognition*, 13, 8–20.

Glanzer, M. and Adams, J. K. (1990). The mirror effect in recognition memory: Data and theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 5–16.

Glenberg, A. and Adams, F. (1978). Type 1 rehearsal and recognition. *Journal of Verbal Learning and Verbal Behaviour*, 17, 455-463.

Gold, J.M., Wilk, C.M., McMahon, R.P., Buchanan, R.W., and Luck, S.J. (2003). Working memory for visual features and conjunctions in schizophrenia. *Journal of Abnormal Psychology*, 112, 61-71.

Goldman-Rakic, P.S. (1987). Circuitry of the prefrontal cortex and the regulation of behaviour by representation knowledge. In F. Plum, and V. Mountcastle (Eds), *Handbook of Physiology*, Vol. 5. Bethesda, MD: American Physiological Society, p.p. 373-417.

Gonslaves, B.D., Kahn, I., Curran, T., Norman, K.A., Wagner, A.D. (2005). Memory strength and repetition suppression: multimodal imaging of medial temporal cortical contribution to recognition. *Neuron*, 47, 751-761.

Goodarzi, M.A., Wykes, T., Hemsley, D.R. (2000). Cerebral lateralization of global-local processing in people with schizotypy. *Schizophrenia Research*, 45, 115-121.

Gooding, D.C. and Braun, J.G. (2004). Visuoconstructive performance, implicit hemispatial inattention, and schizotypy. *Schizophrenia Research*, 68, 261-269.

Gooding, D.C., Matts, C.W., and Rollmann, E.A. (2006). Sustained attention deficits in relation to psychometrically indentified schizotypy: evaluating a potential endophenotypic marker. *Schizophrenia Research*, 82, 27-37.

Gooding, D.C., Miller, M.D., and Kwapil, T.R. (2000). Smooth pursuit eye tracking and visual fixation in psychsis-prone individuals. *Psychiatry Research*, 93, 41-54.

Gooding, D.C. and Tallent, K.A. (2004). Nonverbal working memory deficits in schizophrenia patients: evidence of a supramodal executive processing deficit. *Schizophrenia Research*, 68, 189-201.

Gorfein, D. S. (1987). Explaining context effects on short-term memory. In D. S. Gorfein & R. R. Hoffman (Eds.), *Memory and learning: The Ebbinghaus centennial conference*. Hillsdale, NJ: Erlbaum, p.p. 153-172.

Gorfein, D. S., & Jacobson, D. E. (1972). Proactive effects in shortterm recognition memory. *Journal of Experimental Psychology*, 95, 11-214.

Gorfein, D. S., & Jacobson, D. E. (1973). Memory search in a Brown–Peterson short-term memory paradigm. *Journal of Experimental Psychology*, *99,* 82-87.

Gorfein, D.S. and Schulze, N. (1975). Contextual encoding and recovery from interference in the Brown-Peterson paradigm. *Bulletin of the Psychonomic Society*, 6, 569-571.

Gouzoulis-Mayfrank, E., Voss, T., Moerth, D., Thelen, B., Spitzer, M., and Meincke, U. (2003). Semantic hyperpriming in thought-disordered patients with schizophrenia: state or trait?—a longitudinal investigation. *Schizophrenia Research*, 65, 65-73.

Graf P. and Schacter D.L. (1989). Unitization and grouping mediate dissociations in memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15, 930–940.

Green, R. L. (1987). Effects of maintenance rehearsal on human memory. *Psychological Bulletin*, 102, 403-413.

Gregg, V.H., & Gardiner, J.M. (1994). Recognition memory and awareness: A large effect of study-test modalities on ‘‘know’’ responses following a highly perceptual orienting task. *European Journal of Cognitive Psychology*, 6, 131–147.

Gregg, V., Gardiner, J., Karayianni, I., and Konstantinou, I. (2006). Recognition memory and awareness: a high-frequency advantage in the accuracy of knowing. *Memory*, 14, 265-275.

Groeger, J.A., Field, D., and Hammond, S.M. (1999). Measuring memory span. *International Journal of Psychology*, 34, 359-363.

Guttentag, R.E. and Carroll, D. (1994). Identifying the basis for the word frequency effect in recognition memory. *Memory*, 2, 255-273.

Guttentag, R.E. and Carroll, D. (1997). Recollection-based recognition: word frequency effects. *Journal of Memory and Language*, 37, 502-516.

Haenschel, C., Bittner, R.A., Haertling, F., Rotarska-Jagiela, A., Maurer, K., Singer, W., Linden, D.E.J. (2007). Contribution of impaired early-stage visual processing to working memory dysfunction in adolescents with schizophrenia. *Archives of General Psychiatry*, 64, 1229-1240.

Halford, G.S., Mayberry, M.T., and Bain, J.D. (1988). Set-size effects in primary memory: an age-related capacity limitation? *Memory and Cognition*, 16, 480-487.

Hannula, D.E. and Ranganath, C. (2008). Medial temporal lobe activity predicts successful relationship memory binding. *The Journal of Neuroscience*, 28, 116-124.

Hannula, D.E., Tranel, D., and Cohen, N.J. (2006). The long and the short of it: relational memory impairments in amnesia, even at short lags. *The Journal of Neuroscience*, 26, 8352-8359.

Hartman, M., Steketee, M.C., Silva, S., Lanning, K., and McCann, H. (2003). Working memory and schizophrenia: evidence for slowed encoding. *Schizophrenia Research*, 59, 99-113.

