MEMORY PERFORMANCE AND ADAPTIVE STRATEGIES IN YOUNGER AND OLDER ADULTS DURING SINGLE AND DUAL TASK CONDITIONS

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DECLARATION

"I certify that this work has not been accepted in substance for any degree, and is not currently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations except where otherwise identified by references and that I have not plagiarised the work of others."

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ABSTRACT

Previous research has shown that the aging process is typically accompanied by a decline in a range of cognitive functions, including memory and attention. It has been hypothesised that older adults have reduced cognitive resources, which makes engaging in deeper encoding strategies difficult. However, training older adults in using encoding strategies has been shown to successfully improve their performance. Whether these benefits are apparent when performing more than one task at a time is less known. Owing to the demanding nature of dual tasks, older adults may be more penalised when using an effortful encoding strategy resulting in greater secondary task costs.

Four studies were designed to determine whether encoding strategies (such as imagery/association) have the potential to enhance memory performance in young and older adults in single and dual task conditions. Participants were asked to encode a list of words on their own and also when undertaking a concurrent auditory discrimination task. Study 2 and 3 also examined age-differences in strategy selection and execution by ascertaining which strategies were adopted when participants were free to choose and when asked to use a specific strategy. Study 4 looked at whether the trained strategies could be transferred to an untrained working memory task.

Overall the results revealed that training younger and older adults in encoding strategies can enhance memory performance in single and dual task conditions. However, this was not a consistent finding in all studies. Importantly older adults' increase in performance in the dual tasks did not come at a cost to the secondary task. Results indicated that older and younger adults rely on different strategies to improve performance in single tasks, emphasising the importance to teach a variety of memory strategies and allowing participants to choose. The theoretical and practical implications of the findings are discussed.

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1   Introduction

"By the time you're eighty years old you've learned everything. You only have to remember it."

George Burns (1896-1996)

Aging is often accompanied by physical and cognitive decline. Today's aging population (by 2034 over 23% of the UK population will be aged over 65, Office for National Statistics, 2010) is having a profound effect on society in many ways, including increased health care and pension costs (Silcock & Sinclair, 2012). Therefore the study of aging has become an important area for research. Reports suggest that losing their memory and independence are primary concerns of the elderly (McDougall, 1992; Reese & Cherry, 2004). Although it is evident that people do experience a cognitive decline as they get older, characterised by deterioration in aspects of memory, learning, attention, language use and other mental functions (Woodruff-Pak, 1997), it has been proposed that older adults are able to compensate for these declines by using effective strategies (Verhaeghen, Marcoen, & Gossens, 1992). Therefore it is of paramount importance to examine ways in which cognitive functioning can be enhanced and to continue to research into what constitutes as 'healthy aging'.

There have been a number of theories put forward to account for the cognitive changes that are exhibited with age. Reductions in processing resources such as working memory (Park, Smith, Dudley & Lafronza, 1989), processing speed (Salthouse, 1991) and inhibition (Hasher & Zacks, 1988) have all been offered as explanations of cognitive aging. These processes have therefore been the target of interventions to determine whether these declines can be reduced or negated altogether so that performance is comparable to that of younger adults. One area that has been extensively researched is memory, and how certain memory strategies may improve performance.

To effectively remember information from memory, it must first be encoded, stored and then successfully retrieved. If a breakdown occurs in any of these processes then the information cannot be accessed and is said to be forgotten. Forgetting is thought to occur for a number of reasons; the most prominent theories put forward are the decay and interference account. Decay accounts assume that memory traces are lost or become less

precise over time (Brown, 1958; Peterson & Peterson, 1959; Estes, 1972), whereas interference accounts postulate that new information can interfere with previously learned information (retroactive interference), or that previously learned information can interfere with new information (proactive interference) (Keppel & Underwood, 1962).

One vital aspect of forgetting is encoding, as if information is not encoded effectively, it is less likely to be successfully stored into long-term memory and therefore is vulnerable to forgetting (Schacter, 2001). This would be particularly salient in the older population as the encoding process has been identified as an area in which older adults experience a deficit and therefore a good target for intervention (Bissig & Lustig, 2007; Friedman & Johnson, 2014; Parkinson, Inman & Dannebaum, 1985). Therefore it is the encoding process that will be the focus of the current research, specifically how this can be enhanced through the use of memory strategies, especially in older adults. Examples of encoding strategies that have been commonly investigated in the literature include rote rehearsal (mentally repeating the information over and over), imagery (constructing a picture in your head) and association (associating the information that needs to be remembered with information already known or with other to-be-remembered information) (Dunlosky & Hertzog, 2001)

Such memory strategies rely on both working memory and long-term memory processes, as the information will initially be processed in working memory in order to be encoded into the more permanent long-term memory store (van der Linden, 1998). Although encoding of information can occur quite naturally/automatically, use of effortful strategies typically enhance the encoding process. According to the levels of processing hypothesis (Craik & Lockhart, 1972), a memory trace is more likely to be retrieved at a later stage, if a deeper, more meaningful analysis is conducted on the item as this would result in stronger retrieval cues that can trigger the memory trace. It is believed that memory strategies such as imagery and association "trigger associations, images or stories on the basis of the subject's past experience with the word" (Craik & Lockhart, p165) and therefore improve recall.

Several studies indicate that when older adults are given memory strategy training, they are able to utilise internal memory strategies to enhance their recall performance (Fairchild & Scogin, 2010; Gross & Rebok, 2011; Verhaeghen et al., 1992). However,

most of these studies report age-differences in performances post-training, with older adults still showing reduced performance compared to younger adults. This could be a result of qualitative differences in how the strategy is executed, or that older adults may not derive the same benefit from using the strategy as younger adults (Gaultney, Kipp & Kirk, 2005). Nonetheless it does seem that strategies can improve performance; and age differences are not always found. For example, Caretti, Borella and De Beni (2007) found that when using an imagery strategy, older adults were able to increase their performance and this was comparable to that of younger adults when individual differences were controlled for (i.e. they benefitted from the strategy training to the same degree).

The effectiveness of using an imagery strategy is surprising given that it is considered a demanding and effortful strategy, and that older adults are believed to face a reduction in processing resources (Craik & Byrd, 1982; Hasher & Zacks, 1988). However, accounts emphasising that older adults have reduced attentional resources have been criticised as being too descriptive and have not been fully justified by empirical support (Light, 1991; (Salthouse, 1991). For example, increasing the number of mental operations performed in a span task does not increase age-related differences in a working memory task (Babcock & Salthouse, 1990) which would be predicted by the reduced processing resource theory of cognitive aging (Craik & Byrd, 1982; Hasher & Zacks, 1988).

