A COMMON STORAGE MECHANISM IN SHORT-TERM, WORKING AND LONG-TERM MEMORY? SOME EVIDENCE FROM CONTROL AND SCHIZOPHRENIA SAMPLES.

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List of Abbreviations

APA	American Psychiatric Association
CE	Central Executive
DSM	Diagnostic Statistics Manual
EB	Episodic Buffer
IQ	Intelligence Quotient
LM	Logical Memory
LTM	Long-term Memory
MNM	Verbal Maintenance and Manipulation
MO	Maintenance Only
NART	National Adult Reading Test
NC	Normal Controls
PANSS	Positive and Negative Symptom Scale
PAS	Perceptual Aberration Scale
PI	Proactive Interference
PL	Phonological Loop
QCSR	Queensland Centre for Schizophrenia Research
RT	Reaction Time
SAS	Supervisory Attentional System
SPD	Schizotypal Personality Disorder
SPQ	Schizotypy Personality Questionnaire
STA	Schizotypal Personality Scale
STM	Short-term Memory
SZ	Schizophrenia
SZTPY	Schizotypy
TD	Thought Disorder
TLC	Scale for Thought, Language and Communication
VSSP	Visual Spatial Scratch Pad
WAIS-R	Wechsler Adult Intelligence Scale – Revised
WAIS-III	Wechsler Adult Intelligence Scale – Third Edition
WCST	Wisconsin Card Sort Test
WM	Working Memory
WMS	Wechsler Memory Scale
WMS-R	Wechsler Memory Scale – Revised
WMS-III	Wechsler Memory Scale – Third Edition

Abstract

Background:
Baddeley and Hitch's (1974) multi-component model of working memory (WM) has provided the basis for exploration into the nature of remembering and manipulating information over a short period of time. This model argues that the passive short-term storage system is not involved in the more dynamic working memory tasks and has formed the basis of much research on clinical populations known to have deficits in WM. However, other models argue that short-term memory and working memory rely on common storage facilities. The aim of this thesis was to explore whether there is justification for the continued separation of WM into fractionated components.

Schizophrenia (SZ) is associated with a wide range of cognitive deficits, including working memory problems. There is also some evidence to suggest that psychotic symptoms exist on a continuum and cognitive deficits similar to those found in SZ have been reported in people endorsing "psychotic-like" symptoms without a formal diagnosis of schizophrenia. It was hypothesized that the pattern of errors made by the SZ group would help to delineate the nature of deficit shown on WM tasks.

Methods:

General Methods

In order to explore the structure of WM and performance of groups hypothesized to be impaired on WM tasks, a range of span and non-span tasks were administered. Forty-two (42) control subjects were recruited for the study. Based on their scores on the Schizotypal Personality Questionnaire (SPQ - Raine, 1991), this group was divided into low scoring (NCL = 27) and high scoring (NCH = 15) groups. Thirty (30) people with a DSM-IV diagnosis of schizophrenia were also recruited.

Experiment 1

Experiment one investigated the performance of these groups on simple, complex and delayed span tasks. A simple four-word recall task, with and without interference was used to examine accuracy, error types and any relationship to symptomatology.

Experiment 2

Experiment two set out to investigate the contributions to span performance. All subjects were administered measures of articulation speed, lexical access ability, and a range of STM, WM and LTM tasks.

Experiment 3

This experiment used a cued-recall paradigm to explore proactive interference effects by manipulating phonological and semantic representations over brief periods. The task consisted of trials where the subject studied a series of one or two blocks of four words.

Results:

Experiment 1

The results of this experiment replicated previous findings (Tehan, Hendry & Kocinski, 2001) of similar patterns of performance across the three tasks with performance decrements increasing with task difficulty. The SZ group showed significant deficits even on the simple four-word span task. Patterns of errors were similar across the groups once overall levels of performance

were taken into account. SZ subjects made more movement (order) errors than the other two groups and movement errors were associated with disorganised symptoms. The association between disorganised symptoms and loss of items from the end of the list were suggestive of impaired maintenance of item information. The high schizotypy control group performed below that of the low schizotypy controls, but only a few of the differences were significant.

Experiment 2

For both groups articulation and lexical access formed two of the composites. For the control group, all memory tasks contributed to form one single factor. For the SZ group three separate memory composites were needed. Using regression analyses previous findings (Tehan & Lalor, 2000; Tehan, Fogarty & Ryan, 2004) were replicated for the control group with both lexical access and to a lesser degree, rehearsal speed contributing to memory performance. Rehearsal speed was a more important predictor for recall of familiar materials (such as letters and digits) in the SZ group. The reverse was true for simple word span, with lexical access making a significant impact and rehearsal speed having little impact. For more complex memory tasks, neither articulation rate nor access to lexical memory contributed to the performance of the SZ group. Once again poorer performance for the SZ group was associated with disorganised symptoms.

Experiment 3

The findings from this experiment revealed that even on the simple one block trials, the SZ subjects had difficulty accurately recalling the target word with a category cue, even in the absence of distractor activity. The SZ group made more omissions and significantly more intrusion errors than the control groups. Intrusion errors were associated with disorganised symptoms on the Positive and Negative Symptom Scale (PANSS). Despite their poorer overall performance, the SZ group did not have significantly more block-1 intrusions than the control groups suggesting that the interference effects for semantic and phonemic information were the same.

Conclusions:

This thesis presented evidence which is somewhat supportive of a common storage approach to WM. It calls into question the need to fractionate WM into components. The multi-component model of WM is often used to investigate performance of SZ subjects, a population know to have WM deficits. Errors across a range of STM, WM and LTM tasks were examined in a SZ group and their performance was compared to two groups of controls: a group with high scores on a measure of psychometric schizotypy and one with low scores. Implications regarding the purported source of deficits in WM are discussed.

Certificate of originality

I hereby certify that the work contained in this thesis is the result of original research and has not been submitted for the award of any diploma or higher degree in any other university, and that, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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Linda K. Byrne

List of presentations, publications, and awards

Presentations at Scientific Conferences

1. Byrne, L.K., & Tehan, G. (1999). Working memory and schizophrenia: The role of semantic and phonemic cues. Annual Conference of the Australian Society for Psychiatric Research, Sydney.

2. Byrne, L.K., Tehan, G., & McGrath, J.J. (2000). Schizotypy, Schizophrenia and working memory: the role of phonemic and semantic cues. 6^{th} Bi-annual Australian Schizophrenia Conference, Lorne.

3. Byrne, L.K., & Tehan, G (2001). Serial recall in schizophrenia and schizotypy: examining error type in a working memory task. Annual Conference of the Australian Society for Psychiatric Research, Melbourne.

4. Byrne, L.K., & Tehan, G (2002). Working memory and schizophrenia: the role of phonemic and semantic cues. 2^{nd} Australian Conference for Cognitive Neuropsychology and Cognitive Neuropsychiatry, Sydney.

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Awards

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Chapter 1 – General Introduction and Overview of Thesis

Baddeley and Hitch's (1974) seminal paper describing a model for working memory (WM) has provided the basis of a wealth of research into the mechanisms which underlie remembering and manipulating information over a short period of time. They have conceived WM as a multi-component system for the temporary maintenance and storage of information. Some experimental evidence investigating the nature of short-term memory (STM) and WM has raised concerns regarding the need to have a multi-component system. This thesis will discuss WM theory as it currently stands in relation to verbal material. Specifically, evidence will be presented that is suggestive of a common storage model of WM.

In addition to exploring the proposed structure and contributions to WM, this thesis will examine the performance of a group known to have deficits in aspects of WM. It is well established that there are widespread cognitive deficits in schizophrenia. Of particular interest to many researchers are those cognitive domains that are thought to represent functioning of the frontal areas of the brain. Specifically WM has over the past two decades, grown in prominence in schizophrenia research. There is now a considerable body of evidence derived from MRI and functional imaging studies that indicate disproportionate anomalies in the frontal areas of the brain of individuals with a diagnosis of schizophrenia, particularly in the dorsolateral prefrontal cortex (Buchsbaum et al, 1998; Pantelis et al, 1997). It is this region that is hypothesised to be implicated in working memory, that system responsible for the temporary maintenance and manipulation of information (Baddeley, 1986). In addition to deficits in WM, disturbance of language is a core symptom for some people with schizophrenia. It has been proposed that this disturbance of language is the result of increased activation (or alternatively, decreased inhibition) of associative networks, which leads to increased sensitivity to semantic and phonological codes (Spitzer et. al., 1994). There has been a trend away from viewing schizophrenia as a single entity and movement towards the examination of the association between various groups of symptoms and their impact on cognitive domains. The “positive-negative” dichotomy or the closely linked triad of “positive, negative and disorganised symptoms” has gained acceptance as a more useful way to analyse aspects of performance of schizophrenia subjects.

Many researchers have also been interested in whether cognitive deficits similar to those seen in schizophrenia can be observed in individuals without a formal psychiatric diagnosis, who exhibit similar, but attenuated symptoms. It has been suggested that psychotic symptoms exist along a continuum with normal behaviour at one end and schizophrenia at the other (Crow, 1984). Typically studies of “high risk” or psychosis-prone individuals have used relatives of individuals with a diagnosis of schizophrenia (or other psychotic disorders) and many concur that certain cognitive domains are compromised in relatives (Nuechterlein et al., 2002; Siever et al., 2002). Another approach to the investigation of psychosis-proneness is the study of individuals who are identified via self-report measures of schizotypy (schizophrenia-like behaviour). Psychotic symptoms (such as paranoia, hallucinations and thought disturbances) are relatively common in the normal population (Verdoux & van Os, 2002). As such, exploring cognition in subjects endorsing psychotic-like symptoms may help cast further light on the cognitive processes affected in disorders such as schizophrenia. Many studies of schizotypy have identified a similar factor structure of symptoms to that of schizophrenia (ie. positive-negative-disorganised) (Bergman et. al., 1996; Raine, 1991).

There are a variety of approaches to investigating cognitive deficits in clinical populations. Often neuropsychological tests have been used to examine the pattern of deficits and findings related to areas of brain dysfunction thought to be measured by the selected tests. Another approach is to examine the clinical groups' performance on experimental tasks that have been honed in the normal population in order to examine a given theory of an aspect of cognition. Experimental tasks are often less complex, and the results often clearer to interpret than performance on neuropsychological tasks that may encompass several cognitive domains on a single task.

The aim of this research is to explore whether there is justification for the continued separation of WM into fractionated components. Evidence is presented to support a common storage approach to short-term, long-term and working memory tasks. In addition an exploration of schizophrenia participants on a number of working memory tasks will be undertaken and their performance will be compared with schizotypal and non-schizotypal groups as identified via a self-report inventory of schizotypy.

The three main areas under consideration in this thesis are as follows:

1) Simple, complex and delayed span tasks - In normal memory research, serial order effects have been extensively researched. Serial position curves, the impact of proactive interference, the predominance of speech based codes, and item and order errors have all been shown to be robust and stable phenomena (Baddeley, 1966; Coltheart, 1993; Conrad, 1964; Crowder, 1976; Tehan, Hendry & Kocinski, 2001; Wickelgren, 1965). Evidence will be presented suggesting that simple span provides a reasonable measure for STM; Complex span can be equated to the concept of WM as it is currently conceived and that delayed span can be viewed as a measure of LTM. Span task experiments using subjects with a clinical diagnosis of schizophrenia have almost universally found deficits (Bauman, 1971; Conklin, Curtis, Katsanis & Iacono, 2001; Elvevag, Weinberger & Goldberg, 2002; Elvevag, Maylor & Gilbert, 2003; Frame & Oltmanns, 1982). However, the presumed source of these deficits varies, with some researchers determining that the primary deficit is one of encoding (Aleman, Hijman, de Haan & Kahn, 1999; Cirillo & Seidman, 2003) and others pointing to faulty retrieval mechanisms (Dreher, Banquet, Allilaire, Paillere-Martinot, Dubois & Burnod, 2001). In this research, a simple four-word recall task, with and without interference will be used to examine error types and performance will be examined in relation to symptomatology.

2) Contribution to span – The span task has been extensively used in both clinical and non-clinical research in order to examine deficits in working memory. Although simple in appearance, research has indicated that in normal memory, contributions to performance on span tasks come from a surprising array of sources. Individual differences research has shown that there are multiple influences operating on this task including contributions from rehearsal, output speed, lexical memory and semantic factors (Tehan & Lalor, 2000; Roodenrys, Hulme & Brown 1993; Poirier & Sant-Aubin, 1995). If these same sources of variation contribute to the performance of tasks purported to measure WM and LTM then this could provide evidence against the need for a multi-component system of WM. This research will be briefly reviewed and the impact of symptoms of schizophrenia on these sources will be examined. Specifically, this study will partially replicate a study on contributions to span by Tehan and Lalor (1999) in an attempt to delineate whether individuals with schizophrenia display similar contributions to span performance as control participants.
3) Phonemic codes have been established as being dominant in short-term memory research (Conrad & Hull, 1964; Baddeley, 1998 for review; Tehan & Humphreys, 1998). However, Tehan and his colleagues (Daly, 1999; Tehan & Humphreys, 1996, 1998; Fallon, Groves & Tehan, 1999) have shown that both phonemic and meaning-based codes can and do have an impact on verbal working memory tasks using a cued recall paradigm. Given the problems some individuals with schizophrenia are known to have with meaning and

rhyme-based material, a further aspect of this study will be to examine the performance of clinical subjects on a cued recall task with the expectation once again of differential performance based upon symptomatology.

Current models of working memory and in particular, span performance, serial recall and cued recall in experimental research will be reviewed in Chapter 2. This will include an overview of the predominant models of working memory as they pertain to this research. An introduction to schizophrenia and schizotypy will be presented in Chapter 3. Chapter 4 will examine the performance of individuals with schizophrenia and schizotypy on verbal working memory tasks, particularly those that examine the areas under investigation here. Where there is a gap in the literature (particularly with performance in schizophrenia on cued recall tasks), related literature will be examined in an attempt to hypothesise possible relationships. Chapter 5 will introduce the groups under investigation in the thesis. Chapter 6 is the first of the three experimental chapters and will investigate group performances on a simple serial recall task, a standard recall with interference (working memory) task, and a delayed memory (Brown-Peterson type) task. In particular this chapter will investigate in detail the patterns of errors in performance. Chapter 7 will take an individual differences approach to examine the contributions to span performance among the different groups, attempting to replicate previous research of Tehan and Lalor (2000). The final experimental chapter (Chapter 8) will examine the performance of the groups on a cued recall task, focussing on the influence of the interfering effects of cues and codes on recall. Finally, Chapter 9 will integrate the findings from the three experimental chapters in a general discussion section.

Chapter 2 - Working Memory

2.1 Introduction

The origins of the term "working memory" can probably be attributed to Miller in 1956. Although Atkinson and Shiffrin (1968) are generally acknowledged as truly developing the term, Miller's description of working memory as being "part of the information processing system implicated in the executive control of cognition and behaviour and served as a form of short-term storage" (Miller, Galanter & Pribham,1960, p4), is surprisingly close to the current understanding of the concept.

The interest in working memory and its contribution to the greater understanding of cognition has been extensive over the past two decades. However, the development of the concept, its relevance and application is not without some confusion. Part of the problem stems from the fact that the notion of "working memory" has been embraced by many different theorists with differing and varying agendas in their research (Richardson, 1996). This chapter will firstly introduce the current and probably, most influential model of working memory as envisaged by Alan Baddeley (Baddeley & Hitch, 1974; Baddeley, 1986, 1992a, 1992b, 2000; Baddeley & Wilson, 2002). It will then explore some of the shortcomings of this model and introduce other approaches that may help to extend our understanding of working memory and the tasks used to measure it.

2.2 Baddeley's Model

Working memory is a concept which has evolved from the earlier notion of a unitary short-term memory store (Baddeley, 1992a). Essentially working memory has been defined as a system which is responsible for temporary maintenance and manipulation of information (Baddeley, 1992b). This system can then be used to transfer information to a knowledge storage system, or alternatively, it can be used to guide behaviour. Baddeley's model of working memory (Baddeley, 1986) has proved useful in understanding aspects of human memory and has been used to examine deficits in a range of neurocognitive disorders including Alzheimer's disease (Morris, 1986), Korsakoff's syndrome (Joyce & Robbins, 1991) and Parkinson's disease (Fournet, Moreaud, Roulin, Naegele & Pellat, 1996). This model has also been examined in a range of studies focusing on the neurocognitive deficits associated with schizophrenia (David & Lucas, 1993; Haddock, Slade, Prassad & Bentall, 1996; Salame, Danione, Peretti & Cuervo,1998).

Working memory as originally envisaged by Baddeley (Baddeley & Hitch, 1974; Baddeley, 1986, 1998) was fractionated into three parts, the central executive (CE), and two slave systems, the phonological loop (PL) and the visuospatial sketchpad (VSSP) (See Figure 2.1). A central tenet for all subcomponents of Baddeley's model is that there are three key elements; temporary activation of information, control processes, and limited capacity. As will soon be apparent, a fourth slave system called the episodic buffer has recently been added to the model.

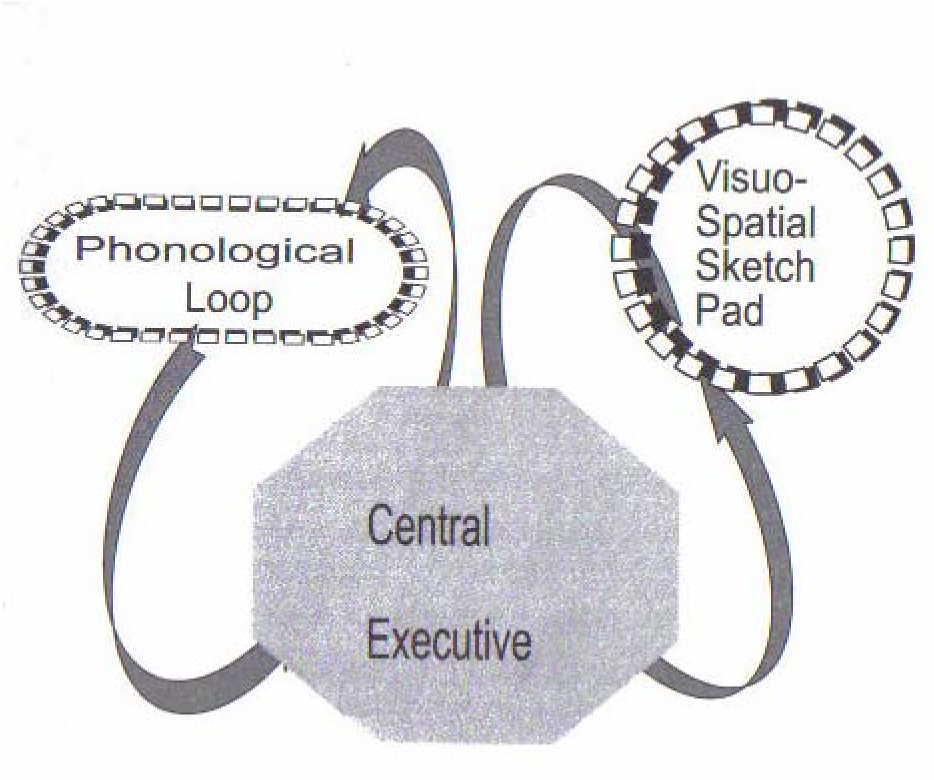

Figure 2.1 – A schematic representation of Baddeley's tripartite model of working memory

(Source: Baddeley & Logie, 1999, p.29)

2.2.1 The Central Executive (CE)

Baddeley suggests the CE is a crucial component of WM (Baddeley, 1986). However, until recent years it was also the area of his model that was the most neglected. While it was assumed that WM was controlled by the CE and that it also served as an extra pool of resources for either processing or storage (Baddeley & Logie, 1999), little of the mechanisms by which these functions were achieved were investigated until recently. Subsequently, Baddeley has expanded upon his idea of the CE (Baddeley, 1996; Baddeley & Logie, 1999), modifying its role to be more in line with the Norman and Shallice (1980) idea of a system for supervising attentional control (the Supervisory Activating System (SAS)). The changes to the role of the CE see a move away from the notion that it may provide extra storage capacity, with all storage now allocated to the slave systems (Baddeley & Logie, 1999). Instead the CE is seen as having potentially multiple roles. In addition to the original idea of coordinating the slave systems, Baddeley (1996) proposes that it operates as an attentional controller, selecting and filtering information entering the system. He also suggests that it has a role in selecting and manipulating material from LTM, although this area is still relatively unexplored (Baddeley, 1996).

In order to measure the operation of the CE, dual tasks must be employed that involve both storage and processing demands (e.g. complex span tasks). Daneman and Carpenter's (1980) reading span task is one such example. In this task the subjects are given sentences of varying length to read, they must also remember the final word presented in the sentence for later recall. Accordingly, WM capacity was then defined as the maximum number of terminal words that could be recalled perfectly (Baddeley, 2003). Turner and Engle's (1989) operation span task is another example. Here the subject is presented with a series of mathematical problems and word pairs (e.g. 7 x 2 – 3 = 12 BOMB). The subject is required to read the problem aloud and then verify whether the given answer is correct, then read the word aloud. After a series of these pairs (increasing in length after an initial presentation of two pairs), the subject is required to recall the presented words. Baddeley (Baddeley & Logie,1999) argues that these tasks are actually not adequate measures of the CE. He reports findings that the demanding processing task had virtually no impact on the subjects span for words, and increasing demands on storage had little effect on processing.

2.2.2 The Slave Systems

In contrast to the CE, the slave systems have been widely researched. Currently there are three storage systems; the Visuospatial Sketch Pad (VSSP), the Episodic Buffer (EB) and the Phonological Loop (PL). For the purpose of this thesis, the VSSP will not be examined here as the experimentation relies primarily upon the storage of small amounts of verbal material – the domain of the phonological loop.

Recall of a series of verbal items in order, after immediate presentation, is influenced by factors relating to both the stimulus items to be remembered and also how those items are presented. Baddeley's (1986) phonological loop (PL) has dominated the literature in this area. The PL originally was conceived as consisting of two parts, a phonological store where to-be-remembered items are held for a few seconds before they decay, and an articulatory loop where items are rehearsed to prevent decay (Baddeley, 2003) and for the recoding of visual information into phonological codes (Baddeley, 2003).

Baddeley (1986) and others using his model (Swanston, 1996) argue that the PL can account for many of the known effects that occur in verbal serial recall tasks. The following signature effects have reliably been found across a range of experimental conditions:

(a) *The word length effect* – This refers to the fact that memory span for short words is greater than span for long words (Baddeley, Thomson & Buchanan, 1975; Coltheart & Langdon, 1998; Neath & Nairne, 1995). This effect is said to occur due to the time-limited nature of the PL. Items within the PL are thought to decay within approximately two seconds if they are not rehearsed (Tehan et al., 2001). The word length effect theoretically occurs because more short words can be rehearsed in a given period of time than long words and thus are better recalled.

(b) *The phonemic similarity effect* - This effect reflects the finding that memory span is worse for lists of similar sounding items than for lists of dissimilar sounding items (Baddeley, 1966b; Conrad & Hull, 1964; Coltheart, 1993). When items in the to-be-remembered list sound the same, errors occur. To-be-remembered items are thought to be stored in the PL based on their phonological features and as a result, if the items share phonemes, confusion in the system arises. The errors that occur tend to be *order* errors, so that errors occur due to a loss of position rather than a loss of item information (Wickelgren, 1965; Tehan et al., 2001).

(c) *Articulatory suppression* - Having participants vocalize an irrelevant speech task during presentation of the to-be-remembered items (e.g. "*the the the")* interferes with rehearsal of to-be-remembered items and leads to reduced recall (Neath, 2000; LeCompte & Shaibe, 1997; Gupta & McWhinney, 1995;). According to Baddeley & Hitch (1994) this is due to subvocal rehearsal being prevented by the concurrent articulation of other speech.

(d) *Unattended Speech* – Performing a verbal serial recall task against a background of continuously spoken words interferes with recall (Baddeley & Salame, 1986).This effect is thought to occur due to the presumption that auditory stimuli have privileged access to the phonological store and the excess speech leads to overload.

(e) *Modality Effect* - Auditory presentation of the study material produces better performance than visual presentation of the same material, and auditory presentation produces memory traces that are more robust to the effects of articulatory suppression and irrelevant speech (Cowan, Saults Elliot & Moreno, 2002; Cowan, Saults & Brown, 2004). The explanation for these effects is that auditory presentation gives items direct access to the phonological store. With visual presentation items can only be stored if the participant is able to articulate the words and thus convert the items to their phonological representation and rehearse them. However, if items are presented visually and rehearsal is prevented, phonological codes cannot be created, performance is impaired and the word length effect disappears (Baddeley, Lewis & Vallar 1984).

2.2.3 The Episodic Buffer

Baddeley (2000) conceded that his tripartite model could not explain several phenomena observed in working memory experiments. For example, the tripartite model does not provide an adequate explanation for the fact that articulatory suppression does not have a devastating impact on recall. While reciting an irrelevant word during visual presentation of to-be-remembered items impacts upon performance, Baddeley (1984) reports that recall of digits under these conditions typically drops from around seven to five items. Articulatory suppression should prevent all rehearsal and have a far more significant impact on the recall of items. Additionally, visual presentation of items to individuals with severely impaired auditory WM results in improved performance (Baddeley, Vallar & Wilson, 1987). Both of these effects leads to the conclusion that there is some sort of visual coding that parallels the acoustic codes presumed to be dominant in this model.

In addition to the problem of how the WM system combines visual and auditory information for the recall of serial information, prose recall presents a further complication. It is well established that recall of meaningful sentences far exceeds the recall of individually presented material such as unrelated words or digits (Baddeley, et. al., 1987). It is presumed that information from LTM is used to chunk together meaningful sections of the sentence, and the number of these chunks is limited to the typical capacity of WM (Miller, 1956). Baddeley's model in its original form had no way of specifying how this information from LTM is stored and then utilized for the retention and recall of prose.

The Episodic Buffer then, has been proposed as an additional storage system for the WM model. It, like the other components is of limited capacity and Baddeley (2000) nominates it as being under the control of the CE. It is assumed to play a crucial role in the integration of information from multiple modes and in operating as an interface between LTM and the two slave systems (see Figure 2.2).

Baddeley (Baddeley & Wilson, 2002) contends that the episodic buffer moves beyond the assumption of Ericsson and Kintsch (1995) and Cowan (1999), who assert that verbal working memory relies on activations from LTM. In his new adaptation of the model, the Episodic Buffer interacts with LTM but does so in an active way to allow new combinations of representations to cope with novelty. Under the control of the CE, the buffer provides a work space for binding information from multiple sources into coherent episodes (thus the name, episodic buffer). According to Baddeley (2000), the CE accesses the buffer via conscious awareness and can also control the content of the buffer by attending to specific sources of information (eg. LTM, other components of the model or even perceptual information). In this way the buffer is thought to be involved in the creation of novel representations of information which can in turn be used for problems solving. For example, Baddeley suggests that the EB can take representations from LTM to plan a novel route between two locations.

Since the addition of the episodic buffer to the model, there has been relatively little work done to support its utility. Baddeley and Wilson (2002) examined the performance of a number of amnesic patients and interpreted their results on a range of neuropsychological measures in the context of the EB. They first looked at two densely amnesic patients (one as a result of encephalitis, the second following a stroke). They presented data showing that both patients had preserved intellectual functioning (as measured by WAIS IQ), normal immediate recall for prose material (based on the logical memory (LM) subtest of the Wechsler Memory Scale (WMS), and severely impaired delayed recall for prose (once again using the LM subtest of the WMS). Intact immediate prose recall in these patients cannot be adequately explained without some way of information from LTM interacting with current WM.

They (Baddeley & Wilson, 2002) then explored the performance of a group of memory impaired (23 densely amnesic) patients. Once again WAIS and LM memory scores were recorded, along with information regarding executive functioning. Unsurprisingly they found universally poor performance on the delayed component of the LM test with almost all patients scoring zero. However, they found a large variation in the immediate prose recall condition. When examining the relationships between the variables, they found a significant positive relationship between immediate prose recall and WAIS scores and a significant negative relationship between immediate prose and executive dysfunction. A further highly significant negative relationship was found between WAIS scores and executive dysfunction. NART scores were not significantly correlated with any measures. Further investigation of the relationship between prose recall, IQ and executive function was explored in a group of Alzheimers patients.

Taken together, Baddeley and Wilson (2002) suggest that immediate prose recall will remain intact in amnesic patients, but only when IQ is relatively high and executive functions are intact. They suggest that the relationship between WAIS scores and immediate prose scores would be expected if the EB has a role to play in immediate prose recall. For their reasoning they draw on the findings of Kyllonen and Christal (1990) that fluid intelligence can be thought of as being largely the same as WM capacity as represented by span tasks that encompass storage and processing of information simultaneously. They contend that the EB is the storage component for WM tasks, and the CE responsible for processing. If immediate recall of prose requires both of these components, they argue that the significant correlations with WAIS scores would be expected as these scores can be used to approximate fluid intelligence. In addition, the association with executive functioning and WAIS scores would also be expected as it is likely that the CE is reliant on intact executive abilities.

However, Gooding and colleagues (Gooding, Isaac & Mayes, 2005) examined the performance of another group of amnesic patients in their laboratory in order to explore whether Baddley's findings applied to their group, and whether the results provided support for the new EB component. They found that their patients did not show the same pattern of correlations. They found no positive correlations between WAIS scores and immediate prose recall. They also found that WAIS and NART scores were highly correlated. The Baddeley and Wilson (2002) paper reported no significant relationship between these two variables. In contrast to the Baddeley and Wilson paper they (Gooding et. al., 2005) found no relationship between any of their executive function measures and immediate prose recall. Overall, they found

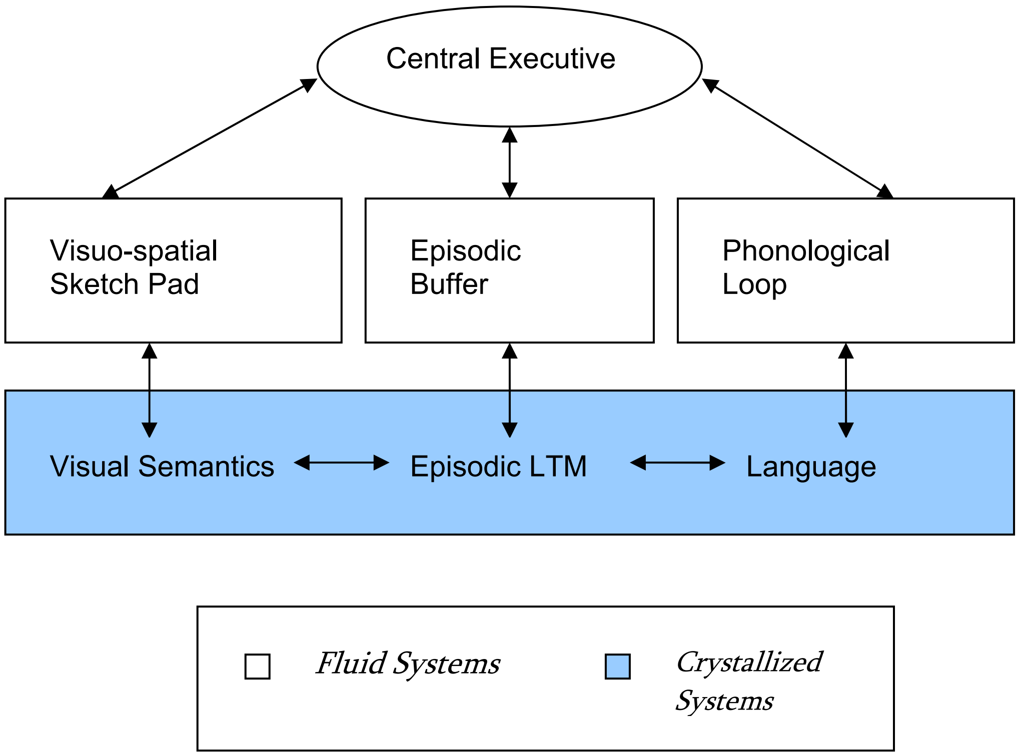

Figure 2.2 Baddeley's revised model of working memory including proposed links to long-term memory, and new episodic buffer component

Source: Baddeley & Wilson, (2002).

that even in patients that had preserved executive functioning, immediate prose recall was impaired. They concluded that their findings did not support the EB hypothesis, although they conceded that differences in the types of patients tested could have contributed.

Baddeley and Wilson (2002) admit that it is hard to test the EB hypothesis with their data from the amnesic patients, but that the results are suggestive of its existence. Gooding et. al. (2005) concur that without further specification of the buffer it is difficult to test with this type of data.

2.2.4 Summary of Baddeley's working memory model

The Baddeley and Hitch (1974; Baddeley, 1986, 2000, 2003) WM model is a multi-structure system which allows cognitive processing and storage over very short intervals of only one or two seconds. The slave systems have been the focus of far more research than the CE, although Baddeley in recent years has sought to address this discrepancy. In terms of understanding remembering over a very short period of time, the PL appears to have replaced the earlier notion of a limited capacity short-term store. The capacity of the PL is thought to be determined by a race between rapid decay of verbal information and how fast a person can refresh this information through rehearsal of the to-be-remembered information. Original conception of the PL and much research examining its structure, has largely seen it as a buffer of limited capacity which is passive and does not support working memory performance (Baddeley, 1986; Swanston, 1996). As such the capacity of the PL, as measured by memory span or immediate serial recall tasks, can be completely explained in terms of a trade-off between decay of the to-be-remembered material and rehearsal speed. However, despite the widespread popularity of this model, it has not been without its critics. The newer EB component is viewed as being able to support more active processes than the PL. However, to date there is little evidence to support its existence. Furthermore, while the EB has been posited as a store that augments the PL, there is as yet no research that addresses this issue or even a description of the PL and EB might interact. The following sections will address the criticisms of the model and discuss alternative approaches.

2.3 Criticism of the Baddeley & Hitch model, and alternative approaches.

2.3.1 Criticisms of the Phonological Loop (PL)

Some researchers have argued the Baddeley model is too simplistic and cannot account for all of the observed phenomena in serial recall tasks (Tehan et al., 2001). Problems with one of the signature effects attributed to the role of rehearsal within the PL, the word length effect, has led some (notably Nairne, 2002) to question the role of rehearsal in remembering verbal material over the short term. Nairne (2002) points to a considerable body of research which undermines this assumption including:

(a) *The dissociation between articulation rate and level of recall*. Under many conditions where articulation rates are held constant, differences can still emerge in the level of recall. Manipulating the to-be-remembered material in terms of phonemic similarity (Schweichert, Guentert & Hersberger, 1990), word frequency (Hulme et. al., 1997), lexicality (i.e. words versus nonwords) (Hulme, Maughan & Brown, 1991), and meaning (e.g. abstract versus concrete words) (Walker & Hulme, 1999) can all produce differences in recall without any appreciable difference in articulation rates.

(b) *Word length effects in the absence of rehearsal.* The elimination of the word length effect under conditions of articulatory suppression was seen as further evidence for the importance of rehearsal (Baddeley,

> Thomson & Buchanan, 1975). Nairne (2002) argues that it is not sufficient to conclude that rehearsal is the key to this phenomenon and once again points to an impressive body of research which indicates that word-length effects can still occur under articulatory suppression. He also suggests that the findings of Coltheart and Langdon (1998) question the role of rehearsal in the word length effect. Coltheart and Langdon (1998) presented the to-be-remembered material at rates that would make rehearsal unlikely (the entire list was presented in under a second), yet still found robust word length effects.

If the race between decay and rehearsal is not enough to explain some of the effects in short-term serial recall, what else may contribute to the differences found on this task? The work of Hulme and his colleagues (Hulme et al., 1991, 1997; Brown & Hulme, 1995; Walker & Hulme, 1999) amongst others, points to a contribution from LTM to memory span via a redintegration process. Hulme et al. (1991) showed that for words and non-words of different spoken duration there was a linear function between speech rate and memory span. However, they found that recall of nonwords was generally worse than recall of words. So while words and nonwords had an equivalent slope, they had different intercepts. They suggested that the equivalence in slope reflected the contribution of subvocal rehearsal processes and the difference in the intercepts reflected the contribution of LTM processes to span performance. They also showed that when subjects were given lists to recall in a different language (i.e. Italian), not surprisingly their performance was worse than for English words. However, when subjects were taught the English translations for the to-be-remembered list items, their span performance improved. Once again this was seen as being indicative of a contribution from LTM. Other studies have similarly pointed to the role of access to lexical memory in contributing to span performance (Poirier & Saint-Aubin, 1995; Schweickert, 1993). Caza and Belleville (1999) also found a role for both lexical and semantic representations in immediate serial recall tasks with superior recall of content (e.g. nouns and verbs) over function (e.g. prepositions, pronouns) words. Similar to other studies, Caza and Belleville (1999) found that function words, while producing inferior recall to content words, were still recalled more frequently than nonwords.

In order to explain these findings, Hulme et. al. (1991) postulate that as the phonological representations decay in the PL, LTM can be accessed to reconstruct this degraded information. Lexical and semantic representations from LTM then, can all play a part in helping to supplement the functioning of the PL. Tehan and his colleagues (Tehan & Lalor, 1999; Tehan, Fogarty & Ryan, 2004*)* examined the role of a range of contributions to span performance including rehearsal, access to lexical memory, output speed, search speed and phonological coding. They found that access to lexical memory contributed more to individual differences in span performance than either rehearsal or output speed (Tehan & Lalor, 1999). They were then able to replicate these findings (Tehan et al., 2004) and show that phonological-coding ability was also a potent source of individual differences to span.

To summarise, according to Baddeley's model, immediate serial recall of verbal material is a relatively straightforward task whereby storage is limited by rehearsal speed. It should be noted that rehearsal is not actually the same as articulation (Baddeley & Wilson, 1985). Rehearsal is the rate at which information is rehearsed silently or subvocally. Actual articulation tends to correlate highly with rehearsal speed (Landauer, 1962; Standing & Curtis, 1989) and as such provides a reasonable overt measure of this covert process. It was proposed that one of the signature effects of the PL, the word length effect, was one of the cornerstones of this model. According to this effect it was assumed that the advantage in recall of short words over longer words was the result of shorter rehearsal time. A growing body of evidence indicates that this clearly is not the case. However the word length effect is to be explained, it cannot be regarded as being as a result of rehearsal. Evidence also suggests that span tasks appear to be more complex than originally thought, with contributions from long-term memory representations of lexical and semantic knowledge. It appears that as the phonological representations rapidly decay over the short-term, to-be-remembered items can be reconstructed via access to long-term word knowledge. Individual difference studies support these notions by showing that speed of lexical access makes more of a contribution to span performance than do measures of rehearsal. Baddeley's (2000) addition of the EB may be the mechanism which compensates for the PL to allow active binding from LTM but as yet there is no description of how this might occur.

An alternative approach to accounting for these disparate findings is given by Nairne (2002). He suggests that there may be no valid reason to believe that remembering over the short term is a vastly different process than retrieving information from LTM. Instead, the notion of separate short and long term stores should be rejected. Rather than assume that lexicality or word class effects that are found in immediate recall are contributions from LTM, it may be that all recall is determined by appropriate retrieval cues. What may differentiate short-term recall from LT recall is the presence or absence of phonological representation of the list items. Support for cueing effects in STM has been varied. The well known release from proactive interference (PI) effect has been regarded as a cueing phenomenon. Wickens et. al. (1963) showed that if subjects were given multiple short-term recall trials where the material was drawn from a single category (eg. *animals)*, their performance would deteriorate across trials. This effect was seen as evidence that confusion would build up over the short-term due to cue overload and the subject would find it more and more difficult to distinguish items from previous trials. If the subjects were then given a list of items from a completely different category (eg. *flowers*), performance would return to near original levels. This increase in performance has been called "*release from PI".*

Tehan and Humphreys (1995, 1996 & 1998) further explored cueing effects in short-term recall. They found (Tehan & Humphreys, 1996) that PI occurred in both an immediate and delayed cued recall tasks when either a taxonomic or ending category cue subsumed both the target item and an interfering foil. In one series of experiments (Tehan & Humphreys, 1996) subjects studied either one or two four-item block trials but it was stressed that they only ever had to remember the most recent block (subjects never knew beforehand whether the trial would be one or two blocks). Category specific PI was then manipulated in the two block trial by including a foil in the first block which shared certain conceptual characteristics with the target in the second block. For example, block one words may be – *jail-silk-orange- book* and the block two words – *page-leap-carrot-witch.* The target word *"carrot"* shares characteristics with the foil *"orange"*. Both can be eaten and share the same colour. If the category cue presented was *"vegetable*", there was no interference effect found for the block one word. However if the category cue subsumed both words (e.g. *"juice"*), PI was frequently observed with the block one word interfering with the subject's ability to correctly recall the target. Other research by Tehan has supported the importance of both category and phonemic cues and codes in immediate recall (Fallon, Groves & Tehan, 1999). Henson (1999) and Estes (1991) in looking at the type of errors that occur in immediate serial recall tasks also found that position information is an important cue when retrieving information over the short-term.

There is growing evidence then to suggest that retrieval of verbal material over the short-term involves more than simply emptying the contents of some short-term verbal buffer. It is likely than even over short periods recall is driven by processes not dissimilar to LTM, with retrieval starting with a cue. Phonemic codes still dominate over the short-term, but when these codes break down, meaning based information can be used as a cue for retrieval.

2.4 The Central Executive Alternative Approaches

Serial recall or span tasks are the most commonly used measures of verbal working memory. Since Miller's (1956) influential paper on the "magic number seven", it has been well established that remembering novel information over a short period is capacity limited. Researchers have long been interested in not only the capacity of short-term memory, but also in the factors involved in how we store and retrieve novel items in the correct order. However, simple span tasks, such as digit span or word span, are seen as reflecting only a storage component of immediate memory (Daneman & Carpenter, 1980). La Pointe and Engle (1990) argue that in order to truly measure WM rather than STM, processing capacity must be measured as well as storage.

A recent paper by Conway and colleagues (Conway, Kane & Bunting, 2005) presented a comprehensive analysis of the methodological soundness of WM span tasks as measurement tools in cognitive research. According to their review WM span tasks such as reading, operation and counting span tasks all share three critical task components. These are immediate and vigilant stimulus presentation, individual administration and sufficient item size. The task needs to be designed to force storage in presence of either processing *or distraction*, so the key issue is preventing rehearsal with the implication being that high level processing is not crucial to the task.

The next section introduces two alternative models to Baddeley's multi-component model of memory and addresses how aspects of the models can be measured.