Hasher, L. and Zacks, R. T. (1988). Working memory, comprehension, and aging: a review and a new view. In G.H. Bower (Ed.), *The Psychology of Learning and Motivation*, 22, 193-225. San Diego, CA: Academic Press.

Hasselmo, M.E. and Bower, J.M. (1993). Acetylcholine and memory. *Trends in Neuroscience*, 16, 218-222.

Hawkins, H. L., Pardo, V. J., and Cox, R. D. (1972). Proactive interference in short-term recognition: trace interaction or competition? *Journal of Experimental Psychology: General*, 92, 43-48.

Healy, A.F. (1974). Separating item from order information in short-term memory. *Journal of Verbal Learning and Verbal Behaviour*, 13, 644-655.

Heinrichs, R.W. and Zakzanis, K.K. (1998). Neurocognitive deficit in schizophrenia: a quantitative review of the evidence. *Neuropsychology*, 12, 426-445.

Henson, R.N.A. (1998). Short-term memory for serial order: the start-end model. *Cognitive Psychology*, 36, 73-137.

Henson, R.N.A. (1999). Coding position in short-term memory. *International Journal of Psychology*, 34, 403-409.

Henson, R. N. A., Rugg, M. D., Shallice, T., Josephs, O., & Dolan, R. J. (1999). Recollection and familiarity in recognition memory: An event-related functional magnetic resonance imaging study. *The Journal of Neuroscience*, 19, 3962-3972.

Henson, R.N.A., Shallice, T., and Dolan, R.J. (1999). Right prefrontal cortex and episodic memory of retrieval: a functional MRI test of the monitoring hypothesis. *Brain: A Journal of Neurology*, 122, 1367-1381.

Hirshman, E. (1998). On the utility of the signal detection model of the remember-know paradigm. *Consciousness and Cognition*, 7, 130-107.

Hirschman, E., Fisher, J., Henthorn, T., Arndt, J., and Passannante, A. (2002). Midazolam amnesia and dual-process models of the word-frequency mirror effect. *Journal of Memory and Language*, 47, 499-516.

Hirshman, E. and Henzler, A. (1998). The role of decision processes in conscious recollection. *Psychological Science*, 9, 61-65.

Hirshman, E. and Master, S. (1997). Modeling the conscious correlates of recognition memory: reflections on the remember-know paradigm. *Memory and Cognition*, 25, 345-351.

Holahan, A.L.V. and O'Driscoll, G.A. (2005). Antisaccade and smooth pursuit performance in positive- and negative-symptom schizotypy. *Schizophrenia Research*, 76, 43-54.

Houston, J.P. (1976). Item versus order information, proactive inhibition, and serial recall. *American Journal of Psychology*, 89, 507-514.

Hutton, S.B. (2008). Cognitive control of saccadic eye movements. *Brain and Cognition*, 68, 327-340.

Jacoby L.L. (1991). A process dissociation framework: separating automatic from intentional uses of memory. *Journal of Memory and Language*, 30, 513-541.

Jacoby, L.L. and Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, 110, 306-340.

Jacoby, L.L., Debner, J.A., and Hay, J.F. (2001). Proactive interference, accessibility bias, and process dissociations: valid subjective reports of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 27, 686-700.

Jager, T., Mecklinger, A., and Kipp, K.H. (2006). Intra- and inter-item associations doubly dissociate the electrophysiological correlates of familiarity and recollection. *Neuron*, 52, 535-545.

Jansma, J.M., Ramsey, N.F., van der Wee, N.J.A., and Kahn, R.S. (2004). Working memory capacity in schizophrenia: a parametric fMRI study. *Schizophrenia Research*, 68, 159-171.

Johnson, M. K., Hashtroudi, S., and Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, 114, 3-28.

Johnson, J.S., Hollingworth, A., and Luck, S.J. (2008). The role of attention in the maintenance of feature binding in visual short-term memory. *Journal of Experimental Psychology: Human Perception and Performance*, 34, 41-55.

Jones, S.H., Gray, J.A., and Hemsley, D.R. (1992). The kamin blocking effect, incidental learning, and schizotypy (a reanalysis). *Personality and Individual Differences*, 13, 57-60.

Jonides, J., Badre, D., Curtis, C., Thompson-Schill, S. L., and Smith, E. E. (2002). Mechanisms of conflict resolution in prefrontal cortex. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function.* Oxford: Oxford University Press, p.p. 233-245.

Jonides, J., Marshuetz, C., Smith, E. E., Reuter-Lorenz, P. A., and Koeppe, R. A. (1998). Inhibition of verbal working memory revealed by brain activation. P*roceedings of the National Academy of Sciences*, 95, 8410-8413.

Jonides, J., Marshuetz, C., Smith, E.E., Reuter-Lorenz, P.A., and Koeppe, R.A. (2000). Age differences in behaviour and PET activation reveal differences in interference resolution in verbal working memory. *Journal of Cognitive Neuroscience*, 12, 188-196.

Jonides, J. and Nee, D.E. (2006). Brain mechanisms of proactive interference in working memory. *Neuroscience*, 139, 181-193.

Joordens, S. and Hockley, W.E. (2000). Recollection and familiarity through the looking glass: when old does not mirror new. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26, 1534-1555.

Kahneman, D. and Treisman, A. (1984). Changing views of attention and automaticity. In R. Parasuraman and D. A. Davies (Eds.), *Varieties of attention*. New York: Academic Press.