An attractive explanation to account for age-related differences in memory is the environmental support framework conceptualised by Craik and Byrd, (1982). According to this framework, "older adults are less able to self-initiate appropriate mental operations, owing perhaps to reduced attentional resources or to a decrease in frontally-based control mechanisms" (Craik & Rose, 2011, p6). Whether age differences will be seen depends on the demands of the task; if the task is more bottom-up or stimulus driven, then this will provide 'environmental support' by providing a context to the information (e.g. recognition as opposed to recall) or making encoding operations easier (using pictures instead of words), and would therefore result in older adults performing as well as younger adults (Craik & Byrd, 1982). It is proposed that processing difficulties in older adults can be overcome by giving strategy instruction at the encoding stage (Troyer, Häfliger, Cadieux & Craik, 2006).

One aspect that has been less studied in the field of cognitive aging is whether older adults are able to adapt their strategy use to changing task demands. Past research investigating adaptive strategy use has mainly centred on decision making and mental arithmetic (Mata, 2006; Lemaire, Arnaud & Lecacheur, 2004). One such study that examined memory performance was conducted by Tournier and Postal (2011), who found that older adults could adapt their strategy use in a paired-associate task by using a sentence generation strategy, but were less able to adapt their strategy use when using an imagery strategy. It was concluded that older adult's preserved verbal knowledge meant that they were able to utilise a sentence generation strategy as well as their younger counter-parts, but this was not the case for the imagery strategy. In a similar study that focused on imagery and rehearsal strategies; Hertzog, Price and Dunlosky, (2012) found that when participants were free to choose a strategy, older adults persisted in using a more superficial/ineffective strategy. These results indicate that perhaps when older adults do not have environmental support and have to self-initiate a strategy, they are unable to implement an effortful but typically more effective strategy.

There is a wealth of evidence to support the claim that individuals who possess a greater working memory capacity yield superior performance in a number of cognitive tasks (Bissig & Lustig, 2007; Cokely, Kelley & Gilchrist, 2006). It has been proposed that having a greater working memory capacity allows for the utilisation of resource demanding strategies, which may be unavailable to those possessing a lower memory capacity (Turley-Ames & Whitfield, 2003; Gaultney et al., 2005). As older adults typically show a decrease in working memory capacity/processing resources then it is conceivable that this may limit or hinder strategy use (Bryan, Luszcz & Pointer, 1999). One way in which to examine this is to use the divided attention paradigm. If older adults have reduced resources then they should be more affected by dividing their attention than younger adults.

This research aims to investigate age differences in strategy use in a memory task, but to also extend this to incorporate circumstances of divided attention. Given that older adults are thought to be constrained by limitations in their processing resources, then in a task that places greater demands on these resources, it is anticipated that they would be penalised, and may be unable to implement effective encoding strategies.

1.1 Statement of Problem

There are a variety of circumstances in everyday life that require us to perform more than one task at a time and to divide our attention between these two tasks, e.g. consider trying to recall a shopping list whilst listening for your train to be announced. Whilst performing these tasks it is important to be able to keep in mind both sets of task demands and to coordinate and allocate cognitive resources between the two. Research has shown that both facets of memory and attention are required in these circumstances (Baddeley, 1986; D'Esposito, Detre, Alsop, Shin, Atlas & Grossman 1995) and this has implications for the older population who are shown to experience declines in these systems.

Research examining divided attention in older adults has revealed mixed findings. Some studies have found that older adults perform worse than younger adults and may even represent a dual-task deficit, particularly at encoding (Craik, Govoni, Naveh-Benjamin & Anderson, 1996; Park et al., 1989.) However, some studies have shown that older adults are able to manage dual-task situations and show no impairment when compared to younger adults (Anderson, Craik & Naveh-Benjamin, 1998; Baddeley & Della Salla, 1996). As such, no coherent picture has emerged from the research regarding whether older adults do experience a deficit at encoding, particularly when attention is divided. Therefore it is difficult to assess whether strategies are likely to be useful for older adults in these tasks, and which ones will be effective.

1.2 Purpose of the research

With the predominantly positive findings of using an elaborative encoding strategy (such as imagery/association) in single-task conditions, a key question of interest is whether they can be utilised to increase performance in dual-task conditions. Therefore the main focus of this research will be to determine whether strategy training will lead to enhanced performance in dual-task circumstances for both younger and older adults. Relatively few studies exist that have investigated this directly, and have either focused on different strategies such as word generation (Whiting, 2003) or merely instructed participants to use a particular strategy (Naveh-Benjamin, Craik, Guez & Kreuger, 2005). Therefore this research will examine whether training in encoding strategies will allow older adults to use them effectively in single and dual task circumstances. It is unclear whether teaching older adults in the use of strategies will act as a form of environmental support and

alleviate task demands, or whether implementation of a demanding strategy will tax already limited resources.

Crucially, even if older adults are able to improve their memory performance by using effective encoding strategies following training, this does not necessarily reflect everyday memory situations where strategies need to be self-initiated. As older adults are typically less likely to engage in encoding strategies, and this may partially mediate age-related changes in episodic memory (Verhaeghen & Marcoen, 1994), this is an important factor and will be examined in the current research. Therefore a secondary aim of this thesis is to establish whether there are age-related differences in self-initiated strategies by observing the use of spontaneous strategy use.

Previous research has indicated that processes such as working memory capacity do influence strategy use as higher working memory capacity has been linked to a greater ability to utilise elaborative encoding strategies (Cokely et al., 2006; Unsworth, Brewer & Spillers, 2011). Therefore, another objective of the research is to determine if individual differences in processing resources such as working memory capacity and executive function can account for successful strategy use. Finally, the contribution of age and individual differences in processing resources such as working memory capacity to strategy adaptivity will be examined.

This research aims to utilise theories of cognitive aging in order to identify whether encoding strategies are effective for older adults in dual tasks. By examining in which situations older adults can improve their memory performance this research can contribute to current understanding in the field. By understanding how and under which circumstances strategy use can enhance recall in older adults, it can help to inform us of the processes involved in performing single and dual tasks. Furthermore, studying age-related differences in cognitive performance will not only identify any limitations exhibited by older adults, but also illuminate compensatory mechanisms adopted which can shape future models of cognitive aging that emphasise gains as well as losses.