2.4.1 Engle's Model

Engle and his colleagues (Conway & Engle, 1996; Rosen & Engle, 1997; Engle, Kane & Tuholski, 1999) have proposed an individual differences approach to WM. In their model (see Figure 2.3) they see STM as LTM traces active above some threshold level, there is also some collection of skills and strategies for maintaining that activation, and a limited capacity attentional control system (seen below as the CE portion). Working memory then, according to this model is essentially STM plus controlled attention, and WM capacity relates to only the controlled attention portion of the system.

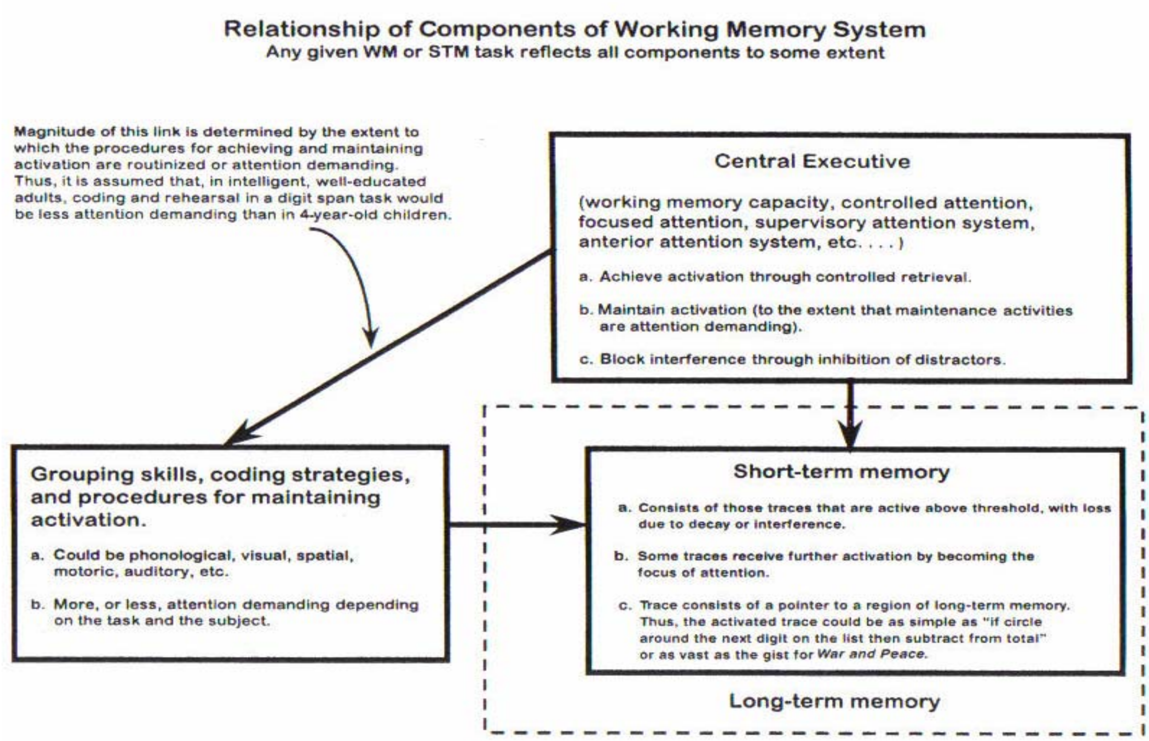

Figure 2.3 – Engle's measurement model

(Source: Engle, Kane & Tuholsky, 1999, p. 106)

Engle et.al. (1999) outline the core elements of their model which includes:

(a) Domain-free limited capacity controlled attention which "is required for maintaining temporary goals in the face of distraction and interference and for blocking, gating, and/or suppressing distracting events" (p. 102).

(b) There may be domain specific codes and maintenance (following Baddeley these may be verbal or visual as in the PL and the VSSP) but the domains are not necessarily restricted to just verbal and visual-spatial information.

(c) Individual differences may occur in both the controlled attention system and in domain specific areas. However, they believe "the differences in capacity for controlled processing are general" (p. 102). So that while it may be possible under certain circumstances to circumvent the limited capacity of the system, limitations will emerge under novel conditions or when faced with interference.

In order to explore their individual differences approach, they turned to complex span tasks such as the reading and operation span tasks (Daneman & Carpenter, 1980; Turner & Engle, 1989) using extreme groups. Extreme groups here are defined as those individuals who score in the upper and lower quartiles on these tasks. They argue that dual tasks are necessary to measure WM capacity as performance on simple span tasks does not reliably predict tasks requiring higher level cognition such as reading and comprehension (Engle, Tuholski, Laughlin & Conway, 1999). Given that performance on complex span tasks have been shown to be related to a range of higher level cognitive tasks such as reading comprehension (Daneman & Carpenter, 1980), reasoning (Kyllonen & Crystal, 1990) and language comprehension (Just & Carpenter, 1992), they (Kane & Engle, 2002) argued that WM capacity has a strong relationship to general fluid intelligence (*g*F). General fluid intelligence as originally conceived by Horn and Cattell (1966, 1967) is similar to Spearman's (1967 as cited in Kaufman, 1990) concept of *g.* It reflects an innate general ability that develops rapidly until the early 20's and then declines across the lifespan (Ryan, Sattler & Lopez, 2000; Wang & Kaufman, 1993). It includes such abilities as problem-solving, memory, learning and pattern recognition and is relatively culture free (Horn & Cattell, 1967).

Using a variety of complex span tasks thought to be good measures of WM, simple span tasks and tests designed to measure *g*F (such as the Raven's Progressive Matrices and Cattell's Culture Fair Test), Engle et al. (1999) set out to investigate whether performance on simple and complex span tasks reflected a single construct or were in fact measures of STM and WM respectively. They also sought to investigate whether the left over variance attributable to WM (after common variance for STM and WM was removed) would correlate with *g*F. They found that their model was better explained by two-factors rather than just a single one. That is, a separate construct was needed for both WM and STM. Their model also showed that there was a strong relationship between WM and *g*F, but did not require a connection between STM and *g*F.

They (Engle et al., 1999) concluded that performance on complex span tasks reflect a storage component of STM and controlled attention processes. Simple and complex span tasks share common storage but the level of processing required for the complex tasks means that controlled attention comes into play. They argue that the controlled attention portion of the WM task shares a strong relationship with *g*F and this is why in multiple studies, performance on complex span tasks can be used to predict performance on high demand cognitive tasks such as reading comprehension and reasoning. Given however, that both simple and complex span tasks share common storage across tasks, one could predict that factors that influence immediate memory tasks should also have an impact on working memory tasks. The literature relevant to this assertion will be examined after a brief examination of an alternative model of working memory devised by Cowan.

2.4.2 Cowan's Model

Cowan's (1988, 1999) model is similar in some respects to both Baddeley's and Engle's model. This model emphasizes the relationship between memory and attention (see Figure 2.4).

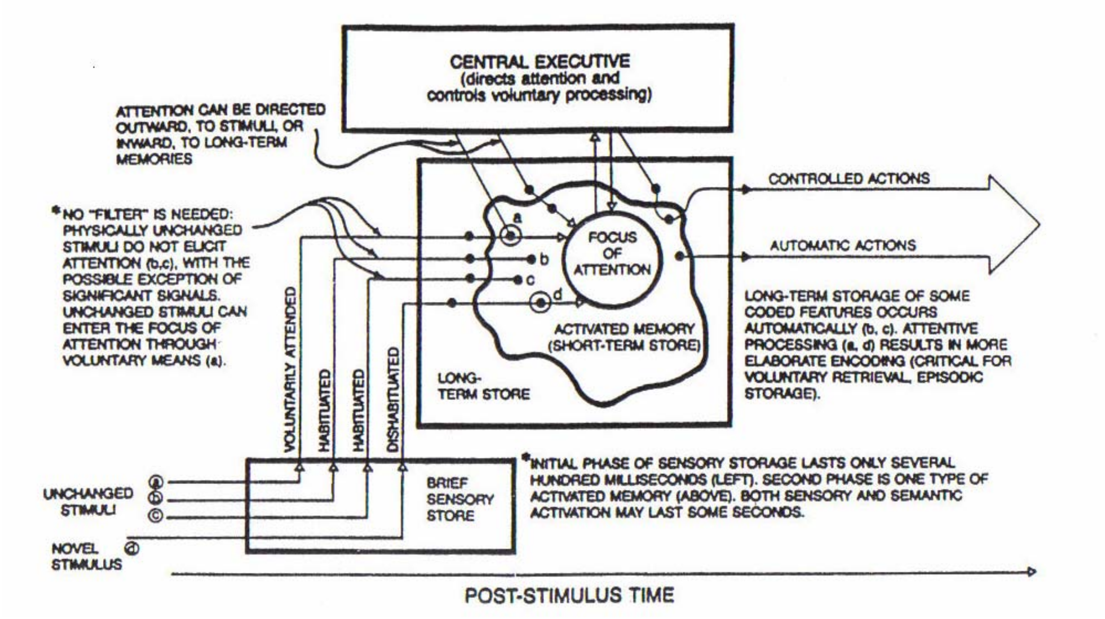

Figure 2.4 The Cowan embedded processes model

(Source: Cowan, 1999, p. 64)

Working memory, according to this model (Cowan, 1999) comprises an activated portion of LTM and the focus of attention. The short-term store, which equates to some degree with the PL of Baddeley's model is merely a currently activated portion of LTM. Within this subset of activated LTM there is an additional process which is the current focus of attention and awareness. Like other models, there are capacity and time limitations. Cowan sees the focus of attention portion as being capacity limited and the activated memory portion (or the ST store) as being time limited. The focus of attention is controlled by both voluntary and involuntary processes and is limited to approximately four items (Cowan, 1988). So, active memory then is the main source for the focus of attention but active memory is limited in that unless an item is brought back into the focus of attention, it will rapidly decay.

Cowan et. al. (1992) demonstrated the dynamics of his model using experiments explaining the word length effect in serial recall. When longer words were in the earlier list positions, forgetting of later items was more pronounced. They assumed that this was a function of the fact that the longer it took to recall the initial items, the harder it became to retrieve later items. Decay begins once items are no longer the focus of attention and if longer items are at the start of the list, the later items undergo more decay than if earlier items were shorter.

Tehan et. al. (2001) propose that given Cowan's assumptions, word length effects should be apparent on any task that involves active memory. If the capacity of the focus of attention is four items, then recall will be good if tested immediately. If however, there is some activity which shifts the focus of attention (e.g. a complex span task where focus of attention is shifted to confirming a mathematical equation) then during this shift in attention the items previously under focus will start to decay (although activation of those items in LTM will be maintained for a brief period of time). La Pointe and Engle (1990) examined whether in fact word length effects did occur in complex span tasks and they found that under a range of different conditions for both simple and complex span tasks the results were similar. That is they found similar patterns of effects across the range of tasks with word length effects demonstrated in complex span tasks.

It seems to follow from this evidence that in terms of measuring the components of Cowan's model, immediate serial recall of four items should be a good measure of the focus of attention. Complex span tasks with the interleaving of items and distractor activity might well be a good measure of "activated LTM" and a delayed recall, Brown-Peterson type task, where the list items are presented first followed by a period of distractor activity may be a good measure of LTM. Other models of WM may argue against the use of this latter task as a measure of LTM, however according to Cowan's model (Cowan, 1999, 2005) (and Baddeley's PL component) with an adequate period of distractor activity, any activated trace should have returned to baseline levels by the end of the retention interval thus making any recall reliant upon LTM.

2.5 Are immediate recall, WM and LTM tasks distinguishable?

The above discussion produces some clear differences. The Baddeley and Hitch (1974, 1994) model suggests that with verbal memory one needs to make the distinction between the Central Executive, Phonological Loop and the Episodic Buffer components of the model. The PL component is measured by immediate serial recall tasks and the central executive is measured by dual tasks like the reading span and operation span. In addition, the EB should also be involved as the storage component of dual tasks. Cowan has a similar approach in that different tasks measure different components of the working memory system. With four item lists, immediate serial recall should be an index of the focus of attention, a complex span task should measure activated LTM and a delayed task should measure LTM. In contrast, Engle (Engle et. al. 1999) suggests that all serial tasks have a common storage component, irrespective of the processing/distractor activity involved. It seems clear that one prediction of the Engle approach is that factors that influence one task should have the same impact on other tasks. This need not be the case for the Baddeley and Cowan approaches. Factors may have an influence on one component (e.g. phonological loop or focus of attention) but not necessarily have an impact upon other components. Tehan et al. (2001) have examined this proposition.

In their first experiment (Tehan et. al., 2001) they examined the word length effect in three tasks all requiring the serial recall of four-word lists. In the first condition (simple span) items had to be recalled in order immediately after presentation. In the complex span version they adapted the Turner and Engle (1999) operation span task where the four words were interleaved with a single math problem that the subject was required to verify as being correct or not. Recall was required after presentation of the four WORD-OPERATION pairs. In the final task, a Brown-Peterson type method was employed where the four words were presented followed by 12 seconds of distractor activity prior to recall. They found that across all three tasks recall was superior for short words over long words. The results of this study replicated the findings of La Pointe and Engle (1990) but also extended the findings to show that word length effects also occur in a Brown-Peterson type task which according to Cowan's assumptions could well be presumed to be a measure of LTM. These findings are at odds with straightforward accounts of Cowan's model. They also pose a challenge to Baddeley's original model unless it is presumed that all three tasks are supported by the PL, a conclusion that seems unlikely (Tehan et. al., 2001). Theoretically, the EB component could allow for the binding of information from LTM but parsimony would then question the need for a PL in the first place. Alternatively, the findings are consistent with a view that common storage mechanisms underlie all three tasks as proposed by Engle and his colleagues.

To seek further evidence for the equivalence across these tasks, Tehan and his colleagues (2001) then turned to phonological similarity effects (where similar sounding lists are harder to recall in order than dissimilar ones). Both the Baddeley and Cowan models would predict that phonological effects would be present on immediate recall tasks. Baddeley (1966) assumes that this is due to confusion in the PL which is phonologically based. Cowan et. al. (1999) make similar assumptions in that STM can be supported by a range of codes including phonological ones. Discrimination between similar items becomes difficult in the short term due to rapid decay of these codes once they leave the focus of attention. Both models should predict that phonological similarity effects should dissipate on a delayed test if one assumes that after 12 seconds of distractor activity all representations should have returned to baseline levels. Consistent with these ideas, Tehan and others (Fallon et. al., 1999; Nairne & Kelley, 1999; Tehan & Humphreys, 1995) also found that the phonological similarity effects were present in immediate recall but not after a delay using the standard correct-in-position scoring for serial recall. However caution is needed in explaining these results.

Fallon, et al. (1999) showed that if alternative measures of recall are utilized the picture differs somewhat. That is, if recall is scored as correct if an item is remembered irrespective of where in the list it is recalled, it turns out that lists of phonologically similar (rhyming) items are actually better recalled than lists of dissimilar items. It was still the case that the similar items were more likely to be recalled in an incorrect position within the list than the dissimilar items (Fallon et al., 1999). Thus it seems that an item advantage for similar words is offset by an order disadvantage and these effects lead to equivalent performance for the similar and dissimilar lists on the delayed test. The Fallon et al. (1999) results show that the absence of phonological similarity effects with correct-in-position scoring cannot be used as evidence that phonological traces have decayed to baseline levels and that to fully account for the data, item and order scoring need to supplement the traditional correct-in-position scoring method.

With the scoring caveats in mind, Tehan et. al. (2001) examined performance across simple, complex and delayed span tasks where phonological similarity was manipulated. They studied phonologically dissimilar lists, phonologically similar lists where all the items rhymed (e.g. *hat cat mat rat bat pat*) and (similar to the Fallon et. al., 1999 study), lists where the items had a high degree of phonemic overlap but did not rhyme consistently (e.g. *man cap mad can cat map cad mat*). The previous work of Fallon et. al. (1999) had found that dissimilar lists were not necessarily equivalent to each other and that there are factors, such as list length that can facilitate recall of dissimilar items. These experiments replicated earlier findings that under immediate recall conditions, dissimilar lists had an advantage over similar lists. They also replicated their previous work (Tehan & Humphreys, 1995; Fallon et al., 1999) showing that the phonological similarity effect is attenuated on delayed recall. The new findings though, suggested that differences between rhyming and dissimilar lists were equivalent for both the complex span tasks and the delayed tasks. They also found that under all conditions, more order errors were made on similar lists than dissimilar ones and that the only difference on the three tasks on item and order scores was “the absence of an item advantage for the rhyming lists on immediate test” (Tehan et. al., 1999, p. 344). The conclusion they made was that all three tasks, in contrast to both the Baddeley and Cowan models, were supported by phonological representations. These results question the need to separate passive and active components within the WM system.

In summary, various working memory models make different predictions about the independence of different serial recall tasks. Some take the approach that different tasks measure different components; others say that all tasks have a common storage component. The Tehan et al (1999) results are in favour of the common storage approach, but their study represents the only one of its type. More data need to be collected and alternative methods of evaluating this question need to be conducted before the separate tasks/separate components approach can be rejected.

2.6 Chapter Summary

The review to this point raises a number of issues that are going to be addressed in the following chapters. The first point is that there is debate as to being able to differentiate among different types of working memory systems.

On the one hand there are those that argue that simple span, complex span and delayed span tasks all share a common storage system. There are those that believe the different tasks measure different components of the working memory system. It seems that there are testable derivatives of these differences. For example, if there are group differences (e.g. clinical schizophrenia, high or low schizotypy) on simple span tasks, these differences may well be apparent across all types of task. However, the different components approach may well posit that differences may well be limited to one task or one process and that group differences may be attenuated or enhanced across the tasks. Such an outcome might be useful in localizing any cognitive deficit or lack thereof. The first empirical chapter (Chapter 6) addresses this issue.

The common storage approach makes a further prediction that has yet to be examined in either a clinical or a normal population. The review has indicated that individual differences on simple span tasks can be predicted by variability in access to lexical memory and to a lesser extent by differences in rehearsal speed. If simple span, complex span and delayed memory all share common storage, then it might be expected that speed of lexical access and rehearsal speed should also be predictors of complex span and delayed span performance. Likewise, it would be interesting to see if the relationship between predictors and task performance was equivalent for different groups. It might be the case that deficits in processes represented in one set of predictors might well explain group differences in performance. Chapter 7 addresses this issue.

Finally, while working memory theories have tended to dominate the literature, there are alternative approaches to memory over short retention intervals. The cue plus code approach developed by Tehan and Humphreys (1996, 1998) is one such approach. From this perspective, deficits in recall can be due to either encoding problems or retrieval problems. The vehicle they use to explore these issues is a short-term cued recall task in which proactive interference is manipulated. Again, it is possible that group differences will be localized to particular types of errors, which will inform models of potential processing deficits. Chapter 8 explores this approach.

Chapter 3 – General Introduction – Schizophrenia and Schizotypy.

3.1 General Introduction

This chapter introduces the concepts of schizophrenia and schizotypy and their theoretical relationship. It also discusses diagnostic issues and symptom clusters and psychometric measurement of schizotypy. Discussion of neuropsychological and cognitive deficits found in schizophrenia and schizotypy is introduced in chapter 4.

3.2 Introduction to Schizophrenia – Classification and diagnosis

The term "*schizophrenia"* and explanations of the core symptoms characterizing this disorder is generally credited to the influential contributions of Bleuler and Krapelin. In its earliest form, Krapelin (1919/1971) divided functional psychosis into two groups: *dementia praecox* (schizophrenia) and *manic-depressive insanity* (bipolar disorder). This division still underlies modern conceptions of mental illness and their classification (Asherson & Owen, 1995). Defining schizophrenia came about by the careful documenting of symptoms and signs by early investigators. Despite the wealth of research undertaken investigating the causes, epidemiology, course and outcome of this devastating illness, diagnosis is still based upon observation of symptoms and self-report of patient's experiences. The noted "antipsychiatrist" Thomas Szasz (1988) reminds us:

> "…….the claim that some people have a disease called schizophrenia (and that some, presumably do not) was based not on any medical discovery but only on medical authority, that it was, in other words, the result not of empirical or scientific work, but of ethical and political making" (p.3).

While Szasz's comments stem partly from a movement legitimately questioning the efficacy of the clinical care and treatment of the mentally ill, particularly during the 1950's and 1960's, the idea that schizophrenia is a construct without scientific basis has long been debunked, with substantial gains being made in understanding the disorder's genetic and neurobiological substrates. However, researchers need to remain mindful of the difficulties associated with researching a disorder, which is still based upon groups of signs and symptoms, however carefully ascertained. Affecting approximately 1% of the population worldwide (Gottesman, 1996; Jablensky, 1995), and with a substantial economic and health burden to our society (Scneerman, 2003), the pathogenesis of this arguably most devastating of all psychopathology, continues to evade researchers.

Diagnosis of schizophrenia in Australia by clinicians generally follows the Diagnostic and Statistical Manual of Mental Disorders – IV (DSM-IV) (APA, 1994) classification system. The key feature for diagnosis under this system is a continuous six month period where a person has experienced symptoms. This period must include one month of two or more active phase symptoms (or less if successfully treated). These active phase symptoms include (a) delusions; (b) hallucinations; (c) disorganised speech; (d) grossly disorganised or catatonic behaviour; and (e) negative symptoms (i.e. affective flattening, alogia or avolition). DSM-IV (p. 285) notes that if the delusions are "bizarre" or the hallucinations consist of a voice keeping a running commentary on a person's behaviour or thoughts, or two or more voices conversing then any of these is sufficient for meeting the active-phase symptoms. In addition to these symptoms, the individual must also have suffered disturbance in social or occupational functioning for a significant portion of the time since the onset of the symptoms.

There is ongoing debate regarding the diagnosis of schizophrenia and about whether it represents a discrete diagnostic category and whether current formulation of the diagnosis should be revised to take into account biological and neuropsychological findings (Tsuang, Stone & Faraone, 2000). Of rising interest to researchers over the past 40 or so years, has been the study of first-degree relatives of individuals diagnosed with schizophrenia without a diagnosis of psychosis, and individuals who on self-report measures, endorse thoughts and behaviours that are "schizophrenic-like".

3.3 Introduction to Schizotypy

> "Irritable, odd, moody, withdrawn or exaggeratedly punctual people arouse, among other things, the suspicion of being schizophrenic".
>
> (Bleuler, 1911/1950, p. 239)

The above description by Bleuler is probably one of the earliest formulations of the idea that there existed a form of unexpressed schizophrenia. Bleuler was trying to convey in this statement that, in his view, many people had behaviours and traits that were "schizophrenic-like" without necessarily suffering from a diagnosable mental disorder. This notion represents the earliest origins of what has now become known as schizotypy. With its genesis in Krapelin (1919/1971) and Bleuler’s work, both of these eminent figures in psychiatry noted that the family members of individuals with dementia praecox were often “odd” and exhibited some of the behaviours of this more serious disorder. They describe the term “latent schizophrenia” which essentially is a personality dysfunction that is qualitatively less severe than schizophrenia, but nonetheless similar in nature (Krapelin 1919/1971 p. 234; Bleuler 1911/1950, p. 239). Bleuler believed that latent schizophrenia was quite common but that often these less affected individuals did not seek treatment (1911/1950, p.239). This view, while certainly not the exclusive one, has persisted and been expanded upon throughout this century.

Rado (1953) coined the word “schizotype” as a combination of “***schizo***_phrenia” and “pheno_***type”***. While Rado (1953) made some ground in developing theoretical links between schizophrenia and schizotypal behaviour, it was not until Meehl’s (1962) seminal paper on schizotypy that an integrated model of the relationship between the two was hypothesized. Meehl (1962, 1990) proposed that schizotypes had a latent liability for schizophrenia (Lenzenweger, 1993). Meehl’s original paper and subsequent revisions have resulted in a strong interest in both the putative relationship between the disorders and also in the nature and manifestation of schizotypal behaviours in general. Indeed if schizotypy represents some form of liability towards schizophrenia, understanding and identifying individuals who exhibit schizotypal traits may assist in early identification of a predisposition to the development of schizophrenia. In turn, early identification could lead to interventions that may ameliorate the effects of this disorder at an earlier stage.

3.4 Theories of schizotypy and the continuum of psychosis.

Continuity models of psychosis vary. Some such as those described by Crow (1986) have bipolar affective disorder at one end of the continuum and schizophrenia at the other and attempt to relate different representations of psychosis along this continuum. Other continuity theories (most notably Eysenck, 1960, 1976 and Claridge, 1987), consider that the continuum of psychosis starts with normal behaviour and then progresses from less severe psychopathology to schizophrenia at the extreme end. In contrast others believe that psychosis is quasi-dimensional or even discontinuous (see Claridge and Beech, 1995 for discussion). Those researchers who advocate the discontinuity model (Lenzenweger & Korfine, 1992; Tyrka et al., 1993) follow Meehl in believing that schizotypy and schizophrenia represent an entirely different taxonomic group than those who do not have a predisposition to psychosis. So while not all schizotypes will decompensate into schizophrenia, you are either schizotypal or not, regardless of your level of functioning.

Debate about whether psychosis exists on a continuum or whether it is a discrete and separable condition from normal behaviour is ongoing. Current formulations of schizotypy are mostly derived from Meehl's theory, first put forward in 1962 and then revised in 1990. In an attempt to explain the genesis of schizophrenia from a neurodevelopmental perspective, Meehl posited that the necessary condition was an inherited "neural integrative defect" (Meehl, 1962, p. 830) which he called *schizotaxia*. It was his view that "*all schizotaxics become…..schizotypic in personality organization" (*p.831) and that schizotaxia was a causal condition that was necessary, but not sufficient for the development of schizophrenia. Further, in Meehl's theory the majority of schizotypes remained well and compensated and only a few, as a result of a myriad of environmental influences decompensate into schizophrenia. He also believed that all affected individuals would develop four traits that were universal to the schizotype; cognitive slippage, anhedonia, interpersonal aversiveness and finally, ambivalence. While the symptoms and signs of schizotypal behaviour have been expanded on, these four core traits have been universally accepted and are reflected in the literature exploring schizotypy and the current diagnosis of schizotypal personality disorder.

Researchers from both sides have presented evidence to support their theory regarding the continuity, or lack of, in psychosis. What is known is that behaviours that are "schizophrenic-like" can be identified in individuals without a diagnosable history of mental illness. Whether they represent a separate class of people, or are merely people who exhibit behaviour as part of a graded range of behaviours has yet to be determined.

Schizotypy in this thesis is as defined by Lezenweger and Korfine (1995), "***a latent theoretical construct that is manifested in "schizotypal" behaviours"*** *(p. 567)*. These behaviours include such things as social isolation, odd behaviour and appearance, and in some instances odd use of language. It needs to be emphasized that schizotypy is **not** the same as DSM descriptions of Schizotypal Personality Disorder (SPD). However, there is consensus that the current formulation of DSM schizotypal personality disorder is a satisfactory representation of schizotypal behaviours (Lenzenweger, 1993). This difference is an important one. SPD represents a collection of symptoms and behaviours, but the development of SPD as a disorder was largely atheoretical as opposed to the concept of schizotypy as conceived and explained by Meehl (1962) and expanded further by others (Lenzenweger, 1993).

DSM-IV defines SPD as being " a pervasive pattern of social and interpersonal deficits marked by acute discomfort with, and reduced capacity for, close relationships as well as by cognitive and perceptual distortions and eccentricities of behaviour, beginning by early adulthood and present in a variety of contexts, as indicated by five or more of the following:

- Ideas of reference (excluding ***delusions*** of reference).
- Odd beliefs or magical thinking that influence behaviour and is inconsistent with subcultural norms (e.g. a belief in telepathy, clairvoyance etc.).
- Unusual perceptual experiences.
- Odd thinking and speech (eg. vague, circumstantial, metaphorical).
- Suspiciousness or paranoid ideation.
- Inappropriate or constricted affect.
- Behaviour or appearance that is odd, eccentric or peculiar.

- Lack of close friends and confidants.
- Excessive social anxiety that does not diminish with familiarity and tends to be associated with paranoid fears rather than negative judgments about self.

(APA, 1994, p.645).

Lenzenweger (1993) explains the possible relationship between the DSM personality disorders and the broader, conceptual notion of schizotypy:

"*It is quite conceivable that Meehl's schizotypy construct may underlie or encompass several of the personality disorder diagnoses on Axis II. For example the schizotype may display not only some schizotypal symptoms but may also reveal paranoid, compulsive, avoidant, and/or schizoid phenomenology" (p. 78).*

The diagnostic classification as it appeared in DSM-III was formulated by Spitzer and Endicott (1987) in an attempt to capture the traits as identified in the family and adoption studies by Kety, Rosenthal, Wender and Schulsinger (1971) and Rosenthal (1971). Lezenweger (1993) cautions against some of the common misconceptions in schizotypy research, one of the most common being the assumption that DSM-IV (or DSM-III-R) diagnosis of SPD is closely linked with Meehl's original notion of the schizotype. However, it is likely that any individual with a diagnosis of SPD is likely to have the underlying trait that Meehl believed was necessary in schizotaxia.

Recently, Tsuang and his colleagues (Tsuang, Stone, Gamma & Faraone, 2003; Tsuang, Stone, Tarbox & Faraone, 2001; Faraone, 2001) have returned to Meehl's original concept of schizotaxia as a latent liability to schizophrenia. They point to a variety of areas of cognitive dysfunction in the absence of psychotic or prodromal features of schizophrenia as supportive evidence of the usefulness of the construct. Further exploration of the neuropsychological and cognitive correlates of both schizophrenia and schizotypy will be discussed in Chapter 4. Tsuang et. al. (2003) conceptualize schizotaxia as being essentially the equivalence of negative schizotypy (i.e. SPD without the positive features) and provide a compelling argument for continued refining of the relationship between schizophrenia, schizotaxia and SPD.

In addition to the focus on relatives of people with schizophrenia in the search for some "latent liability" others have more recently focused on the detection of schizotypal traits in individuals without a familial history of mental illness. Interview schedules, questionnaires and self-report inventories have all been used in order to detect schizotypy in various populations. Interview schedules predominated in earlier studies of schizotypy and indeed Kendler found in his Roscommon Family Studies (Kendler, Thacker & Walsh, 1996) that the structured interview was considerably more sensitive at detecting schizotypal behaviour in the relatives of probands than self report inventories. However, there is now a substantial body of work supporting the use of self-report questionnaires (see Claridge, 1987 for review). In the development of a scale designed to tap the nine symptoms described by the DSM, Raine (1991a) found that a number of high-scorers on his scale met or at least partially fulfilled the clinical diagnosis for SPD adding further weight to the usefulness of well constructed inventories.

Raine's Schizotypy Personality Questionnaire (SPQ) has gained acceptance within the schizotypy literature (Chen, Hsiao, Hsiao & Hwu, 1998; Chen, Hsiao & Lin, 1997;. Daneluzzo, Bustini, Stratta, Casacchia, & Rossi, 1998; Kremen, Faraone, Toomey, Seidman, & Tsuang, 1998; Langdon & Coltheart, 1999; Miller & Burns, 1995; Park & McTigue, 1997) and has been adopted for this thesis. As such a further discussion of its development is warranted.

3.4.1 Schizotypy Personality Questionnaire (Raine, 1991a)

With the revision of DSM-III in 1987, Raine decided to develop a new scale to measure schizotypy that attempted to tap all of the nine symptoms identified under DSM-III-R rather than simply measuring one or two symptoms. Raine's SPQ has gained popularity in recent explorations of SPD and schizotypy in general. In developing this scale, Raine incorporated some of the items from the Schizotypal Personality Scale (STA – Claridge & Broks, 1984) the Perceptual Aberration Scale (PAS – Chapman, Chapman & Raulin, 1978) and the Magical Ideation Scale (Eckblad & Chapman, 1983). In addition he added further items to compliment those from the other scales. Also in order to remain faithful to his approach to developing a scale which would tap all nine aspects of the DSM-III-R SPD, further items were needed. The STA (Claridge & Broks, 1984) and the Schizophrenism scale (Venables, Wilkins, Mitchell & Raine, 1990) were also administered along with the final version of the SPQ to determine convergent validity of the scale. Further, two scales were also administered in order to determine the discriminant validity of the scale. Raine (1991a) reports the selection of these two scales based on the ability of the scales to tap "psychosis-proneness" without tapping the features of SPD. These scales once again, have been mentioned above: Eysenck's Psychoticism scale and Anhedonia, again from the Venables (1990) Schizotypy questionnaire. Neither of these scales was significantly correlated with the SPQ. In order to further validate the SPQ Raine identified the top 10% scorers in his subject pool and these individuals were then given a clinical interview to determine the presence or absence of SPD. He found that six of the 10 top scorers received a clinical diagnosis of SPD.

The weight of evidence in schizotypy research would indicate that inventories can detect elements of schizotypal behaviour, and that these instruments are sensitive to psychotic traits in non-clinical samples (Claridge, 1987). Additionally, they have considerable advantages over interview schedules. For example, one potentially serious limitation of the clinical interview method, is that aside from the issues of time involved in the training for and administration of clinical interview schedules, some subjects may adopt a defensive test-taking attitude in the presence of the interviewer, particularly in response to questions dealing with more pathological elements of schizotypy such as the ideas of reference (Lenzenweger, Bennett, & Lilenfeld, 1997).

Estimates of the prevalence of schizotypal symptoms in the normal population vary. Tien (1991), using a structured diagnostic interview, found that 10% of men and 15% of women had a lifetime prevalence of hallucinations. Other studies using questionnaires with a more comprehensive coverage of psychotic symptoms have found between 17% and 28% of subjects endorse at least some positive psychotic symptoms (Verdoux & van Os, 2002; van Os et. al., 2000). The endorsement of psychotic symptoms in non-clinical populations is also negatively associated with age (Venables & Bailes, 1994; Verdoux et. al., 1998) with younger people more likely to report persecutory and paranormal beliefs and thought disturbances. Religiosity is the only psychotic symptom endorsed more frequently with age (Venables & Bailes, 1994).

3.5 Symptom clusters in schizophrenia and schizotypy

While schizophrenia occupies a single diagnostic category within DSM-IV, the manifestation of symptoms in any one individual is extremely heterogeneous. Individuals may present with bizarre behaviour, unusual speech and florid hallucinations, or they may exhibit flattened affect, seem almost devoid of emotion and display little interest in interpersonal relationships. The wide variety of behaviours shown in this disorder have led some authors to try to divide these signs and symptoms into groups of behaviours that seem to frequently occur together (Crow,1986), or to use factor-analytic techniques to examine potential relationships between symptom clusters (Liddle, 1987). Crow's two-factor model representing "positive" and "negative" symptoms was one of the first. Positive symptoms are those recognized by their presence and include such things as delusions, hallucinations, bizarre behaviour and incoherence of speech (Frith, 1992). Negative symptoms include affective flattening, poverty of speech and poverty of action (Frith, 1992). More recently studies employing factor analysis have revealed a three-factor model (Bilder, Muherjee, Rieder & Pandurangi, 1985; Liddle, 1987; Brown & White, 1992). The general consensus is that while the “negative” cluster is largely unchanged, “positive” symptoms are more accurately broken down to separate inappropriate affect and disorganised speech (the “disorganised” factor) from delusions and hallucinations (“positive” factor). This three-factor model has been commonly adopted (Lucas et. al., 2004; Cameron et al., 2002) and replicated (Brekke, DeBonis & Graham, 1994; Karakula & Grzywa, 1999).

Studies examining schizotypy have similarly investigated the underlying structure of its symptoms. Claridge and his colleagues (1996), using a large number of published scales examining psychosis-proneness, found four factors (aberrant perceptions and beliefs; cognitive disorganization; introvertive anhedonia; and asocial behaviour). Others have examined schizotypal symptoms in relatives of those with schizophrenia and found a three-factor structure similar to that reported in the schizophrenia literature (Bergman, Silverman, Harvey, Smith & Siever, 2000). Confirmatory factor analysis using Raine’s (1991a) SPQ has shown that the SPQ breaks down into three factors of cognitive-perceptual deficits, interpersonal deficits, and disorganised symptoms (Raine et al. 1994). Raine reports that this three factor structure has been replicated in a number of countries with various populations (Gruzelier, Burgess, Stygall, Irving & Raine, 1995; Gruzelier & Kaiser,1996; Chen et al. 1997; Reynolds, Raine, Mellingen, Venables &

Mednick, 2000). In total it has been replicated in at least ten independent samples (see Reynolds et al. 2000 for further details).

3.6 Chapter Summary

Schizophrenia is a serious mental illness defined by a collection of positive, negative and disorganised symptoms. Schizotypy is seen as a latent liability for the development of schizophrenia and has been shown to have a similar cluster of symptoms to schizophrenia. Some theorists argue that schizotypy is the result of genetic and/or neurological deficits that then interact with environmental factors to produce the more serious symptoms of schizophrenia. Aside from identifying schizotypal traits in relatives of people with schizophrenia, in an attempt to help unravel the pathogenesis of the disorder, there has been considerable research examining schizotypal traits in non-clinical populations and this research has largely used self-report inventories to identify high-scoring individuals who may display “psychotic-like” behaviours. Chapter 4 will introduce the literature of the findings related to cognitive impairments found in both schizophrenia and schizotypy.

Chapter 4 - Working Memory in Schizophrenia and Schizotypy

4.1 General Introduction

Impaired performance in working memory has been described by many researchers as being the central deficit underlying many of the dysfunctions found across cognitive domains in schizophrenia (Fleming, Goldberg & Gold, 1994; Goldman-Rakic, 1994a; Weinberger, 1993). However, a review of the literature quickly reveals that "working memory" in schizophrenia studies encompasses a large variety of disparate tasks. Neuropsychological tests that have been called WM tasks include digit span (Conklin et. al. 2001); letter-number sequencing (Gold, Carpenter, Randolph, Goldberg & Weinberger, 1997); the Wisconsin Card Sort Test (WCST) (Pukrop et al., 2003); the Trailmaking Test Part B (Docherty et. al., 1996; Nestor et. al.,1998); the delayed response task (Pukrop et. al., 2003; Park, 1997); the continuous performance test (CPT) (Chen et. al., 1997, 1998); and the Stroop task (Barch & Carter, 1998). In addition to these tasks, many researchers have followed Goldman-Rakic (1991, 1992, 1994a, 1994b) and her ground-breaking research into working memory in non-human primates. Her research focused on using spatial working memory tasks in an attempt to identify regions of the brain implicated in working memory processes. As a result there is still some confusion as to exactly what "working memory" means in schizophrenia research. Lee and Park (2005) recently conducted a meta-analysis of studies exploring WM performance in schizophrenia and to address whether SZ participants demonstrate WM deficits across a range of methodologies. In addition they examined whether any deficits were confined to specific modalities and finally whether or not increasing the delay period of the WM task led to differential deficits in SZ. They found compelling evidence that there are significant WM deficits in all of the modalities that they examined. They also found that increasing a delay beyond one second did not influence the performance difference between SZ participants and healthy controls.

More recently there has been a move towards utilising cognitive models in an attempt to address some of the confusion. As the predominant WM model in cognitive research, Baddeley's multi-component description of WM has been adopted by some researchers in an attempt to better delineate the nature of working memory deficits in schizophrenia and in some cases, schizotypy. Many researchers' (Barch, 2003; Goldman-Rakic, 1991, 1994a; Kim, Glahn, Nuechterlein, & Cannon, 2004; Spindler, Sullivan, Menon, Lim & Pfefferbaum, 1997) have hypothesised that the CE component of WM, as an attentional control system, is disproportionately affected in individuals with schizophrenia.

This chapter will outline the research to date using Baddeley's model with particular reference to the CE and PL components. In addition, research will be presented which poses a challenge to this dominant model. The key questions raised in Chapter 2 will also be incorporated. That is;

(a) Based on the literature, do schizotypes or participants with a diagnosis of schizophrenia vary in their performance across simple, complex, and delayed span tasks?

(b) Is access to lexical memory and/or rehearsal speed impaired in these populations?

(c) Are there impairments in the ability of individuals with schizophrenia or schizotypal participants to encode or retrieve information using cues and codes in short-term memory tasks?

The relationship between working memory deficits and symptom clusters in schizophrenia and schizotypy will be discussed. Finally, the key hypotheses for the experimental chapters will be presented at the end of this chapter. In the main, the focus of the literature review in this chapter will be on verbal tasks. Although an extensive body of work examining spatial working memory deficits in schizophrenia and schizotypy exists, this study aims to explore aspects of current working memory models which encompass the verbal domain. Specifically, phonological and meaning-based information that is processed over a short period of time is central to this thesis. As a result, the literature review was restricted to those papers which either explicitly examined the models under examination here, or that involved tasks that could reasonably be extrapolated to these models.

4.2 Baddeley's Model and its application in schizophrenia and schizotypy research

4.2.1 General findings

One of the few studies to explicitly examine the functioning of the CE and two slave components of Baddeley's model was a 1998 study by Salame and his colleagues (Salame, Danione, Peretti & Cuervo, 1998). This study used a sample of 27 individuals with a DSM-IV diagnosis of schizophrenia and 27 controls matched for age and education level. The PL was assessed using digit span, reading rate, and immediate serial recall. The immediate serial recall (of digits) was also administered under conditions of articulatory suppression and irrelevant speech in order to examine well known effects of the PL. To assess the functioning of the VSSP, Corsi block and pattern span tasks were used. Finally to investigate the functioning of the CE a dual task paradigm was employed using an oral digit serial recall task concurrently with a motor task requiring the subject to place crosses in boxes set out on a page in an erratic pattern. On the dual task, the task difficulty was adjusted so that each subject was tested at their own digit span, so as to equate the difficulty between groups. Subjects were first tested on each component of the dual task and then on the two tasks simultaneously. Findings indicated that the patient group were slower than the control group in both of the single conditions and in the dual condition, but that they were not differentially impaired on the dual task. They also found that performance on the dual task was mediated by reading rate, so that patients who were slow readers were impaired on the task, but the performance of those patients who were faster readers was comparable to controls. In a second experiment, processing of the CE was examined using a random generation of letters task at three different paces (1 every second, then 2 per sec, then 4 per sec). For the random generation task there was an effect for both groups in terms of the rate at which letters needed to be generated. At the fast rate both groups made more omissions, more stereotyped sequences, and more redundant responses but poorer performance was more pronounced for the patient group. In addition, the performance of the patients deviated from randomness more than controls.