Kahneman, D., Treisman, A., and Gibbs, B.J. (1992). The reviewing of object files: object-specific integration and information. *Cognitive Psychology*, 24, 175-219.

Kane, M.J., Hambrick, D.Z., Tuholski, S.W., Wilhelm, O., Payne, T.W., and Engle, R.W. (2004). The generality of working memory capacity: a latent-variable approach to verbal and visuospatial memory span and reasoning. *Journal of Experimental Psychology*, 133, 189-217.

Kane, M.J. and Engle, R. W. (2000). Working memory capacity, proactive interference, and divided attention: limits on long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26, 336-358.

Kappel, S., Harford, M., Burns, V.D., and Anderson, N.S. (1973). Effects of vocalisation on short-term memory for words. *Journal of Experimental Psychology: General*, 101, 314-317.

Karayianni, I. and Gardiner, J.M. (2003). Transferring voice effects in recognition memory from remembering to knowing. *Memory and Cognition*, 31, 1052-1059.

Kayser, J., Tenke, C.E., Gates, N.A., Kroppmann, C.J., Gil, R.B., and Bruder, G.E. (2006). ERP/CSD indices of impaired verbal working memory subprocesses in schizophrenia. *Psychophysiology*, 43, 237-252.

Keller, D. and Kellas, G. (1978). Typicality as a dimension of encoding. *Journal of Experiment Psychology: Human Learning and Memory*, 4, 78-85.

Kelley, C.M. and Jacoby, L.L. (1998). Subjective reports and process dissociation: fluency, knowing, and feeling. *Acta Psychologica*, 98, 127-140.

Keppel, G. and Underwood, B.J. (1962). Proactive inhibition in short-term retention of single items. *Journal of Verbal Learning and Verbal Behaviour*, 1, 153-161.

Khoe, W., Kroll, N.E.A., Yonelinas, A.P., Dobbins, I.G., & Knight, R.T. (2000). The contribution of recollection and familiarity to yes-no and forced-choice recognition tests in healthy subjects and amnesics. *Neuropsychologia*, 38, 1333-1341.

Kimble, M., Lyons, M., O'Donnell, B., Nestor, P., Niznikiewicz, M., and Tommey, R. (2000). The effects of family status and schizotypy on electrophysiologic measures of attention and semantic memory. *Biological Psychiatry*, 47, 402-412.

King, D.J. and Forrester, W. (1970). The influence of semantic and acoustic similarity on retention of short sentences. *Psychonomic Science*, 20, 222-223.

Kinoshita, S. (1995). The word frequency effect in recognition memory versus repetition priming. *Memory and Cognition*, 23, 569-580.

Kirwan, C.B. and Stark, C.E.L. (2004). Medial temporal lobe activation during encoding and retrieval of novel face-name pairs. *Hippocampus*, 14, 919-930.

Knight, J. and Gray, J.A. (1967). Degree of learning, proactive interference, and retention. *Nature*, 216, 406-407.

Knott, L.M. and Dewhurst, S.A. (2007). Divided attention at retrieval disrupts knowing but not remembering. *Memory*, 15, 664-674.

Knowlton, B.J. (1998). The relationship between remembering and knowing: a cognitive neuroscience perspective. *Acta Psychologica*, 98, 253-265.

Knowlton, B.J., and Squire, L.R. (1995). Remembering and knowing: the different expressions of declarative memory. *Journal of Experimental Psychology: Learning,, Memory, and Cognition*, 21, 699-710.

Kyllonen, P.C. and Christal, R.E. (1990). Reasoning ability is (little more than) working memory capacity?! *Intelligence*, 14, 389-433.

Lachar, B. and Goggin, J. (1969). Effects of changes in word length on proactive interference in short-term memory. *Psychonomic Science*, 17, 213-214.

Lee, A.C.H., Buckley, M.J., Gaffan, D., Emery, T., Hodges, J.R., and Graham, K.S. (2006). Differentiating the roles of the hippocampus and perirhinal cortex in processes beyond long-term declarative memory: a double dissociation in demenia. *The Journal of Neuroscience*, 26, 5198-5203.

Lee, J., and Park, S. (2005). Working memory impairments in schizophrenia: a meta-analysis. *Journal of Abnormal Psychology*, 114, 599-611.

Lenzenweger, M.F., Cornblatt, B.A., and Putnick, M. (1991). Schizotypy and sustained attention. *Journal of Abnormal Psychology*, 100, 84-89.

Lenzenweger, M.F. and Korfine, L. (1994). Perceptual abberations, schizotypy, and the wisconsin card sorting test. *Schizophrenia Bulletin*, 20, 345-357.

Lewandowsky, S., Geiger, S.M., and Oberauer, K. (2008). Interference-based forgetting in verbal short term memory. *Journal of Memory and Language*, 59, 200-222.

Lewandowsky, S. Oberauer, K., and Brown, G.D.A. (2009). No temporal decay in verbal short-term memory. *Trends in Cognitive Sciences*, 13, 120-126.

Lewandowsky, S. Oberauer, K., and Brown, G.D.A. (2009). Response to Barrouillet and Camos: interference or decay in working memory? *Trends in Cognitive Sciences*, 146-147.

Lewis, S.J.G., Dove, A., Robbins, T.W., Barker, R.A., and Owen, A.M. (2004). Striatal contributions to working memory: a functional magnetic resonance imaging study in humans. *European Journal of Neuroscience*, 19, 775-760.