In addition to being of theoretical interest, it is also of importance to understand the real-life issues faced by the aging population.

2   Literature Review

2.1   Chapter Overview

This chapter will give an overview of our current understanding of memory and attention (sections 2.2-2.3). In particular, it will describe the key concepts relating to memory (short-term, working, and long term memory) and outline how this can be further fractioned into procedural and declarative memory, before going on to look at attention including selective, focused and divided attention.

This chapter will then, in section 2.3 focus on how memory and attentional processes are affected in normal aging. The underlying theories of cognitive aging will be reported and discussed, and the implications of these for performance in simple memory tasks and dual tasks will be considered. Ways in which to improve memory performance using memory strategies will be examined.

Also the literature concerning the ability to perform more than one task at a time will be reviewed and the links between aging, divided attention, working memory and strategy use explored (Sections 2.3.4- 2.5). Finally, gaps in the literature will be identified and the aims of the current study stated.

2.2   Human Cognition

Human cognition has been defined as the 'collection of mental processes and activities used in perceiving, remembering, thinking and understanding as well as the act of using these processes,' (Ashcraft, 2006, p11). The term cognition refers to mental processes, including attention, perception, learning, memory, language, reasoning and decision-making, and involves the idea of information processing.

2.2.1   Memory

Psychologists define memory as the ability to encode, store and retrieve information. Findings from experimental work have led to the concept of memory being developed and refined over the decades. Inspired by the findings of Brown, (1958) and Peterson and Peterson (1959), showing that individuals exhibit short-term forgetting if asked to repeat a string of three consonants after a delay, a distinction between short-term memory and

long-term memory was proposed. In the 1960's accounts of memory shifted from a unitary model to a multi-component model. The most prominent of which was developed by Atkinson and Shiffrin, (1968), which proposed that information from the environment enters through sensory memory systems, then passes through to a limited capacity short-term store (2-4 items) and later to a long-term store. This model was criticised for not fully explaining all of the research findings, for example some secondary tasks (e.g. repeating digits were not found to effect performance for visually presented word lists). Therefore the model was further refined to include a multi-component for short-term memory, labelled 'working memory' which consisted of separate subsystems dealing with information received from different modalities (Baddeley & Hitch, 1974).

Evidence to support the existence of different subsystems of memory comes from neuropsychological studies of brain damaged patients. For example, the case of H.M (Scoville & Milner, 1957) who exhibited impaired long-term memory[1] as shown by an inability to form new memories, but preserved short-term functioning as tested by digit span, supports the claim for separate short-term and long-term memory systems. However, a single dissociation is not considered sufficient evidence that two systems are independent. The case of K. F (Shallice & Warrington, 1970) who exhibited the opposite pattern to H.M (deficits in short-term memory, but intact long-term memory) have provided evidence of a double disassociation between short-term and long-term memory. Taken together, these cases support the claim of independent systems of short-term/working memory and long-term memory. In addition to the division of memory into long and short-term memory, other divisions have been made and supported by neurological evidence.

Although there is debate on the exact nature of these divisions in memory, the most prominent framework was put forward by Schacter and Tulving, (1994) in which the memory system was divided into five components. These were: the perceptual representational memory (sensory memory), primary memory (short-term memory/working memory), long-term memory, which will now be outlined.

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[1]H.M showed impairment in declarative long-term memory systems, but could learn new skills such as mirror drawing (Milner, 1956) (a non-declarative long-term memory process). This is addressed later in this section, when these concepts are discussed.

2.2.1.1 *The Perceptual Representational System (PRS)*

This system can be best conceptualised as a collection of subsystems that are responsible for the early processing of sensory and perceptual information from different modalities (Tulving & Schacter, 1990). As such, the PRS processes information about the form and structure of words, objects etc. and therefore does not include semantic or associative information (Warrington & Shallice, 1980). Research has shown that people are affected when the sensory properties of the information presented is degraded. For example when Murphy, Craik, Li and Schnieder (2000) presented participants with a paired associate task, performance was decreased when the auditorily presented stimuli were accompanied by background noise. It was concluded that this reduction in performance reflected an inability to create adequate memory traces, although participants had no difficulty in perceiving the stimuli.

Evidence for the existence of the PRS also comes from the repetition priming effect. This is where exposure to a degraded stimulus often leads to increased performance in identifying/processing the stimulus on repeated exposure, even when participants do not acknowledge prior exposure to the stimulus. This highlights that the PRS is an implicit system that does not require conscious awareness (Schacter, 1990), and therefore many memory tasks require the PRS to work in collaboration with other memory systems to elicit explicit responses. Although the PRS is an implicit system, it is not necessarily involved in all implicit tasks, those that rely on conceptual processing will still depend on episodic and semantic memory (Schacter, 1989).

2.2.1.2 *Primary Memory/ Short- Term/Working Memory*

Working memory can be defined as 'the ability to mentally maintain information in an active and accessible state, while concurrently and selectively processing new information,' (Conway et al., 2007, p3). Working memory is important as it is involved with many different areas of cognition such as, memory, language and problem solving (Baddeley & Hitch, 1994). The exact nature of working memory has been the source of debate (Shah & Miyake, 1999) and a number of models have been put forward to explain the precise nature of WM. Most current theories (Baddeley & Hitch, 1974; Cowan, 2001; Engle, Kane & Tulholski, 1999) would postulate that working memory consists of mechanisms for both storage and processing in order for information to be retained and

manipulated for the execution of cognitive tasks. The storage component has a limited capacity and this capacity has an impact on cognitive performance, namely that individuals with a greater capacity perform better in a number of cognitive tasks. It is this storage and processing component that led researchers to distinguish short-term from working memory. Both short-term and working memory possess the storage component, but in addition to this, working memory has an attentional component that allows for manipulation of the information.

The most prominent account of Working Memory (WM) is the model proposed by Baddeley and Hitch (1974, revised by Baddeley, 2000). They theorise that WM consists of a limited capacity store, and is supported by two slave systems, the phonological loop that processes auditory information and the visual-spatial sketchpad that primarily deals with visual information. The WM is overseen by a central executive and aided by the episodic buffer that allows for information that is not exclusively visual-spatial or phonological to be incorporated into this model.