When examining performance on the PL measures, Salame et. al. (1998) found that the pattern of errors made by the patient group was similar to the controls, however patient performance was poorer. They made significantly more errors than the control group, particularly under conditions of articulatory suppression. The patient group also had a greater number of totally omitted lists than the controls. With regard to reading rate, there was a significant effect for group with the schizophrenia group having an articulation rate that paralleled the control group, but that was of a lower magnitude. On the final PL measure, standard digit span, the two groups did not differ significantly. This is in contrast to other findings (Conklin, et. al., 2000; Beatty, Jocic, Monson & Stanton, 1993; Heinrichs & Zakzanis, 1998; Stirling, Hellewell & Hewitt, 1997). Patients tended to omit more items than controls under all conditions of the serial recall task, but their performance was worse under conditions of articulatory suppression. However, even the control subjects demonstrated similar patterns with no strong effect under conditions of irrelevant speech, but attenuated performance under articulatory suppression. Dysfunction in the PL was once again mediated by reading rate. That is, slow-readers with schizophrenia demonstrated significant impairments on PL tasks (except digit span) with sparing of the PL in fast readers with schizophrenia.

Overall, Salame et. al. (1998) concluded that their results pose a challenge for Baddeley's model in that their two purported measures of the CE produced discrepant results, with no apparent differential impairment on the dual task, but impaired performance on the random generation task. As a result, they suggested a further fractionation of the CE was warranted. Functioning of the PL component appeared to be consistent with Baddeley's model with the substantial impairments in patients with a slower reading rate attributed to problems at both the level of the PL and CE. Salame's findings may also be suggestive of supporting the notion that rehearsal speed plays a dominant role in performance on these tasks with faster readers displaying superior performance across tasks.

A more recent study (Kim et. al., 2004) also used Baddeley's model to explore the components of WM. Using 16 SZ patients and 16 controls, demands on the CE were manipulated by examining differences in maintaining verbal information for future recall and also requiring concurrent maintenance and transformation of information. Once again this study also examined the functioning of the VSSP as well as the CE and PL. However, for the reasons mentioned previously only the results relating to the PL and CE functioning will be discussed here. In this study a variant of the delayed response paradigm was used. In the verbal maintenance only condition (MO), subjects were presented with three English consonant-vowel syllables for 1.5 seconds. After the stimulus disappeared from the screen, there was a delay of six seconds and then a probe appeared on the screen. The subject was required to indicate whether the probe matched the previously presented target. Kim et. al. (2004) found that the two groups did not differ in the maintenance only condition. In the verbal maintenance and manipulation condition (MNM) after the material was presented, subjects were required to rearrange the presented syllables according to alphabetized order of syllable consonants. In the response phase, they then had to indicate whether all the target syllables were present in the probe and in the correct order. Scores were recorded for reaction time (RT) and for responses. Surprisingly, Kim et. al. (2004) found no differences in the RT's of the schizophrenia subjects compared to the healthy controls. Almost universally, longer RT's are reported in studies with schizophrenia patients (see van den Bosch, 1994 for discussion). Kim and colleagues (2004) suggest that the RT's may have been equivalent for the two groups due to a relatively short probe presentation time of 1.5 seconds. Results of the accuracy scores suggested that the SZ group found the processing component of the MNM task more difficult than the controls and the authors concluded that introducing the manipulation component differentially affected the SZ group. To explore whether the outcome could be the result of the MNM condition placing more demands on the maintenance system than the MO condition they conducted a further experiment.

In this second experiment maintenance demands were increased in the slave components of the WM system using a variant of the Sternberg Item Recognition Paradigm (Sternberg, 1966). This increase in maintaince demand was employed to examine what effect an augmented load would place on the CE. Here, there were four conditions where the amount of information that needed to be maintained during the delay period was varied. The stimulus was presented for two seconds and the load was three, five, seven or nine letters. After a three second delay, subjects were presented with a probe letter and asked whether it had appeared previously as one of the target letters. In this task RT's were significantly slower for schizophrenia subjects at all levels of the task, but results indicated that they were not differentially affected as load increased. That is, both groups showed decrements to the same degree as the task load increased. So this task indicated that the SZ group demonstrated maintenance deficits even in the absence of manipulation, but increasing the load did not affect SZ subjects more than controls. Kim et. al. (2004) argue that these results suggest that SZ subjects show a tendency for a diminished capacity in maintaining information over a short delay. Further, they are disproportionately affected when required to manipulate information in WM. They conclude that these results are consistent with SZ subjects having a specific deficit in the CE component of the WM system. Although they do point out that only one CE process is being tapped by this task, the coordination of simultaneous maintenance and manipulation of information.

It needs to be noted that the tasks used by Kim and colleagues (Kim et. al., 2004) in exploring elements of Baddeley's model are quite different to the serial recall tasks discussed in Chapter 2, and those used by Salame et. al. (1998). Probe and item recognition tasks differ substantially from serial recall and as such caution in interpreting the findings as having clear implications for the operation of the model. It could be argued that these tasks may, or may not, reflect CE or PL components. However, given the paucity of direct examination of working memory models in the schizophrenia literature, a study which has given careful consideration of the operation of this model and its application to this population was considered relevant, if only to present some evidence of the theorized source of deficits in working memory performance in schizophrenia.

In contrast to findings of specific impairment in the CE in schizophrenia, Spindler et. al. (1997) found that in a task examining CE functioning and functioning of one of the slave systems (in this case the VSSP), there was no evidence to suggest that the CE component was differentially impaired. This research tended to support the notion of deficits being confined to the slave systems, although the generalization to verbal tasks is difficult to establish.

In summary, the few studies specifically examining all components of Baddeley's WM model in schizophrenia, have been equivocal, with some arguing that CE is compromised and others arguing that the deficit lies in the slave systems. Others still suggest that there are problems will all components of the model, and that the CE as a single entity is not supported.

There have been no studies explicitly addressing the application of Baddeley's tripartite model in schizotypy. Research with schizotypal subjects that employ tasks that could be inferred to examine aspects of Baddeley's model will be addressed where appropriate below.

The above research represents those studies that have examined the different components of Baddeley's model in the same experiment. There are a number of studies that focus upon a single component of the model. These studies are described in the sections below.

4.2.2 The Central Executive

There is a substantial body of work using tasks such as the Tower of London and the Wisconsin Card Sort Test in SZ and suggesting that the deficits commonly found in SZ patients on these tasks reflect the CE component of WM (McGrath, Chapple & Wright, 2001; see review Van den Does & Van den Bosh, 1992). However, these will not be reviewed here as it is difficult to equate them with verbal tasks and their relationship to WM as set out in Chapter 2. Instead, where possible, the focus will be on tasks resembling those in the cognitive literature, or at least verbal in nature.

In his extension of his theory regarding the CE, Baddeley (1996) proposed that switching retrieval strategies was an important function of the CE and that this could be measured by random generation tasks. Artiges and his colleagues (2000) were interested in trying to identify the cortical regions involved in WM functions and took PET scans of their subjects during a random generation task. They found that in a sample of eight SZ patients and eight controls, SZ subjects were slower, made less responses and their responses were less random than controls. The task involved oral generation of numbers to a computer generated tone. There were three rates at which the tone was presented, one tone every second, two seconds, or four seconds. As the rate of response was increased, schizophrenia subjects performance declined disproportionately to controls. The results of the

Artiges et. al. (2000) study argued for a deficit in the CE component of WM in schizophrenia and they suggest that the PET findings indicate a problem with the supramedial anterior cingulate region of the brain.

Using a dual-task paradigm, Bressi et. al. (1996) explored whether SZ patients are impaired on the CE component of WM. They argued that if the CE was impaired, this would be reflected in a reduced capacity to perform concurrent tasks. Subjects were required to perform a computerised tracking task while concurrently performing either (a) articulatory suppression; (b) simple RT to a tone; or (c) an auditory digit span task. They found that impairment in patients was particularly prominent when the tracking task was performed with either the RT task or the auditory digit span task. Performance on the concurrent tracking task was also negatively correlated with positive symptoms on Andreasen's (1984) Scale for Positive Symptoms (SAPS). Bressi and colleagues (1996) concluded that their results were consistent with a dysfunction of the central executive of working memory in patients with schizophrenia, and that this deficit may underlie positive symptoms.

These studies provide further evidence for a deficit in the CE component of WM. However, as they did not systematically address whether the PL was intact in the subject populations, an alternative explanation could be that capacity of the PL has been exceeded and places extra demands on the system leading to the decrements in performance. Of course, these explanations beg the question as to whether or not there are distinguishable components in memory.

4.2.3 The Phonological Loop

Using the well known phonological similarity effect of the PL, where similar sounding items are more often recalled in the incorrect order than dissimilar sounding items, Elvevag and her colleagues (2002b) examined whether the observed reduction in verbal span performance in SZ could be explained in terms of an identifiable deficit in the representation and maintenance of phonological codes. They investigated whether their SZ group would be particularly susceptible to confusing words that were phonologically similar. Using 20 lists of six single-syllable consonants they found that patients were impaired relative to controls on the task with reduced overall performance and more omissions of items from the end of the list. However, a lack of interaction effects (group x phonological similarity x serial position) suggested that the poorer performance was not specifically a function of the phonological similarity effect. They concluded that the deficit in recall could not be accounted for by differing mnemonic strategies between the groups as it is likely to resulted in a disproportionate number of movement errors in the confusable lists.

Another study explicitly examining the phonological loop in SZ had a slightly different focus. David and Lucas (1993) used a cognitive neuropsychological study approach to examine whether deficits in the PL could be attributed to auditory hallucinations. They tested three subjects with a history of continuous auditory hallucinations on measures of the PL They examined three hallmark features of the PL: (i) phonological similarity, (ii) word length effect, and (iii) the adverse effect on verbal recall of unattended speech in a series of auditory letter recall tasks. They were interested in whether hallucinations were related to the functioning of the PL and specifically whether the hallucinations functioned like unattended speech and disrupted recall over the short-term. Results of their experiments revealed relatively intact functioning of the PL. All three patients had near normal digit span and while they made more errors than controls, performance of all patients was broadly in the direction expected for a functioning PL. All three subjects showed the expected phonological similarity effect. One of the patients failed to demonstrate the classic finding of elimination of the word length effect under articulatory suppression, however, David and Lucas (1993) propose that this was a result of lapses in attention. Finally, there was no evidence that auditory hallucinations acted in a similar way to unattended speech in disrupting the functioning of the PL.

Once again these studies suggest that while there may be a reduction in the capacity of the PL in SZ patients, the PL operates in the same way as in normal populations.

4.2.4   The Episodic Buffer

This new addition to Baddeley's model (Baddeley, 2000) has received relatively little attention to date in the schizophrenia literature. Burglen and colleagues (2004) provides the only experimental results to date which claim to address the role of the EB in this population. In this study 25 participants with schizophrenia and 25 matched control participants were administered a location and object working memory task. Participants were required to remember either a familiar object, its location within a 3 x 3 grid, or a combination of both object and location features. Burglen et. al., (2004) found that although accuracy for the combination condition was reduced for both groups when compared to performance in the single task conditions, the schizophrenia group performed disproportionately worse than the controls. They speculated that the schizophrenia group may have a deficit in linking the object and the location together to form a new multi-featured representation and that this might in turn infer a problem with the EB component of Baddley's model. To date there have been no studies examining EB function in schizophrenia using verbal material.

The only other comment regarding Baddeley's separation of the maintenance and processing components of WM comes from Barch (2006). She suggests that neuroimaging data showing the activation of the dorsolateral prefrontal cortex (DLPFC) in both maintenance and manipulation aspects of WM tasks provide a challenge for Baddeley's model. Although she (Barch, 2006) concedes that if there is engagement of different regions of the DLPFC for maintenance versus manipulation, then this may be consistent with his (Baddeley, 2000) model.

4.2.5 Summary

Findings in the SZ research examining the components of Baddeley's WM model have been mixed at best. Some argue that the CE component is differentially affected (Kim et. al., 2004; Bressi et.al., 1996), others have not found evidence to support this proposition (Spindler et. al., 1997). Although the differing array of tasks used in these studies means that one should remain cautious in attributing all of these findings to the components of WM as conceived by Baddeley. Deficits in simple storage capacity for SZ subjects have been more consistent (Conklin et. al., 2000 ; Heinrichs & Zakzanis, 1998) and these deficits are likely to contribute to some degree to the WM difficulties in this population, and possibly that of schizotypal individuals.

4.3 Challenges to Baddeley's model

Baddeley's model has not been without challenge, or at least modification in the SZ literature. While Barch (2003) argues that the deficits in WM performance are a result of impaired CE rather than the buffer systems, she also argues that deficits in the CE (or SAS) result in problems with inhibition, selective attention and also influence LTM. This idea is more in keeping with the model presented by Engle et. al. (1999) discussed in the previous chapter. Lee and Park (2005) in their recent meta-analysis suggest because WM deficits occur in SZ regardless of modality, it might be more fruitful to reduce the cognitive components necessary for successful performance on these tasks into dissociable temporal components, rather than focusing on modality specific subsystems as described by Baddeley.

While there do not appear to be any studies explicitly examining the contribution of rehearsal rate or speed of access to lexical information to WM performance in SZ or SZTPY, there are some findings that relate to each of these separately. In a study examining levels of encoding and memory performance in schizophrenia, Brebion and colleagues (Brebion, Smith, Gorman, Malaspina, Sharif & Amador, 2000) suggested that their findings linking processing speed to serial recall provided supportive evidence for the role of rehearsal in serial recall tasks. They do admit that enhanced rehearsal can only be inferred from their results as there was no direct measure of rehearsal rates (processing speed was defined as performance on a speeded digit symbol copying task). The results of Salame and colleagues (1998) mentioned previously are also suggestive that rehearsal speed may be an important contributor to span performance in schizophrenia.

Speed of access to lexical memory has been explored in the schizophrenia population using RT on lexical decision tasks within the priming literature. Most research investigating this in schizophrenia concurs that lexical retrieval efficiency is impaired. In a study examining the relationship between lexical retrieval, semantic organization and verbal fluency, Vinagradov (Vinagradov et. al., 2002) studied 40 outpatients with schizophrenia and 16 normal controls. Lexical retrieval efficiency was measured by simple RT and semantic organization used a program called “Pathfinder” to examine the complexity of the participants’ semantic network. They found that the reduced verbal output on a verbal fluency task was related to impaired lexical access and problems with semantic networks. Although verbal fluency tasks are clearly employing different processes than simple serial span tasks, this experiment lends some weight to the idea that access to lexical information is impaired in this population.

In a similar vein, another study examined the relationship between slowed lexical access, semantic priming and the clinical symptoms of schizophrenia (Minzenberg, Poole, Vinagradov, Shenault & Ober, 2003). The relationship between clinical symptoms and task performance is presented in more detail below, however, the results pertaining to lexical access are relevant. Once again, this study confirmed that lexical access as measured by RT is differentially impaired in this population.

4.4 Are immediate recall, working memory and LTM tasks distinguishable? – Evidence from schizophrenia and schizotypy research

4.4.1 Simple span tasks

Performance on simple span tasks has been used possibly more than any other task to investigate working memory capacity in normal and clinical populations. Span has consistently been found to be impaired in schizophrenia (Aleman, Hijman, de Haan & Kahn, 1999; Conklin et al., 2001). The source of this impairment has been variously suggested to be problems with encoding (Koh, 1978), capacity limitation (Goldberg, Patterson, Tarqqu & Wilder, 1998), a disorder of the central executive processes (Barch & Carter, 1998), and/or disproportionate interference effects (Bauman, 1971; Bauman & Kolisnyk, 1976; Stevens, Donegan, Anderson, Goldman-Rakic & Wexler, 2000). The finding of impaired span performance is not universal though.

Some studies (Morice & Delahunty, 1996; Park & Holzman, 1992) have found digit span performance to be spared. Others note that forward span is spared but the backward span, considered a more difficult task and more representative of a true "working memory" task, is impaired (Stone, Gabrieli, Stebbens & Sullivan, 1998).

In an effort to better delineate the types of processes at play in reduced span performance in schizophrenia, examination of errors in performance has provided some useful clues. To say that performance is "impaired" on span tasks gives little information. A reduced span may be the result of less output (or *item* errors where *omissions* are made). Alternatively, output may be quantitatively intact, but there may be errors made in that output (e.g. *intrusions* of related or unrelated words). Finally depending on the scoring used to determine span, subjects may produce the correct responses but in the incorrect order (*order* errors). Recently a paper by Elvevag, Weinberger and Goldberg (2001) examined in detail the types of errors that are made by schizophrenia subjects in a letter serial recall task. These authors examined *order (*transposition, or movement) errors, and *item* errors (which were further divided into *intrusion* errors and *omission* errors). They hypothesised that a preponderance of a particular type of error would implicate different types of dysfunction in the system. Elvevag et al (2001) found that although schizophrenia subjects recalled less of the words in a 6-item condition, there were not significantly more order errors or intrusions as a function of serial position. This paper concluded that the reduced recall for schizophrenia subjects may be due to increased forgetting (inability to retrieve the item) rather than any deficit in maintaining serial order. These same researchers further investigated this increased forgetting by using a probed recall task (Elvevag et al, 2002a). This study showed that schizophrenia subjects showed equivalent recency effects to controls, but that they lost more information from the beginning of the list. This additional finding led the authors to conclude that participants with schizophrenia did not have a specific impairment in memory for serial order. They proposed that reduced memory for serial order was a result of faulty maintenance of information and that this becomes apparent for longer lists.

Brebion and his colleagues (Brebion, Smith, Amador, Malaspina & Gordon, 1997) found that maintaining serial order was impaired in their population of schizophrenia subjects. They also found evidence for increased intrusions on serial recall tasks. These intrusions consisted of both extra-list items and perseverations from previously presented material. This study was specifically interested in exploring the relationship between performance on various measures of memory encoding and clinical symptoms. The findings as they pertain to symptom clusters are discussed below.

Span performance in schizotypal subjects has not been well explored. One study using participants with a clinical diagnosis of schizotypal personality disorder (Voglmaier et. al., 1997) reported lower mean scores on a standard digit span task compared to controls. In a meta-analysis of 37 studies exploring the cognitive deficits in relatives of patients with schizophrenia

(Sitskoorn et. a., 2004), effect size for the digit span task was in the moderate range.

4.4.2 Complex Span tasks

Several studies using complex span tasks have examined working memory performance, and its relationship to other functions. Bagner, Melinda and Barch (2003) explored whether SZ patients demonstrate impairments in language comprehension and whether deficits could be explained in terms of WM performance. They employed a reading span task where the subject was required to read a series of sentences and retain the last word of each sentence for future recall. Trials commenced with sets of two sentences and increased in length to a maximum of six sentences. Language comprehension was impaired in their SZ sample as was reading span. They found that working memory correlated strongly with language comprehension and this association was stronger for SZ patients than for controls at the more difficult level. These results replicated the findings of Condray, Steinhauer, van Kammen and Kasparek (1996). In this study, as in the previous one, both language comprehension and WM functioning, as measured by the reading span task were examined. Once again SZ subjects showed reduced language comprehension and lower verbal WM capacity compared with controls. In this study WM capacity predicted language comprehension accuracy in both groups. The findings are thus consistent with other findings of a generalized verbal memory deficit in schizophrenia (Heinrichs & Zakzanis, 1998).

Once again scant research exists examining complex span performance in schizotypy. Lenzenweger and Gold (1999) explored auditory working memory in a sample of students divided on a measure of psychometric schizotypy. Using the letter-number sequencing task (Gold et al., 1997) they found no difference between high and low scoring students.

4.4.3 LTM tasks in schizophrenia and schizotypy

In a series of experiments using a modified Brown-Peterson paradigm (Brown, 1958; Peterson & Peterson, 1959) verbal working memory deficits in schizophrenia subjects were seen to be a result of a reduction of overall processing resources in the system (Fleming, Goldberg, Gold & Weinberger, 1995). In this study subjects performed the Brown-Peterson task under four conditions requiring differential processing demands. Five trials of each condition were administered. In each trial subjects were required to read four words out loud. After a 12 second delay, subjects were required to recall the four words. The four conditions (in increasing difficulty level) were (i) control condition with no distractor task in the delay period; (ii) finger tapping during the delay; (iii) counting forward from one during the delay, and finally (iv) backward counting in three's, beginning with 100. Significant differences between the controls and the schizophrenia subjects were found on the two more difficult tasks. These differences were attributed to a failure to properly encode verbal material due to interference in rehearsal processes.

4.4.4 Summary

Virtually all studies exploring simple, complex and delayed span tasks in schizophrenia have shown significant impairments when compared to normal controls. Faulty maintenance, poor encoding and generalised verbal deficits have all been postulated as potential causes for dysfunction. These processes have not been extensively explored using schizotypal subjects. Simple and complex span tasks have been found to be intact when schizotypy is defined by psychometric measures (Lenzenweger & Gold, 1999). However, there is some evidence that relatives of schizophrenia patients without a current diagnosis are impaired on simple span tasks (Sitskoorn, et. al., 2004) as are subjects with a current diagnosis of SPD (Voglmaier et. al., 2004).

4.5 Cues and codes in short-term memory – evidence from schizophrenia and schizotypy

Few studies have explicitly examined the roles of cues and codes in WM in SZ samples. Although there is a rich history in language research suggesting that, at least for some individuals with SZ, associative networks are disordered. The phenomenon of priming effects has usually been explored using the lexical decision task. In this task the subject has to decide whether the presented stimulus is a word or not. Meyer and Schvaneveldt (1971) discovered that if a related word was presented prior to a target word, the target would be recognized (i.e. identified as a word) faster than words without this “cue”. Associative networks have been proposed to explain this effect (Collins & Loftus, 1975; Neely, 1977). Figure 4 shows a proposed structure of an associative network.

Theoretically, the strength of the links is dependent upon how “close” or associated the words are with each other. In other words, when a word is presented, other related words in the system become activated. How activated they are will depend on the strength of the links and the distance from the presented word.

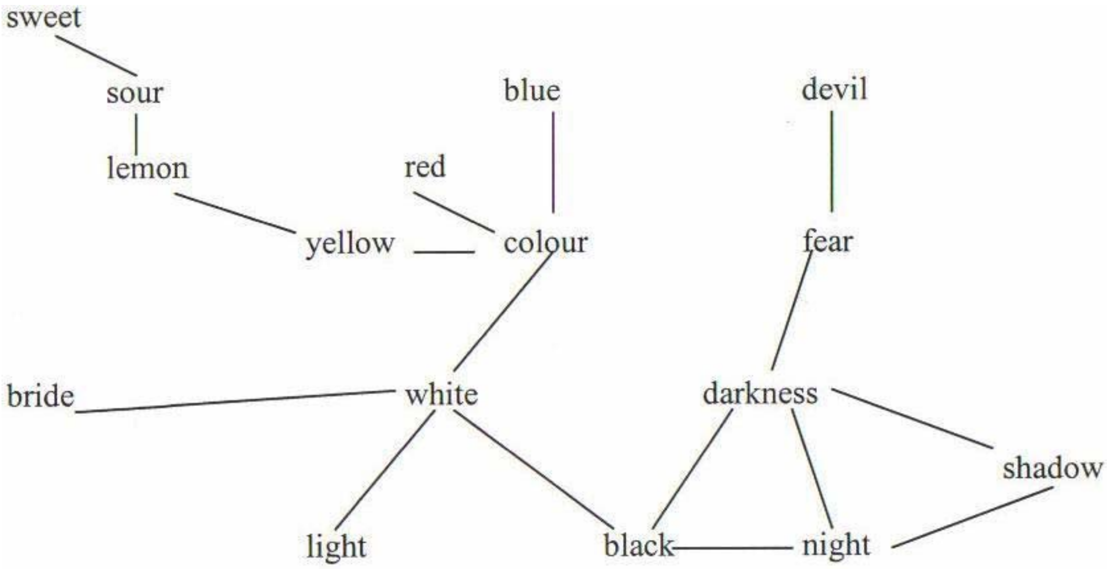

Figure 4 Proposed structure of semantic (association) memory

(Source: Spitzer, 1993, p.58).

Studies of associative networks in schizophrenia using the priming paradigm have produced some interesting results. Some researchers have proposed, based on their experimental findings, that there is increased activation in semantic networks for some participants with schizophrenia which leads to a “hyper-priming” effect (Kwapil, Hegley, Chapman & Chapman, 1990; Spitzer, 1993). Spitzer and his colleagues (1993) have also found evidence for indirect priming for schizophrenia subjects, that is, words that ordinarily should only have a weak association to a presented word, produce an increased priming effect in this group over control subjects. These researchers (Spitzer et. al., 1994) also found that when using phonologically associated words the performance of schizophrenia subjects was different to controls. Spitzer proposed that both semantic and phonological codes are disordered and are either overactive, or less inhibited in schizophrenia. At least one study has reported similar findings in patients demonstrating schizotypal thinking (Pizzagelli, Lehmann & Brugger, 2001). This paper found that indirect (but not direct) semantic priming was stronger for subjects holding paranormal beliefs (i.e. similar to Magical Thinking on the SPQ scale).

Nairne (2002) has argued that short-term recall should be conceptualized as a cue driven process. We know from research using non-clinical controls that under certain conditions there are strong phonological effects in working memory with errors on some tasks occurring based on phonemic confusions (Conrad, 1964; Hull, 1973; Nelson & Batchelder, 1969; Wickelgren, 1965) and there is also the well known advantage of dissimilar list recall over recall rhyming lists (Baddeley, 1966; Coltheart, 1993; Coltheart & Langdon, 1998; Conrad & Hull, 1964). There are also weaker semantic effects (Daly, 2001) in WM tasks with the introduction of semantic information causing interference. If the evidence from the priming research in schizophrenia is correct, and phonological and associative networks are disordered in schizophrenia, we may expect to see disproportionate interference when phonological cues and codes are manipulated in a WM task.

4.6 Symptom clusters and cognitive performance

While cognitive deficits have almost universally been found in studies using schizophrenia subjects, increasingly focus has shifted to examining whether deficits by this group may be related to symptom clusters. The diagnostic category of schizophrenia subsumes a wide variety of clinical symptoms. As previously discussed in Chapter 3, the three-factor model encompassing *positive, negative* and *disorganised* symptoms has gained the widest acceptance (Brown & White, 1992; Arndt, Alliger & Andreasen, 1991; Liddle, 1987).

A number of studies have found differential relationships between positive, negative, and disorganised symptoms and cognitive deficits (Basso, Nasrallah, Olson & Bornstein, 1998; Berman et al, 1997; Cameron et al., 2002; McGrath et al, 2001). Negative symptoms have been reported as being related to deficits in the CE component of WM, as well as deficits in the VSSP and reduced production of words (Cameron et al., 2002). Impaired verbal memory performance, as measured by a combination of span tasks and list learning, has also been linked to negative symptoms (Stirling et al., 1997). Disorganised symptoms have also been found to be related to impaired working memory (Schroder, Tittel, Stockert & Karr, 1996). Some of the schizotypy literature has indicated that there may be links between disorganised symptoms and impaired WM performance. Moritz and colleagues (Moritz, Andresen, Naber, Krausz, & Probsthein, 1999) examined the relationship between the three-factor structure of Raine's (1991a) SPQ and performance on a range of executive-type tasks. Using the Stroop Task and Trails B, they found that the Disorganised factor on the SPQ was related to poorer performance on these tasks. Moritz et. al., (1999) speculated that their findings were due to frontal lobe deficits. Of course, once again these tasks are quite different to span performance but are suggestive that decrements in performance in tasks presumed to rely on WM are differentially affected in schizotypal individuals.

Findings showing associations between positive symptom clusters and cognitive deficits are less consistent. Positive symptoms have been linked in at least one study to increased perseveration errors and a bias towards false alarms on a list learning task (Brebion et al., 1997). Other studies have found strong correlations between positive symptoms (as measured by the PANSS) and impaired performance on digit span tasks (Berman et. al., 1997; Green & Walker, 1986). While positive symptoms as a group have not yielded particularly consistent links with cognitive impairments, one specific type of positive symptom, positive thought disorder, has been shown to be related to specific forms of cognitive failure.

Thought disorder (TD) is used to describe impairments of language and communication observed in some patients with schizophrenia (TD can also occur in other serious psychiatric disturbances such as mania). Positive thought disorder includes a range of communication problems including *derailment, loss of goal, tangentiality, perseveration,* and *distractible speech* (McGrath, 1992). Negative thought disorder generally is a term used to describe *poverty of speech* and is included with other negative symptoms including flattened affect and lack of drive. Positive TD has been associated with WM impairments on tasks such as the WCST and Trails B of the Trailmaking test (McGrath et al., 2001). Harvey and Pedley (1989) found general impairments on digit span with both auditory and visual presentation in their schizophrenia sample. However, positive TD predicted poorer auditory, but not visual performance.

Frith (Frith & Done, 1988; Frith 1992; Cahill & Frith, 1996) has presented an elegant theory of the neuropsychology of schizophrenia developing a cognitive model of the signs and symptoms. While a discussion of his theory is beyond the scope of this thesis, his theory may provide further hints as to the association between errors on cognitive tasks and clinical symptoms. Frith (1988) proposes that negative symptoms of schizophrenia (particularly poverty of action and poverty of speech) reflect a defect in the initiation of spontaneous action. He then suggests (Cahill & Frith, 1996) that this may lead to three distinct patterns of behaviour; (i) they may do nothing, or fail to emit a response; (ii) give a stimulus driven response; (iii) or they may repeat a previous action. One may infer from this theory that negative symptoms may be associated with a failure to respond (or an *omission)* or a perseverative response on span tasks. By contrast, positive symptoms may be the result of a defect in the internal monitoring of action (Frith, 1992). This may result in an inability to distinguish between internally and externally generated events, and in particular a failure of a verbal self-monitoring system (Cahill & Frith, 1996). On span tasks, one may speculate that a failure in the ability to monitor verbal information may result in a higher number of extra-list intrusions as confusion may arise between the external list items and internally generated words.

4.7 The effect of neuroleptic medication on cognition

Any examination of cognitive performance in clinical populations warrants consideration of the potential effects of medication. A full investigation of this is beyond the scope of this thesis but a brief review as it pertains to the cognitive areas under review here is warranted. Generally the findings related to atypical psychotics that are more commonly prescribed to today's patients are reasonably positive. One meta-analysis (Keefe, Silva, Perkins & Lieberman, 1999) found that atypical antipsychotics improved a range of cognitive functions including executive functioning, speed of information processing and verbal fluency. Other studies looking at individual atypical medication (Risperidone and Olanzapine) found positive effects on working memory, attention, verbal memory and executive functioning (Meltzer & McGurk, 1999). Earlier research examining the effect of more traditional neuroleptics on cognitive performance is equivocal. King and Green (1996) reviewed 25 studies using typical antipsychotics and concluded that some functioning such as attention and information processing appear to be assisted by medication. There is some evidence however, that some medications such as anticholinergics, which are typically prescribed in conjunction with older antipsychotics have a negative impact on some cognitive abilities including memory (Spohn & Strauss, 1989). The effects of medication then, need to be taken into account when examining the performance of individuals with schizophrenia.

4.8 Chapter Summary

With regard to WM research in schizophrenia there are wide ranging findings. A variety of tasks and methodologies have been employed to examine SZ performance. Those studies that have used Baddeley's model as a basis for exploring deficits have reported disparate results. Almost universally, researchers agree that WM is impaired in SZ and that depending on the task selected, there may also be impairment in schizotypal individuals. Some identify the deficit as lying in the CE, others attribute it to the functioning of the PL and still others report that it is likely to be both systems impaired. The new addition to Baddeley's model, the EB has yet to be comprehensively tested. When exploring different conceptions of WM, as outlined in the previous chapter, once again we are left with a collection of studies with different findings. Many studies have found simple span tasks to be impaired in SZ and even in some cases in schizotypy. Almost all have reported deficits in complex span tasks and delayed Brown-Peterson type tasks. Access to lexical representations also appears problematic and rehearsal rates are generally reported as being slower than in controls. The lack of uniformity across studies makes it difficult to draw clear conclusions regarding the core source of deficits in verbal WM in SZ. Using novel tasks with this population previously used in experimental paradigms may help to shed some light on the source of deficits in SZ and in schizotypal individuals. Employing these tasks with a population known to have WM deficits may also help to inform our understanding of current memory models. If we find dissociations between aspects of WM models, such as maintenance and manipulation, which according to Baddeley's model are performed by different components, then this may provide support for these distinctions to be made when exploring normal memory functioning. Conversely, if we are unable to find evidence for the separate components, this may be indicative of the utility of a different approach to WM performance.

4.9 Aims of the investigation and experimental hypotheses

The aims of this investigation were two-fold. Firstly, there is still ongoing debate as to whether it is feasible to differentiate amongst different types of working memory systems. The first aim then is to add to the current literature regarding whether the current theories fractionating working memory are justified. Tehan and his colleagues (Tehan et. al. 2001) have suggested that this fractionation may not be warranted. An overarching goal was to explore the performance of a clinical population whose deficits across WM tasks have been previously attributed to multiple components of the WM model. Examining the pattern of performance across the groups may help to clarify whether the multi-component or the common storage approach to WM provides a more parsimonious explanation of any deficits that may be observed.

Evidence has been presented from previous research suggesting that under certain conditions, SZ samples differ from controls on simple, complex and delayed span tasks. The first experimental chapter (Chapter 6) will examine performance and investigate errors across simple, complex and delayed word span tasks. Based on previous research in both clinical and normal populations a number of hypotheses have been developed. These are presented below.

4.9.1 Serial recall hypotheses

Hypothesis 1 – Normal Low Schizotypy Controls (NCL), Normal High Schizotypy Controls (NCH) and Schizophrenia (SZ) subjects should all perform at an equivalent level on a simple four-word span task. Although there are previous findings of impaired span performance in SZ subjects, differences have typically been found as span increases. Using a four-word task should ensure equivalency among the groups. Studies finding impaired span still report forward span estimates in their SZ groups to be over four items (Conklin et. al., 2000; Tamblyn et. al., 1992) and Fleming et. al., (1995) reported no differences between SZ and control groups using a four item recall task.

Hypothesis 2 - On the complex word-span task, it is predicted that the SZ subjects will be impaired compared to the two control groups and that the NCH may demonstrate poorer performance than the NCL group.

Hypothesis 3 - On the delayed Brown-Peterson type condition it is predicted that the SZ group will be impaired compared to both control groups (main effect of group and task).

Hypothesis 4 - Performance by SZ patients is predicted to be related to symptoms. Both negative and disorganised symptoms have previously been linked to impaired WM performance (Cameron et. al., 2002; Stirling et. al., 1997; Schroder et. al., 1996). The common storage approach may posit that symptoms may be related to performance across all tasks.

Hypothesis 5 – The pattern of errors across tasks is predicted to differ as a function of task and group. It is predicted that as the task difficulty increases the SZ group will find it disproportionately more difficult than the control groups to maintain serial order.

Hypothesis 6 – Following Frith (1988, 1992, 1996) It is predicted that error type will be associated with symptom clusters in SZ and NCH groups. Omissions are predicted to be associated with Negative Symptoms. Intrusion errors are predicted to be associated with Positive symptoms as measured by the PANSS and the SPQ.

4.9.2 Individual differences hypotheses

The second experimental chapter (Chapter 7) explores novel territory in order to explore the common storage approach to memory. It is known that in normal populations, access to lexical memory and rehearsal speed contributes to performance on simple span tasks (Tehan & Lalor, 2000; Tehan et. al., in press). Examining the contributions to complex and delayed span performance has not been previously explored. Individuals with schizophrenia are hypothesised to have dysfunctional lexical networks and reduced rehearsal rates (Spitzer, 1998; Condray et. al., 1996). As such, it will be interesting to explore whether in this population the same processes underlie span performance.

Hypothesis 1 – It is predicted that in all groups access to lexical memory and rehearsal speed will be predictors of span performance.

4.9.3 Cue plus code hypotheses

Deficits in encoding and in retrieval have also been hypothesised in SZ research (Goldberg et. al., 1998). Using a cue plus code paradigm, error types will be explored to try and identify the nature of impairment in SZ subjects. It is possible that the different groups will produce different types of errors across tasks, and as such this may be informative as to the potential processing deficits. The design of this experiment follows the study by Tehan and Humphreys (1996) described in Chapter 2. To reinterate, this experiment attempts to strengthen the activated features of a foil over the target by manipulating semantic and phonemic codes. There are four conditions. The first condition has no interference and after presentation of the list items two seconds of verbal distractor follows, the category cue is then presented. The second condition (standard interference) where there is an interfering foil word placed in the first block. This foil is another instance from the same category as the target word appearing in the second block. The third condition also has an interfering foil in the first block. In addition a rhyme of this foil is provided amongst the filler words in the second block, thus manipulating phonological representations. The final manipulation places two associates of the interfering foil as filler words in block two.

Hypothesis 1 – Given that Fleming (Fleming et. al., 1995) found a verbal distractor presented after the presentation of a four item list impaired recall in a SZ sample, it is expected that the SZ group may perform worse than the control groups.

Hypothesis 2 – In the standard interference condition, where another exemplar of the category is included in the first to-be-ignored block, performance is expected to be lower than in the No Interference condition. Sz subjects are predicted to be differentially impaired on this task due to dysfunctional lexical networks.

Hypothesis 3 – Manipulating phonemic and semantic codes by placing items that rhyme, or are associated with the foil in the second block should produce the lowest target recall and a related increase in the recall of the foil.

Hypothesis 4 - In SZ patients it is predicted that they will be differentially impaired on this task and error type will be related to symptoms.

Chapter 5 - Groups

The current research is based upon comparison among three groups. The first is a group with confirmed clinical diagnoses of schizophrenia. The second and third groups have no such diagnosis. However these groups differ on reported schizophrenia-like symptomatology: One group is considered high on the schizotypy dimension and the second is considered to be low on this dimension.

5.1 Site recruitment of clinical participants

Clinical patients were recruited from the community via a research participation register at the Queensland Centre for Schizophrenia Research (QCSR) and from two Queensland psychiatric hospitals. Acute patients were recruited via the Wolston Park Psychiatric Hospital in Brisbane, and long-stay patients were recruited via Baillie Henderson Hospital in Toowoomba, Queensland. Clinical staff at the two referring hospitals were informed of the study and asked to refer patients with a diagnosis of schizophrenia. Patients referred to the investigator were then approached in order to obtain informed consent (see Appendix E – Informed consent sheet).

5.1.1 Inclusion criteria

A current diagnosis of DSM-III-R schizophrenia was required for inclusion in the study. The age range was between 18 and 55 with normal (or corrected to normal) visual acuity. Participants were required to have sufficient English to understand the task and give informed consent without the aid of an interpreter.

5.1.2 Exclusion criteria

Patients with any diagnosis other than DSM-III-R schizophrenia were not invited to participate in the study. Other exclusion criteria included current, severe substance abuse, history of head injury that resulted in a loss of consciousness for more than five minutes, and any medical condition that prevented the competent use of a computer.

5.2 Method of recruitment of patients

5.2.1 Community Based

A selection of the participant register at QCSR received a letter outlining the study. The selection of the potential subjects was determined by the research assistant maintaining the register, and was based upon a number of factors including how recently they had been involved in another study. Participants were then asked to contact the researcher directly if they were interested. Those identified via the register were also contacted via phone within two weeks of the mail out of the letters to ascertain their interest in participating. If they agreed to participate, the researcher then arranged a suitable time to visit them at their house for testing. Informed consent was sought prior to commencement of testing. Twenty-two (22) patients were recruited via this method. Of the 22 patients who consented to be tested, 8 were unable to complete the testing protocol. Of these, three became too agitated during the course of the testing, one was considered to not sufficiently understand what was required during the task and four reported that they became too fatigued and declined a second test session. As a result 14 Community based participants were included in the final sample.

5.2.2 Inpatients

Patients were approached by the researcher after consultation with the treating medical and nursing staff. Patients who had recently required seclusion were not approached. A total of 22 patients were referred to the study via Baillie Henderson Hospital (BHH). Five declined to participate. Five were unable to complete the testing protocol. Of those unable to complete testing, two did not sufficiently understand the task, two were too thought-disordered and their responses were not considered reliable, and one became agitated during the test session and testing was discontinued, resulting in a total of 12 participants from BHH.

Of those patients referred via Wolston Park Hospital, nine were referred via staff at an acute ward. Two of the nine referred declined to participate. Of the seven who agreed to participate, one on initial interview was determined by the researcher to be too unwell to complete the testing session. Two became too agitated during the testing session. This resulted in a total of four patients from the acute ward. Of these patients only one required two separate testing sessions due to the disturbance of auditory hallucinations during the first test session.

A total of 30 participants with a diagnosis of schizophrenia were included in the study.

5.3 Diagnosis, medication status and symptom ratings for schizophrenia participants

5.3.1 Diagnosis

Patients recruited via the participants register at QCSR had previously had consensus diagnosis determined by two psychiatrists. For the remaining subjects the diagnosis of schizophrenia was determined by the researcher based upon an extensive review of medical records, including past admission records, and a review of current mental state based upon the Diagnostic Interview for Psychosis (DIP). Diagnosis using the information from the DIP was confirmed using the OPCRIT algorithm (McGuffin, Farmer & Harvey, 1991). Additional information from the treating psychiatrist and allied health staff was sought where necessary. In those cases where case records held conflicting diagnoses and current mental state interview could not confirm diagnosis, the subject was excluded.

5.3.2 Medication Status

For the schizophrenia group medication status was collected, including antipsychotics and anticholinergics. Control participants were also asked whether they were taking any medication for mental health problems including antidepressants. Three of the participants in the NCL group were taking antidepressants at the time of the study.

A computerized dose conversion program (Lambert, 1998) was used to convert all patient medication levels to chlorpromazine equivalent. Inspection of probability plots revealed marked positive skewness for this variable. Logarithmic transformation was performed in order to normalize the variable. Four of the thirty patient participants were also receiving anticholinergic medication and three were medication free at the time of the study.

5.3.3 Symptom Rating Scale – Positive and Negative Symptoms Scales

The Positive and Negative Symptom Scales (PANSS) was administered to obtain a measure of the severity of symptomatology for each participant (Kay, Fiszbein & Opler, 1987). The PANSS contains 30 items and is administered in a semi-structured interview format over a duration of 30-40 minutes. Additional information provided by hospital staff and family members was sometimes drawn upon for completion of the PANSS. Each item on the PANSS is rated on a seven-point scale (1 = symptom is absent, to 7 = symptom is present to an extreme degree) (See Appendix H). The author was trained in the use of the PANSS via a standard package, consisting of an orientation session with a psychiatrist with many years of experience using the PANSS to familiarise the rater with the instrument and its scoring. Following this a rating session comprised of videotaped patient interviews which were scored and then compared with ratings provided on the tape. A composite index of ratings yielded a Pearson r of 0.87 for the training tapes. In addition the rater administered the scale in a number of other studies and undertook inter-rater reliability exercises on a regular basis during her employment with the Queensland Centre for Mental Health Research and

Peninsular Health. Inter-rater reliability details are provided in Appendix G. The most recent inter-rater reliability calibration undertaken by the rater yielded a Pearson *r* of 0.85. It is acknowledged that it would have been preferable to have at least some of the patients rated independently on the PANSS. However, given financial and time restrictions of the study this was not possible. This issue is addressed in the final chapter.