Linscott, R.J. and Knight, R.G. (2004). Potentiated automaticity memory in schizotypy. *Personality and Individual Differences*, 37, 1503-1517.

Loess, H. (1967). Short-term memory: Word class and sequence of items. *Journal of Experimental Psychology*,74, 556-561.

Luck, S.J. and Vogel, E.K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, 390, 279-281.

Lustig, C. and Hasher, L. (2002). Working memory span: the effect of prior learning. *American Journal of Psychology*, 115, 89-101.

Lustig, C., May, C. P., and Hasher, L. (2001). Working memory span and the role of proactive interference. *Journal of Experimental Psychology: General*, 130, 199-207.

Makovski, T. and Jiang, Y.V. (2008). Proactive interference from items previously stored in visual working memory. *Memory and Cognition*, 36, 43-52.

Mandler, G. A. (1980). Recognizing: the judgement of previous occurrence. *Psychological Review, 87,* 252-271.

Manoach, D. (2003). Prefrontal cortex dysfunction during working memory performance in schizophrenia: reconciling discrepant findings. *Schizophrenia Research*, 60, 285-298.

Manoach, D.S., Gollub, R.L., Benson, E.S., Searl, M.M., Goff, D.C., Halpern, E., Saper, C.B., and Rauch, S.L. (2000). Schizophrenic subjects show aberrant fMRI activation of dorsolateral prefrontal cortex and basal ganglia during working memory performance. *Biological Psychiatry*, 48, 99-109.

Mason, O. and Claridge, G. (2006). The oxford-liverpool inventory of feelings and experiences (O-LIFE): further description and extended norms. *Schizophrenia Research*, 82, 203-211.

Mason, O., Claridge, G., Jackson, M. (1995). New scales for the assessment of schizotypy. *Personality and Individual Differences*, 18, 7-13.

Mathes, B., Wood, S.J., Proffitt, T.M., Stuart, G.W., Buchanan, J.M., Velakoulis, D., Brewer, W.J., McGorry, P.D., and Pantelis, C. (2005). Early processing deficits in object working memory in first-episode schizophreniform psychosis and established schizophrenia. *Psychological Medicine*, 35, 1053-1062.

May, C. P., Hasher, L., and Kane, M. J. (1999). The role of interference in memory span. *Memory and Cognition*, 27, 759-767.

McElree, B. and Dosher, B. A. (1989). Serial position and set size in short-term memory: the time course of recognition. *Journal of Experimental Psychology: General*, 118, 346-373.

McElree, B., Dolan, P. O., & Jacoby, L. L. (1999). Isolating the contributions of familiarity and source information to item recognition: a time course analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25, 563-582.

McKay, A.P., McKenna, P.J., Bentham, P., Mortimer, A.M., Holbery, A., and Hodges, J.R. (1996). Semantic memory is impaired in schizophrenia. *Biological Psychiatry*, 39, 929-937.

Mevorach, C., Humphreys, G.W., and Shalev, L. (2006). Opposite biases in salience-based selection for the left and right posterior parietal cortex. *Nature Neuroscience*, 9, 740-742.

Mitchell, K.J., Johnson, M.K., Raye, C.L., and Greene, E.J. (2004). Prefrontal cortex activity associated with source monitoring in a working memory task. *Journal of Cognitive Neuroscience*, 16, 921-934.

Mohr, C., Graves, R.E., Gianotti, L.R.R., Pizzagalli, D., and Brugger, P. (2001). Loose but normal: a semantic association study. *Journal of Psycholinguistic Research*, 30, 475-483.

Mohr, C., Landis, T., Bracha, H.S., Fathi, M., and Brugger, P. (2005). Levodopa reverses gait asymmetries related to ahedonia and magical ideation. *European Archive of Psychiatry and Clinical Neuroscience*, 255, 33-39.

Montaldi, D., Spencer, T.J., Roberts, N., and Mayes, A.R. (2006). The neural system that mediates familiarity memory. *Hippocampus*, 16, 504-520.

Moritz, S., Andresen, B., Probsthein, E., Martin, T., Domin, F., Kretschmer, G., Krausz, M., Lambert, M., and Naber, D. (2000). Stimulus onset asynchronicity as a modulator of negative priming in schizotypy. *Personality and Individual Differences*, 29, 649-657.

Moritz, S.H., Mass, R., and Junk, U. (1998). Further evidence of reduced negative priming in positive schizotypy. *Personality and Individual Differences*, 24, 521-530.

Moritz, S., Woodward, T.S., Kueppers, D., Lausen, A., and Schickel, M. (2002). Increased automatic spreading of activation in thought-disordered schizophrenic patients. *Schizophrenia Research*, 59, 181-186.

Mueller, S. T. (2005). Non-word and word evaluation and creation software. http://obereed.net/.

Murray, D.J., Birch, D.E., Chase, R.S., Eyolfson, B.H. (1991). The effects of vocalisation at presentation on short-term recognition of three-digit numbers. *Canadian Journal of Psychology*, 45, 462-473.

Neill, W.T., Valdes, L.A., Terry, K.A., and Gorfein, D.S. (1992). Persistence of negative priming II. Evidence for episodic trace retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 993-1000.

Nichols, E.A., Kao, Y.-C., Verfaellie, M., and Gabrieli, J.D.E. (2006). Working memory and long-term memory for faces: evidence from fMRI and global amnesia for involvement of the medial temporal lobes. *Hippocampus*, 16, 604-616.