Other theories emphasise the importance of attentional processes. Cowan's (1995; 2001) embedded-process model suggests that Working Memory consists of two tiers, one which is immediately accessible and essentially the 'focus of attention,' and the other is a larger section of long-term memory that has been activated, and is available but cannot be accessed immediately. It is hypothesised that the focus of attention has a limited capacity, namely 4 chunks, and the activated portion of long-term memory is much larger, and only limited by interference from similar items and decay over time.

In a similar vein, Engle, Kane and Tuholski (1999) proposed that working memory capacity (WMC) reflects controlled attention. Controlled attention refers to the ability to sustain attention by activating memory representations and bringing them into focus and maintaining them, in the face of distracting information. It is evident that the main models for working memory described above include an attentional construct and this overlap between memory and attentional processes will be discussed in more detail later.

Working memory is typically measured by a span task which requires participants to recall information in a specific order, such as digits or words. Span tasks can be classified as either simple or complex in nature (de Jonge & de Jong, 1996). Simple tasks,

sometimes referred to as single-tasks emphasise the role of storage, whereas in more complex tasks such as dual-tasks both storage and processing occur simultaneously, as participants are required to not only remember the information, but to transform it in some way. For example, with regards to digit span the simple measure requires participants to repeat a string of digits that increases by an additional digit over trials. The complex measure also increases by one digit at each trail, but requires participants to repeat the digits in reverse order. Simple span measures have been criticised as not measuring WM, as they do not reflect both processing and storage, which are functions of WM (Engle, Tuholski, Laughlin & Conway, 1999).

It has been proposed that higher working memory spans offer a greater ability to resist interference. This theory is offered support as complex spans measure a person's ability to maintain information in WM whilst processing other information that is irrelevant to the other task. Therefore it may be that complex spans are in fact measuring a person's ability to resist interference from this distracting information, as to perform well on a complex span task a person must perform well on both components on the task (Engle & Kane, 2004).

This is a central premise in the controlled attention framework, as WMC reflects the ability to maintain task goals (control attention) in cases of interference or distraction. In fact, when controlled attention is required in situations free from distraction/interference than differences in WMC are not shown (Kane, Bleckley, Conway & Engle, 2001). This ability has been referred to as 'executive attention' and has been described as "the ability to maintain stimulus and response elements in active memory, particularly in the presence of events that would capture attention away from that enterprise" (Engle & Kane, 2004; p192). Evidence for this framework not only comes from studies of memory span tasks, but also attentional tasks such as dichotic listening (Conway, Cowan & Bunting, 2001; Colflesh & Conway, 2007) and Stroop tasks[2]

Conversely, other authors (e.g. Lustig, Hasher, & Zacks, 2007) have suggested that WM tasks do not measure capacity, but in fact measure inhibitory processes. This is because WM span measures often rely on the ability to inhibit previous trials and focus on the

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[2]The relationship between memory and attention is discussed in section 2.2.4 where more information about these studies is given.

current trial. This will cause proactive interference as irrelevant information in the form of the 'old' words presented from the trials before will build up and lead to more errors[3]

2.2.1.3 *Long-term Memory*

Long-term memory refers to the system for storing information, in order for it to be retrieved at a later stage which could span from hours to decades later. The storage capacity of long-term memory is hard to quantify (Landauer, 1986), but is thought to be very vast. Various attempts to classify the long-term memory system have been made over the years, and as a result different taxonomies have been proposed, which will be briefly outlined.

In the 1960's, studies showing that amnesic patients such as H.M could learn new skills such as mirror drawing (but with no conscious recollection of performing the task) (Milner, 1962) sparked debate as it was contrary to the prevailing idea that memory was a unitary concept. However it was incorporated into the current theories, as motor skills were regarded as a distinct process, separate from the rest of 'memory'. In the 1970's, research findings of amnesic patients showing learning and retention (other than motor skills) (Warrington & Weiskrantz, 1968) led to attempts to categorise long-term memory in order to account for these findings. Such explanations were still unitary in nature, but focussed on poor retrieval (Warrington & Weiskrantz, 1970).

It was not until the 1980's when researchers proposed new theories to explain these findings, leading to a dichotomy of memory systems, one of which was preserved in amnesics (Cohen & Squire, 1980). Of these theories were the taxonomy of declarative and procedural memory (Cohen & Squire, 1980), which emphasised that motor skills were not unique but a larger subset of skills which are protected in amnesia, e.g. mirror drawing, category learning and cognitive skill learning (Squire & Franbach, 1990; Knowlton & Squire, 1993). Other dichotomies included a distinction between explicit and implicit memory (Graf & Schacter, 1978) and memory and habit (Mishkin, Malamut & Bachevalier, 1984).

These models of long-term memory were further developed to incorporate findings from neuropsychological studies that revealed existing dichotomies to be too simplistic

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[3]Links between working memory and inhibition are discussed further in section 2.3.2.3

(Tulving, 1985). Therefore a multiple memory framework was established proposing further divisions in the systems of declarative and non-declarative systems.

Declarative memory refers to knowledge that is consciously recalled, whereas procedural memory comprises of unconscious memories such as skill and habit learning. Typically declarative memory is measured by explicit memory tasks and procedural by implicit memory tasks. Declarative memory is further divided into episodic and semantic memory. Some researchers have argued that taxonomies are "descriptive rather than explanatory" (Willingham & Goedert, 2001, p257) and divisions based on the processes that are disrupted/preserved in amnesic patients are rather circular in nature as distinctions are defined to fit the findings (Ostegaard & Jernigan, 1993). Nevertheless such taxonomies have prevailed in the literature, and despite such criticisms are useful for inspiring future research and developing new theories.

2.2.1.4 *Episodic memory*

Episodic memory is best described as memory for personally experienced events. Particular events experienced at a certain place and time are remembered. It is believed that there is a degree of overlap between episodic and semantic memory, but they should be regarded as separate subsystems of long-term memory. Episodic memory is distinguished from other forms of memory as it allows individuals to mentally "travel back into her personal past" (Tulving, 1998, p265) and therefore requires autonoetic awareness (remembering one's past), whilst retrieval from semantic memory requires only noetic awareness.