Standard PANSS scoring according to the manual provides three scores representing positive and negative symptoms and general psychopathology. However, three dimensions representing positive, negative and disorganised factors have been used previously in examining symptom profiles and working memory performance (Cameron et al., 2002) and these were also used here. The dimensions were based on a number of studies examining the structure of the symptoms (Kay & Sevy, 1990; Liddle, 1987; Marder, Davis & Chouniard, 1997; Mass, Schomig, Hitschfeld, Wall & Hansen, 2000). These three dimensions were constructed based upon Liddle's (1987) formulation: *Reality Distortion* (Positive construct) – Item P1 – delusions, Item P3 – hallucinations, Item P5 grandiosity, Item P6 suspiciousness, and Item G9 unusual thought content; *Psychomotor Poverty* (Negative Construct) – Item N1 blunted affect, Item N2 emotional withdrawal, Item N3 poor rapport, Item N4 passive/apathetic social withdrawal, Item N6 lack of spontaneity and flow of conversation, Item G7 motor retardation, Item G16 active social avoidance; and *Disorganised* – Item P2 conceptual disorganisation, Item N5 difficulty in abstract thinking, Item G10 disorientation, and Item G11 poor attention. The mean of each of the three composites (Positive, Negative and Disorganised) formed the dimension scores.

5.4 Method of recruitment of normal controls

Thirty-five of the normal controls were recruited via the subject pool of psychology students at the University of Southern Queensland. A further 16 were recruited from hospital staff and relatives and friends of hospital staff. Control participants were directly questioned about psychiatric history and on this basis two participants were excluded due to past psychotic episodes. Additional exclusion criteria for controls were the same as for the patients (See Appendix F for Consent Form). Those with a history of head injury, or other neurological condition and those with current, severe substance abuse were also excluded. Based upon these criteria, 49 control participants were tested. Seven participants were excluded due to missing data, resulting in 42 participants in the control group.

5.4.1 Schizotypal Participants

The 42 non-clinical participants were assessed for schizotypal symptoms, and were categorized into high and low schizotypal groups based upon scores on Raine's (1991a) Schizotypal Personality Questionnaire (SPQ). The SPQ, as mentioned in Chapter 2, was developed to tap the nine dimensions of Schizotypal Personality Disorder as described in DSM-III-R. The questionnaire is a 74-item, self-report questionnaire with a yes/no response format (See Appendix I). The questionnaire gives nine-subscale scores; Ideas of Reference, Social Anxiety, Odd beliefs/Magical thinking, Unusual perceptual experiences, Eccentric/odd behaviour and appearance, No close friends, Odd speech, Constricted affect, and Suspiciousness/paranoid ideation. All items endorsed as “yes” are scored as one. Raine (1991a) reports that the scale has high internal validity (0.91) and test-retest reliability (0.82).

Similar to the three-factor model of schizophrenia (positive, negative and disorganisation), Raine and his colleagues (1994) proposed a three-factor structure for schizotypy identifying cognitive-perceptual, interpersonal and disorganised features. Subsequent research has confirmed the three factor model (Gruzelier et al., 1995; Brekke, Raine & Thomson, 1995; Wuthrich & Bates, 2002).

Control participants whose total SPQ score was greater than the lowest total score of the patient sample were included in the high -schizotypy group. This resulted in a total of 27 participants in the low schizotypy group and 15 in the high schizotypy group. This method was chosen in order to use the schizophrenia participants as a benchmark for levels of schizotypy. This represents a novel approach of separating the non-clinical control group. One common method used to identify individuals deemed to be “high schizotypal” is to select the top 10% scorers on the SPQ (Raine, 1991b). The reason in this thesis for not choosing this method was conceptually driven by an attempt to link performance to the underlying theory of Meehl’s schizotypy. Here we used the premise that by definition to have a clinical diagnosis of schizophrenia, one must be a schizotype. If we can presume that the SPQ indeed captures the essence of whatever it is to be a “schizotype”, then obtaining scores similar to the schizophrenia group were thought to be a reasonable measure of schizotypal behaviour.

Control participants from the psychology subject pool received course credit for participation in the experiment and other control participants and SZ participants received a $15.00 shopping voucher in return for participation.

5.5 Estimating premorbid IQ

5.5.1 National Adult Reading Test (NART)

The NART (Nelson, 1982) is a word-reading test widely used as a method of obtaining an estimate of an individuals premorbid IQ. The subject is required to read and correctly pronounce a series of irregular words. Originally developed as a measure of premorbid intelligence, in dementia patients, it was developed on the basis that word-reading ability is highly correlated with general intellectual ability, and that this word-reading ability is relatively resistant to neurological impairment (Lezak, 1995; Wechsler, 1958). Spreen and Strauss (1998) report that the NART is among the most reliable tests in clinical use. The NART has been used previously with schizophrenia populations examining neuropsychlogical functioning (Nelson et al., 1990; Brown & White, 1992). It has demonstrated good test-retest reliability with this population (Smith, Roberts, Brewer & Pantelis, 1998). It has also been found to be a reliable way of estimating premorbid intellectual functioning in acutely ill schizophrenia participants (O’Carroll et al., 1992).

For each subject, the NART error score was converted to a predicted WAIS-R Full Scale IQ corrected for age, gender and education using Australian normative data (Willshire, Kinsella & Prior, 1991).

5.6 Testing

Participants were tested individually. All control participants were tested in a single session. Twenty-five of the thirty patient participants were also tested in a single session and the remaining five were tested in two sessions. All patients and control participants completed a clinical interview prior to testing. The order of task presentation was counterbalanced with half of the participants completing the tasks in the following order; NART, alphabet articulation, counting backwards from twenty, serial threes, digit span, letter number sequencing, computerised non-span tasks (lexical decision task, word reading rate, non-word reading rate, odd-word reading rate), word span task, cued recall task. The other half of the participants completed the tasks in the following order; computerised non-span tasks, cued recall task, word span task, NART, alphabet articulation, counting backwards from twenty, serial threes, digit span, letter number sequencing. The examiner kept a record of the presentation order for the control and clinical participants to ensure it was alternated each time.

5.7 Ethics approval and consent

Written and oral descriptions of the study were given to all, and written consent was obtained. All participants were over 18 years of age. Approval for the study was obtained from the ethics committees of the University of

Southern Queensland, Baillie Henderson Hospital, Toowoomba and Wolston Park Hospital, Brisbane. Copies of the consent form are provided in Appendix E and F.

5.8 Data analysis, missing data

Data analysis was performed using version 10.0 of the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, frequency distributions, and normal probability plots were examined for each variable in the analysis. Missing data were not analysed. Valid outliers were retained for analysis. Any outliers identified as being due to data entry errors were corrected.

Of the schizophrenia group, all completed the first section of testing (paper and pencil attention/short-term recall and non-span computerized tasks). However, four of these individuals did not complete the serial recall task, leaving 26 of the patient group for this analysis. A further four individuals could not complete the cued recall section. Twenty-two of the patient sample were included in this analysis.

5.8.1 Serial Recall and Cued Recall analysis

Initial comparisons were made of interactions of performance of the groups across task type. Data were analysed using univariate and repeated measures analysis of variance (ANOVA) as well as t-tests. Group constituted a between-participants factor (SZ = Schizophrenia; NCL = Normal Control – Low Schizotypy; NCH = Normal Control – High Schizotypy). Task type formed a within-participants factor. Within group and interaction effects were examined within a multivariate ANOVA design (Wilk's lambda).

Post-hoc analyses employed the Tukey's Honestly Significant Difference (HSD) statistic.

5.8.2 Contribution to span

In order to assess the efficacy of the various tasks in terms of prediction of span, Pearson product-moment correlations between span and respective variables were examined. A standard multiple-regression analysis was also conducted in order to assess the independent (ie. unique) contributions of the various independent variables to the variance in the dependent measures.

5.9 Demographic information, key variables and potential confounding variables

Table 5.1 displays the demographic characteristics for the three groups. The final numbers for the groups were Schizophrenia (SZ) = 30, Normal-High Schizotypy (NCH) = 15, Normal-Low Schizotypy (NCL) = 27.

Chapter 4 introduced the idea that the relationship between cognitive performance and medication effects warrants investigation. As a result it was decided *a priori* that medication dosage may be a confounding variable. Correlation matrices of log transformation of medication with the variables under consideration in the experimental chapters were inspected (see Appendix J). Inspection of the correlation matrix suggested that medication dosage was not related to the experimental variables.

Table 5.1 – Characteristics of Participants

	Schizophrenia	Normal Control Low Schizotypy	Normal Control High Schizotypy
Number	30	27	15
Age Mean (sd)	36.9 (9.4)	30.1 (12.0)	27.3 (10.6)
Male:Female Ratio	21:9	12:15	6:9
Yrs of Educ Mean (sd)	10.6 (1.6)	12.2 (1.5)	11.3 (1.8)
Estimated premorbid IQ Mean (sd)	92.9 (11.3)	102.6 (9.8)	95.9 (12.2)
Chlorpromazine equiv. Mean (sd)	827.8 (599.7)	na	na
Length of Illness Mean (sd) **Range**	15.4 (8.52) 1-36	na	na
Anticholinergic med Yes:No	4:26	na	na
Antidepressants Yes:No	na	3:24	na

On the NART IQ measures there were significant differences among the groups ($F_{(2,71)}$ = 5.19, *p* = 0.008). Post-hoc analyses using the Tukey's HSD statistic indicated that the differences were between the NCL group and the SZ group only (p = .007). Although it is recognised that it is optimum to match groups on potentially confounding variables such as IQ, in populations where there are often generalised IQ deficits such as schizophrenia (Aylward, Walker and Bettes, 1984), this is not always possible. Exploring the patterns of error performance will be the primary method presented here in order to investigate the likely source of impaired performance across tasks. Analysis of error performance has contributed important knowledge to the understanding of recall in normal cognition (Estes, 1991; Henson, 1999). However, in SZ populations it is less common. Elvevag and colleagues

(2001) as described earlier, have undertaken such an analysis and their sample also had significant differences in IQ means between the controls and clinical groups. However, IQ as measured by the NART will be considered as a possible confounding variable in the analyses of the main hypotheses.

Analysis of variance (ANOVA) revealed significant differences in years of education $F_{(2,71)} = 6.55$, $p = .002$. Post-hoc analyses using Tukey's HSD statistic indicated that the differences were between the schizophrenia group and the NCL group ($p = .002$). The correlation between NART scores and years of education was significant (Pearson $r = 0.480$, $p = .000$).

There was also a significant difference between the groups on the variable of age ($F_{(2,71)} = 4.88$, $p = 0.01$). Post-hoc analyses using Tukey's HSD statistic indicated that the SZ group were significantly older than the NCH group ($p = .01$). The differences between the NCL group and the SZ group were not significant ($p = 0.056$), nor were the differences between the two control groups ($p = 0.675$). The influence of age will also be examined in relation to the main hypotheses.

Overall, there were no significant gender differences between the groups (Pearson $X^2 = 5.27$, df = 2, $p = 0.072$). However, the SZ group contained more males than the other two groups and as such the influence of gender on performance will be considered further in the experimental chapters.

5.9.1 Symptom rating scales

Table 5.2 displays the mean ratings of the patient group on the Positive and Negative Symptom Scale (PANSS) for standard scoring as per the manual (Kay, 1982) which generates a positive score, a negative score, a general psychopathology score and a total score. In addition, mean positive, negative and disorganised scores as per Liddle's (1987) formulation in section 5.3.3 above were also calculated and are also displayed in Table 5.2.

Table 5.2 – PANSS Scores

	SZ
PANSS – Positive – Mean (sd) Range	16.93 (6.32) 7-31
PANSS –Negative – Mean (sd) Range	16.6 (5.96) 7-32
PANNS – General psychopathology Mean (sd) Range	35.43 (9.54) 18-57
PANSS – Total Score Mean (sd) Range	68.96 (17.04) 34-100
PANSS – Positive Factor (Reality Distortion) – Mean (sd) Range	8.63 (4.46) 3-18
PANSS –Negative Factor (Psychomotor Poverty) – Mean (sd) Range	10.87 (5.62) 5-25
PANSS –Disorganisation Factor – Mean (sd) Range	11.63 (3.24) 6-20

The clinical group displayed a range of symptoms. Fourteen of the schizophrenia group had predominantly positive symptoms, 15 predominantly negative and one had mixed symptoms. All of the schizophrenia group scored above the 75th percentile in overall symptoms according to the PANSS manual (Kay, 1982).

5.9.2 SPQ Scores

Table 5.3 below shows the SPQ scores for the three groups for the nine sub-scales. It also shows the three factor scores as derived by Raine et al (1994). Groups differed significantly on all SPQ scores and factors. Tables D1 through to D13 in Appendix D show the results of post hoc analysis examining differences between groups (Tukey's HSD). The SZ group scored significantly higher on all measures of the SPQ compared to the NCL. The SZ and NCH group only differed on Unusual Perceptual Experiences. On this measure, the SZ group's score was significantly higher than the score for either of the two control groups. There were no significant differences on the composite or total scores between the SZ and NCH group.

Table 5.3 – SPQ Scores (Mean (sd))

	Schizophrenia – (n = 30)	NCL (n = 27)	NCH (n = 15)	ANOVA
1. Ideas of Reference	3.40 (2.27)	0.704 (0.99)	3.53 (2.69)	$F_{(2,71)}$ = 15.83 p = 0.000
Range	0-7	0-3	0-9	
2.Excess soc anxiety	3.60(2.04)	2.07(1.85)	5.06(2.12)	$F_{(2,71)}$ = 11.33 p = 0.000
Range	0-8	0-7	1-8	
3. Magical Thinking	2.96(1.99)	1.37(1.41)	2.46(2.06)	$F_{(2,71)}$ = 5.62
Range	0-7	0-5	0-6	p = 0.005
4. Unusual percept.	3.00(2.07)	0.55(0.80)	1.53(1.30)	$F_{(2,71)}$ = 18.05
Range	0-7	0-3	0-4	p = 0.000
5. Odd Behaviour	3.00(1.38)	0.25(0.59)	1.80(2.14)	$F_{(2,71)}$ = 28.45
Range	1-6	0-2	0-7	p = 0.000
6. No Friends	3.30(1.97)	1.48(1.42)	3.00(2.70)	$F_{(2,71)}$ = 6.55
Range	0-7	0-4	0-8	p = 0.000
7. Odd Speech	3.83(2.18)	1.52(1.25)	4.00(1.53)	$F_{(2,71)}$ = 12.67
Range	0-9	0-4	0-9	p = 0.000
8. Constricted Affect	3.00(1.53)	0.85(0.91)	2.47(1.81)	$F_{(2,71)}$ = 17.45
Range	0-6	0-3	0-6	p = 0.000
9. Suspiciousness	3.23(1.87)	0.59(0.89)	3.87(1.85)	$F_{(2,71)}$ = 28.73
Range	0-7	0-3	1-7	p = 0.000
10. Total Score	29.4(9.10)	9.40(4.37)	27.7(10.10)	$F_{(2,71)}$ = 51.03
Range	15-47	2-17	10-46	p = 0.000
Cognitive/Perceptual Factor	12.60(5.69)	3.22(2.76)	12.53(5.01)	$F_{(2,71)}$ = 30.29 p = 0.000
Range	2-25	0-8	2-21	
Interpersonal Factor	13.13(5.17)	5.00(3.39)	15.07(5.41)	$F_{(2,71)}$ = 27.79
Range	1-22	0-12	5-26	p = 0.000
Disorganisation Factor	6.83(3.18)	1.78(1.50)	6.07(3.52)	$F_{(2,71)}$ = 25.79 p = 0.000
Range	1-14	0-4	0-14	

5.9.3 Relationship between PANSS scores and SPQ scores

Table 5.4 displays the correlations between PANSS scores and SPQ scores for the SZ group.

Table 5.4 Correlations between PANSS and SPQ factor scores

	SPQ cognitive perceptual factor	SPQ interpersonal factor	SPQ disorganisation factor	PANSS positive factor	PANSS negative factor	PANSS disorganised factor
SPQ cognitive perceptual factor	1	.236	.482(**)	.254	-.332(*)	-.007
SPQ interpersonal factor	.236	1	.278	-.331(*)	.457(**)	-.018
SPQ disorganisation factor	.482(**)	.278	1	.043	-.075	-.090
PANSS positive factor	.254	-.331(*)	.043	1	-.357(*)	.499(**)
PANSS negative factor	-.332(*)	.457(**)	-.075	-.357(*)	1	.248
PANSS disorganisation factor	-.007	-.018	-.090	.499(**)	.248	1

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

It was expected that positive correlations would be found between the PANSS reality distortion (positive) and the SPQ cognitive/perceptual factors, the PANSS psychomotor poverty (negative) and the SPQ interpersonal factors and the PANSS disorganised and SPQ disorganised factors. Negative correlations were expected between the PANSS psychomotor poverty and the SPQ cognitive/perceptual factors and between PANSS reality distortion and SPQ interpersonal factors. Due to the expected relationships between these factors Spearman's one-tailed correlations were conducted.

Contrary to expectations the correlations between the SPQ cognitive/perceptual factor and the PANSS reality distortion (positive) factor were not significant. There was a significant negative correlation between the SPQ cognitive/perceptual factor and the PANSS psychomotor poverty (negative) factor. The expected correlations were found between the SPQ interpersonal factor and the PANSS psychomotor poverty factor. Finally, there was no relationship between the SPQ and the PANSS disorganised factors.

This suggests that the SPQ may be appropriate to capture the negative aspects of schizophrenia symptomatology, may be less appropriate at tapping the positive and disorganised dimensions. As a result of the low correlations between the positive dimensions and disorganised dimensions of these two instruments, when considering the relationship between symptoms and tasks in the experimental chapters, the SPQ scores will be used for the control groups, and the PANSS scores will be used for the schizophrenia group. Perhaps the lack of association between these measures is related to the level of insight in the schizophrenia group. There have been conflicting findings regarding the accuracy of self-report measures in schizophrenia samples. Atkinson, Zibin and Chuang (1997) for example found that using self-report inventories with people with chronic mental illness are likely to contain biases due to cognition (particularly insight) and recent life events. However, others more recent studies (Ready & Clark, 2002; Morris, Fiszdon, Richardson, Lysaker & Bryson*, in press*) have found that active psychiatric symptoms do not diminish the ability of accurate self report of personality and symptom dimensions.

5.10 Chapter Summary

Thirty participants with a DSM-IV diagnosis of schizophrenia were recruited from inpatient settings and the community. Diagnosis was determined using the Diagnostic Interview for Psychosis and medical records. Clinical symptoms were assessed using the PANSS. A further 42 participants with no history of psychosis were recruited from the community and first-year psychology subject pool to form a control group. Based upon scores on the SPQ, the control group were divided into a high (n = 15) and low scoring group (n = 27). The cut-off scores for the high scoring group were determined by scores of the group with schizophrenia on the SPQ.

The schizophrenia group were older and had more males than the two control groups. This group (SZ) also had significantly lower mean premorbid IQ score as indicated by the NART and less years of education than the NCL group. As a result of these differences, the NART, age and gender will be considered as possible confounding variables.

The percentage (36%) of the control subjects allocated to the "high schizotypy" group is somewhat higher than may have been predicted based on studies of psychosis-proneness in non-clinical samples. Endorsement of psychotic symptoms in normal populations of up to 28% have previously been reported (Verdoux et. al., 1998). Higher rates of schizotypic symptomatology have been reported in younger groups (Venables & Bailes, 1994; Verdoux et. al., 1998) with young adults more likely to hold (and share) unusual beliefs (Verdoux & van Os, 2002). The NCH group were significantly younger than the other two groups and the higher rates of schizotypic symptoms compared to the NCH may well be related to their age.

All groups were administered paper and pencil and computerised working memory tasks. Results from these experiments are presented in the following chapters.

<u>Chapter 6 - Serial Recall</u>

6.1 Chapter Overview

This chapter presents empirical results related to simple, complex and delayed span tasks. Results of Tehan et al.'s (2001) research seriously question the need to distinguish between separate passive and active stores in a WM system. As previously discussed they found signature effects of the PL (i.e. word length and phonological similarity effects) in a standard simple serial recall task. In addition, they also found these effects in a dual-task complex span task assumed to measure CE functioning and in a delayed recall, LTM task. Research has indicated that performance of complex and delayed span tasks is compromised in SZ and there has been conflicting results for simple span tasks. The results pertaining to schizotypy populations on span tasks are equivocal. Examining error patterns has been fruitful in trying to delineate the underlying deficits in span tasks in schizophrenia, but few such studies exist. Some studies (notably Brebion et. al., 2000) have shown that on serial recall tasks, subjects with schizophrenia make more *item* (intrusions and omissions) and also more movement errors. The current experiment addresses these issues by comparing the performance of individuals with a current diagnosis of schizophrenia, and two groups of controls divided by scores on a measure of schizotypy across simple, delayed and complex span tasks. Movement, intrusion and omission errors will be explored in detail.

The complex span task used in these experiments is not equivalent to that often used in literature examining performance in normal populations. The operation span task developed by Turner and Engle (1999) presented words interleaved with mathematics problems that needed to be solved by the participant while retaining the words. However, in a pilot study for this experiment using participants with schizophrenia, it was found that this task was too difficult. Previous research (Tehan et. al., 2001) employing both the standard complex operation span task and reading digits aloud between words (a complex span task with less processing demands that is used here) found that the pattern of effects for these two tasks was the same, but the overall level of performance was superior in the latter task. Due to the likely event of floor effects in the schizophrenia group, we opted to use the simpler task with less processing demands. Also the recent paper by Conway et. al. (2005) suggest that the key issue span tasks is the prevention of rehearsal which should be achieved by reading the digits aloud. However, it is recognized that in changing this task some of the face validity of it being a dual-task working memory measure may be lost.

The hypotheses related to this chapter are as follows:

Hypothesis 1 – Normal Low Schizotypy Controls (NCL), Normal High Schizotypy Controls (NCH) and Schizophrenia (SZ) subjects should all perform at an equivalent level on a simple four-word span task. Although there are previous findings of impaired span performance in SZ subjects, differences have typically been found as span increases. Using a four-word task should ensure equivalency among the groups. Studies finding impaired performance still report forward span in their SZ groups over four items (Conklin et. al., 2000; Tamblyn et. al., 1992) and Fleming et. al., (1995) reported no differences between SZ and control groups using a four item recall task.

Hypothesis 2 - On the complex word-span task, it is predicted that the SZ subjects will be impaired compared to the two control groups and that the NCH may demonstrate poorer performance than the NCL group.

Hypothesis 3 - On the delayed Brown-Peterson type condition it is predicted that the SZ group will be impaired compared to both control groups (main effect of group and task).

Hypothesis 4 - Performance by SZ patients is predicted to be related to symptoms. Both negative and disorganised symptoms have previously been linked to impaired WM performance (Cameron et. al., 2002; Stirling et. al., 1997; Schroder et. al., 1996). The common storage approach may posit that symptoms may be related to performance across all tasks.

Hypothesis 5 – The pattern of errors across tasks is predicted to differ as a function of task and group (once again main effect for group and error type). It is predicted that as the task difficulty increases the SZ group will find it disproportionately more difficult than the control groups to maintain serial order.

Hypothesis 6 – Following Frith (1988, 1992, 1996), It is predicted that error type will be associated with symptom clusters in SZ and NCH groups. Omissions are predicted to be associated with negative symptoms. Intrusion errors are predicted to be associated with positive symptoms as measured by the PANSS and the SPQ.

6.2 Method

6.2.1 Participants

The sample consisted of 26 subjects with a current DSM-IV diagnosis of schizophrenia (SZ), 27 normal control subjects with a low score on psychometric schizotypy (NCL), and 15 subjects with a high score on psychometric schizotypy (NCH). Information on recruitment of subjects is presented in Chapter 5. All subjects were tested individually.

6.2.2 Materials

The word pool used to create the memory trials consisted of 210 words of one to four syllables (See Appendix C). Words were selected from the Shapiro and Palermo (1970) norms. Participants completed 30 trials in which they were told that they would be presented with four words and that their primary task was to remember the four words in order. To create the 30 trials for each person, 120 words were randomly sampled from the word pool and randomly allocated to the four serial positions. Recall of the four words was examined under three conditions. The first condition was a simple span task involving recall of four words immediately after presentation. The second was a complex span task in which each of the four to-be-remembered words was followed by a two digit number (e.g. *fish* 19 *basket* 52 *reel* 87 *accordion* 61), The final delayed recall task once again consisted of four words and four digits. In this condition all four, two-digit numbers appeared after the four words creating a delay prior to recall of the to-be-remembered words (e.g. *kerb hoard addict detergent 65 21 49 17)* and subjects were instructed once again to say the numbers out loud. There were 10 trials of each type and the each subject was presented with a randomized order of 30 trials. Unique sets of trials were generated for each participant.

The four-word length of the simple span trial was selected to reflect Cowan's (1988) model that the focus of attention is limited to approximately four items. Also, Chapman and Chapman (1978) suggest that it is important to address the issue that often schizophrenia subjects show a generalised deficit across task types and it is difficult to state with certainty whether impaired performance is the result of such a generalised deficiency, or a more circumscribed problem. Given that some studies have found a reduction in simple span for SZ patients, a subspan task was chosen so as to better equate difficulty level. In addition this four-word span task has been used previously (Tehan et. al., 2001; Tehan et. al., 2004) to examine various influences on serial recall in normal populations.

6.2.3 Procedures

Participants were informed that on each trial they would be presented with four words and that their primary task was to remember the four words in order. They were also told that on some trials a two digit number would appear and that whenever they saw a digit on the screen they were to say the number out loud. A training trial consisting of four examples was administered to all subjects with schizophrenia. The training trial was also offered to all other subjects (all declined).

The serial recall lists started with the presentation of a “READY” sign and an audible beep. The words and digits were then presented at a rate of one word per second in the centre of a computer screen. A row of question marks appeared after the final item as a cue to commence recall. Stimuli were presented on an Apple Mac II computer. The experimenter manually recorded all responses on a hard copy of the input file.

6.2.4   Dependent measures

There are a number of different ways of scoring serial recall data. The traditional and thus most frequently used measure of correct performance is where recall is counted as correct only if the item is recalled in the correct serial position. This is the first approach that is adopted here. Other researchers have suggested that serial recall is a two-part process. The first involves discriminating items on the current trial from those presented on previous trials. The second part of the process is determining the correct position of an item within the list. This process is reflected in two scoring procedures. Thus, with the first an item is scored as correct if it is recalled. What position it is recalled in is irrelevant. This form of scoring is commonly called item scoring. This form of scoring is commonly used in complex span tasks (e.g. LaPointe & Engle, 1990) and is becoming more widely used in simple span tasks particularly where the similarity of the list items is important. To reiterate, item scoring (item information) becomes simply the total items recalled correctly for each trial. The final measure is one specifically aimed at within list memory for order. Discriminating serial positions within a list can be achieved by scoring the number of order errors, corrected for item recall

(Poirer & Saint-Aubin, 1995). For this type of scoring, the number of order errors made is calculated as a proportion of the total items recalled. Analyses for all three scores are provided here, following Tehan et. al. (2001).

Errors that participants make can be informative as to the locus of any differences in performance between groups, but as discussed by Elvevag et al. (2001), errors types are rarely examined in serial recall tasks with SZ subjects. A number of different errors can be made on a serial recall task. Subjects may make an omission error. This occurs when the subject fails to recall a list item and responds with the word "something" or “pass”. Order errors can be made, where a list item is recalled but is recalled in an incorrect position as discussed above. So for example if a given stimulus sequence were ABCD and the participant responded with the sequence ACBD, then the first and last responses are scored as correct in position and the second and third items are scored as order errors. If the sequence presented was ABCD and the participant only recalled the final two items, CD, then both of these items would be scored as order errors. If the participant only recalled the final two items BUT ALSO indicated that two other (forgotten) items preceded thos recalled (e.g. if their verbal response was “something, something, C, D”) then the two items would be scored as correct in position.

Omission and movement errors are the most frequently observed error types. Less frequent, but equally important, are the intrusions that participants make, that is the items that are recalled but were not on the study list. Sometimes, these items will have similar characteristics to the forgotten items. In many instances the recalled item will sound like the forgotten word. That is, they will share many phonological features (eg. "*hedge"* recalled when "*edge"* was presented, or "*mop"* recalled instead of "*mob")*. In other instances the intruding word will have meaning-based characteristics in common (eg. "*tree"* recalled when *"willow"* was presented; "*thin"* recalled when "*skinny"* was presented). Also, the items might come from prior trials, or may be a perseveration of a response that is made across trials. Finally, there are those errors that are not traceable to any of the above effects. In the current thesis omission, order errors (transpositions), phonological and semantic errors are studied in detail. The remaining errors, because they are relatively rare, are categorised under the label of other errors. As mentioned above, movement (transposition errors) were calculated as a proportion of the total items recalled. Omissions were calculated as a proportion of the total errors (not including transpositions) and finally, intrusion errors were also calculated as a proportion of total errors. So movement errors were considered as a separate class to other errors. Other errors (omissions, phonological, semantic and other intrusions) were all considered together.

6.2.5 Possible confounding variables

In chapter 5 it was reported that the SZ group were older than the NCH group. The NART scores of the NCL group were also significantly higher than the SZ group and there were more males in the SZ group. As a result correlations were conducted between these (age, gender and NART scores) possible confounding variables and the dependent variables under consideration. Full correlation matrices are presented in Appendix L. Inspection of the data revealed that only the NART emerged as a likely confounding variable. To examine the influence of the NART, analysis of covariance (ANCOVA) were conducted. For all ANCOVA's preliminary checks were conducted to ensure there were no violations of assumptions including linearity, normality, homogeneity of variances and reliable measurement of the covariate. Assumption of homogeneity of variance was violated for omission and extra-list intrusion variables. In order to avoid type I error a more conservative alpha level was adopted for these analyses.

6.3 Results

6.3.1 Correct in Position

Performance on the proportion of items recalled in their correct position is summarised in Figure 6.1 and the means and standard deviations are displayed in Table 6.4. It is clear that more words were recalled in the correct position for the simple span task, than for either the complex or delayed conditions. A 3 (task) x 3 (group) repeated measures ANOVA confirmed this result with group (SZ, NCL, NCH) as the between-groups variable, and task type (simple, complex and delayed span) as within-groups variable. There was a main effect for task $F_{(2, 64)} = 89.10$, $p = .000$, and for group, $F_{(2,65)} = 21.16$, $p = .000$. The interaction between task type and group was not significant, $F_{(4, 130)} = 1.63$, $p = .171$.

Post-hoc analysis (using Tukey's HSD) revealed that the SZ group performed significantly worse than either of the two control groups (NCL, $p = 0.000$;

NCH, p = .004). The two controls groups did not differ from each other (p = .092).

To explore the possible influence of age on the dependent variables bivariate correlations were examined. Age was not associated with any of the span tasks in any of the groups. The highest correlation for the SZ group was between the simple span task and age (-0.032). The highest correlations for the NCL and the NCH group were between age and the complex span task (-0.192 and -0.315 respectively).

Due to the differences between the groups on NART IQ scores, additional analyses were undertaken to explore whether it was a confounding variable.. Table 6.1 displays the correlations between NART scores and the three span tasks.

For the schizophrenia group NART scores were associated only with the simple span task. In the two control groups almost all of the correlations between the NART and the span tasks were significant. In the NCL group the NART and complex span correlation were not significant, nor was the correlation between NART and simple span in the NCH group, although it approached significance (p = 0.06).

Table 6.1 – Correlations between NART scores and word span measures

SZ group	NART IQ SCORE	Simple span	Complex span	Delayed Span
NART IQ SCORE	1	.541(**)	.112	.163
Simple Span	.541(**)	1	.077	.423(*)
Complex Span	.112	.077	1	.680(**)
Delayed Span	.163	.423(*)	.680(**)	1
NCL group				
NART IQ SCORE	1	.424(*)	.328	.443(*)
Simple Span	.424(*)	1	.718(**)	.651(**)
Complex Span	.328	.718(**)	1	.824(**)
Delayed	.443(*)	.651(**)	.824(**)	1
NCH group				
NART IQ	1	.491	.547(*)	.566(*)
Simple Span	.491	1	.697(**)	.614(*)
Complex Span	.547(*)	.697(**)	1	.877(**)
Delayed Span	.566(*)	.614(*)	.877(**)	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Although not all of the dependent variables were strongly correlated with the NART scores, particularly for the SZ group, further exploration among the dependent variables and NART score were explored using repeated measures analysis of covariance (ANCOVA). The main effect for task was no longer significant once the NART was entered as a covariate ($F_{(2,63)}$ = 0.34,

p = 0.711). However the main effect for group remained significant ($F_{(2,64)}$ = 14.25, p = 0.000) with the SZ still performing below either of the control groups (NCL p = 0.000, NCH p = 0.001).

6.3.2 Item Information

Item recall, where list items were scored as correct, regardless of the order in which they were recalled is summarised in Figure 6.1; means and standard deviations are displayed in Table 6.4. Again, there was a main effect for task, $F_{(2,64)}$ = 122.11, p = 0.000. A main effect for group also remained with the SZ subjects performance again impaired compared to the control groups, $F_{(2,65)}$ = 17.46, p = 0.000. There was a small but significant task by group interaction, $F_{(4,130)}$ = 2.64, p = 0.036. Post hoc comparisons (Tukey's HSD) again revealed that the SZ group's performance was significantly worse than the performance of both the NCL (p = 0.000) and the NCH (p = 0.011) groups. The NCL and NCH groups did not differ from each other (p = 0.115).

To explore the possible confounding influence of NART scores, correlations were performed between NART scores and dependent variables. Table 6.2 displays the correlations. In addition a repeated measures ANCOVA was performed using the NART as a covariate.

The patterns of correlations were similar to those found for the correct in position variables. For the SZ group, the only significant relationship was between the item information on the simple span task and the NART. For the control groups, all correlations were significant except for the relationship between NART scores and item information for simple span in the NCH group. Once again, this correlation approached significance (p = .06).

Table 6.2 – Correlations between NART and Item Information

SZ group	NART IQ SCORE	Item Information Simple Span	Item Information Complex Span	Item Information Delayed Span
NART IQ SCORE	1	.449(*)	.307	.183
Item Information Simple Span	.449(*)	1	.423(*)	.424(*)
Item Information Complex Span	.307	.423(*)	1	.466(*)
Item Information Delayed Span	.183	.424(*)	.466(*)	1
NCL group				
NART IQ SCORE	1	.408(*)	.383(*)	.443(*)
Item Information Simple Span	.408(*)	1	.694(**)	.578(**)
Item Information Complex Span	.383(*)	.694(**)	1	.766(**)
Item Information Delayed Span	.443(*)	.578(**)	.766(**)	1
NCH group				
NART IQ SCORE	1	.485	.660(**)	.581(*)
Item Information Simple Span	.485	1	.547(*)	.436
Item Information Complex Span	.660(**)	.547(*)	1	.805(**)
Item Information Delayed Span	.581(*)	.436	.805(**)	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

When NART scores were entered into an ANCOVA, similar to the findings for correct in position variables, the main effect for task was no longer significant ($F_{(2,63)}$ = 1.62, p = 0.21). Once again the main effect for group remained significant ($F_{2,64)}$ = 11.07, p = 0.000).

6.3.3 Order (Movement Errors)

The probability of making an order error in relation to item recall is summarised in Figure 6.1 with the means and standard deviations displayed in Table 6.4. Note that movement errors are recorded in relation to *item* recall, rather than being considered in relation to other errors (specifically intrusions and omissions). Order errors increased with task difficulty, with fewer errors on the simple recall task than in either the complex or delayed conditions. Once again a 3 x 3 ANOVA confirmed this with a main effect for task type, $F_{(2,64)} = 22.22$, $p = 0.000$. There was also main effect for group, $F_{(2, 65)} = 12.30$, $p = 0.000$, but no task by group interaction effect, $F_{(4, 130)} = 0.995$, $p = 0.41$.

The possible confounding effects of the NART and age were once again considered when examining order errors. Examination of the correlations between age and order errors revealed significant correlations only for the NCL group, and only in the complex (0.455, $p = 0.017$) and delayed conditions (0.396, $p = 0.41$). Due to the lack of association between age and the variable of interest except in the best performing group, age was not considered for any further analysis.

Table 6.3 displays the correlations between order errors and NART scores.

Table 6.3 – Correlations between NART and Order Information

SZ group (n=26)	NART IQ SCORE	Order Information Simple Span	Order Information Complex Span	Order Information Delayed Span
NART IQ SCORE	1	-.564(**)	.161	-.162
Order Information Simple Span	-.564(**)	1	-.029	.503(**)
Order Information Complex Span	.161	-.029	1	.469(*)
Order Information Delayed Span	-.162	.503(**)	.469(*)	1
NCL group (n=27)				
NART IQ SCORE	1	-.383(*)	-.190	-.345
Order Information Simple Span	-.383(8)	1	.658(**)	.758(**)
Order Information Complex Span	-.190	.658(**)	1	.758(**)
Order Information Delayed Span	-.345	.758(**)	.758(**)	1
NCH group (n=15)				
NART IQ SCORE	1	-.425	-.296	-.377
Order Information Simple Span	-.425	1	.745(**)	.861(**)
Order Information Complex Span	-.296	.745(**)	1	.906(**)
Order Information Delayed Span	-.377	.861(**)	.906(**)	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

NART scores seemed most associated with order errors in the simple span task. To examine the influence of the NART on order errors in more details an ANCOVA was performed using the NART as a covariate. There was no main effect for task with the introduction of the NART ($F_{(2,63)}$ = 2.66, p = .078). The main effect for group remained ($F_{(2,64)}$ = 7.82, p = .001), and there was no interaction effect between task and group $F_{(4,128)}$ = 1.85, p = .123)

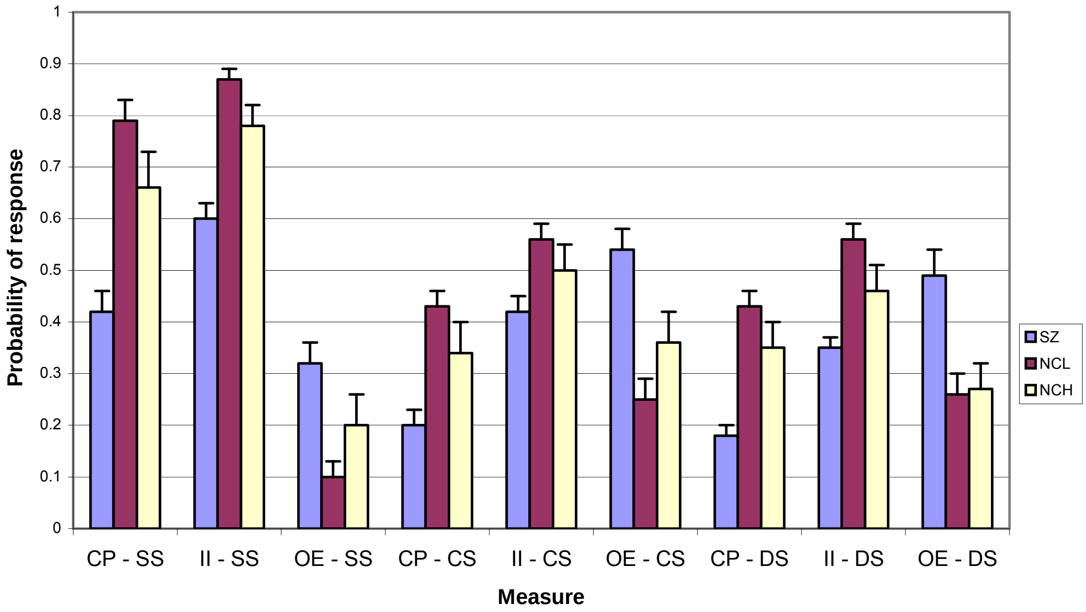

Figure 6.1 - Response probabilities, 95% CI's for Item and Order Recall - Simple, Complex and Delayed Span

Note : SZ – Schizophrenia Group; NCL – Low Schizotypy Control; NCH – High Schizotypy Control; CP – Correct in Position; II – Item Information (proportion correctly recalled regardless of position); OE – Order Errors; SS – Simple Span; CS – Complex Span; DS – Delayed Span.

Table 6.4 – Mean (sd) Item and Order Recall – Simple, Complex and Delayed Span

	Groups		
	SZ (n = 26)	**NCL (n = 27)**	**NCH (n = 15)**
Correct in Position			
Simple Span	0.42 (0.21)	0.79 (0.19)	0.66 (0.25)
Complex Span	0.20 (0.14)	0.43 (0.17)	0.34 (0.22)
Delayed Span	0.18 (0.13)	0.43 (0.18)	0.35 (0.21)
Item Information			
Simple Span	0.60 (0.18)	0.87 (0.11)	0.78 (0.14)
Complex Span	0.42 (0.14)	0.56 (0.16)	0.50 (0.18)
Delayed Span	0.35 (0.56)	0.56 (0.18)	0.46 (0.18)
Order Errors			
Simple Span	0.32 (0.23)	0.10 (0.17)	0.20 (0.23)
Complex Span	0.54 (0.22)	0.25 (0.18)	0.36 (0.24)
Delayed Span	0.49 (0.27)	0.26 (0.18)	0.27 (0.21)

Note: Correct in position – Mean proportion of items recalled in the correct position.
Item Information – Mean proportion correctly recalled in any position.
Order Errors – Mean proportion of movement errors as function of total words recalled.
SZ – Schizophrenia Group; NCL – Low Schizotypy Control; NCH – High Schizotypy Control.

6.3.4 Intrusion Errors

Error information is presented in Figure 6.2 and Table 6.5. Due to the small number of phonological and semantic intrusion errors, all intrusion types were combined for each task and each group. Intrusion and omission errors are reported as proportions in order to avoid artificially inflating differences between the groups due to SZ subjects overall worse performance. Once again a 3 (task) x 3 (group) repeated measures ANOVA was conducted with group (SZ, NCL, NCH) as the between-groups variable, and task type (simple, complex and delayed span) as a within-groups variable. There was a main effect again for task with more intrusions on the simple span tasks than either the complex or delayed conditions $F_{(2,64)}$ = 34.37, p = 0.000. There was no group effect indicating that the SZ group did not have more intrusion errors than the other groups as a proportion of total errors $F_{(2, 65)}$ = 0.353, p = 0.704. There was no significant interaction between the task and the group $F_{(4,130)}$ = 0.84, p = 0.50.