Norman, K.A. and O'Reilly, R.C. (2003). Modeling hippocampal and neocortical contributions to recognition memory: a complementary-learning-systems approach. *Psychological Review*, 110, 611-646.

Oberauer, K. (2005). Binding and inhibition in working memory: individual and age differences in short-term recognition. *Journal of Experimental Psychology: General*, 134, 368-387.

Oberauer, K. and Kliegl, R. (2004). Simultaneous cognitive operations in working memory after dual-task practice. *Journal of Experimental Psychology: Human Perception and Performance*, 30, 689-707.

Oberauer, K. and Kliegl, R. (2006). A formal model of capacity limits in working memory. *Journal of Memory and Language*, 55, 601-626.

Oberauer, K. and Lange, E.B. (2008). Interference in verbal working memory: distinguishing similarity-based confusion, feature overwriting, and feature migration. *Journal of Memory and Language*, 58, 730-745.

Oberauer, K. and Lange, E.B. (2009). Activation and binding in verbal working memory: a dual-process model for the recognition of non-words. *Cognitive Psychology*, 58, 102-136.

Oberauer, K. and Lewandowsky, S. (2008). Forgetting in immediate serial recall: decay, temporal distinctiveness, or interference? *Psychological Review*, 115, 544-576.

Obiols, J.E., Garcia-Domingo, M., de Trincheria, I., and Domenech, E. (1993). Psychometric schizotypy and sustained attention in young males. *Personality and Individual Differences*, 14, 381-384.

O'Driscoll, G.A., Lenzenweger, M.F., and Holzman, P.S. (1998). Antisaccades and smooth pursuit eye tracking and schizotypy. *Archive of General Psychiatry*, 55, 837-843.

Olson, I.R., Page, K., Sledge-Moore, K., Chatterjee, A., and Verfaellie, M. (2006). Working memory for conjunctions relies on the medial temporal lobe. *The Journal of Neuroscience*, 26, 4596-4601.

O'Neill, M.E., Sutcliffe, J.A., and Tulving, E. (1976). Retrieval cues and release from proactive inhibition. *American Journal of Psychology*, 89, 535-543.

Öztekin, I. and McElree, B. (2007). Proactive interference slows recognition by eliminating fast assessments of familiarity. *Journal of Memory and Language*, 57, 126-149.

Park, S. and Holzman, P.S. (1992). Schizophrenics show spatial working memory deficits. *Arch Gen Psychiatry*, 49, 975-982.

Park, S., Holzman, P.S., and Lenzenweger, M.F. (1995). Individual differences in spatial working memory in relation to schizotypy. *Journal of Abnormal Psychology*, 104, 355-363.

Park, S. and McTigue, K. (1997). Working memory and the syndromes of schizotypal personality. *Schizophrenia Research*, 26, 213-220.

Parkin, A.J., Gardiner, J.M., and Rosser, R. (1995). *Consciousness and Cognition*, 4, 387-398.

Perfect, T.J., Mayes, A.R., Downes, J.J., and Eijk, R. (1996). Does context discriminate recollection from familiarity in recognition memory? *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology*, 49A, 797-813.

Perlstein, W.M., Carter, C.S., Noll, D.C., and Cohen, J.D. (2001). Relation of prefrontal cortex dysfunction to working memory and symptoms in schizophrenia. *American Journal of Psychiatry*, 158, 1105-1113.

Peterson, L.R. and James, L.H. (1967). Successive tests of short-term retension. *Psychonomic Science*, 8, 423-424.

Peterson, L.R. and Peterson, M.J. (1959). Short-term retention of individual verbal items. *Journal of Experimental Psychology: General*, 58, 193-198.

Petrusic, W. M. and Dillon, R. F. (1972). Proactive interference in short-term recognition and recall memory. *Journal of Experimental Psychology*, 95, 412-418.

Piskulic, D., Olver, J.S., Norman, T.R., and Maruff, P. (2007). Behavioural studies of spatial working memory dysfunction in schizophrenia: a quantitative literature review. *Psychiatry Research*, 150, 111-121.

Postle, B. R. (2003). Context in verbal short-term memory. *Memory and Cognition*, 31, 1198-1207.

Postle, B. R., Berger, J. S., Goldstein, J. H., Curtis, C. E., and D'Esposito, M. (2001). Behavioural and neurophysiological correlates of episodic coding, proactive interference, and list length effects in a running span verbal working memory task. *Cognitive, Affective, and Behavioural Neuroscience*, 1, 10-21.

Postle, B. R. and Brush, L. N. (2004). The neural bases of the effects of item-nonspecific proactive interference in working memory. *Cognitive, Affective and Behavioural Neuroscience*, 4, 379-392.

Postle, B.R., Brush, L.N., and Nick, A.M. (2004). Prefrontal cortex and the mediation of proactive interference in working memory. *Cognitive, Affective, and Behavioural Neuroscience*, 4, 600-608.

Quamme, J.R., Yonelinas, A.P., and Normal, K.A. (2007). Effect of unitization on associative recognition in amnesia. *Hippocampus*, 17, 192-200.

Radke, R.C. and Grove, E.K. (1977). Proactive inhibition in short-term memory: availability or accessibility? *Journal of Experimental Psychology: Human Learning and Memory*, 3, 78-91.

Raffone, A. and Wolters, G. (2001). A cortical mechanism for binding in visual working memory. *Journal of Cognitive Neuroscience*, 13, 766-785.

Raine, A. (1991). The SPQ: a scale for the assessment of schizotypal personality based on DSM-III-R criteria. *Schizophrenia Bulletin*, 17, 555-564.