The most conclusive evidence that episodic memory is a separate system from semantic memory comes from case studies inferring a double dissociation. K.C (Tulving, Hayman & Macdonald, 1991); a severely amnesic man who can remember facts, has a normal vocabulary and can play chess and bridge, but who cannot remember specific events from his life provides evidence for an intact semantic but impaired episodic memory. Providing further support for the distinction is the case of L.P, documented by De Renzi, Liotti, and Nichelli (1987), who displays the opposite pattern. L.P performs normally on recognition tests (testing episodic memory) but displays impaired semantic memory reflected in his inability to name famous people (De Renzi et al., 1987).

Episodic memory is typically tested using various recall and recognition tasks, for example asking participants to determine if they have previously encountered items from a word list. One paradigm that is commonly used to test episodic memory is free recall. In a free recall task participants are presented with a long list of words, pictures, sentences etc. and asked at a later stage (seconds, hours) to recall the items without the aid of any cues. Typical instructions for a free recall task would be "please write down all the items you remember from the list", whereas for cued- recall cues are given, for example some of the words may be given to aid retrieval of the others.

2.2.1.5 *Semantic memory*

Semantic memory can be best described as an individual's general knowledge about the world (Tulving, 1972). Unlike episodic memory, semantic memory is not context-bound, meaning that the time/place the memory was created is not pertinent. Semantic memory includes a wide variety of organised information such as facts, concepts and vocabulary. Semantic knowledge is often represented in the human processing system as a large network of words/concepts, commonly referred to as 'nodes', connected by associated pathways. Therefore when an individual hears a word or concept a node is activated and this spreads to activate related or associated nodes. A common way of measuring semantic memory is through the semantic priming paradigm, in which two words are presented sequentially, and the participants must remember one of the words in the pair when presented with the other. Results typically show that when the words are semantically similar (e.g. horse-zebra) participants respond quicker and more accurately than if they are not (e.g. zebra-book) (Balota, Dolan, & Duchek, 2000) and this is commonly referred to as the semantic priming effect.

Another commonly used test of semantic memory is the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1978, 1983) in which sixty pictures of objects are presented to participants in order to be identified. It starts with fairly common objects being presented such as a bed and progresses to more difficult items e.g. an abacus. Findings show that people between the ages of 20-69 typically score about 57 out of 60 (Farmer, 1990).

2.2.1.6 *Procedural memory*

Procedural memory refers to the learning of motor and cognitive skills which have an underlying automatic component to them (e.g. learning to drive a car; play the piano, reading). Often, these skills involve implicit memory and do not require conscious recollection, including of the initial learning of the skill/task.

Procedural memory is tested by use of the priming paradigm, as this does require conscious recall. It is typically found that the meaning of a word is processed more rapidly following initial presentation of a similar word. For example if the word PENCIL was presented after the word PEN, then it would be processed quicker than if the word CHAIR preceded it.   The principle being that the word PEN would activate the corresponding internal representation in memory and this would spread to other nodes, and result in quicker responses for similar words. Other tasks that work on a similar principle are word-stem tasks, where participants who are asked to complete word fragments are more likely to use a word they were earlier exposed to. For example people who were presented with the word purple are likely to respond with the word purple when asked to complete the word fragment PU_____. It has been demonstrated that although amnesics typically perform poorly on free recall and recognition tasks, they often display priming effects (Graf & Schacter, 1985), indicating that there are distinctions between procedural and other forms of memory.

2.2.1.7 *Summary*

The review of research presented thus far has supported the notion that memory is best conceptualised as a group of separate systems. Neuropsychological evidence provides support for a distinction between short-term and long-term memory stores (Milner, 1966; Shallice & Warrington, 1970). Furthermore, the existence of different sub-systems of long-term memory is claimed. Declarative memory supports consciously recalled information and is further fractioned into episodic and semantic memory, whilst procedural memory refers to memory for motor or skill learning that does not require conscious recollection of the learning phase.

Working memory is a refined concept of short-term memory and it is argued that it possesses an attentional construct, in addition to a limited capacity storage component (Engle, Tulholski, Laughlin, & Conway, 1999). There are many theories that have been

put forward to explain the construct of working memory, but most current theories do subscribe to the description given by Miyake and Shah (1999), that the storage components allow information to be active for a brief period of time and the controlled and executive attentional processes allow for manipulation of this information to occur in order for the task to be completed.

As the focus of this research is to determine whether memory strategies are effective in dual-tasks, it is important to consider how attention may have an impact. Dual- tasks represent a situation in which attention has to be divided, so the literature concerning divided attention will be reviewed. As working memory is considered to have an attentional element, the interface between memory and attention will also be discussed.

2.2.2   Attention

Despite William James' (1950/1890) claim that "everybody knows what attention is", there is still debate as to how to conceptualise this rather complex process. The difficulty lies in adequately describing the different processes, as the word 'attention' suggests a unitary concept. Instead attention refers to a broad concept, which includes processes such as keeping track of information, filtering certain information and responding to stimuli over a long period of time. To reflect this, researchers have concluded that there are "varieties of attention" (Parasuraman & Davies, 1984) which will be outlined now.

2.2.2.1   _Selective Attention_

The ability to filter certain information from a wide array of stimulus information is called selective attention. Selective attention can be best conceptualised by imagining yourself at a cocktail party with multiple conversations going on, and you have to selectively attend to your own conversation (this is dubbed the 'cocktail party effect', Cherry, 1953). One way to investigate this is by using dichotic listening tasks. In a dichotic listening task, participants are presented with two messages simultaneously (one in each ear) and asked to repeat the message from one ear (shadowing), whilst ignoring the other. Participants typically perform very badly when asked to recall the message from the ignored stream, but can often recall characteristics about the speakers voice (Moray, 1959).

Most selective attention tasks focus on one stream of information, but in the example of the cocktail party there are multiple streams of information that need to be processed. For

example, not only is the speakers voice important, but also visual information from the lips and face and irrelevant information in all modalities also needs to be ignored. This highlights how important it is for us in many everyday situations to coordinate input from different sensory modalities; often referred to as cross modal integration.

Research looking at cross-modal selective attention has typically found that it is quite difficult to ignore information presented in one modality, whilst attending to stimuli presented in another, even though they are very different (Broadbent, 1956; Simon & Craft, 1970). It has been argued that people may possess modality-specific attention, and that two streams of visual and verbal material should not interfere with each other (Wickens, 1980) as separate resources are required[4]. However, recently evidence has suggested that spatial location may be an important determinant in whether cross-modal interference will occur.