There were no significant correlations between intrusion errors and either NART scores or age for any of the groups, as a result no further investigation of these variables as possible confounds was undertaken in relation to intrusion errors.

6.3.5 Omission errors

More omission errors were made on the complex and delayed tasks than on the simple span task. A 3 x 3 repeated measures ANOVA confirmed this $F_{(2,}$

$_{64)}$ = 15.16, p = 0.000. There was no main effect for group $F_{(2,65)}$ = 0.81, p = 0.449 nor was there a task by group interaction , $F_{(4,130)}$ = 2.06, p = 0.089.

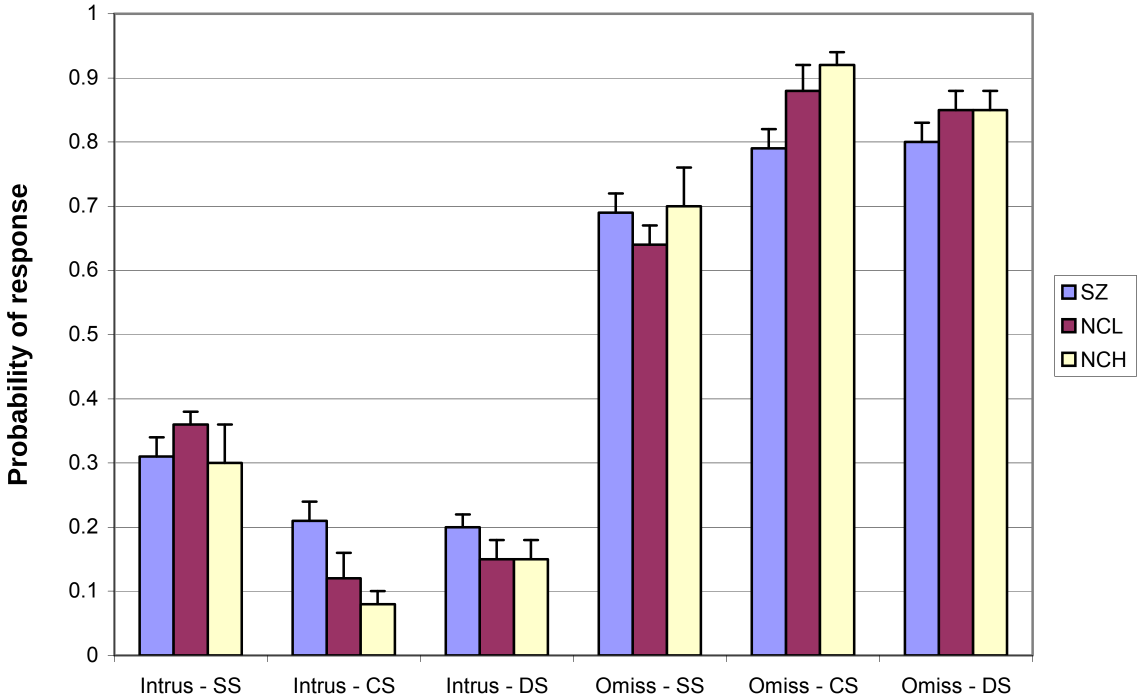

Figure 6.2 – Probabilities and 95%CI's for errors in simple, complex and delayed span

Note : SZ – Schizophrenia Group; NCL – Low Schizotypy Control; NCH – High Schizotypy Control; Intrus – Intrusions; Omiss – Omissions; SS – Simple Span; CS – Complex Span; DS – Delayed Span.

Table 6.5 – Errors on Span Tasks *

	Groups		
	SZ (n = 26)	**NCL** (n = 27)	**NCH** (n = 15)
Intrusions			
Simple Span	0.30 (0.14)	0.34 (0.36)	0.30 (0.25)
Complex Span	0.21 (0.14)	0.12 (0.18)	0.08 (0.06)
Delayed Span	0.20 (0.14)	0.13 (0.14)	0.15 (0.10)
Omissions			
Simple Span	0.69 (0.14)	0.62 (0.37)	0.70 (0.24)
Complex Span	0.79 (0.14)	0.88 (0.18)	0.92 (0.06)
Delayed Span	0.80 (0.14)	0.87 (0.14)	0.85 (0.10)

* Total errors does not include movement errors – intrusions of all types plus omissions

There were no significant correlations between intrusion errors and either NART scores or age for any of the groups, as a result no further investigation of these variables as possible confounds was undertaken in relation to omission errors.

6.3.6 Total Output

In order to assess whether SZ patients simply had less verbal output on all tasks than the control groups, means and standard deviations (Table 6.6) are reported for total output. This figure (Figure 6.3) includes all words produced including intrusion errors. Table 6.6 summarises the total output. There was a main effect for task $F_{(2,64)}$ = 101.34, p = 0.000. There was also a significant effect for group with the SZ $F_{(2,64)}$ = 7.46, p = 0.001. Finally, there was a task by group interaction effect $F_{(4,130)}$ = 3.09, p = .018. Post hoc comparisons indicated that on the complex span task, the SZ patients produced similar levels of verbal output to the other groups (NCL p = 0.435, NCH p = 0.999), On the simple span task the SZ group produced significantly less words than either of the two controls groups (NCL p = 0.000, NCH p = 0.005). Finally, on the delayed span task the SZ group produced less words than the NCL group (p = 0.005) but an equivalent number to the NCH group (p = 0.373). The two control groups did not differ from each other in the total verbal output produced across the three tasks (simple span - p = 0.423, complex span - p = 0.574, delayed pan - p = 0.326).

To explore the possible influence of the NART on total output repeated measures ANCOVA was performed with NART as the covariate. In keeping with the previous analyses, once the NART was entered as a covariate the main effect for task was no longer significant ($F_{2,63}$= 1.26, p = 0.291). The main effect for group remained significant ($F_{2,64}$= 3.60, p = 0.03).

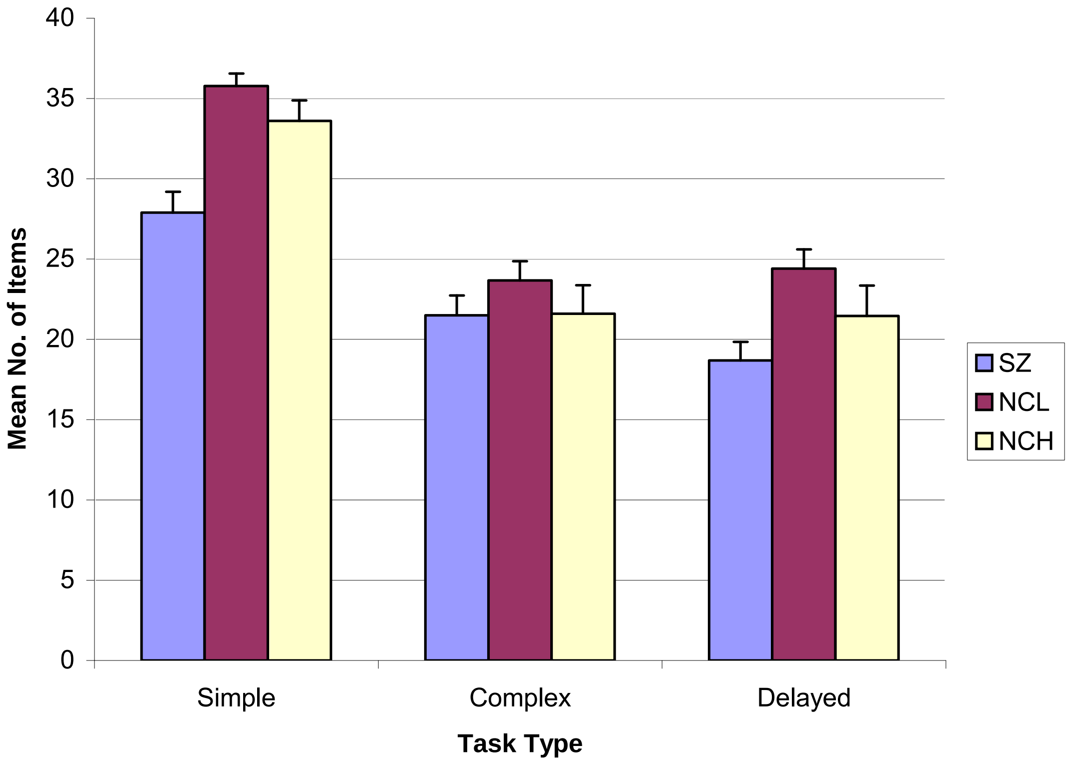

Figure 6.3 - Mean total production, 95% CI's (Total Output)

Note: SZ - Schizophrenia; NCL – Low Schizotypy Control; NCH – High Schizotypy Control

Table 6.6 – Total Output

(mean total production output including intrusion errors)

		Group	
	SZ (n = 26)	**NCL** (n = 27)	**NCH** (n = 15)
Task			
Simple Span	27.88 (6.64)	35.77 (4.03)	33.60 (4.98)
Complex Span	21.50 (6.20)	23.66 (6.26)	21.60 (6.83)
Delayed Span	18.69 (5.91)	24.40 (6.17)	21.46 (7.27)

SZ = Schizophrenia Group; NCL = Normal Control – Low Schizotypy; NHL = Normal Control High Schizotypy
(standard deviation)

6.3.7 Serial Position Effects

6.3.7.1 Simple Span

Results showed that SZ subjects recalled significantly less words than either control groups even in the most simple of the tasks. This was in spite of the task being equal to or below all SZ subjects span (as determined by their digit span score – see table 6.7). Serial position effects were examined for the simple span task in order to explore whether more words were lost from the beginning or the end of the list. Figure 6.4 displays the mean number of items recalled for the groups across serial positions and Table 6.8 shows the mean and standard deviations for items recalled for each serial position by group. All groups lost information across positions. However, it is clear that the SZ subjects recalled fewer words at each serial position. It also appeared that they lost more information towards the end of the list even though it was equal to or less than span. A 4 x 3 repeated measures ANOVA confirmed this with a main effect for position $F_{(3,63)}$ = 102.33, p = 0.000. There was also a main effect for group $F_{(2, 65)}$ = 16.89, p = 0.000 and a position by group interaction $F_{(6, 128)}$ = 4.49, p = 0.000.

Table 6.7 – Digit Span (actual span achieved)

Group	Mean (standard deviation)	Range
SZ	4.93 (0.868)	4 - 8
NCL	6.37 (1.11)	5 - 9
NCH	5.73 (1.44)	4 - 8

SZ = Schizophrenia Group; NCL = Normal Control – Low Schizotypy; NHL = Normal Control High Schizotypy

Post-hoc comparisons revealed that the SZ group performed significantly below the NCL group at all serial positions (p = 0.001, 0.000, 0.000, 0.000 respectively). However, on the first two serial positions, the SZ group and the NCH group were not significantly different (p = 0.077, .077 for positions 1 and 2). The SZ group recall of the last two items on the list was significantly below the NCH group (p = .002, .002 respectively). The two control groups performance was equivalent for recall on the first three serial positions (p = .497, .220, .099 respectively), but on the final item the NCH group recalled less items than the NCL group (p= .022).

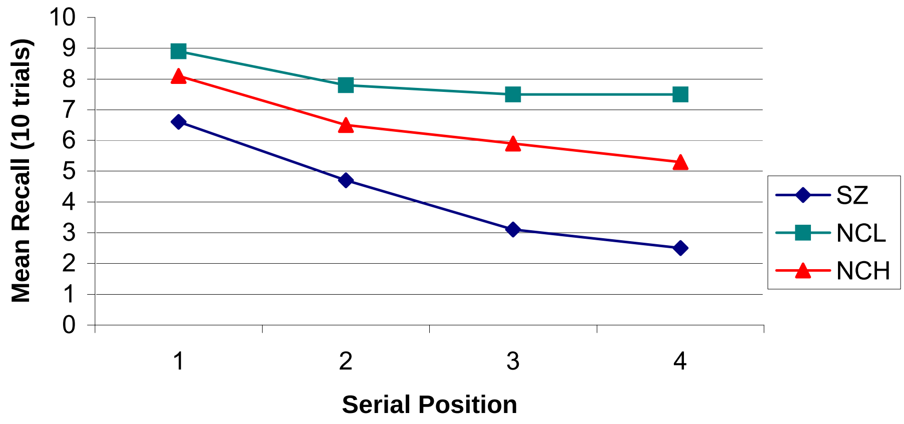

Figure 6.4 - Serial Position Curve - Simple Span

Table 6.8 – Serial Recall x Position
(mean number items recalled in each serial position)

		Group	
	SZ (n = 26)	**NCL** (n = 27)	**NCH** (n = 15)
Simple Span			
Serial Position 1	6.57 (2.68)	9.82 (1.36)	8.13 (2.36)
Serial Position 2	4.73 (2.47)	7.77 (2.12)	6.47 (2.82)
Serial Position 3	3.11 (2.10)	7.48 (2.33)	5.87 (2.95)
Serial Position 4	2.50 (2.34)	7.48 (2.32)	5.33 (2.79)
Complex Span			
Serial Position 1	3.85 (2.03)	6.44 (2.33)	5.33 (2.77)
Serial Position 2	2.35 (2.19)	3.63 (2.36)	3.20 (2.65)
Serial Position 3	1.15 (1.41)	2.63 (1.84)	2.13 (1.92)
Serial Position 4	0.77 (1.34)	4.48 (2.64)	2.80 (2.70)
Delayed Span			
Serial Position 1	3.85 (2.34)	6.63 (2.66)	6.33 (2.53)
Serial Position 2	1.85 (1.71)	4.67 (2.65)	4.00 (2.70)
Serial Position 3	0.88 (1.07)	2.89 (1.50)	1.60 (1.76)
Serial Position 4	0.54 (1.76)	3.11 (2.36)	1.87 (2.03)

SZ = Schizophrenia Group; NCL = Normal Control – Low Schizotypy; NHL = Normal Control High Schizotypy

6.3.7.2 <u>Complex Span</u>

Serial position effects were examined for the complex span task. Table 6.4 displays the means and standard deviations for recall across the four serial positions for the complex task. Figure 6.5 illustrates the serial position effects for the three groups. A 4 x 3 repeated measures ANOVA indicated a main effect for position $F_{(3,63)} = 42.50$, $p = 0.000$ and a main effect for group $F_{(2,65)} = 11.63$, $p = 0.000$. There was also a position x group interaction effect $F_{(6, 128)} = 3.56$, $p = 0.003$.

Post hoc comparisons (Tukey's HSD) revealed that the SZ group recalled significantly less words than the NCL group in positions one ($p = 0.000$) , three ($p = 0.007$) and four ($p = 0.000$), but not in position two ($p = 0.126$). Compared to the NCH group, the SZ groups recall of words in position one ($p = 0.127$), two ($p = 0.508$) and three ($p = 0.188$) did not differ, but they were able to recall fewer words than the NCH group in the final serial position ($p = 0.019$). Although the performance of the NCH group was uniformly below that of the NCL group, none of the differences were significant across the four serial positions ($p = 0.305$, $p = 0.838$, p = 0.640, $p = 0.059$).

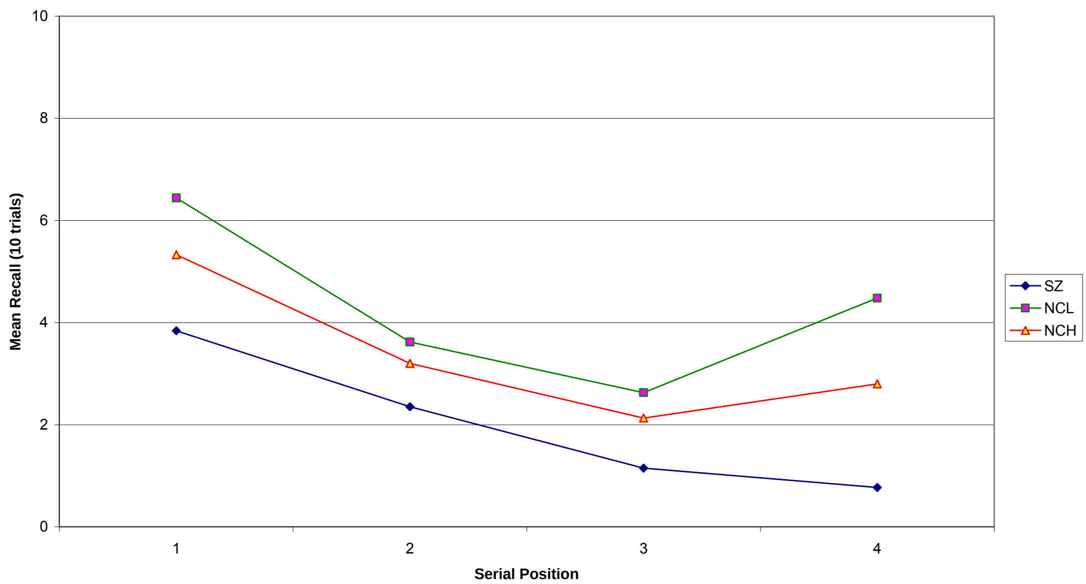

Figure 6.5 - Serial Position Curve - Complex Span

6.3.7.3 Delayed Span

Examination of the serial position effects on the delayed span task revealed a similar pattern to the complex span task. Once again Table 6.4 displays the mean and standard deviations for each of the serial positions for the groups on the delayed task and Figure 6.6 illustrates the serial position effects. A 4 x 3 repeated measures ANOVA once again showed a main effect for position $F_{(3,63)} = 61.42$, $p = 0.000$ and for group $F_{(2,65)} = 15.64$, $p = 0.000$. Although for the delayed task there was no interaction effect $F_{(6,128)} = 1.52$, $p = 0.178$. Post hoc comparisons indicated that the SZ group recalled fewer words than the NCL group at each of the four serial positions (all <0.001). Compared to the NCH group, the SZ group recalled fewer words in position one ($p = 0.009$) and two ($p = 0.017$). In the final two serial positions recall between the NCH and the SZ group did not differ ($p = 0.273$, $p = .077$ respectively). The NCL group and the NCH group's performance did not differ in positions one ($p = 0.924$), two ($p = 0.653$) and four ($p = 0.10$). However, the NCH group recalled fewer words in position three ($p = 0.017$) than the NCL group.

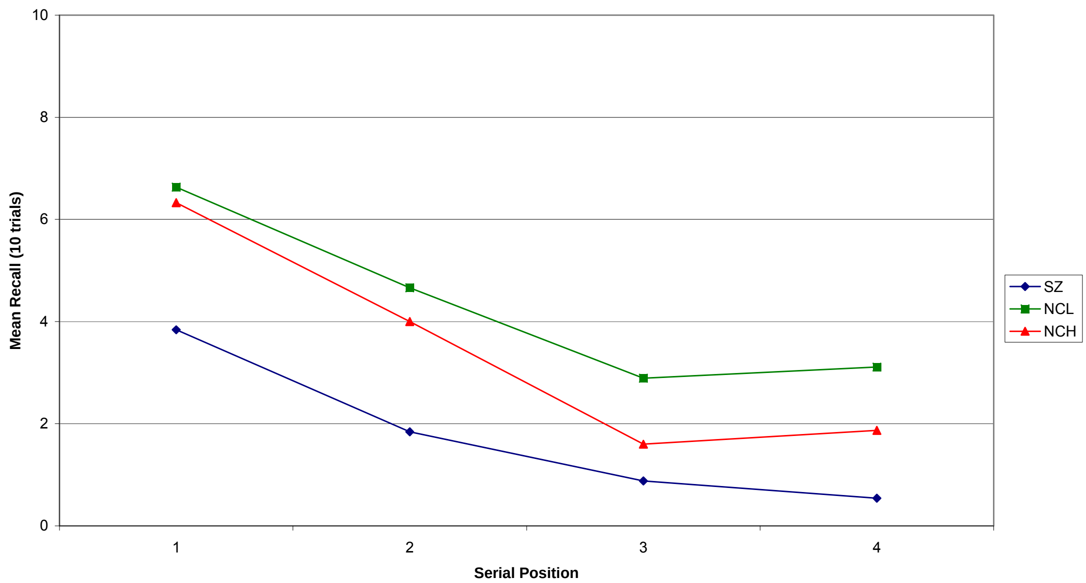

Figure 6.6 - Serial Position Curve - Delayed Span

6.3.8 Relationship between task type, errors and symptoms

In order to investigate whether symptom clusters or SPQ scores were related to serial recall performance or errors on the simple span tasks, correlations between the simple span and symptom variables were examined. Pearson product moment correlations are presented below in Table 6.9. In the SZ group, the PANSS Disorganization factor was related to reduced recall of the last two items in the simple span task. It was also related to Intrusion errors and total recall on the simple span task. High SPQ scores were related to reduced recall particularly of the final two items. The SPQ-Interpersonal factor was related to an increase in order errors. All three SPQ factors were associated with higher Intrusion errors. Only the SPQ-Cognitive/Perceptual factor was related to increased omissions.

Table 6.9 – Correlations between symptoms and simple span performance

	SPQ 1	SPQ 2	SPQ3	SPQ-T	PANSS1	PANSS2	PANSS3	PANSST
	(n=42)	(n=42)	(n=42)	(n=42)	(n=26)	(n=26)	(n=26)	(n=26)
WS 1	-.286	-.224	-.233	-.268	-.126	-.100	-.328	-.235
WS 2	-.285	-.178	-.251	-.252	-.286	-.074	-.356	-.316
WS 3	-.264	-.194	-.150	-.220	-.123	-.139	-.392*	-.208
WS 4	-.412**	-.332*	-.308*	-.393*	-.128	-.209	-.395*	-.333
TOTAL	-.338*	-.252	-.253	-.307*	-.405*	-.166	-.415*	-.320
ORDER	.244	.280	.195	.267	-.181	.081	-.078	-.181
INTRUS	.480**	.212	.291	.335*	-.305	.092	.437*	.344
OMISS	.246	.130	.196	.211	.314	.123	.413*	.402*

SPQ 1 = Disorganisation; SPQ2 = Cognitive/Perceptual; SPQ3 = Interpersonal; SPQT = SPQ total Score; PANSS1 = Reality Distortion; PANSS2 = Psychomotor Poverty; PANSS3 = Disorganisation; PANSST = PANSS total score; WS1 = simple span serial position 1; WS2 = serial position 2; WS3 = serial position 3; WS4 = serial position 4; TOTAL = Simple span total correct recall; ORDER = movement/order errors; INTRUS = Intrusion Errors; OMISS = Omission errors

p<.05; **p<.01

Table 6.10 – Correlations between symptoms and complex and delayed span performance

	SPQ 1	SPQ 2	SPQ3	SPQ-T	PANSS 1	PANSS 2	PANSS 3	PANSS T
	(n=42)	(n=42)	(n=42)	(n=42)	(n=26)	(n=26)	(n=26)	(n=26)
CS-CIP	-.294	-.317(*)	-.353(*)	-.363(*)	.311	-.161	.079	.191
CS-II	-.318(*)	-.229	-.315(*)	-.325(*)	-.104	-.074	-.232	-.107
CS-OI	.229	.286	.219	.278	-.471(*)	.156	-.277	-.316
CS-Intrus	.136	-.150	.004	-.039	-.042	.201	.230	.116
CS-Omiss	.317(*)	.234	.299	.330	-.067	.160	.023	.017
CS-Output	.292	-.245	-.308(*)	-.328(*)	.067	-.160	-.023	-.017
DS-CIP	-.319(*)	-.383(*)	-.338(*)	-.400(**)	.284	-.135	-.005	.123
DS-II	-.345(*)	-.413(*)	-.407(*)	-.446(*)	-.054	-.150	-.077	-.138
DS-OI	.190	.201	.114	.200	-.376	.167	.084	-.122
DS-Intrus	.095	.019	-.104	-.002	.241	.152	.336	.333
DS-Omiss	.229	.354(*)	.402(**)	.378(*)	-.145	-.030	-.207	-.162
DS-Output	-.228	-.355(*)	-.385(*)	-.374(*)	.145	.009	.219	.151

SPQ 1 = Disorganisation; SPQ2 = Cognitive/Perceptual; SPQ3 = Interpersonal; SPQT = SPQ total Score; PANSS1 = Reality Distortion; PANSS2 = Psychomotor Poverty; PANSS3 = Disorganisation; PANSST = PANSS total score; CS = Complex span; DS = Delayed span; CIP = correct in position; II = Item information; OI = Order information; Intrus = Intrusions; Omiss = Omissions; Output = Total verbal output including errors
p<.05; **p<.01

Exploration of the correlations between the SPQ factors and the complex span tasks in the two control groups reveal that the cognitive/perceptual factor is associated with more omissions (see Table 6.10). The interpersonal and the disorganised factors are both associated with fewer words recalled in the correct position in the complex span condition. In the delayed condition, all three factors are associated with recalling fewer words in the correct position. The interpersonal and disorganised factors are also correlated with more omissions in the delayed condition.

For the schizophrenia group, most of the correlations between the PANSS factors and task variables were not significant, with the exception of a single significant correlation between the reality distortion factor and loss of order information in the complex span condition.

6.4 Discussion

Performance across simple, complex and delayed span tasks for the control subjects conformed to previous findings of Tehan et. al. (2001). The control participants demonstrated good recall for simple span, and reduced performance on the complex and delayed span tasks. The Tehan et. al. (2001) study explored two of the signature effects of passive short-term storage (i.e. the word length effect and the phonological similarity effect). The experiment presented here used a combination of short and long words in the four item lists. However, the proportion of words recalled by the control group were quite similar to the proportions reported in the Tehan study. There were increased movement errors as the task became more difficult. With regard to the SZ participants, one of the challenges when comparing the performance of individuals with SZ to those without illness, is to ensure some measure of equivalence in task difficulty level (Chapman & Chapman, 1974). The simple span task on this occasion required participants to only recall four items. Four items were chosen to reflect Cowan's (1990) focus of attention. As all subjects including the SZ group had a span of at least four items, as measured by their forward digit span, it was expected that SZ performance may not be especially impaired on this task. The findings however, clearly indicate that the SZ group had considerable difficulty even at the simplest level and so hypothesis one was not supported. The SZ group's performance was significantly poorer than either of the control groups on almost all measures. It is possible that the rate of presentation of one word per second was insufficient time for SZ subjects to process all of the list information. Hartman and her colleagues (Hartman, Steketee, Silwa, Lanning & McCann, 2002) examined whether SZ subjects' impairments on a WM task was a result of failure to maintain information in the WM system, or a failure to encode information at input. They found that SZ subjects needed the experimental stimulus to be presented for a significantly longer period of time in order to achieve similar rates of recall to control subjects

Hypotheses two and three were supported with the SZ group performing worse than the other two groups in both the delayed and complex span conditions. On all tasks the NCH group performed worse than the NCL group, and better than the SZ group, but these differences were generally not significant. It was predicted that the control group with high psychometric schizotypy scores (NCH) would exhibit reduced performance compared to the NCL group on the more difficult tasks (complex and delayed span). While the mean scores of this group were consistently below the NCL group, the differences did not reach significance. It must be noted that the sample size here was relatively small and differences may have reached significance with a larger sample.

An interesting and unexpected effect arose when an ANCOVA was performed to control for the possible confounding effect of NART scores on the simple, complex and delayed recall performance. Once NART was controlled for, the main effect for task disappeared. While the NART has been used here as a measure of premorbid IQ ability, it is also a reading measure. As such it likely to have much in common with some of the measures of lexical access examined in the following chapter. In Chapter 2 the concept of redintegration was introduced. Hulme et. al. (1991) suggested that redintegration from LTM occurs in serial recall tasks and is a process which accounts for much of the variation not explained by rehearsal processes. It may be that the NART in this experiment is aligned with redintegration and that we are in fact partialing out the redintegration factor when we use the NART as a covariate. It seems that once the NART has been controlled for, the tasks appear equivalent. These results are suggestive of a common storage component underlying all three tasks. The group differences remained on all tasks after controlling for the influence of the NART.

Hypotheses four five and six were somewhat related. It was predicted that performance of the SZ group would be related to symptoms (H4) and that errors would also be related to symptoms in both the SZ group and the NCH group (H6). Hypothesis five was also related to errors and predicted that errors across the tasks would differ as both a function of task and group. The symptom data will be presented together so information relating to H5 will be presented before H4 and H6.

In terms of error patterns, Elvevag et al., (2001) hypothesized that SZ subjects may show a higher proportion of movement errors on serial recall tasks due to problems with mnemonic strategies (using letters as stimuli), however, they found no support for this proposition. The Elvevag study scored movement errors as a proportion of all errors as opposed to the method adopted in this thesis (order errors calculated as a proportion of the total items recalled). Using an index of the proportion of words recalled in their order of presentation, Brebion et. al., (2000) in contrast, did find evidence for more movement errors in serial recall tasks using schizophrenia subjects. In the study presented here there was a main effect for group indicating that as a proportion of total items recalled, SZ patients made more movement errors. It may be that words, in contrast to letters, are more difficult to recall and thus result in less efficient strategies in coding serial position. Elvevag et. al., (2000) also predicted that due to either decreased inhibition, or internal interference, SZ subjects may display a higher proportion of intrusion errors than normal controls. Once again they found that as a proportion of total errors made, intrusion errors constituted only a small percentage of errors and that SZ subjects did not make a disproportionate number of intrusions. In our study, despite hypothesizing that words may result in increased internal interference (or similar to Spitzer et. al. (1994) proposition, reduced inhibition), and may result in a higher rate of intrusion, this was not supported. However, others (Brebion etl.al., 2000) have found evidence for increased intrusion errors in this population. In the experiment presented here, all groups made more intrusion errors on the complex span and the delayed span task compared to the simple span task. The SZ group did not make more intrusions as a function of total errors than the control groups. Similarly, they did not make disproportionately more omission errors than the other groups. So, hypothesis five was partially supported with more movement errors, but no more omission or intrusion errors reported for the SZ group. Examination of serial position effects did reveal that the SZ group were less likely to recall the last two items than the NCL group on the simple span task. Recall of the item in the fourth serial position was also reduced for the NCH group compared to the NCL. This is in contrast to Elvevag's (2001) finding that four item lists were not significantly impaired in SZ subjects. However, once again it may be that using words, and a relatively fast presentation rate in the present study resulted in poorer performance. In both the complex and delayed conditions, the SZ group recalled fewer words than the NCL group in almost every serial position. On the complex span task the SZ group's performance in serial positions one, two and three was equivalent to that of the NCH group. However, the SZ group recalled fewer words in the final serial position than the NCH group. On the delayed span task the SZ group recalled fewer words in position one and two than the NCH group, but the two groups performance was similar for recall of words in the final two serial positions. An inspection of the serial position curves suggests that the SZ group do not exhibit a recency effect on these tasks.

The presentation of the three tasks was randomized for all participants. This meant that the participants did not know which condition they would be presented with from trial to trial and there was a constant switching between the three conditions of simple, complex and delayed tasks. Given that task switching is problematic for individuals with schizophrenia (Meiran, Levine, Meiran, & Henik, 2000; Robert, et. al. 1998), the randomization of the trials may have placed them at a further disadvantage over the control groups.

Finally, performance on the simple, complex and delayed span tasks was examined with reference to symptoms. The three-factor PANSS scores were correlated with span tasks variables for the SZ group and three-factor SPQ scores were correlated with the span task variables for the control groups. It was predicted that omissions would be related to negative symptomatology (PANSS Psychomotor Poverty) in the SZ sample and possibly to the similar SPQ factor (Interpersonal). This was not supported. Only the PANSS disorganised factor and total PANSS score were associated with omissions indicating that those participants displaying the most severe symptoms had most difficulty producing a response. Negative symptoms in the SZ group were not related to any of the output or error measures. It was also hypothesized that intrusions would be related to positive symptoms. Once again this was not supported. However, disorganised symptoms were related to a number of measures including reduced overall output and poorer recall of items in position three and four on the simple span task. Disorganised symptoms have been found to be related to a range of cognitive impairments in SZ (Lucas et. al., 2004; Cameron et. al., 2002). For the complex and delayed conditions there were virtually no correlations between any of the variables (whether they be recall performance or error type) and symptoms as measured by the PANSS in the SZ group. The single correlation between order information in the complex condition and the reality distortion (positive) factor should be viewed with some caution in the absence of any other relationships.

For the control groups there were several small to moderate correlations between many of the SPQ measures and poorer performance on various tasks. On the simple span task, higher scores on the SPQ cognitive perceptual factor were associated with poorer overall recall and increased intrusions. In the complex and delayed conditions a different pattern emerged with the SPQ interpersonal and disorganised factors being associated with poorer overall recall, more omissions and reduced overall output. High scores on the SPQ have been associated with impaired performance in relation to spatial working memory (Park & McTigue, 1997), the Wisconsin Card Sort Test (Daneluzzo et. al., 1998) and the continuous performance test (Chen et. al., 1997; 1998). Relatively little work has been done regarding the relationship between the SPQ and performance on verbal WM tasks and the findings presented here go some way to expanding on our knowledge in this area.

6.5 Chapter Summary

This chapter examined performance across simple, complex and delayed span tasks in three groups, healthy controls with high and low scores on a measure of psychometric schizotypy and a group with a clinical diagnosis of schizophrenia. The patterns of performance by the control groups largely replicate the findings of Tehan et. al., (2001) suggesting that similar patterns are found across all three tasks with performance decrements related to task difficulty. Performance by the schizophrenia group showed deficits on even the simplest of the tasks. Group differences could not be explained simply by differences in IQ as measured by the NART. In addition we had an unexpected finding of the main effect for task on the simple, complex and delayed span tasks disappearing once the NART was controlled for. Equivalency across these tasks is supportive of some common storage mechanism underlying all three tasks. Patterns of errors were similar across the groups once overall levels of performance were taken into account. Schizophrenia participants did make more order errors than the other two groups and this was negatively correlated with disorganised symptomatology. The results presented in relation to the main effect for group lend further support to the notion that similar storage mechanisms may account for the results on all three tasks. The association between disorganised symptoms and loss of items from the end of the list are suggestive of impaired maintenance of item information with a lack of recency effect. Additionally, correlations were found between higher scores on the SPQ interpersonal and disorganised factors and poorer span performance in the complex and delayed conditions. This may suggest that as the tasks become harder, those control subjects who endorse psychotic-like symptoms begin to perform in a similar way to the schizophrenia group.

Chapter 7 - Individual Differences – Contribution to Span Performance.

7.1 Chapter Overview

Research presented in Chapter 2 indicated that individual differences on simple span tasks can be predicted by variability in access to lexical memory, and to a lesser extent, by differences in rehearsal speed. Tehan and colleagues (1999) have speculated that simple, complex and delayed span tasks share commonalities that question the need for separable components of working memory as conceptualised by the work of Baddeley (Baddeley & Hitch, 1974) and Cowan (Cowan et. al., 1999). To add further support to this proposition, if simple, complex and delayed span tasks all share common storage, then it might be expected that speed of access to lexical memory and rehearsal speed may be predictors of complex and delayed span.

As detailed in Chapter 4, there has been limited research to date using SZ patients or at-risk populations examining either of these variables in relation to span tasks. Some researchers have speculated that SZ have impaired rehearsal processes on verbal WM tasks (Elevevag 2002a) and at least one study (Salame et. al., 1998) found that faster articulation speed contributed to better performances on WM tasks. Other research has shown that slowed lexical access in schizophrenia is related to positive and disorganised symptoms of schizophrenia (Minzenberg et. al., 2003). Speed of access to lexical memory in SZ has also been examined in relation to verbal fluency tasks. Vinogradov et. al., (2002) found that in a SZ sample, speed of access to lexical memory (using a reaction time measure on a lexical decision task) was negatively correlated with verbal fluency. They concluded that impaired lexical retrieval and variation in semantic memory organization was related to impaired verbal output in SZ. So with some research indicating that schizophrenia has an impact upon speed of access to lexical memory, the pattern of predictors underlying performance on span tasks may be different for this population.

Thus, the current experiment examines the contribution of speed of access to lexical memory and articulation speed to recall performance across simple, complex and delayed working memory tasks. As noted in Chapter 2, rehearsal according to Baddeley's model (Baddeley & Wilson, 1985) is not by actual articulation, but is a covert, subvocal process. However, others (Landauer, 1962; Standing & Curtis, 1989) report that actual articulation speed correlates with rehearsal speed and Baddeley has always used measures of articulation speed to operationalise rehearsal speed. Caveats to this relationship will be further raised in the discussion. Such an examination has never been completed with either a normal population or with a clinical population, so the results are very much exploratory at this stage.

7.2 Method of Analysis

The first issue regarding the analyses in this chapter is to do with the way in which the participants are grouped and then how the different groups are treated. The previous chapter hinted at some differences between the high and low schizotypy groups, but these differences tended to be weaker than the differences between the schizophrenia group and the rest. Thus, the first decision is to collapse across schizotypy types to form two groups, a normal control and a clinical schizophrenia group. With regards to how one might treat the two groups, the assumption that underpins the thesis is that there may well be differences in the cognitive processes between the SZ group and the normal controls. As such, the assumption being tested in this chapter is that the pattern of individual differences may be different for the clinical group than for the control group. Therefore, separate but parallel analyses will be conducted for the two groups.

In doing the analyses, the aim is to adopt a construct approach rather than an individual measures approach. Thus, different measures of articulation speed (alphabet, counting and serial 3's), lexical access ability (lexical decision, word naming, non-word naming, and pseudohomophone naming) have been adopted, as have a number of different measures of memory (digit span forward, digit span backward, letter-number sequencing, word span, operation span and delayed span). However, it is assumed that these individual tasks are imperfect measures of the underlying psychological constructs of articulation speed, lexical access ability, and perhaps separate constructs for short-term memory and working memory. The problem arises as to how to combine the measures such that they represent the underlying constructs. Historically, factor analytic procedures have been the most widely used method and in recent times structural equation modeling has become prevalent. In both instances large numbers of participants are required to obtain reliable data. Given the low number of participants in the current study, such methods are unlikely to provide reliable composite measures. A solution to this problem has been attempted in the following way.

Firstly, there are a number of studies that show that the three measures of articulation speed that have been selected from the WMS-R consistently load on the same factor (Bornstein & Chelune, 1988; Roid, Prifitera & Leadbetter, 1988). Likewise, at least two published papers (Tehan & Lalor, 2000; Tehan, Fogarty & Ryan, 2004) contain identical lexical access measures to those used here. At face value one might question whether non-word and pseudohomophone naming are tests of lexical access given that by definition there are no lexical representations stored in memory for non-words. However, these four tasks are the most widely used measures in the word decoding (word reading) and lexical access literature. Just as importantly, in the Tehan and Lalor (2000), and Tehan et al. (2004) research the four measures loaded on the same factor when analyzed using factor analysis and structural equation modeling. Thus on both theoretical and empirical grounds there is reason to suppose that the four measures are tapping important processes in deriving a response to be recalled. These two Tehan data sets are also important because they also contain similar measures of articulation speed and show that the measures of articulation speed are highly correlated with each other but are less highly correlated with the measures of lexical access. Thus, in the current experiment, the first step is to compare the pattern of correlations among lexical access and speed of articulation measures obtained here with the pattern of correlations found in previous studies.

The second step is to explore the underlying structure of the memory measures. In earlier chapters the point was made that there is substantial disagreement about the independence of short-term memory tasks and working memory tasks. In the individual differences literature the distinction has been hard to maintain, given that simple span measures and working memory measures tend to be highly correlated and very often load on the same factors when factor analytic procedures are used (Bayliss, Jarrold, Gunn & Baddeley, 2003; Conway, Cowan, Bunting, Therriault & Minkoff, 2002; Engle, Tuholski, Laughlin & Conway, 1999). Thus, the second expectation would be that there should be high levels of correspondence among the memory measures.

Given that the expected patterns emerge, the next step is to form composites. The procedure will be to standardize the scores on each variable and then simply to sum the standardized scores of the respective measures into their appropriate composites. In the Tehan and Lalor (2000) and the Tehan, Fogarty and Ryan (2004) data sets, the factor loadings (and Beta weights) were roughly equivalent for all measures in their respective sets. Thus simple unitary weightings seem appropriate. Using this method it is expected that three composites will be formed, one for articulation speed, one for lexical access and one for memory performance. There is the proviso that at least theoretically, two memory composites may be necessary one for short-term memory and one for working memory.

The final step is to examine the relative contribution of speed of articulation and lexical access ability to memory performance, by way of multiple regressions. The two composite scores will serve as independent variables and will be regressed onto the memory composite(s) as the DV(s).

7.3 Hypothesis relating to contributions to span performance

Hypothesis 1 – It is predicted that access to lexical memory and articulation speed will be predictors of memory performance for the control group.

Hypothesis 2 - Results from the previous chapter suggest that the patterns of performance of schizophrenia patients broadly conform to that of controls, but at a reduced level. As such it may be expected that the lexical access and articulation speed may also be predictors of span performance. However, it is also expected that clinical variables will have an impact on the performance of the schizophrenia group.

7.4 Methods

7.4.1 Participants

For this chapter, analyses were undertaken for those participants with a complete data set. This resulted in a total of 26 subjects with a current DSM-IV diagnosis of schizophrenia (SZ), and 42 control subjects (high and low schizotypy groups were combined). Information on recruitment of subjects is presented in Chapter 5. All subjects were tested individually.

7.4.2 Measures

Articulation Tasks

7.4.2.1 Alphabet, backwards counting and serial threes

These three tasks comprise the Mental Control component of the Wechsler Memory Scale Revised (Wechsler, 1981). In the alphabet task, subjects are instructed to repeat the alphabet as quickly as possible. A digital stopwatch recorded the time taken and number of errors was also noted. In the backwards-counting task, subjects are instructed to count backwards from 20 to 1 as quickly as possible, once again, time taken (in seconds) and errors are recorded. In the final "serial 3's" task, participants are instructed that they are to start at 1 and then add three to this and each subsequent number until they are instructed to stop. Subjects are stopped when they reach the number 40. Once again time taken and number of errors is also recorded.

Lexical Access Tasks

7.4.2.2 Lexical decision

Subjects were presented with a list of 40 low frequency, five-letter strings from the Toronto Word Pool norms (Friendly, Franklin, Hoffman, & Rubin, 1982). The letters in 20 of these words were substituted to create phonotactically legal nonwords (e.g. abort → amort) (see Appendix A). The newly created nonwords were then randomly interspersed among the remaining words. The list was divided into four columns and was displayed on the computer screen for 20 seconds. The subjects were required to look at each letter string and decide as quickly as possible whether the letter string was an English word or not. Instructions in this and subsequent speed tasks stressed the need for accuracy. The subjects were to go as fast as they could, provided they made accurate responses. Lexical performance was calculated by summing the number of correct responses within the 20-second time limit. In addition, errors were also recorded and reported as a total.