Rajaram, S. (1993). Remembering and knowing: two means of access to the personal past. *Memory & Cognition*, 21, 89–102.

Rajaram, S. (1996). Perceptual effects on remembering: Recollective processes in picture recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 22, 365-377.

Rajaram, S. (1998). The effects of conceptual salience and perceptual distinctiveness on conscious recollection. *Psychonomic Bulletin & Review*, 5(1), 71–78.

Rajaram, S. and Geraci, L. (2000). Conceptual fluency selectively influences knowing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 264, 1070–1074.

Ranganath, C., Cohen, M.X., and Brozinsky (2005). Working memory maintenance contributions to long-term memory formation: neural and behavioural evidence. *Journal of Cognitive Neuroscience*, 17, 994-1010.

Ranganath, C., DeGutis, J., and D'Esposito, M. (2004). Category-specific modulation of inferior temporal activity during working memory encoding and maintenance. *Cognitive Brain Research*, 20, 37-45.

Ranganath, C., Yonelines, A.P., Cohen, M.X., Dy, C.J., Tom, S.M., and D'Esposito, M. (2004). Dissociable correlates of recollection and familiarity with the medial temporal lobes. *Neuropsychologia*, 42, 2-13.

Rawlings, D. and Claridge, G. (1984). Schizotypy and hemisphere function. III. Performance asymmetries on tasks of letter recognition and local-global processing. *Personality and Individual Differences*, 5, 657-664.

Reder, L.M., Angstadt, P., Cary, M., Erickson, M.A., and Ayers, M.S. (2002). A reexaminination of stimulus-frequency effects in recognition: two mirrors for low- and high-frequency pseudowords. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28, 138-152.

Reder, L.M., Nhouyvanisvong, A., Schunn, C.D., Ayers, M.S., Angstadt, P., & Hikari, K. (2000). A mechanistic account of the mirror effect for word frequency: A computational model of remember–know judgements in a continuous recognition paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26, 294–320.

Reed, P., Wakefield, D., Harris, J., Parry, J., Cella, M., and Tsakanikos, E. (2008). Seeing non-existent events: effects of environmental conditions, schizotypal symptoms, and sub-clinical characteristics. *Journal of Behaviour Therapy*, 39, 276-291.

Rhodes, S.M. and Donaldson, D.I. (2007). Electrophysiological evidence for the influence of unitization on the processes engaged during episodic retrieval: enhancing familiarity based remembering. *Neuropsychologica*, 45, 412-424.

Roediger, H.L. III, & McDermott, K.B. (1995). Creating false memories: remembering words not presented in lists. *Journal of Experimental Psychology: Learning Memory and Cognition*, 21, 803-814.

Rugg, M.D., Cox, C.J.C., Doyle, M.C., and Wells, T. (1995). Event-related potentials and the recollection of low and high frequency words. *Neuropsychologia*, 33, 471-484.

Rugg, M.D. and Yonelinas, A.P. (2003). Human recognition memory: a cognitive neuroscience perspective. *Trends in Cognitive Sciences*, 313-319.

Ryan, J. (1969a). Grouping and short-term memory: different means and patterns of grouping. *The Quarterly Journal of Experimental Psychology*, 21, 137-147.

Ryan, J. (1969b). Temporal grouping, rehearsal, and short-term memory. *Quarterly Journal of Experimental Psychology*, 21, 148-155.

Saling, L.L. and Phillips, J.G. (2007). Automatic behaviour: efficient not mindless. *Brain Research Bulletin*, 73, 1-20.

Sands, S.F. and Wright, A.A. (1980). Primate memory: retention of serial list items by a rhesus monkey. *Science*, 209, 938-940.

Schneider, F., Habel, U., Reske, M., Toni, I., Falkai, P. and Shah, N. (2007). Neural substrates of olfactory processing in schizophrenia patients and their healthy relatives. *Psychiatry Research: Neuroimaging*, 155, 103-122.

Shiffrin, R. M. andSchneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, 84, 127-190.

Shulman, A.I. (1974). The declining course of recognition memory. *Memory and Cognition*, 2, 14-18.

Skinner, E.I. and Fernandes, M.A. (2008). Interfering with remembering and knowing: effects of divided attention at retrieval. *Acta Psychologica*, 127, 211-221.

Spitzer, M., Braun, U., Hermle, L., and Maier, S. (1993). Associative semantic network dysfunction in thought-disordered schizophrenic patients: direct evidence from indirect semantic priming. *Biological Psychiatry*, 34, 864-877.

Staresina, B.P. and Davachi, L. (2006). Differential encoding mechanisms for subsequent associative recognition and free recall. *The Journal of Neuroscience*, 26, 9162-9172.

Steel, C., Hemsley, D.R., and Jones, S. (1996). Cognitive inhibition and schizotypy as measured by the oxford-liverpool inventory of feelings and experiences. *Personality and Individual Differences*, 20, 769-773.

Steel, C., Hemsley, D.R., and Pickering, A.D. (2002). Distracter cueing effects on choice reaction time and their relationship with schizotypal personality. *British Journal of Clinical Psychology*, 41, 143-156.

Steel, C., Hemsley, D.R., and Pickering, A.D. (2007). Associations between schizotypal personality traits and the facilitation and inhibition of the speed of contextually cued responses. *Psychiatry Research*, 150, 131-140.

Sternberg, S. (1966). High-speed scanning in human memory. *Science*, 153, 652-654.