For example, Spence, Ranson and Driver (2001) found that performance was worse when relevant verbal and irrelevant (distracting) visual information was presented at the same location, as opposed to when they were separated spatially. This does not support the multiple resource theory as the two tasks rely on different resources and therefore should not be affected by spatial location. They are more consistent with a hybrid model of cross-modal attention as posited by Posner, (1990) which states that there are spatial links between visual and verbal information.

These findings also have links to divided attention, as often the two tasks involve different modalities. In fact it is a common finding, that when the spatial separation is increased for two relevant streams (auditory/visual) this makes it more difficult to attend to both simultaneously (Spence & Driver, 1996). Therefore the aspects that make dual tasking more difficult make selective attention easier (e.g. irrelevant sounds are placed in a different location to relevant visual stimuli).

2.2.2.2 *Focused Attention*

Focused attention tasks are similar to selective attention tasks as distracting information is present, however the difference is that participants are aware of the location of the target.

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[4]This concept is discussed in more detail when examining the literature on divided attention (2.2.3.4)

Tasks used to assess focused attention include cued versions of selective attention tasks, or choice-reaction tasks. Focused attention tasks require concentration and are influenced by various factors including motivation and fatigue (Rogers, 2000).

2.2.2.3   *Sustained Attention*

Sustained attention refers to the ability to process information over a certain period of time. Vigilance tasks are used to test sustained attention, in which participants must respond to random stimuli (Parasuraman, 1984). One such vigilance task, often used in the laboratory, is the clock task (Mackworth, 1948) in which participants watch a clock hand move around a blank clock face and have to report when the clock moves a double-step. It is found that people's attention typically wanes after 25- 35 minutes on these tasks when performance drops substantially (Pattyn & Soetens, 2004). It is believed that this may be due to under-arousal of the supervisory attentional system due to insufficient workload to successfully engage these processes (Stuss, 1995). Others postulate that performance declines as attentional capacity is decreased due to sustained mental effort (Grier, Warm, Dember, Matthews, Galinsky & Szalma, 2003).

2.2.2.4   *Divided Attention*

When two tasks are performed concurrently this is referred to as dual-tasking. Typically, performance in one or both tasks is worse when they are completed together compared to when they are performed individually. It is argued that performance in the two tasks decreases due to dual-task interference, meaning that one task interferes with the other in some way. However, there is some debate in why this interference occurs and in which conditions this can be minimised or increased.

Bottle-neck theories as advocated by Craik, (1947) and Broadbent, (1958) have theorised that dual-task interference is dependent on the type of tasks performed. Similar tasks will compete for the same pathways and therefore as parallel processing cannot occur, and tasks have to 'queue' in order to be processed this will cause a bottleneck. Welford (1952) argues that support is given to this claim using the Psychological Refractory Period (PRP) paradigm in which two reaction time tasks are performed in close temporal succession. The interval between the two tasks known as the stimulus onset asynchrony (SOA) is manipulated and results show that although responses to the first stimulus are unaffected,

responses to the second stimulus are slowed with decreasing SOA. This supports the claims of a central bottleneck as attending to the second stimulus can only occur after processing of the first one has occurred. The PRP effect is robust, and has been shown in a number of different circumstances, e.g. across different modalities, and even in simple tasks(for a review see Pashler, 1998).

Capacity theories move away from structural explanations and instead emphasise processing limitations. Kahneman (1973) postulated that processing capacity is limited in nature and is shared among the tasks. According to this theory there are a general pool of resources that need to be shared across the two tasks. If one task is highly demanding and exceeds capacity, then resources will be taken up with task, resulting in less resources allocated to the second task. This attention can be flexibly allocated across the two tasks and interference should only occur if the capacity is exceeded, which can be shown with declines in one or both of the tasks. Task difficulty is a factor in this model, irrespective of whether the tasks rely on different or similar processes. Instead, it is how difficult the task is and how much of the limited capacity it occupies that will ultimately have an effect on how well the tasks are performed.

Wickens (1984) postulated a multiple resource framework which assumed separate pools of resources limited in capacity. If tasks require different resources then performance will be greater than if they need to share resources. Moreover, Wickens argued that increasing task difficulty in one task will not result in increased interference if separate resources are utilised and resources cannot be allocated to take advantage of a reduction in required resources if one task is made easier. This theory has been criticised as lacking specificity as the term 'resources' is not very well defined (Hirst & Kalmar, 1987).

McLeod and Posner (1984) like Wickens (1984) have also argued that interference is task dependent; however, unlike Wickens, it is not the modality of the task that is important, but rather the stimulus- response compatibility. This has been revised by Greenwald (2004) who found that when there was a direct and obvious relationship between stimulus and response (input and output) (e.g. say A when see A) then dual-task decrements are not found.

Another alternative is the notion of cross-talk (e.g. Navon & Miller, 1987) according to which two tasks which rely on similar representations or processes will lead to 'confusion' or 'cross-talk' between them, and result in interference or disruption of the processing of one of the tasks, thus limiting dual-task performance. Conversely, Fracker and Wickens (1989) theorised that performing two tasks together leads to cooperation between them and should lead to similar levels of performance in both. Arrington, Altmann and Carr (2003) believed that similar tasks should contribute to increased task-switching abilities. Although cross-talk may not be the sole cause of interference, there are circumstances in which similar tasks have been shown to exacerbate this interference (Navon & Miller). However, these have been rather extreme cases of similarity and in more typical/moderate situations the research is more inconsistent. It has been postulated that the similarity may only be present when the tasks are at the molar level rather than the micro-level. Molar-level tasks are more encompassing, e.g. 'driving' 'holding a conversation' whereas micro-level tasks are processing operations over a short space of time. Pashler (1998) suggested that task similarity may be very influential in the molar-level tasks, which rely heavily on switching attention between the two tasks, as demonstrated in the continuous type dual-tasks.