7.4.2.3 Word naming task

The materials for the task included 50 low frequency five-letter words from the Toronto Word Pool norms (see Appendix A). The word list was divided into five columns, and the subjects were required to read the words aloud moving down the columns until the list disappeared from the screen. A word-naming score was calculated by summing the total number of words read correctly within the 20-second interval.

7.4.2.4 Non-word naming

In this task the 42 stimulus items were constructed in the same way as the nonwords used in the lexical decision task. The participants were presented with three columns of 14 nonwords (see Appendix A) and were instructed to read down the column as quickly as possible, reading each nonword aloud. Once again the list disappeared from the screen after 20 seconds and the score was calculated by summing the number of letter-strings correctly pronounced within the 20-second time limit.

7.4.2.5 Pseudoword Naming

The Turse Phonetic Association Test (Turse, 1940) is a pseudohomophone-naming task (a naming task using nonwords that sound like words when pronounced e.g., *phocks→fox, kayj→cage, durt→dirt, etc.*). Lexical access literature was accessed to find appropriate examples of such pseudohomophones. A total of 42 pseudohomophones (see Appendix A) were presented in three columns on the computer screen. The subjects were instructed that they would be presented with a series of nonwords that, when pronounced, would sound like legitimate English words. Their task was to read aloud down each column as quickly as possible. Once again the number of pseudohomophones correctly pronounced in 20 seconds was summed and this score was used as a dependent variable. In this task subjects were told that letter strings would appear on the screen and if they pronounced the strings phonetically, they would sound like a proper word. Participants had to pronounce as many words as they could in a 20 second period before the screen went blank.

Span Tasks

7.4.2.6 Digit Span

This version of digit span is taken from the Wechsler Memory Scale – Revised (WMS-R) (Wechsler, 1981). In this task subject are read a series of digits at the rate of one per second. There are two sub-tasks, digits forward and digits backward. Digits forward starts with two digits in a string; the task consists of two trials at each digit length from two until nine. The examiner stops the task when the subject fails two trials of the same length string. Digits backwards consist of strings from two to eight. Once again the digits are read at the rate of one per second. In this task though, the subject is instructed that on completion of the read digits, he/she is to repeat them back to the examiner in the reverse order.

Digit span in the format presented in the Wechsler scales is the most common format for the presentation of serial recall of verbal material (Lezak, 1997). Considered a test of short-term storage capacity, or attentional capacity, it has been used extensively in psychiatric research as a measure of short-term verbal memory (Conklin et. al., 1998; Stirling et. al., 1997). Scoring on this task traditionally allocates one point for each correct string, and the total is then summed. The manual for the WMS-R provides adjusted aged scaled scores. However, for the purposes of this chapter, the number of digits actually achieved, that is, the number correctly recalled in the presented order, was used as the dependent variable, with separate scores for digits forward and backward.

7.4.2.7 *Letter-number sequencing.*

Based on the task originally developed by Gold, Carpenter, Randolph, Goldberg and Weinberger (1997), this measure of working memory and attention has since been incorporated into the WAIS-III and the WMS-III. Interspersed digits and letters are presented orally to a subject. They are told that they need to listen to the information and then tell the examiner the numbers first, in order from smallest to largest digit, and then the letters in alphabetical order. Thus, they are required to simultaneously track this information, sequence the stimuli and then recall the reorganized sequence to the examiner. For example a sequence may be presented as *"7-T-4-A"*. The subject must reorganize the sequence and produce the string as "*4-7-A-T".* The raw score of the number of correctly recalled letters and digits was used as the dependent measure.

7.4.2.8 *Simple , Complex and Delayed Word Span*

These tasks were fully described in Chapter 6. But briefly, 30 trials (10 of each) were presented to each participant. The simple span task involved presentation of four words presented on an Apple Mac II at the rate of one word per second. Participants then were asked to recall all four words immediately after presentation when a question mark appeared on the screen. The second condition was a complex span task in which each of the four to-be-remembered words was followed by a two-digit number (e.g. *fish* 19 *lice* 52 *reel* 87 *keats* 61). As previously detailed, this task is much simpler than the complex span task of Engle and Turner (1990), however, screening with some schizophrenia patients prior to data collection indicated that the Engle and Turner task was too difficult for this subject group. Shifting attention away from the to-be-remembered words by reciting the digits aloud was thought to provide a version of the complex span task that would not be beyond the SZ group's capabilities. The final delayed recall task once again consisted of four words and four digits. In this condition all four, two-digit numbers appeared after the four words creating a delay prior to recall of the to-be-remembered words (e.g. *kerb hoard addict detergent 65 21 49 17)* and subjects were instructed once again to say the numbers out loud. The order of the three conditions was randomly distributed across the thirty trials. Total words correctly recalled in position across the trials were summed and used as the span measure.

7.4.3 Procedures

Testing was conducted under standard laboratory conditions for all control subjects. Tasks were administered in the following order for all participants; Articulation Tasks, Digit Span (forward and backward), Lexical Access Tasks, Word Span Tasks. Timing measures were obtained using a standard digital stopwatch, and the experimenter recorded all verbal responses. Total testing time was approximately 90 minutes.

7.4.4 Confounding variables

In chapter 5 it was reported that the SZ group were older than the NCH group. The NART scores of the NCL group were also significantly higher than the SZ group and there were more males in the SZ group. As a result correlations were conducted between these (age, gender and NART scores) possible confounding variables and the dependent variables under consideration. Full correlation matrices are presented in Appendix L. Inspection of the data revealed that only the NART emerged as a likely confounding variable.

7.5 Results

7.5.1 Group Differences on Measures

The previous chapter indicated that there were group differences across the memory measures examined. The first analysis of this chapter explores standard descriptive statistics for all the measures used and then explores group differences. Table 7.1 summarizes the data.

Table 7.1 – Descriptive statistics for articulation, lexical access and memory measures

	Clinical Group		Control Group		Group Differences	
	Mean	Std. Deviation	Mean	Std. Deviation	*F* (1,66)	*p*
CountBack	9.50	4.13	6.67	1.60	15.95	0.0002
Alphabet	5.75	1.93	5.16	1.73	1.70	0.1967
Count3	20.95	6.26	18.54	8.08	1.68	0.1989
LexDec	11.85	4.89	17.55	3.58	30.66	0.0000
WordNam.	23.42	7.75	29.67	4.81	16.88	0.0001
NonwordNam	13.08	4.72	18.02	4.81	17.24	0.0001
Pseudohom	4.23	3.61	7.05	3.86	8.98	0.0038
DigFwd	5.04	0.87	6.14	1.26	15.37	0.0002
DigBack	3.38	1.02	4.55	1.27	15.49	0.0002
LetNumSeq	5.08	2.92	10.00	2.72	49.61	0.0000
Simple Span	17.15	8.40	29.57	8.91	32.53	0.0000
Comp Span	7.96	5.61	15.81	7.68	20.38	0.0000
Del Span	7.19	5.18	16.00	7.59	27.08	0.0000

Group differences were initially explored by an ANOVA for each variable, which indicated that there were overall differences between the groups (See Table 7.1). More importantly, group comparisons for the individual measures revealed that there were reliable differences on all measures save for quickly articulating the alphabet and counting in threes.

As in the previous chapter the impact of the NART scores as a possible confounding variable needed to be explored. An ANCOVA was performed to compare differences between the groups on the memory, lexical access and articulation measures. The independent variable was the group (schizophrenia, control) and the dependent variables were as per Table 7.1. Participants NART scores were used as the covariate in the analysis. Table 7.2 displays the adjusted means for the two groups once the influence of the

NART has been accounted for and the results of the analysis. After adjusting for the NART all of group differences remained significant.

There were significant relationships between all of the variables and the NART except for the counting backwards variable (p = .07). Lexical decision and digit span backwards were significant at p < .05. All others were significant at p < .01. The NART explained between 5% (count backwards) and 34% (digit span forward) of the variance in the dependent variables.

Table 7.2 – Output for ANCOVA analysis including adjusted means

	Clinical Group		Control Group		Group Differences		
	Adj Mean	Std. Error	Adj.Mean	Std. Error	*F* (1,66)	*p*	*eta squared*
CountBack	9.24	.563	6.82	.438	9.96	.000	.235
Alphabet	5.51	.348	5.31	.27	5.02	.009	.134
Count3	19.91	1.41	19.17	1.10	5.49	.006	.145
LexDec	12.35	.80	17.23	.62	20.07	.000	.382
WordNam.	24.51	1.10	28.99	.862	18.67	.000	.365
NonwordNam	13.99	.849	17.45	.661	21.22	.000	.395
Pseudohom	4.90	.689	6.62	.532	13.98	.000	.301
DigFwd	5.30	.186	5.98	.45	28.52	.000	.467
DigBack	3.53	.229	4.45	.178	11.88	.000	.268
LetNumSeq	5.68	.038	.712	.029	49.25	.000	.602
Simple Span	.473	.033	.380	.026	34.08	.000	.512
Comp Span	.223	.031	.383	.025	15.96	.000	.329
Del Span	.207	.476	9.62	.370	22.59	.000	.410

As the differences between the groups remained significant after the introduction of the NART as a covariate, it was not considered in further analyses.

The results confirm the findings of Chapter 6 that there are differences in memory performance, but they show that group differences are more widespread in that there are clear differences in measures assumed to tap ability in accessing lexical memory. The differences in articulation speed do not seem to be as robust, although still observable with counting backwards. This measure (and that of word naming) seems somewhat at odds with the rest of the measures in that the variability among the clinical group is over twice that in the control group, which is not the case with any of the other variables. Looking at the distribution of scores, there were some outliers who were faster than their peers, but they did not differ to the extent that there were grounds for excluding them.

7.5.2 Correlations

The correlations between the measures are summarized in Table 7.3.
In looking at the control group there are three things to note. Firstly, the three purported measures of articulation speed correlate reasonably highly with each other. Secondly, the four measures of lexical access do not correlate as highly with each other. This is problematic. Moreover, the word naming variable seems to correlate more highly with the articulation measures. This would be worrisome except that Tehan and Lalor (2000) found in their factor analyses that this measure loaded on both the speed of articulation and lexical access factors. That is, the current pattern of correlations involving word naming has been observed before. Thirdly, all the memory measures are intercorrelated. The five forward recall measures are highly correlated; backward recall appears to be less so. On the basis of the correlations

observed here, there is no justification for forming separate short-term memory and working memory composites. Rather the high correlations among memory measures replicate previous findings and suggest a single memory composite should be derived. Lastly, as a general statement, both the articulation and lexical access measures are correlated with all the memory measures although for individual correlations on individual measures, those correlations may not be significant. In short, the pattern of correlations observed here are by and large consistent with expectations and replicate previous findings. The only real concern is the lack of consistency among the lexical access measures.

In looking at the clinical group, the three articulation measures are correlated, but not as highly as was the case with the control group. In contrast, the measures of lexical access are all highly correlated; much more so than with the control group. The correlations among the memory measures are very different to that observed in the control group. Forward digit span, backward digit span and letter-number sequencing are highly correlated with each other, weakly correlated with word span and not correlated with either operational span or delayed span. Word span appears to be weakly correlated with most of the other memory measures. The two most difficult tasks are not correlated with any other memory measures but are correlated with each other. The pattern of correlations leads one to suspect that there are three constructs here. The first involves the recall of highly familiar materials such as digits and letters that are repeated from trial to trial. The second reflects simple span for words and the third represents complex span for words. Lastly, articulation speed and lexical access measures are generally correlated with the familiar materials memory measures, lexical access seems to be correlated with the simple word span measure, but articulation measures are not. Lastly, none of the measures correlate with the complex span tasks. In short, the individual difference effects in the clinical group look very different to those observed in the control group.

7.5.3 Regressions

The consistent pattern of correlations involving speed of articulation and lexical access measures obtained across both groups suggested that composites for the articulation and lexical access constructs should be formed. Thus, z-scores for each person were calculated for each of the seven variables. The z-score was based upon the means and standard deviations for each group. The articulation composite score was then calculated by simply summing the z-scores for the alphabet, counting backward and counting in three's measures. Likewise, the lexical access composite was calculated by summing the z-scores for the lexical decision, word naming and pseudohomophone naming tasks.

Table 7.3 – Correlations between articulation, lexical access and memory measures

Control Group													
	Count Back	Alphabet	Count 3s	Lex Dec	Word Name	Nonword Name	Pseudo-hom	Dig Fwd	Dig Back	Let Num Seq	Word Span	Op Span	Del Span
CountBack	1.00	0.58**	0.61**	-0.09	-0.57**	-0.37*	-0.15	-0.45**	-0.24	-0.46**	-0.57**	-0.53**	-0.56**
Alphabet	0.58**	1.00	0.51**	-0.10	-0.50**	-0.25	-0.11	-0.39*	-0.22	-0.39*	-0.33*	-0.34*	-0.41**
Count3	0.61**	0.51**	1.00	-0.24	-0.51**	-0.42**	-0.34*	-0.49**	-0.27	-0.60**	-0.54**	-0.58**	-0.63**
LexDec	-0.09	-0.10	-0.24	1.00	0.29	0.53**	0.20	0.37*	0.27	0.19	0.37*	0.35*	0.29
WordNam.	-0.57**	-0.50**	-0.51**	0.29	1.00	0.56**	0.23	0.41**	0.15	0.51**	0.50**	0.58**	0.58**
NonwordNam	-0.37*	-0.25	-0.42**	0.53**	0.56**	1.00	0.39*	0.58**	0.40**	0.49**	0.46**	0.53**	0.44**
Pseudohom	-0.15	-0.11	-0.34*	0.20	0.23	0.39*	1.00	0.41**	0.11	0.29	0.45**	0.38*	0.36*
DigFwd	-0.45**	-0.39*	-0.49**	0.37*	0.41**	0.58**	0.41**	1.00	0.41**	0.67**	0.67**	0.64**	0.65**
DigBack	-0.24	-0.22	-0.27	0.27	0.15	0.40**	0.11	0.41**	1.00	0.23	0.30	0.29	0.33*
LetNumSeq	-0.46**	-0.39*	-0.60**	0.19	0.51**	0.49**	0.29	0.67**	0.23	1.00	0.49**	0.68**	0.64**
WordSpan	-0.57**	-0.33*	-0.54**	0.37*	0.50**	0.46**	0.45**	0.67**	0.30	0.49**	1.00	0.73**	0.65**
OpSpan	-0.53**	-0.34*	-0.58**	0.35*	0.58**	0.53**	0.38*	0.64**	0.29	0.68**	0.73**	1.00	0.85**
DelSpan	-0.56**	-0.41**	-0.63**	0.29	0.58**	0.44**	0.36*	0.65**	0.33*	0.64**	0.65**	0.85**	1.00
Clinical Group													
	Count Back	Alphabet	Count 3s	LexDec	Word Name	Nonword Name	Pseudo-hom	Dig Fwd	Dig Back	Let Num Seq	Word Span	Op Span	Del Span
CountBack	1.00	0.31	0.43*	-0.50**	-0.59**	-0.37	-0.30	-0.20	-0.35	-0.37	-0.43*	-0.07	0.13
Alphabet	0.31	1.00	0.50**	-0.18	-0.38	0.03	-0.31	-0.30	-0.37	-0.48**	-0.22	-0.04	0.09
Count3	0.43*	0.50**	1.00	-0.37	-0.32	0.00	-0.26	-0.05	-0.32	-0.50**	-0.30	0.16	0.15
LexDec	-0.50**	-0.18	-0.37	1.00	0.74**	0.52**	0.55**	0.31	0.25	0.31	0.64**	-0.02	0.10
WordNam.	-0.59**	-0.38	-0.32	0.74**	1.00	0.54**	0.64**	0.35	0.50**	0.62**	0.66**	0.03	0.17
NonwordNam	-0.37	0.03	0.00	0.52**	0.54**	1.00	0.38	0.01	0.16	0.15	0.43*	-0.25	-0.19
Pseudohom	-0.30	-0.31	-0.26	0.55**	0.64**	0.38	1.00	0.22	0.15	0.35	0.33	0.14	0.02
DigFwd	-0.20	-0.30	-0.05	0.31	0.35	0.01	0.22	1.00	0.62**	0.46**	0.34	-0.17	-0.08
DigBack	-0.35	-0.37	-0.32	0.25	0.50**	0.16	0.15	0.62**	1.00	0.69**	0.32	-0.08	0.03
LetNumSeq	-0.37	-0.48**	-0.50**	0.31	0.62**	0.15	0.35	0.46**	0.69**	1.00	0.46**	0.14	0.15
WordSpan	-0.43*	-0.22	-0.30	0.64**	0.66**	0.43*	0.33	0.34	0.32	0.46**	1.00	0.06	0.39*
OpSpan	-0.07	-0.04	0.16	-0.02	0.03	-0.25	0.14	-0.17	-0.08	0.14	0.06	1.00	0.68**
DelSpan	0.13	0.09	0.15	0.10	0.17	-0.19	0.02	-0.08	0.03	0.15	0.39*	0.68**	1.00

** Correlation is significant at the 0.01 level (2-tailed) ; * Correlation is significant at the 0.05 level (2-tailed)

Calculating memory composites was done in the same manner. For the control group, the z-scores of all six memory tasks were summed. For the clinical group the z-scores for the forward and backward digit span and the letter-number sequencing measures were summed, to form a *familiar materials* composite. The forward word span score served as the second measure. The third composite was formed by summing the scores of the operation span and delayed span composites. The patterns obtained with the individual measures are, not surprisingly, maintained with the composite scores. Thus for the Control Group, articulation and lexical access composites are correlated with the memory composite, with lexical access having the higher correlation. With the clinical group, articulation and lexical access composites are correlated with both the familiar materials and forward word span measures, but not with the complex span composite.   Correlations for the composite scores are presented in Table 7.4.

Table 7.4 – Composite score correlations

	Articulation	**Lexical access**	**Familiar Materials**	**Simple span (word span)**	**Complex-Delayed Span**
SZ					
Articulation	1.00	0.47**	0.39*	0.37*	-0.09
Lexical Access	0.47**	1.00	0.48**	0.61**	0.09
Fam Materials	0.39*	0.48**	1.00	0.37*	0.00
Simple Span	0.37*	0.61**	0.37*	1.00	0.27
Comp-Delay Span	-0.09	0.09	0.00	0.27	1.00
	Articulation	**Lexical Access**	**Memory**		
Control					
Articulation	1.00	0.49**	0.67**		
Lexical Access	0.49**	1.00	0.66**		
Memory	0.67**	0.66**	1.00		

The determinants of memory performance were evaluated via standard multiple regression techniques where articulation and lexical access composites were simultaneously regressed onto the memory composites. In the case of the control group, there was a single DV, that of the memory composite. For the clinical group there were three such regressions; one each for the three memory measures. The outcomes of these analyses are presented in Table 7.5

Table 7.5 – Regression analyses for clinical and control groups on composite measures

Control				
Memory	R Square	df	F	Sig.
	0.59	2,39	27.65	0.0000
		Beta	t	Sig.
	Articulation	-0.33	3.20	0.0026
	Lexical Access	0.66	6.41	0.0000
Schizophrenia				
Familiar Materials	R Square	df	F	Sig.
	0.29	2,24	4.96	0.0158
		Beta	t	Sig.
	Articulation	-0.41	-2.09	0.0478
	Lexical Access	0.21	1.08	0.2921
Forward Word Span	R Square	df	F	Sig.
	0.42	2,24	8.53	0.0015
		Beta	t	Sig.
	Articulation	-0.16	0.87	0.3895
	Lexical Access	0.56	3.13	0.0045
Complex Span	R Square	df	F	Sig.
	0.01	2,24	0.16	0.8507
		Beta	t	Sig.
	Articulation	0.13	0.57	0.5736
	Lexical Access	0.06	0.27	0.7849

For the control group, individual differences in articulation speed and lexical access accounted for a significant 59% of the variance in the scores on memory performance. Both factors significantly contributed to memory performance, but the beta weights and t-values would indicate that lexical access ability was the more important of the two variables. This finding replicates those of Tehan and Lalor (2000) and Tehan et al., (2004).

With the clinical group, the patterns change. With memory for digits and letters as the composite DV, 29% of the variance is accounted for by the two predictor composites. However, it appears that it is the individual differences in rehearsal ability that are producing this effect, in that the beta weight for articulation is twice that of lexical ability and differences in lexical ability are not significantly making a contribution to explanatory power. With forward word span, the pattern is reversed in that differences in lexical access ability make a significant contribution to the 42% of common variance whereas articulation speed has little impact. In this instance the beta weight for lexical access is three times that of the articulation measure. As far as memory performance on the complex span tasks go, neither variable has an explanatory role in memory performance.

In order to supplement the above findings, three additional regression analyses were undertaken for both groups with Letter-Number Sequencing, Complex Span and Delayed Span as the dependent variables. These analyses directly examined the contributions of articulation speed and lexical access in those tasks generally seen as measures of WM (letter-number sequencing and complex span) and LTM (delayed span). Table 7.6 displays the results of these analyses.

Table 7.6 – Regression Analyses - Supplementary

Control				
Let/Num Seq	R Square	df	F	Sig.
	0.393	2,39	12.63	0.000
		Beta	t	Sig.
	Articulation	-.419	2.91	.006
	Lexical Access	.302	2.09	.043
OpSpan				
	R Square	df	F	Sig.
	.489	2,39	18.66	.000
		Beta	t	Sig.
	Articulation	-.340	2.57	.014
	Lexical Access	.465	3.52	.001
Del Span				
	R Square	df	F	Sig.
	.492	2,39	18.88	.000
		Beta	t	Sig.
	Articulation	-.458	3.48	.001
	Lexical Access	.350	2.66	.011
Schizophrenia				
Let/Num Sequenc				
	R Square	df	F	Sig.
	0.389	2,24	7.32	0.003
		Beta	t	Sig.
	Articulation	-.510	2.75	.011
	Lexical Access	.190	1.02	.316
OpSpan				
	R Square	df	F	Sig.
	.001	2,24	0.10	.990
		Beta	t	Sig.
	Articulation	.009	.036	.972
	Lexical Access	-.024	.101	.920
Del Span				
	R Square	df	F	Sig.
	.043	2,24	.519	.602
		Beta	t	Sig.
	Articulation	.233	1.00	.326
	Lexical Access	.147	.634	.533

The results for the control group are similar across the three tasks with both rehearsal ability and speed of lexical access making significant contributions.

For the clinical group, neither rate of articulation nor speed of lexical access predict performance on complex or delayed span tasks. On the somewhat easier Letter-Number sequencing task rehearsal ability is the only contributor.

7.5.4 Relationship to clinical variables

Given the patterns of performance were somewhat different for the two groups, correlations between the articulation, lexical access and memory variables and measures of symptoms were examined for the schizophrenia group (see Table 7.7).

Table 7.7 Correlations between symptom measures, articulation, lexical decision and memory variables for Clinical group

	Articulation	Lexical Access	Familiar Materials	Forward Word Span	Complex Span
PANSS Real Distortion	0.156	**-0.399***	0.024	-0.181	0.325
PANSS Poverty	0.301	-0.368	**-0.432***	-0.166	-0.161
PANSS Disorganisation	0.252	**-0.639****	**-0.462***	**-0.415***	0.040
PANSS total	**0.391***	**-0.625****	-0.387	-0.320	0.171

p<.05; **p<.01

Examining the correlations matrix for the clinical group, disorganized symptoms are negatively associated with memory for digits and letters and forward word span.   There was also a modest correlation between the reality distortion (positive) factor on the PANSS and lexical access. A more robust association was found between the disorganised factor and lexical access. More prominent negative symptoms also appear to be associated with poorer recall of familiar materials.

7.6 Discussion

The results showed that the control group performed as per previous research with high correlations among the articulation variables and less robust, but still generally significant correlations among lexical access variables. They also replicate findings of high correlations between STM and WM components that lend further support to the idea that it is hard to distinguish between tasks. Similar to prior findings of Tehan and colleagues (Tehan & Lalor, 2000; Tehan et. al., 2004), both lexical access and rehearsal are predictors of performance on STM tasks. In addition they also show that these two variables predict WM performance as well. The supplementary regression analyses for the control group clearly show that lexical access and to a less extent, articulation speed are predictors of two tasks widely regarded in the literature as being measures of WM (letter-number sequencing and complex span) as well as delayed span. It appears that for the control group, there is little support for regarding these tasks as measuring different constructs.

With regard to the schizophrenia group, it appears that they are similar to controls on measures of articulation speed. On two out of three articulation measures there are no differences between groups. There are large differences in lexical access measures which are likely to be consistent with a generalised language deficit in SZ (Condray et. al., 2002) and more specific deficits in lexical access associated with positive and disorganised symptoms (Minzenberg et. al., 2003). For this group it appears that there may be some grounds to consider the need to distinguish between different memory tasks, but it does not fall neatly with the STM – WM – LTM distinction. If this were the case, digit span and forward word span (simple span) should line up, and LNS should line up with WM. It seems likely that the results of the Schizophrenia group can be attributed to the difficulty level of the tasks, with the tasks presented representing three levels of difficulty. Recalling familiar material (e.g. digits and letters that are repeated from trial to trial), this group seems to rely almost totally on rehearsal as a strategy. As the tasks become more difficult, such as a simple word span task (where each item appears only once in the session), they, like the control group are forced to rely upon lexical memory to reconstruct degraded traces to assist in recall. On the complex span tasks, it appears that neither strategy works. Symptomatology once again seems to interfere with performance, at least on some of the more straightforward tasks. For both recall of familiar material and simple word span, disorganised symptoms are associated with decrements in performance. Also associations were found between the positive and disorganised factors of the PANSS and lexical access. This is supportive of the findings of Minzenberg et. al. (2003).

7.7. Chapter Summary

This chapter set out to replicate the previous findings of Tehan and associates (Tehan & Lalor, 2000; Tehan et. al., 2004) that both access to lexical information and articulation speed provide important contributions to span. It extended this finding by showing that in addition to immediate span tasks, at least in normal populations, both rate of access to lexical knowledge and articulation speed also have a role to play in tasks traditionally thought of as measures of WM and LTM. Lexical access and not articulation speed was found to be a more important contributor in this group in contrast to the Baddeley and Hitch (1974) model. Theoretically the EB component of Baddeley's (2000) model could explain how lexical access is accessed in order to support these findings. Alternatively, the findings could support the idea that a common storage mechanism underlies all three tasks and separation into component parts is unnecessary. Further discussion of these alternatives will be raised in the final chapter.

Based upon results in the previous chapter, the participants with high scores on psychometric schizotypy were combined with the rest of the normal controls. The schizophrenia group showed similar patterns of associations to the control group with regard to articulation rate. However, it appeared that there was an effect related to task difficulty with more complex tasks resulting in very poor performance. For the more difficult tasks (complex and delayed span) it appeared that there was no effective strategy in assisting recall. The large variation in lexical access abilities was likely related to symptomatology with disorganised patients being less able to effectively complete the tasks.

Chapter 8 Cued Recall

8.1 Chapter Overview

As stated previously, Tehan and Fallon (1999) helped to develop a model of verbal working memory that reflected not only the contribution of phonemic information to recall over brief retention periods, but also incorporated findings suggesting a contribution from semantic representations in LTM. In a series of experiments Tehan and his colleagues (Tehan & Humphreys, 1995, 1998; Daly, 2001) used a cued-recall paradigm to explore proactive interference effects by manipulating phonological and semantic representations over periods where the retention interval was brief. The task consisted of trials where the subject studied a series of one or two blocks of four words. In the event of a two-block trial, subjects were instructed to ignore the first block of words, and to concentrate only on the second. At the end of the trial a category cue appeared on the screen and the subject was prompted to recall the instance of that category. In the delay condition, a two-second verbal shadowing task (two two-digit numbers appeared on the screen and the subject was required to read them aloud) was used. The one-block trials served only as fillers (the category cue always appeared immediately after the fourth word in the one-block trials) with the two-block trials being critical.

With the two-block trials, there were four possible permutations; (a) no interference which essentially was a control trial where none of the items in the first block were related to the target word (an example of the control trial might be *relief-exam-reaction-tin* (!) *optical-elastic-admiral-message* with the category cue "MILITARY RANK"); (b) a standard interference condition where there was an instance of the same category in the first to-be-forgotten block, and the instance in the first block served as an interfering foil of the target word (e.g. *focus-brick fiction-stitch* (!) *issue-steel-illusion-civil* (category cue "BUILDING MATERIAL"); (c) a third condition manipulated phonological representations by providing a rhyme of the interfering first-block foil in amongst the filler words in the second block (e.g. *mind-jeep-opinion-grocery* (!) *standard-van-yolk-weep"* category cue "VEHICLE"). So in this condition the target is "van" but the rhyming filler "weep" reinforces the interfering foil "jeep"; (d) the final manipulation possible is the semantic condition where two associates of the interfering block-one foil are used as filler words in block-two (e.g. *enemy-pine-knob-unite* (!) *beggar-cedar-needle-cone* category cue "KIND OF WOOD".

Proactive interference in this task can be gauged by a decrease in the level of the block-2 target recall in the two-block lists containing both a target and a foil compared to the control condition, and an increase in the number of times the block-1 foil is recalled instead of the target. Daly (2001) found on both immediate and delayed tests, that the presence of rhymes or associates in the second block reinforced the block one foil and thus produced increased levels of proactive interference via increased recall of the foil and decreased recall of the target. This suggests that both phonological and meaning-based information play a role in the recall of verbal material over brief periods of time. So representations from long-term memory are somehow activated and used in immediate memory.

In SZ and schizotypy research, cues and codes in short-term memory have not been examined in any systematic way. Spitzer (1994) has found evidence of increased phonological and semantic priming in individuals with schizophrenia. This has been explained by disinhibition in the associative memory network, particularly in people with thought disorder. While the paradigm is different, research in cognitive psychology (Tehan & Humphreys, 1998; Daly, 2001) has shown that in short-term memory tasks, phonemic and semantic codes provide the starting point for recall and that interference effects are dependent upon the codes and cues. Given that working memory has consistently been found to be impaired in schizophrenia, a cued recall task which allows examination of error types may provide further insight into the nature of the deficit on verbal working memory tasks.

8.2 Cue plus code hypotheses

Hypothesis 1 – This experiment attempts to strengthen the activated features of a foil over the target by manipulating semantic and phonemic codes. There are four conditions. The first condition has no interference and after presentation of the list items two seconds of verbal distractor follows. The category cue is then presented. It is expected that the SZ group will perform below the other two groups on this task.

Hypothesis 2 – In the standard interference condition, where another exemplar of the category is included in the first to-be-ignored block, performance is expected to be lower than in the no interference condition. SZ subjects are predicted to be differentially impaired on this task due to dysfunctional lexical networks.

Hypothesis 3 – Manipulating phonemic and semantic codes by placing items that rhyme, or are associated with the foil in the second block should produce the lowest target recall and a related increase in the recall of the foil.

Hypothesis 4 - Once again in SZ patients it is predicted that they will be differentially impaired on this task and error type will be related to clinical symptoms.

One block trials were also examined. Evidence from the four-word simple span task presented in Chapter 6 indicated that SZ subjects performed at a much lower rate than the control groups even though all subjects had a span of at least four words (as determined by the standard digit span task from the Wechsler Memory Scale – third edition). The one-block trial provides a base-line measure to examine SZ performance on the cued recall task.

8.3. Methods

8.3.1 Participants

The sample consisted of 22 subjects with a current DSM-IV diagnosis of schizophrenia (SZ), 26 normal control subjects with a low score on psychometric schizotypy (NCL), and 15 subjects with a high score on psychometric schizotypy

(NCH). Information on recruitment of subjects is presented in Chapter 5. All subjects were tested individually.

8.3.2 General Method

Daly (2001) outlined a methodological issue encountered in designing cued recall experiments in that it was difficult to know when equivalent degrees of semantic and phonological similarity had been achieved. Phonological similarity has most frequently been studied in serial recall experiments. Given previous research, it might be assumed that phonological codes will have a stronger influence on immediate memory tasks than meaning-based items. Therefore following Daly (2001) in selecting associates to foil items for interference trials, two associate items were chosen and used for filler items. For the selection of items in the rhyme condition, the methodology followed Tehan and Humphreys (1998) where a single rhyming item was selected and used as a filler item.

8.3.3 Materials

This section first details how word pools were created for the critical two-block trials (Word Pools 1 & 2) and the one-block “filler” trials (Word Pool 3) of the experiments. The construction of the one-block and two-block trials is then described.

8.3.3.1 *Word Pool 1: Target, Foil, Associative, and Rhyming Items.*

In creating Pool 1, 40 categories were selected from the taxonomic categories of the University of South Florida category norms (McEvoy & Nelson, 1982). From each category a target word was selected. This word was a one- or two-syllable concrete noun that was a relatively weak instance of the category, having been produced under controlled association procedures by around 1.5% of participants on most occasions. The next item selected was the foil to the chosen target item. The foil was a high-dominant instance of the same category as the target, being produced under controlled association procedures by an average 36% of participants. Each target-foil set was matched for word frequency and syllabic characteristics.

The two associatively-related items to the foil were selected from the Nelson, McEvoy, and Schreiber norms (unpublished manuscript, 1994). Associates were one- or two-syllable words and were in most cases concrete nouns. Associative strength ranged from .005 to .084. An example would be: for the category "PART-OF-A-FACE", the target item might be "chin", the selected foil "nose", and associates of the foil item might be "tissue" and "blow".

The rhyming instance to each of the 40 foil items was selected from the South Florida rhyme-category norms (Walling, McEvoy, Oth, & Nelson, 1983). In selecting the rhyming item, it was ensured that the item was not a member of the relevant taxonomic category, and as far as possible was a concrete noun, having similar characteristics to other filler items. An example would be: for the category "PART-OF-A-FACE", the target item might be "chin", the selected foil "nose" and the rhyme of the foil item might be "hose".

The selected items (target, foil, associates, and rhyme) are provided in Appendix B.

8.3.3.2 Word Pool 2: Filler Items

These items were selected from the unused categories of the McEvoy and Nelson (1982) category norms and from the Shapiro and Palermo (1970) norms such that there was no overlap in category membership of filler and critical items. Multiple items were selected from each category which meant that it was possible for a list to contain two (rarely three) items from the one category. Filler items generally met syllabic requirements that applied to target, foil, and associate items, and were concrete nouns.

8.3.3.3 Word Pool 3: One-Block Trials

A further 10 categories were selected from the taxonomic categories of the University of South Florida category norms (McEvoy & Nelson, 1982). The criteria for target selection were as described for the two-block trials. Filler items were selected as for the filler items in Word Pool 2. The same set of one-block trials was used for all participants.

8.3.3.4 Construction of One-Block Trials

Target words for these four-word trials were equally allocated to either the first or last list-position. The category cue was always placed immediately after the last word on the list. A concrete example would be:

Block 1	chin page navy jail
Cue	PART-OF-A-FACE.

8.3.3.5 Construction of Two-Block Trials

Items from Pool 1 and 2 were used to create the two-block trials. Items were selected without replacement from the stimulus pools. In the control (no-interference) condition, four filler items from Pool 2 were placed in the first block. In the second block, the target item was allocated evenly to either the second or third list-position across the trials. Filler items from Pool 2 were placed in the remaining list positions of the second block. For example:

CONTROL (No-Interference)

Block 1	toast deck hero trick
Block 2	page chin navy jail
Cue	PART-OF-A-FACE

For the standard interference condition, the target item was placed in the second block in the same way as the control condition. The interfering foil to the target item was selected from Pool 1 and placed in the first block, such that the target and foil were always in the same serial position. Target-foil serial positions were equally divided between positions 2 and 3 across trials. An example might be:

STANDARD (Interference)

Block 1	toast nose hero trick
Block 2	page chin navy jail
Cue	PART-OF-A-FACE

In the interference-plus-associates condition, for each target item the appropriate foil and two associate items were selected from Pool 1. Target and foil placement was as for the standard interference condition. The associates to the foil were then placed in the second block with the target item. Associate items were placed in the first and third positions of the second block. For example:

INTERFERENCE+ASSOCIATES

Block 1	toast nose hero trick
Block 2	tissue chin blow jail
Cue	PART-OF-A-FACE

In the interference-plus-rhyme condition, the rhyming item was placed in position two or three in the second block of items, depending on target placement. The target and foil always shared the same list position, so the rhyme was never in the same list position as the foil. For example:

INTERFERENCE+RHYME

Block 1	toast nose hero trick
Block 2	page chin hose jail
Cue	PART-OF-A-FACE

For each participant, 10 trials were constructed in each of the interference conditions (control, standard, plus-associates, and plus-rhyme). The assignment of materials to list condition and the order of the two-block trials were randomised for each participant. The Hyper-Card Software environment was used for the creation and storage of the experimental procedure and individual trials.

8.4 Procedures

Participants were tested individually. They were seated in front of an Apple Macintosh II desktop computer and provided with written instructions. Participants were told that their task was to remember four words such that they could verbally recall one word when given a category cue. On some occasions the four words would be individually presented, and then the cue would follow; on other occasions the individually-presented four words would be followed by an exclamation mark, and then another four words would be individually presented, followed by the category cue. An example of each of these list conditions was supplied with the list items in lower-case, and the category cue in upper-case, with instructions indicating items would be so presented on experimental trials. Participants were instructed that on those occasions when the exclamation mark appeared, they were to forget the four words that they had just observed, and concentrate only on the next four words. When the category cue appeared they were to recall from the last set of words the word that best matched the cue. Participants were also told that whenever a number appeared on the screen, they were to repeat the number out loud. They were not given information about when the numbers might appear. Participants were told to respond as quickly as possible following the cue and to say "Pass" if they could not recall a word from the relevant list presented. It was stressed that on all trials subjects were to learn the first set of words on the assumption that they would be tested on them, and to forget those items only when the exclamation mark appeared.

Prior to commencing trials, the experimenter verbally repeated the experimental instructions to ensure participants understood the test requirements. All SZ subjects were given four practice trials (one x one block and three x two block) before the experiment was commenced. All other participants were offered the practice trial, all declined. The start of each trial was indicated by an audible tone. The study items were then individually presented in lower-case in the centre of the computer screen, at a rate of one word per second. On two-block trials, the block separator (!) was presented for one second. At the end of the presentation of the second block, and before the category cue, two two-digit numbers appeared on the screen for the subject to say out loud, creating a two second delay. The category cue was shown in upper case for two seconds and participants were given five seconds to provide a response before a tone indicated the next trial was to commence. The experimenter recorded participant responses on hard copies of the experimental trials.

8.5 Dependent measures

8.5.1 One-block trials

For the one block trials there were three measures. Target recall was the first and this was recorded when the participant responded with the instance of the category presented in the trial. Total correct responses were summed across the 10 presented trials. The second was omissions. An omission was recorded whenever the participant failed to give a response when the category cue was presented. Finally, intrusions were recorded. An intrusion was any word that was produced when the category cue was presented, that was not a correct target response.

8.5.2 Two-block trials

Scoring for the two-block trials was identical to the scoring for the one block trials except for the addition of an extra scoring variable for the standard interference, rhyme interference and associative interference trials. For all of these a fourth type of error could be made where the participant responded with the block-one foil instead of the target (block-two) word. This was scored as a block-one intrusions

8.6 Possible confounding variables

In chapter 5 it was reported that the SZ group were older than the NCH group. The NART scores of the NCL group were also significantly higher than the SZ group and there were more males in the SZ group. As in previous chapters correlations were conducted between these (age, gender and NART scores) possible confounding variables and the dependent variables under consideration. Full correlation matrices are presented in Appendix L. Once again inspection of the data revealed that only the NART emerged as a likely confounding variable.

8.7 Results

8.7.1 One-block trials

Means and standard deviations for performance on block one trials by the three groups are reported in Table 8.1. Figure 8.1 summarizes performance of the groups on the one-block trials. One way analysis of variance was conducted for target recall, omissions and extralist intrustions. The assumption of homogeneity of variance was violated for all three variables and so a more conservative significance level was adopted in order to avoid a type I error. One-way ANOVA revealed a significant main effect for group on target recall, $F_{(2,60)}$ = 15.75*, p* = .000. Post-hoc analyses (Tukey's HSD) revealed the SZ group performed significantly below both of the control groups, and that the control groups did not differ from each other (Target recall SZ < NCL, *p = .000;* SZ<NCH, *p = .000*; NCL = NCH*, p* = .964*)*. There was also a significant main effect for group for omissions, $F_{(2,60)}$ = 12.60*, p* = .000. Once again post-hoc analyses revealed the difference to be that the SZ group had a larger number of omissions than the control groups (SZ>NCL *p* = .000; SZ>NCL, *p* = .001; NCL=NCH *p* = .999). Finally, one-way ANOVA revealed no main effect for group on the number of intrusions made on the one-block trials, $F_{(2, 60)}$ = 2.96, p = .059.

Table 8.1 Means (sd) for cued recall one block trials (prob)

	SZ	NCL	NCH
Target Recall	0.69 (0.21)	0.92 (0.11)	0.91 (0.10)
Omissions	0.24 (0.18)	0.06 (0.10)	0.06 (0.08)
Extra List Intrusions	0.07 (0.11)	0.02 (0.04)	0.03 (0.07)

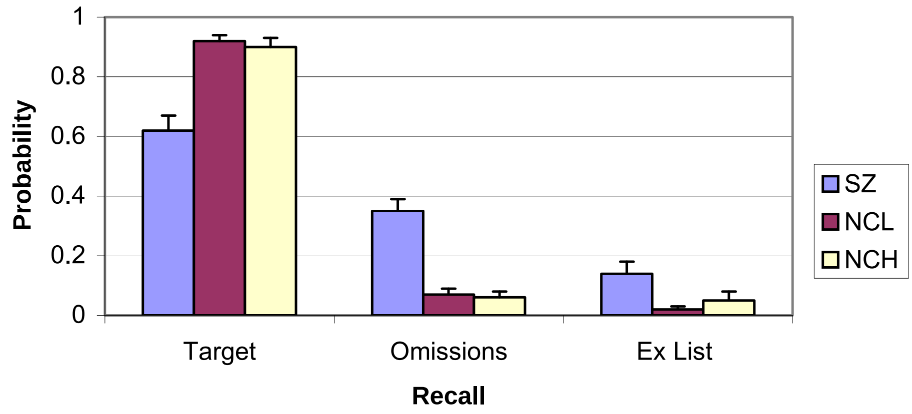

Figure 8.1 - Cued Recall One Block Condition

To explore the possible confounding effect of NART scores on the block 1 trials, Analyses of Covariance (ANCOVA) were conducted for target recall and omissions with NART score as the covariate. After adjusting for NART scores the difference among the groups was still significant for target recall $F_{(2,59)}$ = 12.92, p = .000, eta squared = .31. There was a weak relationship between the NART scores and target recall as indicated by an eta squared value of .11. Table 8.2 presents the means (unadjusted and adjusted) and standard deviations for each of the groups for target recall and omissions. The results of the ANCOVA for omissions on block-one trials were similar to the target recall. After adjusting for NART scores the difference among the groups was significant $F_{(2,59)}$ = 10.46, p = .000, eta squared = .26.