Stevens, A.A., Goldman-Rakic, P.S., Gore, J.C., Fulbright, R.K., and Wexler, B.E. (1998). Cortical dysfunction in schizophrenia during auditory word and tone working memory demonstrated by functional magnetic resonance imaging. *Archives of General Psychiatry*, 55, 1097-1103.

Strack, F. and Foerster, J. (1995). Reporting recollective experiences: direct access to memory systems? *Psychological Science*, 6, 352-358.

Tan, H.-Y., Choo, W.-C., Fones, C.S.L., and Chee, M.W.L. (2005). FMRI study of maintenance and manipulation processes within working memory in first-episode schizophrenia. *American Journal of Psychiatry*, 162, 1849-1858.

Tell, P. M. (1971). Influence of vocalisation on short-term memory. *Journal of Verbal Learning and Verbal Behaviour*, 10, 149-156.

Tell, P. M. and Voss, B. X. (1970). The influence of vocalisation activity on short-term recall. *Psychonomic Science*, 21, 120-121.

Tolan, G.A. and Tehan, G. (1999). Determinants of short-term forgetting: decay, retroactive interference, or proactive interference? *International Journal of Psychology*, 34, 258-292.

Trautner, P., Dietl, T., Staedtgen, M., Mecklinger, A., Grunwald, T., Elger, C.E., and Kurthen, M. (2004). Recognition of famous faces in the medial temporal lobe. *Neurology*, 63, 1203-1208.

Treisman, A. and Zhang, W. (2006). Location and binding in visual working memory. *Memory and Cognition*, 34, 1704-1719.

Tsakanikos, E. and Claridge, G. (2005). More words, less words: verbal fluency as a function of positive and negative schizotypy. *Personality and Individual Differences*, 39, 705-713.

Tsakanikos, E. and Reed, P. (2003). Visuo-spatial processing and dimensions of schizotypy: figure-ground segregation as a function of psychotic-like features. *Personality and Individual Differences*, 35, 703-712.

Tsakanikos, E. and Reed, P. (2006). Do positive schizotypy symptoms predict false perceptual experiences in nonclinical populations? *The Journal of Nervous and Mental Disease*, 193, 809-812.

Tsujimoto, S. and Sawaguchi, T. (2005). Neuronal activity representing temporal prediction of reward in the primate prefrontal cortex. *Journal of Neurophysiology*, 93, 3687-3692.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology*, 26, 1-12.

Turner, M. L. and Engle, R. W. (1989). Is working memory capacity task dependant? *Journal of Memory and Language*, 28, 127-154.

Turriziani, P., Oliveri, M., Salerno, S., Costanzo, F., Koch, G., Caltagirone, C., Carlesimo, G.A. (2008). Recognition memory and prefrontal cortex: dissociating recollection and familiarity processes using rTMS. *Behavioural Neurology*, 19, 23-27.

Turvey, M.T., Cremins, J.J., and Lombardo, T. (1969). Taxonomic categories and proactive interference in short-term memory. *Psychonomic Science*, 15, 307-308.

Turvey, M.T. and Egan, J.F. (1969). Contextual change and release from proactive interference in short-term verbal memory. *Journal of Experiment Psychology*, 81, 396-397.

Turvey, M.T. and Egan, J.F. (1970). Release from proactive interference in short-term memory as a function of change in visual and phonemic structure and retention interval. *Perception and Psychophysics*, 7, 169-172.

Underwood, B. J. (1957). Interference and forgetting. *Psychological Review*, 64, 49-60.

Underwood, B. J. and Ekstrand, B. R. (1966). An analysis of some shortcomings in the interference theory of forgetting. *Journal of Experimental Psychology: General*, 73, 540-549.

Underwood, B. J. and Ekstrand, B. R. (1967). Word frequency and accumulative proactive inhibition. *Journal of Experimental Psychology: General*, 74, 193-198.

Underwood, B. J. and Ekstrand, B. R. (1967). Studies of distributed practice XXIV: differentiation and proactive inhibition. *Journal of Experimental Psychology: General*, 74, 574-580.

Underwood, B.J. and Freund, J.S. (1968). Errors in recognition learning and retention. *Journal of Experimental Psychology*, 78, 55-63.

Unsworth, N. and Engle, R.W. (2007). On the division of short-term and working memory: an examination of simple and complex span and their relation to higher order abilities. *Psychological Bulletin*, 133, 1038-1066.

Van Asselen, M., Kessels, R.P.C., Kappelle, L.J., and Postma, A. (2008). Categorical and coordinate spatial representations within object-location memory. *Cortex*, 44, 249-256.

Van Asselen, M., Van der Lubbe, R., and Postma, A. (2006). Are space and time automatically integrated in episodic memory? *Memory*, 14, 232-240.

Verfaellie, M. and Treadwell, J.R. (1993). Status of recognition memory in amnesia. *Neuropsychology*, 7, 5-13.

Visscher, K.M., Kahana, M.J., and Sekular, R. (2009). Trial-to-trial carryover in auditory short-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 35, 46-56.

Vogel, E.K., Woodman, G.F., and Luck, S.J. (2001). Storage of features, conjunction, and objects in visual working memory. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 92-114.

Wagner, A., Desmond, J.E., Glover, G.H., and Gabrieli, J.D.E. (1998). Prefrontal cortex and recognition memory: function-MRI evidence for contextual-dependent retrieval processes. *Brain*, 121, 1985-2002.