Memory is another factor that has been implicated in dual-tasking. According to Baddeley (1986), the central executive component of working memory is responsible for sharing resources between storage and processing. One function of the central executive is to plan and control behaviour and in dual-tasks to allocate resources between the two tasks, based on the priorities as determined by the individual (Chipunza & Mandeya, 2005). If two tasks are utilising the same resource then by allocating more resources to one (if assigned a higher level of priority, for instance) less resources are allocated to the other (Baddeley & Della Salla, 1996). D'Esposito et al. (1995) confirmed that working memory was important for performing dual tasks using neuroimaging. They found that activity in the dorsolateral prefrontal cortex (one of the known structures of the brain sub serving working memory) was recorded with dual tasks but not single tasks. This finding indicates that working memory (specifically the central executive) is used in dual-tasks (where the two individual tasks are not working memory based) for the allocation and coordination of attentional resources. Furthermore, it was found that the distribution of recruited areas in the prefrontal cortex was varied, which may be indicative of people using different strategies when dual-tasking (D'Espositio et al., 1995).

Complex span tasks used to measure WMC have been classified as dual-tasks, as they are involved in both processing and storage. This suggests a direct link between WMC and performance in dual-task situations as if complex span tasks are measures of how well a person can perform two simultaneous tasks together then this would be reflected in their WMC. Therefore a person who performs well in the complex span task (dual-task) would have a higher WMC, and a person who performs badly would exhibit a low WMC. High working memory capacity has also been associated with an increased ability to resist interference, as complex span tasks require the maintenance of information (list of items), in spite of other irrelevant information that also has to be processed (Engle, Kane & Tuholski, 1999). Complex spans differ from simple span measures as they tap attentional processes as controlled executive attention is needed to guard from the distracting information from the secondary task.

However, increased interference from the introduction of a secondary task has been associated with higher WMC (see Cokely, Kelley & Gilchrist, 2006; Delaney & Sahakyan, 2007; Rosen & Engle, 1997; Conway, Tuholski, Shisler & Engle, 1999) Presumably lower spans are less able to deal with interference anyway, but when an additional load is added, higher spans are unable to inhibit information and perform in line with low spans (Engle & Kane, 2003).

In a study examining the relationship between WMC and interference, Oberauer, Lange, and Engle (2004) devised dual-task tests to test a number of hypotheses. It was hypothesised that there would be a negative correlation between WMC scores and dual-task costs, interference would be influenced by similarity and dual-task costs would correlate across domains (domain general). The results showed that dual-task costs were not correlated with WMC scores, suggesting that higher WMC does not lead to an increased resistance to interference.

However, it has been proposed that dual-task performance should be viewed as essentially a reflection of WMC and single-task performance reflects WMC and additional resources/strategies. Cowan (2001) proposed that people can hold about 4 chunks in memory and serial recall can extend because of special strategies (e.g. chunking). By adding a secondary task, disruption to these strategies occurs, and is

confirmed by research showing that single-task strategies cannot effectively be applied to dual-task situations (Roslin, Sylwan & Galera, 1999). This theory can also apply to Baddeley's perspective, as single-tasks may rely more on the slave systems present in WM (VSSP, PL). By adding a secondary task these slave systems may become disrupted, and therefore may lead to the central executive/episodic buffer taking over (Baddeley, 2000). Oberauer et al. (2004) concluded that individual differences in dual-task situations may reflect an ability to use strategies/slave systems efficiently.

2.2.2.5 *Relationship between Memory & Attention*

Although its exact nature has been debated, it has been argued that working memory lies between the constructs of memory and attention (Miyake & Shah, 1999; Ludwig, 2005). Indeed, most models of working memory incorporate attention into their framework and posit that attention regulates the content of working memory. In Baddeley and Hitch's model (1974) model this is the role of the central executive, in Cowan's (2001) model the central executive directs the focus of attention, and Engle and colleagues' model (1999; 2004) model theorises that executive attention drives the availability of information in WM.

There are many parallels between the Supervisory Attentional System (Norman & Shallice, 1986) and Baddeley's central executive. The relationship between attention and memory is often described as being 'multi-faceted,' with both being important contributors to cognitive performance (Fougnie, 2008).

Attention has been described as a 'gate-keeper' to WM, only allowing the most salient information (directly relevant to the task) to enter the limited capacity of WM. The attentional blink (AB) paradigm provides evidence for this as after an initial visual target is presented, processing the subsequent target is delayed by approximately 700msecs (Broadbent & Broadbent, 1987). This highlights the capacity limitations of WM (Jolicoeur, 1999). Although it could be argued that this is due to a bottleneck for encoding information into WM, it is claimed that the observed AB effect is instruction dependent, demonstrating that encoding is reliant on top-down control. ERP (event-related potential) studies provide further support for the link between attention and working memory, highlighting that attention determines which stimuli will gain access to WM after early processing has taken place.

Evidence from anti-saccade tasks and dichotic listening tasks, also provide support for a close relationship between memory and attention. Anti-saccade tasks involve participants being asked to direct their gaze in the opposite direction to a peripheral target, and is an example of a volitional action which is thought to involve attentional focus (Reuter & Kathmann, 2004). It has been found that working memory capacity predicts performance on anti-saccade tasks, with higher spans performing better than low spans (Kane, Bleckley, Conway & Engle 2001). Dichotic listening tasks involve playing a different message to each participant's ear, and asking them to repeat one message, whilst ignoring the other. Typically, participants fail to recall anything about the ignored message, other than superficial information, for example the speakers tone/gender. However, it has been documented that if the participants name is included in the to-be-ignored message, then one third of participants manage to hear it (Moray, 1959). An interesting finding is that individuals possessing a low working memory span are more likely to hear the name as opposed to high spans (65%, to 20% respectively) (Conway, Cowan & Bunting, 2001). This has been taken as support that those with a high span are better at focusing their attention and suppressing irrelevant information.

This position was further asserted by the findings of Colflesh and Conway (2007) in their dichotic listening divided attention task. In that study participants were instructed to attend to both messages, and performance was measured accordingly. Results showed that those with a high WMC were more likely to hear their name (67%) as opposed to 35% of low spans. Although at first glance this appears paradoxical to the controlled-attention framework as this is the opposite pattern of results found by Conway, et al. (2001), it shows that WMC are better able to focus their attention to fulfil task goals. This is the same in the selective attention task, as they are asked to ignore the message.

Pashler (1988) has described attention as the "selection of information over other information" (p5) and this process is evident in tasks such as the Stroop task, in which the colour of the ink is pertinent, but the name of the colour is to be ignored. Kane and Engle (2003) found that both low and high spans differed in their results in a Stroop task. It was demonstrated that when congruence was at 75% (75% of the time the colour and name of the ink matched, 25% of the time they did not) higher spans performed better than lower spans. It was concluded that as there were no differences between high and low spans in the 0% congruence condition, it was not a failure to inhibit irrelevant information per se,

but rather impairments in inhibition when the context makes it difficult to maintain task goals.