Table 8.2 Adjusted means (standard error) for cued recall one block trials (prob)

	SZ	NCL	NCH
Target Recall	0.71 (0.03)	0.90 (0.03)	0.92 (0.04)
Omissions	0.23 (0.03)	0.07 (0.03)	0.05 (0.03)

8.7.2 Two-block trials

Table 8.3 displays the means and standard deviations for probability of target recall, omissions and extra list intrusions in the no interference, standard interference, rhyme and associate conditions.

Table 8.3 Means (standard deviations) for cued recall two block trials

	SZ	NCL	NCH
No Interference			
Target Recall	.48 (.25)	.68 (.15)	.64 (.17)
Omissions	.38 (.25)	.25 (.15)	.27 (.18)
Ex List Intrus	.14 (.19)	.06 (.08)	.09 (.12)
Standard Interfer			
Target Recall	.42 (.25)	.69 (.20)	.65 (.15)
Omissions	.36 (.23)	.18 (.13)	.22 (.14)
Ex List Intrus	.14 (.18)	.05 (.08)	.06 (.11)
Block 1 Intrus	.09 (.10)	.08 (.08)	.07 (.09)
Rhyme Interfer			
Target Recall	.33 (.21)	.57 (.24)	.53 .17)
Omissions	.28 (.24)	.15 (.14)	.15 (.15)
Ex List Intrus	.11 (.11)	.07 (.11)	.05 (.07)
Block 1 Intrus	.29 (.20)	.22 (.17)	.27 (.16)
Assoc Interfer			
Target Recall	.40 (.23)	.56 (.22)	.51 (.25)
Omissions	.33 (.22)	.17 (.13)	.14 (.12)
Ex List Intrus	.16 (.14)	.07 (.09)	.09 (.10)
Block 1 Intrus	.12 (.17)	.19 (.18)	.26 (.21)

8.7.2.1 Target recall

Figure 8.2 summarises the target recall from the two-block trials. A 4 x 3 repeated measures ANOVA was conducted with recall condition as the within-subjects variable and groups as the between-subjects factor. There was a main effect for interference condition, $F_{(3,180)}$ = 11.13, p =.000 and also for group, $F_{(2,60)}$ = 11.53, p = .000. Post-hoc tests again confirmed that the SZ group performed more poorly than the two control groups and that the two control groups did not differ from one another. There was no condition by group interaction, $F_{(6,180)}$= .67, *p* = .675.

Possible confounding effect of NART scores on the target recall for the two block trials were explored via repeated measures ANCOVA using NART score as the covariate. Results of evaluations of assumptions of normality, linearity and multicollinearity and homogeneity of variance-covariance matrices were satisfactory with the exception of one analysis. The assumption of homogeneity of variance was violated for the extra-list intrusion variable. After adjusting for NART scores the group differences for target recall were still significant, $F_{(2,59)}$ = 8.67, p = .000, partial eta squared = .23. There was a weak relationship between the NART scores and target recall as indicated by a partial eta squared value of .09. Table 8.4 presents the means (unadjusted and adjusted) and standard deviations

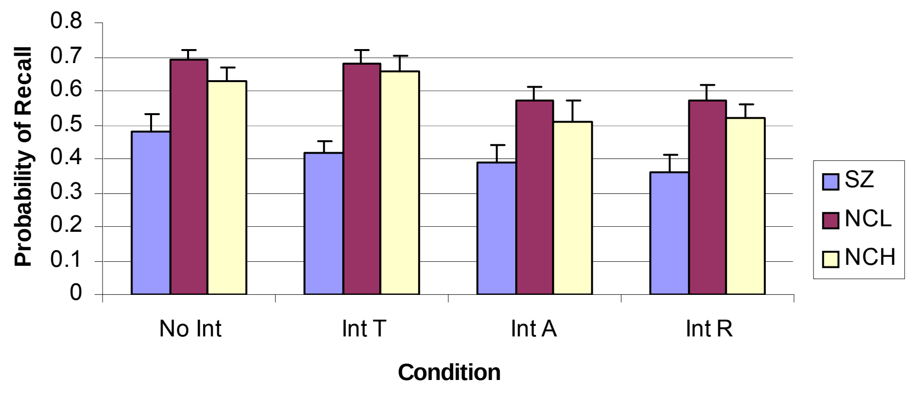

Figure 8.2 - Cued Recall 2-Block Target Recall

No Int = No interference condition; Int T = Standard interference condition; Int A = Associative interference condition; Int R = Rhyme interference condition.

Table 8.4 Adjusted means (standard error) for cued recall two block trials (NART covariate)

	SZ	NCL	NCH
No Interference			
Target Recall	.49 (.04)	.67 (.04)	.65 (.05)
Omissions	.38 (.04)	.26 (.04)	.26 (.05)
Ex List Intrus	.13 (.03)	.07 (.03)	.09 (.04)
Standard Interfer			
Target Recall	.43 (.04)	.67 (.04)	.66 (.05)
Omissions	.35 (.04)	.19 (.04)	.21 (.05)
Ex List Intrus	.13 (.03)	.05 (.03)	.06 (.03)
Block 1 Intrus	.09 (.02)	.08 (.02)	.07 (.02)
Rhyme Interfer			
Target Recall	.35 (.05)	.55 (.04)	.54 (.05)
Omissions	.27 (.04)	.16 (.04)	.15 (.04)
Ex List Intrus	.11 (.02)	.06 (.03)	.06 (.03)
Block 1 Intrus	.28 (.04)	.23 (.04)	.26 (.05)
Assoc Interfer			
Target Recall	.41 (.05)	.54 (.05)	.52 (.06)
Omissions	.32 (.04)	.18 (.03)	.14 (.05)
Ex List Intrus	.15 (.03)	.08 (.02)	.09 (.03)
Block 1 Intrus	.11 (.04)	.20 (.04)	.26 (.05)

In order to test for interference effects, two comparisons need to be made on the basis of the literature review. The first compares the control condition with the standard interference condition. Given the assumption that the presence of a rhyme or associates should enhance interference, the second comparison compares the standard interference condition with the average of the rhyme and associates conditions. The first test indicated that there was no significant difference between control and standard interference conditions, $F_{(1,62)} = .47$, $p = .495$. There was a significant difference between the standard interference condition and rhyme and associates conditions, $F_{(2,62)} = 13.38$, $p = .001$. There was no significant difference between the rhyme condition and the associates condition ($p = 0.574$).

8.7.2.2 Omissions

Figure 8.3 summarises the omissions from the two-block trials. A 4 x 3 repeated measures ANOVA was conducted with recall condition as the within-subjects variable and groups as the between-subjects factor. There was a main effect for condition, $F_{(3,180)}$ = 9.08, *p* =.000 and also for group, $F_{(2,60)}$ = 6.96, *p* = .002. There was no condition by group interaction, $F_{(6,180)}$ = .58, *p* = .745. Post-hoc tests again showed that the SZ group made more omission errors than the two control groups (the two control groups did not differ from each other). More omission errors were made in the control (no interference) condition than in the standard interference condition, $F_{(1,62)}$ = 5.37, *p* = .024. Fewer omission errors were made in both the rhyme and associates conditions compared to the standard interference condition, $F_{(1,62)}$ = 8.46, *p* = .023.

A repeated measures ANCOVA was again conducted to examine any influence of the NART scores on omissions. As with the target recall, results of evaluations of assumptions of normality, linearity and multicollinearity and homogeneity of variance-covariance matrices were satisfactory. After adjusting for NART scores the group differences for target recall were still significant, $F_{(2,59)}$ = 5.46, p = .007, partial eta squared = .16.

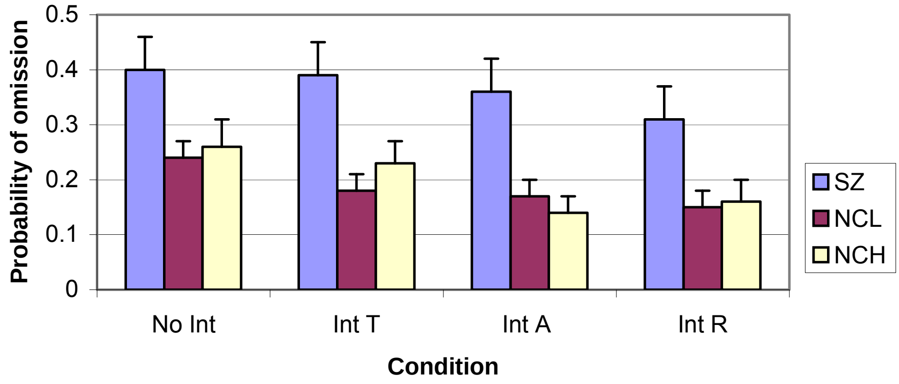

Figure 8.3 - Cued Recall 2-Block Trials - Omissions

No Int = No interference condition; Int T = Standard Interference condition; Int A = Associative interference condition; Int R = Rhyme interference condition.

8.7.2.3 Extra-list Intrusions

Figure 8.4 summarises the extra-list intrusions on the two-block trials. A 4 x 3 repeated measures ANOVA was conducted with recall condition as the within-subjects variable and groups as the between-subjects factor. There was no main effect for condition, $F_{(3,180)}$ = 1.83, p =.143 but a significant effect for group, $F_{(2,60)}$ = 3.79, p = .028. There was no condition by group interaction, $F_{(6,180)}$ = .746, p = .419 . Again the SZ group made more extra-list intrusions than the other two groups and the two controls groups did not differ from each other. Adjusting for the possible influence of NART scores via repeated measures ANCOVA revealed that the effect for group was no longer significant $F_{(2,59)}$ = 2.91, p = .06 (partial eta squared .09).

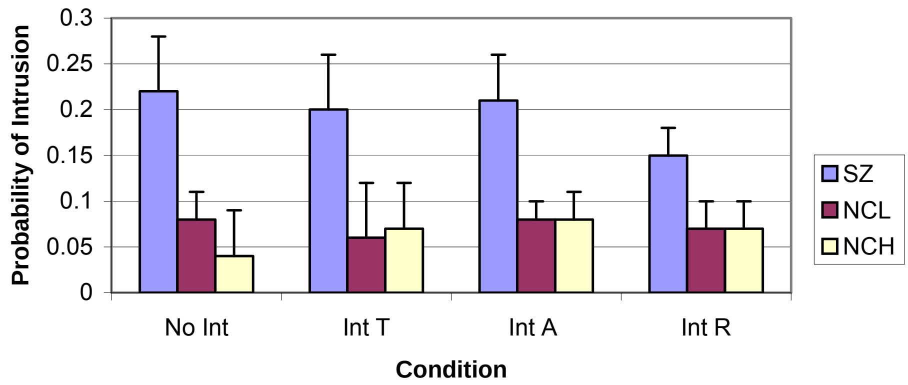

Figure 8.4 - Cued Recall 2-Block Trial - Extra List Intrusions

No Int = No interference condition; Int T = Standard interference condition; Int A = Associative interference condition; Int R = Rhyme interference condition.

8.7.2.4 Probability of foil recall from block one

Figure 8.5 summarises the probability of recalling the foil from block-one on the two-block trials. A 3 x 3 repeated measures ANOVA was conducted with recall condition as the within-subjects variable and group as the between-subjects factor. There was a significant main effect for condition, $F_{(2,120)}$ = 28.01, p =.000 but no main effect for group, $F_{(2,60)}$ = .241, p = .786. This time there was a significant condition by group interaction, $F_{(4,120)}$ = 2.83, p = .027. This was likely the result of both the SZ and the NCH groups being more susceptible to recalling the foil in the rhyme condition. There were more block-1 intrusions in the rhyme and associates condition than in the standard interference condition, $F_{(2,59)}$ = 24.15, p = .000. Given that there was no main effect for group, analysis of covariance was not performed for block one intrusions.

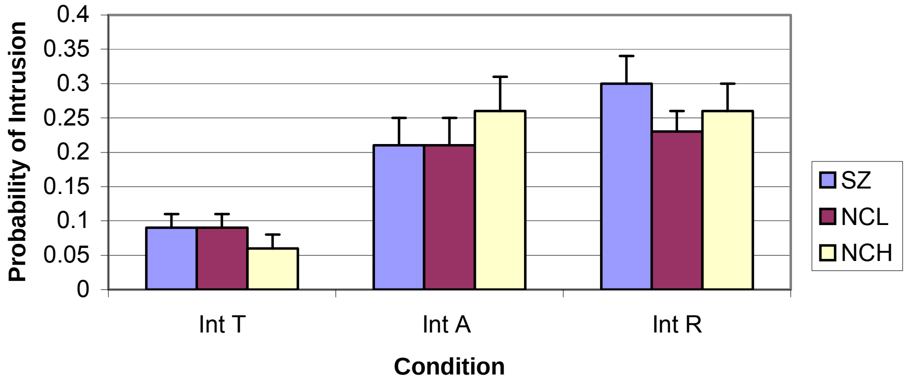

Figure 8.5 - Cued Recall Block 1 Intrusions

Int T = Standard interference condition; Int A = Associative interference condition; Int R = Rhyme interference condition.

8.8 Relationship between tasks and symptom clusters

Table 8.3 shows the correlations between various symptom measures and cued recall variables. For the control participants, the only significant correlation was between the SPQ cognitive/perceptual factor and block 1 intrusions in the rhyme condition (.317, p = .04). In terms of SZ symptomatology, PANSS psychomotor poverty factor was negatively associated with block one intrusions for the standard interference condition (-.530, p = .013) and there was a positive relationship between the PANSS disorganisation factor and intrusions in the no interference two-block condition (.550, p =.010). Due to the low numbers of intrusion errors, only the no interference intrusions were included in Table 8.5.

Table 8.5 – Correlations between symptoms and cued recall variables

	1 Blk Target Recall	No Int Targ Recall	SI Targ Recall	Assoc Targ Recall	Rhyme Targ Recall	1 Blk Omiss	No Int Omiss	SI Omiss	Assoc Blk 1 Intrus	Rhym Blk 1 Intrus	No Int Intrus
SPQ Tot	-.125	-.014	-.003	-.013	-.204	.137	.071	-.265	.122	.252	-.091
SPQ cog/p	-.111	-.064	.024	-.022	-.254	.132	.104	-.260	.135	.317*	-.069
SPQ int	-.112	.097	.029	.052	-.137	.075	-.030	-.251	.053	.136	-.088
SPQ dis	-.061	-.176	-.104	.175	-.158	.071	.190	-.132	.202	.128	-.056
PANSS RD (pos)	.279	-.055	.046	.098	.109	-.211	.110	.299	.273	.116	-.037
PANSS pov (neg)	-.325	-.003	-.090	-.027	.062	.281	-.047	-.530*	-.217	-.336	.047
PANSS dis	-.163	-.346	-.156	-.104	.037	-.119	-.059	-.162	-.003	-.280	.550**
PANSS tot	-.057	-.002	.077	.164	.249	.055	-.071	-.267	.023	-.225	.102
PANSS CD	-.072	-.005	-.112	.167	.304	-.056	-.153	.231	.065	-.223	.183

* *p* = .05, ***p* = .01

1 Blk = one block; No Int = No Interference; SI = Standard Interference; Assoc Targ = Associative Interference Target Recall; Omiss = Omissions; Intrus = Intrusions

SPQ Tot = SPQ Total Score; SPQ cog/p = SPQ Cognitive/Perceptual; SPQ Int = SPQ Interpersonal factor; SPQ dis = SPQ Disorganization factor; RD = PANSS Reality Distortion Factor; pov = PANSS psychomotor poverty Factor;dis = PANSS disorganization; CD = PANSS Conceptual Disorganization

PANSS Correlations presented for 22 SZ participants; SPQ Correlations presented for 42 control participants.

8.9 Discussion

Firstly, the findings on the simple one-block trials revealed that once again, even on a relatively simple task, the SZ subjects had disproportionately more difficulty accurately recalling the target word with a category cue, even without any distractor activity. They were only able to correctly give the target word on just over 60% of the time compared to around 90% recall by both of the control groups. The SZ patients made far more omissions than either control group and had significantly more intrusion errors. These differences in target recall, omissions and intrusion errors among the groups remained after controlling for any influence that the NART scores may have been exerting. Intrusion errors were associated with disorganised symptoms on the PANSS. Brebion and colleagues (2000) have previously found that intrusion errors on span tasks are associated with both positive and disorganised symptoms as measured by the PANSS. It is possible that the rate of presentation of the stimuli made it difficult for the SZ patients to process and encode all four words and as a result they were unsure of the instance of the category cue. Anecdotally, it appeared to the experimenter that the increased number of intrusions by the SZ group were simply the result of guessing. It appeared that extra-list words given by this group would often be a high frequency member of the category presented.

With regard to the two-block trials, the findings here on a cue plus code working memory task are similar to that found by Daly (2001). Recall of the target item was higher in the no interference and standard interference conditions than on either the associative or rhyme conditions. Introducing either associative or rhyming interference decreased the ability to correctly recall the target item. The error data support a proactive interference account in that for the interference conditions, there were fewer omission errors than in the control condition, and there was an increased tendency for the foil to be recalled. This was particularly the case when a rhyme or associates of the foil were added to the second block. As such, PI effects emerged in precisely the expected pattern.

While the SZ group recalled less of the target words across conditions, their errors were interesting. This group had a similar error pattern to the control groups, in that interference effects were equivalent. As was the case in the serial recall experiments the SZ group made more omission errors. However, they did not make more block-1 intrusions, but did make more extralist intrusions than the two control groups.

Examining the data regarding the probability of recalling the block-one interfering foil, introducing either associative or rhyming distractors increased the likelihood of recalling the foil. It was hypothesised that if SZ subjects were more sensitive to associative and rhyming interference, they may display an exaggerated effect when these distractors were introduced. Although visual inspection of the data suggested that the SZ group were more likely to produce the block-one foil in the rhyme condition compared to the other two groups, the difference was not statistically significant. However, most of the research regarding impaired associative networks in SZ specifically relates to the core symptom of thought disorder (TD), which not all SZ patients display. In the sample of SZ subjects here, no formal measure of TD was administered. However, the PANSS conceptual disorganization is based on cognitive-verbal processes observed by the rater during the interview. Aspects of TD such as circumstantiality, loose associations, thought block, tangentially and loose associations are all used as a basis for rating the conceptual disorganization item. Correlations between memory task performance and the conceptual disorganization item were calculated. There were no significant associations between the conceptual disorganization item and task performance. It may be that the sample size of TD subjects was too small, or as stated earlier, the fast presentation rate decreased recall overall and masked the underlying effects. Certainly in rhyme interference condition, SZ patients did recall the foil more often than did the control groups, but this did not reach significance.

With regard to schizotypy, NCH subjects did not significantly differ from the other control group on any measures here. Across recall conditions, the mean score for the NCH group was consistently lower than that of the NCL group, however, as for the data reported for Chapter 6 on serial recall tasks, the differences did not reach significance. The high psychometric schizotypy group was relatively small here and as such effects may be more apparent with a larger subject group. There was only one significant correlation between the SPQ cognitive/perceptual factor and the block 1 intrusions in the rhyme condition.

8.10 Chapter Summary

The aim of this chapter was to examine the model of verbal WM presented by Tehan and Fallon (1999). They presented evidence suggesting that in tasks over very brief periods of time that are typically viewed as not being supported by LTM, retrieval of items relies on both phonological and meaning based cues and codes as a starting point. The findings here provide further evidence in support of the notion that remembering over the short-term is influenced by LTM factors. While it approaches the central tenet of this thesis from a slightly different direction, it is suggestive once again of the need to question multi-component models of WM.

It was hoped that manipulating phonological and semantic information across tasks would produce attenuated performance in the Schizophrenia group. This was based on the premise proposed by Spitzer (1994) and others that this group has impaired semantic networks. However, whether the tasks were too difficult due to the presentation rate, or other variables, the only clear finding was that the Clinical group showed impairments across all tasks and that the impairments were roughly in the same direction as the Control group.

Chapter 9 – General Discussion

9.1 Chapter Overview

The final chapter restates the aims of the research presented in this thesis. Evidence, which raises questions regarding the need to view WM, STM and LTM as being separate components, is discussed. Replication of findings regarding the role of speed of access to lexical information and rehearsal rate in memory tasks and why the same patterns may not hold true for the schizophrenia population is reviewed. Further findings specifically related to the performance of participants with schizophrenia are reviewed. Equivocal and absent findings relating to individuals obtaining high scores on psychometric schizotypy are also considered. Implications of the current research are presented, as they pertain to current models of working memory and also in relation to potential sources of the impairment in the clinical group. A critique of the current research is also explored before future research questions are presented.

9.2 Review of the research objective

The aims of this research were largely two-fold. Firstly, the assumptions underlying current models of WM were explored. Baddeley and Hitch's (1974) seminal model has played a predominant role in shaping working memory theory, viewing it as a multi-component system with storage and processing as separate but interacting entities. Cowan (1999) too argues for multiple interactive components. Others such as Engle (1990) and Tehan (Tehan & Humphreys 1986; Tehan et. al., 2001, 2004) have called into question the need to view WM, STM and LTM as completely separate systems and argue that there is evidence to support a common storage model. This thesis examined the second proposition, that common storage underlies tasks presumed to measure WM, STM and LTM. Secondly, the performance of a clinical group (individuals with schizophrenia) known to have impairments on WM tasks was examined. While the hypothesis that impairments in this population would be found is hardly new, it was expected that the nature of the errors made on tasks and differential performance across task type would help to isolate the presumed cause of the deficits. Previous research exploring WM deficits in SZ has found deficits across modalities. Baddeley's model has gained some favour in clinical research for exploring WM deficits in SZ. This is likely to be a result of its predominance in the field. A third, more exploratory proposition was also examined. Individuals without a clinical diagnosis of schizophrenia, but high on a measure of psychometric schizotypy were expected to exhibit a reduced performance across a variety of the experimental tasks. These findings are also discussed.

9.3 Review of the experimental studies

9.3.1 Chapter 6 – Serial Recall

Chapter six employed simple, complex and delayed word span tasks to explore whether performance on these tasks broadly conformed to the previous research of Tehan and colleagues (2001). Further, based upon a body of literature indicating widespread impairments of schizophrenia subjects on similar tasks, it was predicted that patterns of errors would prove useful in identifying potential sources of deficits. A more tentative exploration of schizotypal performance was also undertaken. Three of the six hypotheses presented in Chapter 6 were supported. These all related to the expectation that the schizophrenia group's performance would be impaired compared to the normal control groups across the more difficult tasks and that as the tasks became more effortful, increased order errors would occur in this group (over and above the usual findings of increased order errors in the normal population). In support of the notion that there is a common storage mechanism which underpins performance on all three span tasks, when the NART was entered as a covariate, the main effect for task disappeared. While this initially was a surprising finding, it may be that rather than acting as a proxy IQ measure, here we are seeing it act as a measure closely associated with the concept of redintegration which relies upon lexical information from LTM. This is not particularly surprising as the NART is a measure of reading. Partialing out the NART may in effect be taking out the redintegration factor resulting in the three tasks appearing equivalent.

Surprisingly the first hypothesis which proposed that the SZ subjects would perform in a similar manner to the other groups on a simple four-word recall task was not supported. There could be a number of explanations for this finding. The speed of presentation of this task (1 word per second) may have been too fast for the schizophrenia group. Impaired speed of processing is an enduring feature of schizophrenia (Brebion et. al., 1998; King, 1991; Nuechterlein, 1977). However, altering the speed of presentation changes the phenomenon under investigation as the effects of STM and WM are presumed to operate under time limitations (Baddeley, 1986; Cowan, 1999). Using words as stimuli instead of numbers or letters clearly increases the task difficulty for this population. The finding of reduced performance on the four-word, no-delay task suggests that this group had difficulty initially encoding the presented information. If internal representations of the information are not formed during the initial presentation, then performance errors will occur. Elvevag and colleagues (2001, 2002a) did not find support for increased item or order errors when they used letters as stimuli in a similar type of experiment with a group of participants with a diagnosis of schizophrenia. The hypotheses relating to the relationship between clinical symptoms and error patterns were also not supported. While omissions were more frequent in the clinical group, they were not related to negative symptoms, but were related to overall levels of psychopathology as measured by the PANSS total score. Intrusions occurred in the SZ group at a similar rate to the NCL group and were not related to positive symptoms. Finally, it was hypothesized that the NCH group would display a pattern of performance across tasks that fell somewhere between the other two groups. Visual inspection of group and task performance would seem to support this notion, but generally the differences were not significant; probably due to insufficient power.

9.3.2 Chapter 7 – Contributions to span performance

The goal of Chapter 7 was to replicate the previous findings of Tehan's group (Tehan & Lalor, 2000; Tehan et. al., 2004) that rehearsal speed and access to lexical memory both contributed to span performance. In addition this chapter sought to extend these findings to explore whether these same variables contributed to performance on measures of WM and LTM. If indeed this was the case, it would provide more evidence in favour of a common storage model of WM. As the performance on the NCH group had been quite similar to the other control group, both non-clinical groups were combined in this chapter. The hypothesis that these rehearsal speed and access to lexical memory would contribute to performance on all three span tasks was supported in the Normal Control Group. Inspection of the correlations between tasks for this group suggested that there was considerable overlap among the tasks assumed to reflect a single underlying latent construct and the measures were thus combined into rehearsal, lexical access and memory constructs. For the variables considered to be measures of lexical access (lexical decision, word naming, nonword naming and pseudohomophone naming) the correlations were not particularly high. However, the correlations were consistent with previous research (Tehan & Lalor, 2000) and as a result they were combined for the regression equation. The fact that a single memory construct appeared is further evidence against a need to fractionate memory in three different stores. Regression analysis revealed that both rehearsal and lexical access speed contributed to memory performance, but that speed of access to lexical memory provided a greater contribution. For the clinical group, the picture was less clear. The memory tasks did not correlate to the same degree as in the Control group.

However, the division was not a clear STM-WM-LTM split. The division here seemed to be based on familiarity with the task material and difficulty level. On tasks where letters and digits were used on all trials it appeared that rehearsal is the key, with lexical access being more important for word recall. However, as tasks become more difficult, performance seems to plummet to levels where neither strategy works. As in Chapter 6, disorganised symptoms appeared to play a role in impeding performance on the more straightforward tasks.

9.3.3 Chapter 8 – Cued recall

The final experimental chapter presented evidence that meaning and rhyme-based codes both have a role to play in remembering over the short-term. The implication of these findings is that LTM processes appear to contribute to WM performance. These findings replicate the earlier work of Fallon and Tehan (1999) and Daly (2001). The principal idea behind this type of experiment is that features from one item in the list can reinforce other items. Research has previously shown that recall of an interfering foil can be enhanced by including rhyming filler items (and to a lesser extent by including associates that share meaning-based features). Tehan (Tehan & Humphreys 1995, 1998; Tehan & Tolan, 1999) found that phonological codes are transient and can be eliminated after two seconds of distractor activity. The results here show that even with distractor activity, phonological codes still have an impact on performance. Once again this would suggest that recall on these tasks rely upon processes from LTM. Of further interest was the performance of the clinical group on these tasks. Disordered language is a common finding in schizophrenia and it has been argued that there are disruptions to semantic networks in this population (Spitzer, 1994). As such it was predicted that manipulating meaning and rhyme-based information would lead to more errors than for control subjects. Generally this finding was not supported. While the performance of the schizophrenia group was once again impaired relative to the performance of the other groups, the patterns of errors was similar. The finding that the clinical group were significantly impaired on a one-block trial that produces near ceiling performances in control subjects raises the issue of task difficulty. Similar to the findings of the SZ group's performance on the simple span task, impairment on the one block trial once again suggests that this group failed to adequately encode the presented words.

By way of summary, the research reported here replicates a number of previous findings and it produces a number of novel results that inform current thinking both about working memory theory as whole and about cognitive abilities of those with schizophrenia. Firstly, a number of previous findings are replicated: the delayed span and complex span tasks are much more difficult than the simple span tasks; access to lexical memory makes more of a contribution to simple span tasks than does rehearsal; proactive interference in cued recall can be enhanced by inserting phonologically or semantically similar items to the foil in the list; and, finally, that subjects with schizophrenia show a deficit in all these tasks compared to a control group. Replicating these findings allows some confidence with the more novel aspects of the research. There are two novel findings worthy of comment. The first is that simple, complex and delayed span appear to have a common storage component as is evidenced by the fact that lexical access explains more variance in these tasks than does rehearsal, and that when lexical access is partialed out statistically, there is no overall difference in the three tasks. Secondly, while the clinical group performs more poorly on all tasks (even when the effects of IQ are partialed out), the profile of errors is identical to the control group and this is true of both serial recall and cued recall tasks. That is, the schizophrenia patients show the same pattern of performance across all tasks as the control group. The only possible exception to this is the role of rehearsal in the complex and delayed span tasks. The clinical group may perform the task more poorly than the control group, but they appear to use the same processes as those in the control group but may simply not encode the items to the same extent.

9.4 Implications of the current research

9.4.1 Implications for WM models

9.4.1.1 Baddeley's Model

Baddeley's model represents the most widely adopted and explored multi-component approach to WM. This system allows processing and storage over very short intervals of only one or two seconds. The CE coordinates the storage components (PL and VSSP), and controls attention, selecting and filtering information that enters the system. The PL provides storage of small amounts of verbal material and its capacity is determined by a race between rapid decay of the information and how fast a person can refresh the information via rehearsal. The newer episodic buffer component has been proposed as an additional storage system. It is under the control of the CE and is assumed to play an important role in the integration of information from multiple sources. Information from LTM is proposed to be one possible source. The findings presented in Chapter 7 indicate that at least in control samples, access to lexical information is a more important source of variation in WM than rehearsal. Further evidence for the contribution of LTM effects over the short-term was presented in Chapter 8. Semantic and phonological cues and codes were clearly present in the cued recall task. Tehan and colleagues (Tehan et. al., 2001) found evidence for the word length effect and the phonological similarity effect in WM and LTM tasks, findings inconsistent with the original multi-component model. While these effects were not examined here, the patterns of performance were remarkably similar in the control sample on the simple, complex and delayed span tasks in Chapter 6. We also propose that the finding in Chapter 6 of the tasks (simple, complex and delayed span) appearing equivalent once the effects of the NART are controlled for, indicate that some common storage mechanism is likely to underpin all three tasks. This is based on the view that the NART is acting here as a redintegration component.

The findings of the three experimental chapters are at odds with Baddeley's original tripartite model. With the introduction of the EB component, it is possible that the influence of LTM factors such as lexical access is being exerted via this new component. The EB component is still relatively untested in terms of experimental data. It is difficult therefore, to evaluate whether the current experiments are adequate to address the viability of the EB. However, it is also not possible to rule out its effect.

9.4.1.2 Engle's Model

Engle and colleagues have presented an individual differences approach to WM (Engle et. al., 1999). In this model simple and complex span tasks share *common storage*. The level of processing required for the complex tasks mean that controlled attention is called into play. STM is simply a subset of long-term memory active above some threshold. According to Engle's model the decrements in performance on the complex and delayed span tasks presented in Chapter 6 can be explained by the increased attentional demands required as the task difficulty increases. The findings presented in Chapter 7 and 8 indicating an important contribution from LTM to WM performance, are also consistent with Engle's model. Further, the impaired performance of the SZ group could be explained by poorer skills and strategies in maintaining the traces above threshold. An inability or deficit in controlling or focusing attention on the presented information may have resulted in more rapid decay of information from activated portions of memory. In the SZ group it appears that even simple tasks such as a four-word recall task or a simple cued recall task without delay (at least when presented in the current format) require considerable attentional demands. Engle (Engle et. al., 1999) also proposes that the dorsolateral prefrontal cortex

(DLPFC) and associated structures are responsible for mediating the controlled processing functions of WM. They suggest that individual differences in the functioning of the DLPFC are responsible for the differences among individuals in controlled processing (Engle, et. al., 1999). The DLPFC has been the focus of much research into the putative neuroanatomical substrate of schizophrenia. There are consistent findings of anomalies in this region in early-onset and chronic schizophrenia (Buchsbaum et. al., 1998; Pantelis et. al., 1997).

9.4.1.3 Cowan's Model

Cowan's model shares similarities with both Baddeley's and Engle's approach. He (1988, 1999) emphasises the relationship between attention and memory. The ST store is an activated part of LTM (and is time limited), and the focus of attention is within the ST store and is capacity limited to four items. Cowan's approach has different tasks measuring different components of the system. Cowan's model however, does not necessarily have common storage underlying each component. Although his model may predict that simple and complex span tasks may be supported by common storage (as long as the duration of any distractor task in the complex span still allowed for the items in memory to be activated above a baseline level), any distractor that was of such duration as to return activation to baseline (as in a long-term memory task) presumably would not rely on the same storage mechanism. As such the findings previously discussed which undermine Baddeley's multi-component model apply also to the model provided by Cowan. Evidence presented in Chapter 6 indicated that in the

SZ group deficits were observed across all tasks. According to Cowan's model this would imply that the SZ group has impairments across all three components. A more parsimonious explanation may be that instead of all three components being affected, there is a core deficit which underlies performance on the tasks presented.

In summary, the results presented here support the idea that simple, complex and delayed span tasks appear to have some common storage mechanism, at least in non-clinical populations. In addition it was also shown that access to lexical information, and rehearsal speed contribute to performance on all three tasks, but that using information from LTM actually is more important that rehearsal.   While this is a direct challenge to the traditional approach that recalling over a short-period is simply a race to keep the items activated above some threshold by rehearsal processes, with the addition of the EB component to Baddeley's model, it is possible that the experimental effects observed here may be explained by LTM processes activated by the EB to influence the operation of the PL component.   The results presented suggest that on all three tasks, while rehearsal is important, reindegration processes allow for recall over and above the contribution of rehearsal.   The multi-component model of WM has held a pre-eminent position in clinical research of memory. However, a recent review of neuroimaging research examining neuranatomical activation during WM tasks suggests that Cowan's embedded processes model provides a better account of the findings than Baddeley's model (Chien, Ravizza & Fiez, 2003). Findings from the cued recall tasks are in keeping with prior findings of Tehan and colleagues.

In cued recall contextual cues activate the list items (being asked to remember all four words in the most recent block) and then the category cue activates its associates. The interaction of the contextual and category information can lead to either enhanced recall or incorrect recall depending upon item manipulation.

9.4.2 Implications – Schizophrenia and Working Memory

The schizophrenia group under investigation here performed below the Control groups across almost all tasks. While this result was certainly not controversial, it was somewhat unexpected that severe impairments were found even on what appeared on the surface to be fairly straightforward tasks. Impairment in span performance has been attributed variously to impaired rehearsal rate (Salame et.al., 1998), poor encoding, reduced storage capacity (Goldberg et. al., 1998b) and faulty retrieval processes. It was hoped that the findings here would shed some light on the potential source of defects. Examining the findings from Chapter 7 on the contribution to span performance in the schizophrenia group, it appeared that measures of rehearsal speed were quite similar to the control group. Rehearsal also was a contributor to performance on the simple tasks of recalling familiar materials, but less so on the more complex tasks. It would seem at the most basic level that rehearsal speed is not the main contributor to impairments on span tasks. Indeed, in observing the clinical subjects during task performance, it did not appear that they (as a group) were engaging in rehearsal strategies. In fact, it appeared as if most of their effort was directly at simply attending to the task. The poor performance on even the simplest tasks by this group may be the result of faulty encoding. Attending to the information presented at the rate of one word per second appeared to be more effortful than for the control participants. This seemed to result in an inability to form the appropriate representations of the item information. In addition, access to lexical information was slowed in this population. This may have also contributed to improper (or absent) encoding. Slowed lexical retrieval in participants with schizophrenia has been found by others (Minzenberg et. al. 2003; Vinagradov et. al., 2002) and disordered lexical networks have been proposed contributing to poor performances on priming tasks (Spitzer, 1998; Maher, Manschreck & Rucklos, 1980). The significant negative correlation between disorganised symptoms as measured by the PANSS and lexical access would suggest that they have a role to play in interfering with lexical processes in this population. However, examining the processes in more detail is impeded by the apparent decrements caused purely because of task difficulty. In order to investigate aspects of WM it was necessary to employ a paradigm where timing of item presentation is paramount. However, the result of this was that often performance of the schizophrenia group was markedly affected because they needed more time to orient to and process the information. Elvevag and colleagues (2001a) had used letters and numbers as stimuli and while they found decrements in performance in their group with schizophrenia, they were not as marked as presented here. However, part of the reason for choosing words was an attempt to investigate whether error patterns would be changed with more meaningful information. As always it appears that there is a trade-off between using tasks which may help break down the deficits into component parts, and creating tasks that are too difficult for the clinical group.

Despite the difficulties found across tasks, there were some findings which suggest that the underlying processes in WM in schizophrenia are not so different to the processes in controls. If errors are examined in this group relative to their own performance, schizophrenia subjects did not make proportionally more omissions or intrusion errors compared to controls. The same findings were evident on the cued recall task with the manipulation of phonological and semantic information having no more of an impact on this group than it did in the healthy control groups.

9.4.3 Implications – Schizophrenia and Associative Networks

The presence of abnormalities in the automatic spreading activation semantic networks of schizophrenia subjects has been suggested by some (Spitzer 1993; Maher et. al., 1980). It was proposed that if semantic associations are disordered in schizophrenia, this dysfunction might be observable on a cued recall task. It was expected that PI might be greater in the schizophrenia group in this study and that disordered associations would result in the semantically (or phonological) related foil being recalled more often than in the control group, however, this was not the case. Anecdotally, some of the clinical subjects had far more block one intrusions in the cued recall task than the mean level of block one intrusions for the group. These same subjects also accounted for most of the semantically related intrusion errors on both the word span and cued recall tasks. However, when the results were viewed across the group the effects disappeared. Viewing their case history and notes, it seemed that these subjects were also more thought-disordered than the other clinical subjects. It would be interesting to repeat some of the experiments with a group selected on the basis of TD symptoms.

9.4.4 Implications – Schizotypy and Working Memory

Certainly the area least convincing in this thesis is that schizotypal behaviour, as measured by the SPQ, have any significant impact on the performance on WM tasks. While the mean performance of this group across span tasks fell between the two other groups, the difference was not reliable. The cut-off point chosen here to identify schizotypal subjects was lower than in many other studies using the SPQ. (Traditionally, to identify individuals deemed to be “high schizotypal” the top 10% scorers are selected and their performance measured against other Control groups (Raine, 1991b). The reason in this thesis for not choosing this method was conceptually driven by an attempt to link performance to the underlying theory of Meehl’s schizotypy. Here we used the premise that by definition to have a clinical diagnosis of schizophrenia, one must be a schizotype. If we can presume that the SPQ indeed captures the essence of whatever it is to be a “schizotype”, then obtaining scores similar to the schizophrenia group were thought to be a reasonable measure of schizotypal behaviour. The study by Moritz et. al. (1999) did show a relationship between impaired performance on some working memory tasks and the disorganised factor of the SPQ using a college sample. In this study they did not use cut-off scores but simply looked at the correlations between factors and task performance. While not span tasks (they used the trail-making test and the stroop task), it does suggest that in well samples deficits can still be found. It may be that the sample size in this experiment was too small and without enough power to find the hypothesized effects. However, it is possible to do a type of meta-analysis across experiments and across means. Table 9.1 shows the means for high and low schizotypal groups across the eleven occasions where independent measures of memory performance were taken. A paired sample t-test between High and Low means is significant, $t_{(10)} = 2.49$, $p = .034$. This meta-analysis suggests that the distinction between the two groups is real and that memory deficits are possible. However, the deficits are nowhere near as robust as with the clinical group.

***Table 9.1.* Meta analysis of memory performance of the three groups**

	Clincal	High Schzotypal	Low Schzotypal
Digit Span Forward	4.93	5.73	6.37
Digit Span Backward	3.23	4.80	4.41
Letter-Number Sequencing	4.67	9.27	10.41
Simple Word Span	17.15	25.80	31.67
Complex Word Span	7.96	13.40	17.15
Delayed Word Span	7.19	13.80	17.22
Cued Recall - Immediate	6.91	9.07	9.19
Cued Recall - No Interference	4.82	6.33	6.73
Cued Recall - Standard Interference	4.18	6.53	6.77
Cued Recall - Associates	3.91	5.07	5.58
Cued Recall - Rhymes	3.27	5.27	5.65

Note: Cued recall scores have been converted from proportions to number correctly recalled.

9.5 Critique of the current research

It is clear that several qualifying points need to be made in reference to the results presented in the experimental chapters. The first relates to the selection of the clinical sample. The average length of illness in this group was 15 years. This group then, represented those with fairly chronic illness. Future studies should address a better mix of patient participants (those that are more acutely ill, chronic stable group, first-episode etc.). The SZ group were also less educated (and had lower NART IQ scores) and were older than the other groups. Although both age and the NART were explored (and where appropriate controlled for) as possible confounding variables, a better solution would have been more careful matching of the control samples to the SZ group. It is acknowledged that this lack of matching was a major limitation of this study. . Better matching of this sample to the control group would have helped to address some of these confounding issues. Methodological issues such as this in clinical research frequently pose a challenge for the researcher (Sher & Trull, 1996). That said, the sample size for the schizophrenia group while not optimal, still matched or exceeded the sample sizes of many of the studies reviewed (Elvevag et. al., 2001; Kim et. al., 2004; Salame et. al., 1998) and differences in education and age levels are also frequently found in the literature. Any future research will need to address this issue in order to be able to make more confident assertions about the results found.

The issue of inadequate matching probably had the greatest impact on the findings related to the control groups with high scores on the SPQ (NCH group). This group was younger and was predominantly female, whereas the SZ group were older and largely male. Research has indicated that younger people more likely to report thought disturbances, persecutory and paranormal beliefs (Venables & Bailes, 1994; Verdoux et. al., 1998). It may also be the case that the items that were endorsed by this group did not adequately mirror the type and range of symptomatology observed in SZ. Better matching in terms of age and gender may have seen more robust results in the NCH group.

A related issue was the lack of correspondence between PANSS and SPQ scores for the SZ group. Given that both the PANSS and the SPQ have been found in some studies to have a similar underlying structure of three factors, it was expected that there would be more of a concordance between the scores on these two measures. It may be (as raised in Chapter 5) that using a self-report inventories with the SZ group was affected by their lack of insight.