Watkins, O. C., and Watkins, M. J. (1975). Buildup of proactive inhibition as a cue-overload effect. *Journal of Experimental Psychology: Human Learning and Memory*, 1, 442-452.

Weeks, R.A. (1975). Auditory location as an encoding dimension. *Journal of Experimental Psychology: Human Learning and Memory*, 104, 316-318.

Weiss, A.P., Goff, D.C., Duff, M., Roffman, J.L., and Schacter, D.L. (2008). Distinguishing familiarity-based from source-based memory performance in patients with schizophrenia. *Schizophrenia Research*, 99, 208-217.

Wentura, D., Moritz, S., and Frings, C. (2008). Further evidence for "hyper-priming" in thought-disordered schizophrenic patients using repeated masked category priming. *Schizophrenia Research*, 102, 69-75.

Wheeler, M.E. and Treisman, A.M. (2002). Binding in short-term visual memory. *Journal of Experiment Psychology: General*, 131, 48-64.

Whimbey, A.E. and Fischhof, V. (1968). PI in STM resulting from the semantic similarity of items. *Psychonomic Science*, 13, 127-128.

White, N.M. (2009). Some highlights of research on the effects of caudate nucleus lesions over the past 200 years. *Behavioural Brain Research*, 199, 3-23.

Wickens, D. D. (1970). Encoding categories of words: an empirical approach to meaning. *Psychological Review*, 77, 1-15.

Wickens, D. D, Born, D. G., and Allen, C. K. (1963). Proactive inhibition and item similarity in short-term memory. *Journal of Verbal Learning and Verbal Behaviour*, 2, 440-445.

Wickens, D. D. and Gittis, M. M. (1974). The temporal course of recovery from interference and degree of learning in the Brown-Peterson paradigm. *Journal of Experimental Psychology: General*, 102, 1021-1026.

Wickens, D.D., Moody, M.J., and Dow, R. (1981). The nature and timing of the retrieval process and of interference effects. *Journal of Experimental Psychology: General*, 110, 1-20.

Wilken, P. and Ma, W. J. (2004). A detection theory account of change detection. *Journal of Vision*, 4, 1120-1135.

Wilkins, S. and Venables, P.H. (1992). Disorder of attention in individuals with schizotypy personality. *Schizophrenia Bulletin*, 717-723.

Winograd, E. and Smith, W. S. (1996). List differentiation with varied trials on both lists. *Science*, 152, 1101-1102.

Wright, J.H. (1967). Effects of formal interitem similarity and length of retention interval on proactive inhibition in short-term memory. *Journal of Experimental Psychology*, 75, 366-395.

Wright, A.A., Urcuioli, P.J., Sands, S.F. (1986). Proactive interference in animal memory. In D.F. Kendrick, M.E. Rilling, M.R. Denny (Eds), *Theories of animal memory.* Hilldale, NJ, England: Lawrence Erlbaum Associates, Inc., p.p. 101-125.

Xu, Y. and Nakayama, K. (2007). Visual short-term memory benefit for objects on difference 3-D surfaces. *Journal of Experimental Psychology: General*, 136, 653-662.

Yonelinas A.P. (1994). Receiver-operating characteristics in recognition memory: Evidence for a dual-process model. *Journal of Experimental Psychology: Learning Memory, and Cognition*, 20, 1341-1354.

Yonelinas A.P. (1997). Recognition memory ROCs for item and associative information: the contribution of recollection and familiarity. *Memory and Cognition*, 25, 747-763.

Yonelinas, A.P. (1999). The contribution of recollection and familiarity to recognition and source-memory judgments: a formal dual-process morel and an analysis of receiver operating characteristics. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25, 1415-1434.

Yonelinas, A.P. (1999). Consciousness, control, and confidence: the 3 Cs of recognition memory. *Journal of Experimental Psychology: General*, 130, 361-379.

Yonelinas, A.P. (2001). Components of episodic memory: the contribution of recollection and familiarity. *Philosophical Transactions: Biological Sciences*, 356, 1363-1374.

Yonelinas, A.P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, 46, 441-517.

Yonelinas, A.P. and Jacoby, L.L. (1994). Dissociations of processes in recognition memory: effects of interference and of response speed. *Canadian Journal of Experimental Psychology*, 48, 516-534.

Yonelinas, A.P. and Jacoby, L.L. (1995). The relationship between remembering and knowing as bases for recognition: effects of size congruency. *Journal of Memory and Language*, 34, 622-643.

Yonelinas, A.P., & Jacoby, L.L. (1996). Noncriterial recollection: Familiarity as automatic, irrelevant recollection. *Consciousness & Cognition*, 5, 131-141.

Yonelinas, A.P., Kroll, N.E.A., Dobbins, I., Lazzara, M., and Knight, R.T. (1998). Recollection and familiarity deficits in amnesia: convergence of remember-know, process dissociation, and receiver operating characteristic data. *Neuropsychology*, 12, 323-339.

Yonelinas, A.P, Kroll, N.E.A., Dobbins, I.G., Soltani, M. (1999). Recognition memory for faces: when familiarity supports associative recognition. *Psychonomic Bulletin and Review*, 6, 418-661.

Yonelinas, A.P, Kroll, N.E.A., Quamme, J.R, Lazzara, M.M., Sauve, M.-J., Widaman, K.F, Knight, R.T. (2002). Effects of extensive medial-temporal lobe damage or mild hypoxia on recollection and familiarity. *Nature Neuroscience*, 5, 1236-1241.