The Schizophrenia group were quite heterogeneous in terms of symptoms. Perhaps a selection of participants based upon specific symptoms may have been more fruitful. For example, only some of this group displayed symptoms of TD. Thought Disorder has been found to have characteristic disruption to semantic networks (Spitzer, 1998). When collecting the data for this research the Scale for the Assessment of Thought, Language and Communication (TLC) was also administered (Andreasen 1979a; Andreasen 1979b). However, TLC scores were not used in the final analysis. This decision was made as there was no second rater for the TLC items and as a result inter-rater reliability could not be established. In addition the author while receiving training on the TLC did not regularly employ this measure in other research and so was not confident of the ratings achieved. Examining a TD measure such as the TLC may have revealed clearer patterns in terms of semantic disturbance. Alternatively, selecting a group which showed more pronounced TD may have led to more clear results in the cued recall experiment.

Another major limitation relates to only one rater completing the PANSS for the SZ group. Ideally the symptoms of the SZ should have been assessed by a second rater on the PANSS blind to the original ratings. It is acknowledged that failing to provide inter-rater reliability for PANSS scores for this study raises the possibility that the symptom ratings were somewhat inaccurate. A second rater was not employed for this study due to a lack of funds to employ an adequately trained person. Inter-rater reliability results were provided for the original training for the PANSS. In addition, during the course of this research, the author was employed on several projects utilising the PANSS and inter-rater reliability is provided for this rater on two additional studies. All were above 0.80 recommended for adequate inter-rater reliability to be established on the PANSS (Kay et.al., 1988). However, it is acknowledged that without the checks and balances provided by a second rater, the symptom ratings need to be interpreted with caution.

The issue of task difficulty has previously been raised. Clearly, the schizophrenia group found the complex and delayed span tasks very difficult. This was despite the fact that the complex span task had been modified from the original word-operation span task employed in other research (Tehan et. al., 2001; LaPointe & Engle, 1990). While altering the timing used in the tasks would fundamentally change the nature of the experiments, it is possible that it may have allowed better exploration of the underlying problems. Longer presentation times may have given the SZ group the opportunity to better encode the words. This may have resulted in better approximation of tasks difficulty between the groups, at least at the simplest level of the task.

A further limitation of this research was the relatively modest sample size, coupled with the problems with the matching of the samples led to some further caution needing to be exercised when interpreting some of the statistical results. The regression equations presented in Chapter 7 need to be interpreted with some caution. This is particularly true for the regression equations relating to the SZ group. While the control group regression equations were similar to those of previous studies (Tehan & Lalor, 2000; Tehan et. al., 2004). With a sample size of only 26 it is possible that the results may not be replicated with another sample.

In terms of generalisability of the findings, it will be necessary to reassess the variables under consideration here with a larger, better matched group. Additionally, a larger sample of better matched high schizotypal subjects would be needed. Since the completion of this study, further research with a larger schizotypal group has been conducted with some promising results (Byrne & Doepke, *unpublished observations)*.

Despite several significant limitations of the current research, the results presented here provide a novel approach to exploring the current models of working memory. Ordinarily well controls (often student samples) have been employed to test these models. While there has been an increasing number of studies interpreting WM performance of clinical subjects within the framework of these models, usually standardised neuropsychological are employed with some modified WM tasks. The aim of these studies has more often than not, been to explore the nature and source of the deficits rather than to test the robustness of any particular model. The results presented here suggest that many of the underlying processes found in normal memory are also found in this SZ sample. The nature of errors are quite similar for the two groups albeit with a far larger number of omissions from the SZ group. The findings of Chapter 7 suggest that the SZ group rely far more on rehearsal strategies than the control group for very simple tasks. While this finding needs to be replicated in a larger sample it may still provide some hints as to the fundamental cause of WM failure on verbal tasks in this group.

9.6 Future research

Despite the above caveats, the research presented here provides a starting point to examine a number of lines of investigation. With regard to the results pertaining to the normal controls, the results presented in Chapter 7 show something new: that it appears that the same processes underlie simple, complex and delayed span tasks. It would be worthwhile to attempt to replicate these results using the more traditional complex and delayed span tasks. This would assuage potential concerns that the results here are a reflection of all tasks being relatively simple manipulations of a serial recall task and do not place enough demands upon the normal memory systems to truly be measures of WM or LTM. Of course the approximately 50% decrement in performance in the complex and delayed tasks compared to the simple task might suggest otherwise.

While the results pertinent to the schizotypal group were weak at best, they still provide some hints that there may be some similarities of mechanisms for this group to the mechanisms that create problems for the schizophrenia group. Using a larger sample size and selecting the group with higher cut-off scores on the SPQ may lead to more robust findings.

While the overall results of the Schizophrenia group led to largely unsurprising results pointing to large group differences, some of the individual performances (particularly on the cued recall tasks) lead the researcher to believe that this paradigm is still worth investigating in this population. Once again more careful selection of subjects with known language problems may indeed lead to a different pattern of results than found here. Some important results may have been lost in the group data. Additionally, it would be interesting to apply these types of experiments to the First-Episode Psychosis (FEP) population. Those presenting with FEP have deficits that are usually similar to more established SZ, but are free of some of the confounds of chronicity of illness (Bilder et. al., 2000; Fitzgerald et. al., 2004; Lucas et. al., 2004; Saykin et. al., 1994). Generally, they have less difficulty in completing experimentally tasks than chronically ill subjects, and as such may provide a valuable insight into the mechanisms of verbal WM performance early in the course of schizophrenia.

Exploring other signature effects of passive short-term storage such as the word length effect, phonological similarity effect, articulatory suppression and irrelevant speech effect in schizophrenia samples may also help to tease apart the source of impairments. Elvevag (2002b) found no evidence for increased susceptibility to phonemic confusion in a schizophrenia sample. However, little other research explicitly examining these effects has been undertaken in clinical populations.

9.7 Conclusion

The research presented here explored current models of WM and examined whether as Baddeley and Cowan argue, there is need for separation of WM and LTM and whether WM can be further fractionated into component parts, or in contrast, whether it is possible that there is a common mechanism which underscores performance on STM, WM and LTM, as argued by Engle and Tehan and Colleagues. The results here show that there is further support for this second proposition. They also go some way to identifying what some of the commonalities are, in that both rehearsal speed and access to lexical memory are important. This research also reiterated the widespread findings that verbal working memory is impaired in schizophrenia. The source of the impairment remains elusive and further work needs to be done to address some of the methodological issues inherent in working with this population.

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Appendix A – Stimuli for Non-span tasks

Lexical Decision

arrow	upset	vapour	soble
elect	anbel	rocky	organ
vider	argor	dotin	alter
basin	tapid	osmer	pader
tofer	olive	rival	putil
laket	salad	abide	decay
cable	renny	abame	unite
linen	daker	dilot	apple
narty	canal	nerry	adopt
bovel	elbow	bifer	otera

Word Naming

tiger	penny	money	payment
garden	armour	party	ruby
engine	insult	amaze	owner
dealer	bucket	event	berry
opera	native	fountain	welcome
sober	paper	million	cigar
highway	robin	novel	survey
winter	parrot	rider	noble
picture	lava	kiwi	rapid
maker	arctic	racquet	willow
pupil	layer	traffic	fever
label	pilot	angel	needle
umpire	pony		

Non-word Naming

amort	arrot	billum	sager
rosty	fotar	regit	refeb
holad	bolen	nolev	lamet
mebit	maver	nurek	liben
hodor	patum	natib	fabal
wotar	enber	detay	tupelo
catin	cipil	rafow	cotor
audil	belac	bero	homet
deris	tolen	damin	sakin
pamer	ciler	jemit	pobet
byrop	pacur		

Odd-word naming

nayshun (nation)	snaik (snake)	ainjel (angel)
kayj (cage)	sics (six)	kwea (queer)
figa (figure)	pikcha (picture)	sekshun (section)
tyga (tiger)	wimen (women) y	ooth (youth)
sercl (circle)	konka (conquer)	creecha (creature)
dainja (danger)	dizeez (disease)	ona (owner)
scail (scale)	taim (tame)	skreem (scream)
flie (fly)	laik (lake)	mair (mare)
eega (eager)	urlee (early)	badj (badge)
ruf (rough)	sinsear (sincere)	masheen (machine)
wissl (whistle)	harber (harbour)	cumpus (compass)
botm (bottom)	sercut (circuit)	cansa (cancer)
cotij (cottage)	dorta (daughter)	enuf (enough)
trane (train)	crum (crumb)	slane (slain)

Appendix B - Cued Recall Word Pool

One block items

Category Cue	**Target**	**Filler**	**Filler**	**Filler**
RELATIVE	uncle	pacific	racquet	senate
GREEN VEGETABLE	spinach	cap	probe	saw
TYPE OF BREAD	rye	congress	pin	stapler
PRECIOUS GEM	ruby	keeper	million	navy
KIND OF EXPLOSIVE	dynamite	onion	cap	staple
UNIT OF LENGTH	metre	light	native	nose
TIME OF DAY	night	umbrella	screw	mandarin
CITRUS FRUIT	lemon	jealousy	limp	nickel
BIRD OF PREY	eagle	carriage	cup	page
PART OF SPEECH	noun	walking	digit	wire

Two-block items

Category cue	**Foil**	**Target**	**Assoc**	**Assoc**	**Rhyme**
PROFESSION	lawyer	dancer	sue	divorce	foyer
BUILDING MATERIAL	brick	steel	bat	red	trick
GYMNASTIC EVENT	beam	vault	steel	rafter	seam
CIRCUS ACT	trapeze	juggler	swing	net	ease
MILITARY RANK	captain	admiral	football	team	cap
WEAPON	sword	cannon	sheath	fencing	soared
LIVING ROOM FURNITURE	couch	lamp	potato	sleep	pouch
DAIRY PRODUCT	cheese	cream	mouse	cracker	knees
TYPE OF DANCE	waltz	polka	wedding	bridal	false
WILD ANIMAL	bear	cougar	polar	hug	bare
TYPE OF FLOWER	tulip	lily	dutch	windmill	lip
TYPE OF GOVERNMENT	monarch	republic	throne	subjects	ark
KIND OF WOOD	pine	cedar	needle	cone	fine
WATER SPORT	swimming	fishing	stroke	dip	slimming
FIREFIGHTING EQUIPMENT	hose	ladder	wet	spray	pose
CHEMICAL ELEMENT	oxygen	zinc	tent	mask	proxy
PROFESSIONAL SPORT	tennis	golf	court	net	menace
TYPE OF HAT	straw	bonnet	broom	hay	slaw
PART OF A BOAT	sail	helm	wind	hoist	mail
MEDICAL SPECIALTY	surgeon	dentist	plastic	hospital	surge
TYPE OF CRIME	robbery	kidnap	bank	purse	snobbery
TYPE OF TOY	ball	rattle	strike	beach	hall
TYPE OF NUT	almond	acorn	eyes	sliver	carmen
HAIR COLOUR	blonde	brown	bleach	dizzy	fond
BATHROOM ITEM	mirror	cabinet	reflection	crack	nearer
BREED OF DOG	husky	pointer	arctic	snow	dusky
MAJOR APPLIANCE	oven	iron	bake	gas	coven
TYPE OF SPICE	garlic	clove	bread	pizza	lick
RELIGIOUS ARTICE	rosary	candle	chant	beads	rosemary
BATHROOM FIXTURE	toilet	shower	flush	paper	toy
TYPE OF HERB	parsley	cloves	green	curls	ghastly
EARTH FORMATION	hill	island	climb	height	will
CARPENTER’S TOOL	saw	ruler	tooth	hack	sore
FARM EQUIPMENT	plow	rake	furrow	crop	brow
MUSICAL INSTRUMENT	horn	clarinet	honk	fog	warn
PIECE OF JEWELRY	necklace	earring	choke	throat	speck
VEHICLE	jeep	van	desert	army	weep
COSMETIC	blush	mascara	cheek	pale	plush
WRITING IMPLEMENT	pencil	chalk	case	sharp	stencil
TYPE OF FASTENER	button	staple	hole	belly	mutton

Appendix C - Serial Recall Word List

Crude	restaurant	crust	maths	speech
Holiday	caffeine	outlaw	urn	fly
Chore	dip	joke	ice	lighter
Smell	stretch	gravel	surplus	antique
Slag	quiver	traffic	vanilla	chairman
Native	honk	riddle	pamphlet	navahoe
Brat	bureau	brothel	money	reel
Needle	newton	shout	body	wardrobe
Prairie	creep	parrot	clone	star
Wave	queer	jump	goodbye	ghetto
Witch	dwelling	sight	enzyme	squeal
Quick	umpire	danger	mob	gaze
Helicopter	scare	snooze	bowl	flight
Thrust	dive	graph	hair	spray
Bulb	intermission	dray	ache	kerb
Hoard	addict	detergent	compound	scar
Odour	insult	lice	winter	grill
Poke	moon	oyster	dinosaur	arctic
Sample	disease	toast	welcome	line
Stop	block	journey	highway	echo
Jersey	contract	syringe	broom	concord
Survey	vase	neck	tray	fish
dealer	volt	fountain	sum	willow
cage	crumpet	arrow	gipsy	hopscotch
flame	relic	plan	noose	morning
tower	telescope	termite	captive	write
cramp	hardy	waist	lasagne	french

wink	event	romance	ruby	sale
keats	onion	lynch	number	cocoon
net	rubble	sapphire	fang	capsule
garden	noun	mud	sandwich	hero
steinbeck	town	Bangladesh	doll	basin
dance	racquet	uniform	fever	wrapper
tertiary	autumn	gnome	east	alcohol
rhyme	insomnia	jail	dusk	edge
career	million	pupil	planet	resume
thermometer	payment	quarrel	bribe	salmon
pitcher	elevator	apple	thought	zodiac
girl	bushel	label	mask	jam
tax	cigar	umbrella	ivory	orphan
gem	flea	primate	butt	rampage
gang	fang	tear	scissors	scholar

Appendix D – Group differences on SPQ Scores

Table D1 – *p* Values for Post hoc group differences on SPQ 1 – Ideas of Reference

	SZ	NCL	NCH
SZ		.000	.976
NCL			.000

SZ = Schizophrenia; NCL = Normal Control – Low Schizotypy;

NCH = Normal Control – High Schizotypy.

Table D2 - *p* Values for Post hoc group differences on SPQ 2 – Excessive Social Anxiety

	SZ	NCL	NCH
SZ		*.014*	.059
NCL			*.000*

Table D3 - *p* Values for Post hoc group differences on SPQ 3 – Magical Thinking

	SZ	NCL	NCH
SZ		.004	.660
NCL			.153

Table D4 - *p* Values for Post hoc group differences on SPQ 4 – Unusual Perceptual Experiences

	SZ	NCL	NCH
SZ		.000	.010
NCL			.128

Table D5 - *p* Values for Post hoc group differences on SPQ 5 – Odd Behaviour

	SZ	NCL	NCH
SZ		.000	.020
NCL			.002

Table D6 - *p* Values for Post hoc group differences on SPQ 6 – No Friends

	SZ	NCL	NCH
SZ		.002	.880
NCL			.050

Table D7 - *p* Values for Post hoc group differences on SPQ 7 – Odd Speech

	SZ	NCL	NCH
SZ		.000	.960
NCL			.000

Table D8 - *p* Values for Post hoc group differences on SPQ 8 – Constricted Affect

	SZ	NCL	NCH
SZ		.000	.454
NCL			.002

Table D9 - *p* Values for Post hoc group differences on SPQ 9- Suspiciousness

	SZ	NCL	NCH
SZ		.000	.413
NCL			.000

Table D10 - *p* Values for Post hoc group differences on SPQ - Total

	SZ	NCL	NCH
SCP		.000	.784
NCL			.000

Table D11 - *p* Values for Post hoc group differences on SPQ Cognitive Perceptual Factor

	SZ	NCL	NCH
SZ		.000	.987
NCL			.000

Table D12 - *p* Values for Post hoc group differences on SPQ Interpersonal Factor

	SZ	NCL	NCH
SZ		.000	.592
SCN			.000

Table D13 *p* Values for Post hoc group differences on SPQ Disorganisation Factor

	SZ	NCL	NCH
SZ		.000	.758
NCL			.000
NCH			

Appendix E – Consent Form (Clinical Group)

WORKING MEMORY AND SCHIZOPHRENIA: THE ROLE OF SEMANTIC AND PHONEMIC CUES.

USQ AUSTRALIA

CONSENT FORM

This study is designed to look at how people with certain illnesses remember things over a very short period of time. In order to learn more about how all people remember things in a very short space of time, we will ask you to do some simple computer tasks and some paper and pencil tasks. We will also ask some questions about your illness and record a brief sample of your speech.

I acknowledge that:

1. I have been provided with information as to the nature and purpose of the project and as to the extent of my involvement.
2. I am aware that, although the project is directed to the expansion of medical and psychological knowledge generally, it may not result in any direct benefit to me.
3. I am aware that I may withdraw from the study at any time without affecting my treatment in any way
4. I am aware that I may request further information about the project as it proceeds and that I may withdraw from participation at any time.
5. I understand that some of the interview will be recorded on audiotape and I consent to such recordings. I can request that the tape be erased at any time.
6. All information collected and test results will be treated confidentially and I will not be identified in any way.

If you have any questions, I understand that I can direct them to either Linda Byrne, Ph: 07 32718485; or Dr John McGrath, Ph: 07 3271 8592; or Dr Gerry Tehan 07 46312100.

If you have any complaints about the study at any time feel free to contact Ms Nadia Beer at the WPH Office of Patients Friend, Telephone 3271 8249.

Signature ……………………………..

Witness………………………………

Date ………………………………

Appendix F – Consent Form (Control/NonClinical)

WORKING MEMORY AND SCHIZOPHRENIA: THE ROLE OF SEMANTIC AND PHONEMIC CUES.

CONSENT FORM

This study is designed to look at how people with certain illnesses remember things over a very short period of time. In order to learn more about how all people remember things in a very short space of time, we will ask you to do some simple computer tasks and some paper and pencil tasks. We will also ask some questions about your medical history and record a brief sample of your speech.

I acknowledge that:

1. I have been provided with information as to the nature and purpose of the project and as to the extent of my involvement.
2. I have been informed as to the nature and extent of any risk to my health or well-being.
3. I am aware that, although the project is directed to the expansion of medical and psychological knowledge generally, it may not result in any direct benefit to me.
4. I am aware that I may request further information about the project as it proceeds and that I may withdraw from participation at any time.

I understand that in respect of any information obtained during the course of the project, confidentiality will be maintained to the same extent as for my general medical records and that, in the event of the results being published, I will not be identified in any way.

I understand that it is proposed to record an interview on audio tape and I consent to such recordings. I understand that the same confidentiality will be observed so far as the audio tapes is concerned and further, that I may at may time request that the tape be erased. If I have any questions, I understand that I can direct them to either Linda Byrne, Ph: 07 32718485; or Dr John McGrath, Ph: 07 3271 8592; or Dr Gerry Tehan 07 46312100.

Signature ……………………………..

Witness………………………………

Date ………………………………

APPENDIX G – Inter-rater reliability of Positive and Negative Symptoms Scale

Inter-rater reliability from PANSS training (1999) – 0.87
(conducted via training video under supervision of Professor John McGrath, Qld Centre for Mental Health Research)

Inter-rater reliability from antenatal study (2000)_- 0.89
(Based on inter-rater reliability between author and consultant psychiatrist employed with Qld Centre for Mental Health Research)

Most recent inter-rater reliability – PANSS training, international Phase 4 - medication trial (2005) - 0.85
(PANSS reliability training conducted in Toronto Canada by Janssen-Cilag)

Appendix H – Positive and Negative Symptom Scale Score Sheet

POSITIVE SUBSCALE	1 ABS	2 MIN	3 MILD	4 MOD	5 MOD / SEV	6 SEV	7 EXT
P1 Delusions							
P2 Conceptual Disorganisation							
P3 Hallucinatory Behaviour							
P4 Excitement							
P5 Grandiosity							
P6 Suspiciousness/Persecution							
P7 Hostility							
NEGATIVE SUBSCALE							
N1 Blunted Affect							
N2 Emotional Withdrawal							
N3 Poor Rapport							
N4 Passive/Apathetic Social Withdrawal							
N5 Difficulty in Abstract Thinking							
N6 Lack of Spontaneity and Flow of Conversation							
N7 Stereotyped Thinking							
GENERAL PSYCHOPATHOLOGY SUBSCALE							
G1 Somatic Concern							
G2 Anxiety							
G3 Guilt Feelings							
G4 Tension							
G5 Mannerism and Posturing							
G6 Depression							
G8 Uncooperativeness							
G9 Unusual Thought Content							
G10 Disorientation							
G11 Poor Attention							
G12 Lack of Judgement and Insight							
G13 Disturbance of Volition							
G14 Poor Impulse Control							
G15 Preoccupation							
G16 Active Social Avoidance							

Appendix I – Schizotypal Personality Questionnaire

NAME……………………………………… MALE/FEMALE (Circle One)

DATE OF BIRTH………………………… TODAY'S DATE………………………………..

Please answer each item by circling Y (Yes) or N (No). Answer all items even if unsure of your answer. When you have finished, check over each one to make sure you have answered them.

Y	N	1. Do you sometimes feel that things you see on the TV or read in the newspaper have special meaning for you?
Y	N	2. I sometimes avoid going to places where there will be many people because I will get anxious
Y	N	3. Have you had experiences with the supernatural?
Y	N	4. Have you often mistaken objects or shadows for people, or noises for voices?
Y	N	5. Other people see me as slightly eccentric (odd)
Y	N	6. I have little interest in getting to know other people
Y	N	7. People sometimes find it hard to understand what I am saying
Y	N	8. People sometimes find me aloof and distant
Y	N	9. I am sure I am being talked about behind my back
Y	N	10. I am aware that people notice me when I go out for a meal or to see a film
Y	N	11. I get very nervous when I have to make polite conversation
Y	N	12. Do you believe in telepathy (mind-reading)?
Y	N	13. Have you ever had the sense that some person or force is around you, even though you cannot see anyone?
Y	N	14. People sometimes comment on my unusual mannerisms and habits
Y	N	15. I prefer to keep to myself
Y	N	16. I sometimes jump quickly from one topic to another when I am speaking
Y	N	17. I am poor at expressing my true feelings by the way I talk and look
Y	N	18. Do you often feel that other people have got it in for you?
Y	N	19. Do some people drop hints about you or say things with a double meaning?
Y	N	20. Do you ever get nervous when someone is walking behind you?
Y	N	21. Are you sometimes sure that other people can tell what you are thinking?
Y	N	22. When you look at a person, or yourself in the mirror, have you ever seen the face change right before your eyes?
Y	N	23. Sometimes other people think that I am a little strange
Y	N	24. I am mostly quiet when with other people
Y	N	25. I sometimes forget what I am trying to say
Y	N	26. I rarely laugh or smile
Y	N	27. Do you sometimes get concerned that friends or co-workers are not really loyal or trustworthy?
Y	N	28. Have you ever noticed a common event or object that seemed to be a special sign for you?
Y	N	29. I get anxious when meeting people for the first time
Y	N	30. Do you believe in clairvoyancy (psychic forces, fortune telling)?
Y	N	31. I often hear a voice speaking my thoughts aloud
Y	N	32. Some people think that I am a very bizarre person
Y	N	33. I find it hard to be emotionally close to other people
Y	N	34. I often ramble on too much when speaking
Y	N	35. My "non-verbal" communication (smiling and nodding during a conversation) is poor
Y	N	36. I feel I have to be on my guard even with friends
Y	N	37. Do you sometimes see special meanings in advertisements, shop windows, or in the way things are arranged around you?
Y	N	38. Do you sometimes feel nervous when you are in a group of unfamiliar people?

Y	N	39. Can other people feel your feelings when they are not there?
Y	N	40. Have you ever seen things invisible to other people?
Y	N	41. Do you feel that there is no-one you are really close to outside of your immediate family, or people you can confide in or talk to about personal problems?
Y	N	42. Some people find me a bit vague and elusive during a conversation
Y	N	43. I am poor at returning social courtesies and gestures
Y	N	44. Do you often pick up hidden threats or put-downs from what people say or do?
Y	N	45. When shopping do you get the feeling that other people are taking notice of you?
Y	N	46. I feel very uncomfortable in social situations involving unfamiliar people
Y	N	47. Have you had experiences with astrology, seeing the future, UFO's, ESP or a sixth sense?
Y	N	48. Do everyday things seem unusually large or small?
Y	N	49. Writing letters to friends is more trouble than it is worth
Y	N	50. I sometimes use words in unusual ways
Y	N	51. I tend to avoid eye contact when conversing with others
Y	N	52. Have you found that it is best not to let other people know too much about you?
Y	N	53. When you see people talking to each other, do you often wonder if they are talking about you?
Y	N	54. I would feel very anxious if I had to give a speech in front of a large group of people
Y	N	55. Have you ever felt that you are communicating with another person telepathically (by mind-reading)?
Y	N	56. Does your sense of smell sometimes become unusually strong?
Y	N	57. I tend to keep in the background on social situations
Y	N	58. Do you tend to wanter off the topic when having a conversation
Y	N	59. I often feel that others have it in for me
Y	N	60. Do you sometimes feel that other people are watching you?
Y	N	61. Do you ever suddenly feel distracted by distant sounds that you are not normally aware of?
Y	N	62. I attach little importance to having close friends
Y	N	63. Do you sometimes feel that people are talking about you?
Y	N	64. Are you thoughts sometimes so strong that you can almost hear them?
Y	N	65. Do you often have to keep an eye out to stop people from taking advantage of you?
Y	N	66. Do you feel that you are unable to get "close" to people?
Y	N	67. I am an odd, unusual person
Y	N	68. I do not have an expressive and lively way of speaking
Y	N	69. I find it hard to communicate clearly what I want to say to people
Y	N	70. I have some eccentric (odd) habits
Y	N	71. I feel very uneasy talking to people I do not know well
Y	N	72. People occasionally comment that my conversation is confusing
Y	N	73. I tend to keep my feelings to myself
Y	N	74. People sometimes stare at me because of my odd appearance

Appendix J – Medication variables

Table J1 – Correlations between medication dosage and experimental variables

	Log transformation of Chlorpromazine equiv
Variable	
NART	0.127
Count	0.222
Alphabet	-0.060
Serial 3's	0.322
Lex Decision	-0.356
Word Naming	-0.249
Non-word Naming	-0.370
Pseudohomophone Naming	0.128
Digit Span Forward	-0.248
Digit Span Backward	-0.402*
Letter number sequencing	-0.149
Simple Span	-0.363
Complex Span	-0.403
Delayed Span	0.003

*correlation is significant at the 0.05 level two-tailed

Appendix K – Additional correlations for Chapter 8

Table K1 - Correlations between NART scores and cued recall variables (Target Recall and Block 1 Intrusions)

	Target Recall					Block 1 - Intrusions		
	No Int	**Int T**	**Int A**	**Int R**	**XX**	**Int T**	**Int A**	**Int R**
SZ								
NART	.268	.212	.360	**.446***	.391	.204	-.111	-.062
NCL								
NART	-.012	.108	.187	.112	**.439***	.063	-.020	.003
NCH								
NART	.081	.255	.173	.326	.051	-.059	-.205	-.405

*$p < .05$

SZ = schizophrenia, NCL = normal control low schizotypy, NCH = normal control high schizotypy, No Int = no interference, Int T = standard interference, Int A = associative interference, Int R = rhyme interference, XX = one block control trials

Table K2. – Correlations between NART scores and cued recall variables (Omissions and Extra List Intrusions)

	Omissions					Extra List Intrusions				
	No Int	**Int T**	**Int A**	**Int R**	**XX**	**No Int**	**Int T**	**Int A**	**Int R**	**XX**
SZ										
NART	-.082	-.072	-.051	-.150	-.193	-.223	-.268	-.304	-.235	-.418
NCL										
NART	-.056	-.280	-.234	-.044	**-.438***	.005	.065	-.041	.371	.313
NCH										
NART	-.170	**-.585***	-.162	-.176	.082	.255	.373	.186	**.535***	-.162

Appendix L – Selected raw data and SPSS output

Table L1 – Chapter 6 – Serial Recall – Correlations Age, Gender, NART with item information and total output

		age	gender	nart iq	ws percent correct (excl trans)	word span no int total output (inclu error)	word span int 1 total correct (exclud trans)	word span int 1 total output	ws int 2 total correct exclud trans	word span int 2 total output
age	Pearson Correlation	1	-.058	.025	-.284(*)	-.212	-.269(*)	.089	-.223	-.069
	Sig. (2-tailed)		.631	.834	.019	.083	.026	.469	.068	.578
	N	72	72	72	68	68	68	68	68	68
gender	Pearson Correlation	-.058	1	.071	.211	.112	.151	.069	.085	-.120
	Sig. (2-tailed)	.631		.554	.084	.364	.220	.576	.493	.328
	N	72	72	72	68	68	68	68	68	68
nart iq	Pearson Correlation	.025	.071	1	.578(**)	.474(**)	.438(**)	.368(**)	.492(**)	.359(**)
	Sig. (2-tailed)	.834	.554		.000	.000	.000	.002	.000	.003
	N	72	72	72	68	68	68	68	68	68
ws percent correct (excl trans)	Pearson Correlation	-.284(*)	.211	.578(**)	1	.868(**)	.660(**)	.333(**)	.713(**)	.498(**)
	Sig. (2-tailed)	.019	.084	.000		.000	.000	.006	.000	.000
	N	68	68	68	68	68	68	68	68	68
word span no int total output (inclu error)	Pearson Correlation	-.212	.112	.474(**)	.868(**)	1	.575(**)	.379(**)	.611(**)	.548(**)
	Sig. (2-tailed)	.083	.364	.000	.000		.000	.001	.000	.000
	N	68	68	68	68	68	68	68	68	68
word span int 1 total correct (exclud trans)	Pearson Correlation	-.269(*)	.151	.438(**)	.660(**)	.575(**)	1	.700(**)	.861(**)	.715(**)
	Sig. (2-tailed)	.026	.220	.000	.000	.000		.000	.000	.000
	N	68	68	68	68	68	68	68	68	68
word span int 1 total output	Pearson Correlation	.089	.069	.368(**)	.333(**)	.379(**)	.700(**)	1	.573(**)	.693(**)
	Sig. (2-tailed)	.469	.576	.002	.006	.001	.000		.000	.000
	N	68	68	68	68	68	68	68	68	68
ws int 2 total correct exclud trans	Pearson Correlation	-.223	.085	.492(**)	.713(**)	.611(**)	.861(**)	.573(**)	1	.813(**)
	Sig. (2-tailed)	.068	.493	.000	.000	.000	.000	.000		.000
	N	68	68	68	68	68	68	68	68	68
word span int 2 total output	Pearson Correlation	-.069	-.120	.359(**)	.498(**)	.548(**)	.715(**)	.693(**)	.813(**)	1
	Sig. (2-tailed)	.578	.328	.003	.000	.000	.000	.000	.000	
	N	68	68	68	68	68	68	68	68	68

Table L2 – Chapter 6 – Serial Recall – Correlations Age, Gender, NART with order, omission and extra-list intrusions

		Age	gender	nart iq	ws - intrusion errors as proportion of total errors	ws no int omission proportion	proportion of transpositions errors	int 1 transposition proportion	ws 1 - intrusions errors as proportion of total	ws int 1 omission proportion	ws int 2 - trans proportion	ws 2 - omissions proportion	ws 2 - intrusions as proportion of total errors
age	Pearson Correlation	1	-.058	.025	-.017	.070	.291(*)	.398(**)	.262(*)	-.262(*)	.351(**)	-.010	.010
	Sig. (2-tailed)		.631	.834	.888	.570	.016	.001	.031	.031	.003	.938	.938
	N	72	72	72	68	68	68	68	68	68	68	68	68
gender	Pearson Correlation	-.058	1	.071	-.101	.041	-.225	-.110	-.294(*)	.294(*)	-.205	.252(*)	-.252(*)
	Sig. (2-tailed)	.631		.554	.412	.741	.065	.373	.015	.015	.094	.039	.039
	N	72	72	72	68	68	68	68	68	68	68	68	68
nart iq	Pearson Correlation	.025	.071	1	.092	-.073	-.551(**)	-.241(*)	-.091	.091	-.360(**)	.114	-.114
	Sig. (2-tailed)	.834	.554		.457	.557	.000	.048	.462	.462	.003	.353	.353
	N	72	72	72	68	68	68	68	68	68	68	68	68
ws - intrusion errors as proportion of total errors	Pearson Correlation	-.017	-.101	.092	1	-.901(**)	-.121	-.114	.258(*)	-.258(*)	-.140	-.394(**)	.394(**)
	Sig. (2-tailed)	.888	.412	.457		.000	.324	.355	.034	.034	.254	.001	.001
	N	68	68	68	68	68	68	68	68	68	68	68	68
ws no int omission proportion	Pearson Correlation	.070	.041	-.073	-.901(**)	1	.166	.142	-.244(*)	.244(*)	.164	.314(**)	-.314(**)
	Sig. (2-tailed)	.570	.741	.557	.000		.176	.248	.045	.045	.182	.009	.009
	N	68	68	68	68	68	68	68	68	68	68	68	68
proportion of transpositions errors	Pearson Correlation	.291(*)	-.225	-.551(**)	-.121	.166	1	.511(**)	.244(*)	-.244(*)	.706(**)	-.127	.127
	Sig. (2-tailed)	.016	.065	.000	.324	.176		.000	.045	.045	.000	.302	.302
	N	68	68	68	68	68	68	68	68	68	68	68	68
int 1 transposition proportion	Pearson Correlation	.398(**)	-.110	-.241(*)	-.114	.142	.511(**)	1	.116	-.116	.718(**)	.046	-.046

	Sig. (2-tailed)	.001	.373	.048	.355	.248	.000		.347	.347	.000	.709	.709
	N	68	68	68	68	68	68	68	68	68	68	68	68
ws 1 - intrusions errors as proportion of total	Pearson Correlation	.262(*)	-.294(*)	-.091	.258(*)	-.244(*)	.244(*)	.116	1	-1.000(**)	.194	-.489(**)	.489(**)
	Sig. (2-tailed)	.031	.015	.462	.034	.045	.045	.347		.000	.114	.000	.000
	N	68	68	68	68	68	68	68	68	68	68	68	68
ws int 1 omission proportion	Pearson Correlation	-.262(*)	.294(*)	.091	-.258(*)	.244(*)	-.244(*)	-.116	-1.000(**)	1	-.194	.489(**)	-.489(**)
	Sig. (2-tailed)	.031	.015	.462	.034	.045	.045	.347	.000		.114	.000	.000
	N	68	68	68	68	68	68	68	68	68	68	68	68
ws int 2 - trans proportion	Pearson Correlation	.351(**)	-.205	-.360(**)	-.140	.164	.706(**)	.718(**)	.194	-.194	1	-.032	.032
	Sig. (2-tailed)	.003	.094	.003	.254	.182	.000	.000	.114	.114		.796	.796
	N	68	68	68	68	68	68	68	68	68	68	68	68
ws 2 - omissions proportion	Pearson Correlation	-.010	.252(*)	.114	-.394(**)	.314(**)	-.127	.046	-.489(**)	.489(**)	-.032	1	-1.000(**)
	Sig. (2-tailed)	.938	.039	.353	.001	.009	.302	.709	.000	.000	.796		.000
	N	68	68	68	68	68	68	68	68	68	68	68	68
ws 2 - intrusions as proportion of total errors	Pearson Correlation	.010	-.252(*)	-.114	.394(**)	-.314(**)	.127	-.046	.489(**)	-.489(**)	.032	-1.000(**)	1
	Sig. (2-tailed)	.938	.039	.353	.001	.009	.302	.709	.000	.000	.796	.000	
	N	68	68	68	68	68	68	68	68	68	68	68	68

Table L3 – Chapter 7 – Individual Difference (contribution to span) Correlations between Age, Gender, NART and chapter variables

		age	gender	nart iq	counting in secs	alphabet in secs	mental control (3 count) in secs	lexical decision no. correct	word naming no.	non-word naming	odd word naming	digits forward span number achieved	digits backward actual span achieved	letter number sequencing raw	ws percent correct (excl trans)	ws int 1 percentage correct exclude trans	ws - int 2 - percent correct exclud trans
age	Pearson Correlation	1	-.058	.025	.342(**)	-.070	.198	-.323(**)	-.101	-.245(*)	-.163	1	-.058	.025	.342(**)	-.070	.198
	Sig. (2-tailed)		.631	.834	.003	.558	.096	.006	.397	.038	.172		.631	.834	.003	.558	.096
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
gender	Pearson Correlation	-.058	1	.071	-.103	-.037	-.002	.272(*)	.221	.175	.396(**)	-.058	1	.071	-.103	-.037	-.002
	Sig. (2-tailed)	.631		.554	.387	.756	.989	.021	.062	.143	.001	.631		.554	.387	.756	.989
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
nart iq	Pearson Correlation	.025	.071	1	-.329(**)	-.351(**)	-.349(**)	.404(**)	.505(**)	.538(**)	.497(**)	.025	.071	1	-.329(**)	-.351(**)	-.349(**)
	Sig. (2-tailed)	.834	.554		.005	.003	.003	.000	.000	.000	.000	.834	.554		.005	.003	.003
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
counting in secs	Pearson Correlation	.342(**)	-.103	-.329(**)	1	.402(**)	.456(**)	-.513(**)	-.648(**)	-.464(**)	-.342(**)	.342(**)	-.103	-.329(**)	1	.402(**)	.456(**)
	Sig. (2-tailed)	.003	.387	.005		.000	.000	.000	.000	.000	.003	.003	.387	.005		.000	.000
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
alphabet in secs	Pearson Correlation	-.070	-.037	-.351(**)	.402(**)	1	.506(**)	-.206	-.464(**)	-.214	-.174	-.070	-.037	-.351(**)	.402(**)	1	.506(**)
	Sig. (2-tailed)	.558	.756	.003	.000		.000	.082	.000	.071	.145	.558	.756	.003	.000		.000
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
mental control (3 count) in secs	Pearson Correlation	.198	-.002	-.349(**)	.456(**)	.506(**)	1	-.375(**)	-.455(**)	-.344(**)	-.311(**)	.198	-.002	-.349(**)	.456(**)	.506(**)	1
	Sig. (2-tailed)	.096	.989	.003	.000	.000		.001	.000	.003	.008	.096	.989	.003	.000	.000	
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
lexical decision no. correct	Pearson Correlation	-.323(**)	.272(*)	.404(**)	-.513(**)	-.206	-.375(**)	1	.661(**)	.620(**)	.504(**)	-.323(**)	.272(*)	.404(**)	-.513(**)	-.206	-.375(**)
	Sig. (2-tailed)	.006	.021	.000	.000	.082	.001		.000	.000	.000	.006	.021	.000	.000	.082	.001
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
word naming no.	Pearson Correlation	-.101	.221	.505(**)	-.648(**)	-.464(**)	-.455(**)	.661(**)	1	.634(**)	.501(**)	-.101	.221	.505(**)	-.648(**)	-.464(**)	-.455(**)
	Sig. (2-tailed)	.397	.062	.000	.000	.000	.000	.000		.000	.000	.397	.062	.000	.000	.000	.000

	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
non-word naming	Pearson Correlation	-.245(*)	.175	.538(**)	-.464(**)	-.214	-.344(**)	.620(**)	.634(**)	1	.482(**)	-.245(*)	.175	.538(**)	-.464(**)	-.214	-.344(**)
	Sig. (2-tailed)	.038	.143	.000	.000	.071	.003	.000	.000		.000	.038	.143	.000	.000	.071	.003
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
odd word naming	Pearson Correlation	-.163	.396(**)	.497(**)	-.342(**)	-.174	-.311(**)	.504(**)	.501(**)	.482(**)	1	-.163	.396(**)	.497(**)	-.342(**)	-.174	-.311(**)
	Sig. (2-tailed)	.172	.001	.000	.003	.145	.008	.000	.000	.000		.172	.001	.000	.003	.145	.008
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
digits forward span number achieved	Pearson Correlation	-.186	.221	.618(**)	-.395(**)	-.353(**)	-.399(**)	.521(**)	.496(**)	.518(**)	.489(**)	-.186	.221	.618(**)	-.395(**)	-.353(**)	-.399(**)
	Sig. (2-tailed)	.118	.062	.000	.001	.002	.001	.000	.000	.000	.000	.118	.062	.000	.001	.002	.001
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
digits backward actual span achieved	Pearson Correlation	-.209	.251(*)	.396(**)	-.393(**)	-.287(*)	-.339(**)	.481(**)	.453(**)	.456(**)	.307(**)	-.209	.251(*)	.396(**)	-.393(**)	-.287(*)	-.339(**)
	Sig. (2-tailed)	.078	.034	.001	.001	.014	.004	.000	.000	.000	.009	.078	.034	.001	.001	.014	.004
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
letter number sequencing raw	Pearson Correlation	-.259(*)	.236(*)	.571(**)	-.513(**)	-.401(**)	-.512(**)	.554(**)	.679(**)	.529(**)	.476(**)	-.259(*)	.236(*)	.571(**)	-.513(**)	-.401(**)	-.512(**)
	Sig. (2-tailed)	.028	.046	.000	.000	.000	.000	.000	.000	.000	.000	.028	.046	.000	.000	.000	.000
	N	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
ws percent correct (excl trans)	Pearson Correlation	-.284(*)	.211	.578(**)	-.569(**)	-.329(**)	-.469(**)	.641(**)	.669(**)	.582(**)	.532(**)	-.284(*)	.211	.578(**)	-.569(**)	-.329(**)	-.469(**)
	Sig. (2-tailed)	.019	.084	.000	.000	.006	.000	.000	.000	.000	.000	.019	.084	.000	.000	.006	.000
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
ws int 1 percentage correct exclude trans	Pearson Correlation	-.269(*)	.151	.438(**)	-.398(**)	-.279(*)	-.416(**)	.422(**)	.473(**)	.446(**)	.418(**)	-.269(*)	.151	.438(**)	-.398(**)	-.279(*)	-.416(**)
	Sig. (2-tailed)	.026	.220	.000	.001	.021	.000	.000	.000	.000	.000	.026	.220	.000	.001	.021	.000
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68

ws - int 2 - percent correct exclud trans	Pearson Correlation	-.223	.085	.492(**)	-.364(**)	-.288(*)	-.450(**)	.451(**)	.532(**)	.440(**)	.392(**)	-.223	.085	.492(**)	-.364(**)	-.288(*)	-.450(**)
	Sig. (2-tailed)	.068	.493	.000	.002	.017	.000	.000	.000	.000	.001	.068	.493	.000	.002	.017	.000
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68