It is argued that if WMC only measures the amount of storage available then it should not predict performance in tasks that rely on attentional processes such as anti-saccade, dichotic listening tasks and Stroop tasks. It is therefore postulated that WMC reflects an individual's ability to control executive attention (Engle, 2002).

It is clear that the two constructs can be viewed as being related and that there is converging evidence to suggest that attention is controlled and directed by the central executive component of working memory (Baddeley, 1986, Cowan, 1995, Engle, 2002).

2.2.2.6 Summary

By reviewing the literature, it is apparent that there are a variety of different systems that constitute attention. Attention can be best defined as a construct supporting the selection of relevant information in the face of distracting information and using this information to respond accordingly. In the divided attention literature, there are controversies surrounding the question of when interference is displayed, depending on the theoretical viewpoint taken. Kahneman (1973) argued that as attention has a limited capacity, it is only when this has been exceeded that performance will decline. Others argue that there are multiple resources (Wickens, 1984) so interference will only occur if the tasks share resources, whereas others postulate that if tasks rely on the same processes 'cross-talk' can occur, resulting in diminished performance (Navon & Miller, 1987) similar tasks will lead to less interference and instead cooperation (Fracker & Wickens, 1989).

Evidence has also been put forward to suggest that memory and attention are closely related constructs. The relationship between memory and attention appears to be underpinned by the central executive component of working memory (Baddeley, 1986). Indeed, it is this component that has been referred to as the 'gate keeper' of attention and has been likened to the SAS (Baddeley, 1990). The examination of the findings from divided attention studies provides further support for this overlap as it has been suggested that the central executive is important for allocating resources between the two tasks (Baddeley,1986).

Now that the literature concerning memory and attention has been reviewed, how these processes are affected in aging will now be discussed.

2.3 Cognitive Aging in Healthy Older Adults

Memory performance in old age is an area that has been extensively studied in cognitive psychology and it is well documented that people experience declines in memory and attention as they age (e.g. Craik & Jennings, 1992; Salthouse, 1991). However, whether a decline is apparent or the extent of the decline is very much dependent on the construct under investigation and the nature of the task.

2.3.1 The Pattern of Decline

It has been shown that there are facets of cognition that appear to be affected by aging and others that seem not to be affected at all, or at least affected to a lesser degree. A loose consensus would be that abilities that rely on accumulated knowledge and long-term memory (crystallised abilities) seem to be preserved in older age, whereas areas of cognition that involve 'fluid' abilities such as speeded responses, problem solving, and rely on short-term memory are adversely affected (Anstey & Low, 2004).

An example of this division would be episodic and semantic memory. Episodic memory is thought to represent a 'fluid' ability, as it deals with novel information and events to be remembered are often unpredictable (Craik, 2000). Conversely semantic memory (factual knowledge, independent of time/context) is dependent on accumulated knowledge and schemas, and thus represents a 'crystallised' ability and is not shown to decline in the aging process (Brickman & Stern, 2009). Additionally, older adults also outperform younger adults on tests of semantic memory, even when they have lower levels of education, suggesting that as people age they are exposed to a broader range of information and therefore continue to accumulate semantic knowledge and form new nodes and pathways (Radvansky, 2006).

Consistent with this view, is the finding that working memory is affected by aging, namely that aging leads to a decrease in capacity (Cowan, 1995, 2001; Baddeley & Hitch, 1994, 2000). Other cognitive capacities such as processing speed and inhibition have all been implicated in aging, and have been put forward as the underlying mechanisms of the changes exhibited in cognitive aging. These concepts will be evaluated as theories of cognitive aging. Before this, a brief consideration of how attention is affected by aging will be given.

Plude and Doussard-Roosevelt (1989) found that there are reliable age-differences in selective attention tasks, but only in conjunction tasks, where two or more features have to be searched (e.g. finding a red X in a field of green X's and red Q's). If the item in the visual search is familiar then no age-related differences are found. For example, Clancy and Hoyer (1994) asked both young and older adults who were or had been X-ray technicians to look for abnormalities in X-rays and found that there were no differences in performance. This is in line with previous research that has demonstrated that skill or expertise may allow older adults to perform similarly to younger adults despite declines in cognitive processes (Salthouse, 1990). Different theories have been put forward to account for this, but the compensation perspective is the most prominent. This theory suggests the decline in various cognitive processes characterised in aging can be offset by the development of compensatory mechanisms that are made possible through skill (Bosman & Charness, 1996)

Madden (1983) also found that age-related differences were also eliminated when cues were provided to the older adults. However this has been criticised as it may change the parameters of the task, so it resembles more of a focused attention task in which age-related differences are not typically found (Rogers, 2000). This finding has not been supported by more recent studies and it has even been suggested that older adults perform worse when a cue (such as an arrow) is present (Folk & Hoyer, 1992). This discrepancy could be explained by the perceptual load hypothesis (Lavie, 1995) which states that in cases where there is low perceptual load then there is more interference from task irrelevant stimuli. This is due to there being a limited capacity for perception and that in cases where the perceptual load is high (perceptual identification is more demanding, increased target stimuli) then all of the capacity is utilised in processing the task-relevant stimuli and therefore less distractor processing will occur. In the context of aging, where it is believed that there is a decline in inhibitory control mechanisms (Hasher & Zacks, 1988) low perceptual load may exacerbate these deficits (Maylor & Lavie, 1988)

Tasks pertaining to sustained attention require on-going vigilance to look for a target event. Research has shown that there is little difference between the performance of older and younger adults (McDowd & Shaw, 2000; Bunce & Sisa, 2009). Tasks of vigilance

have been criticised as the exposed time of the stimulus may be too short to report the target action (Giambra, 1993).

Divided attention is an area in which age-related differences have been shown (McDowd & Craik, 1998). However, there is debate as to whether this is a consistent finding, and whether there are certain circumstances in which age-related differences are not found. As this thesis is concerned with age-related differences in dual-task studies, the literature regarding this will be discussed in more detail later.

Numerous theories have been proposed to explain why these age-related declines are found. For example, inhibition theories have been favoured heavily as an explanation for older adults performing worse than younger adults in attention tasks. However, speed of processing and resource accounts have also been proposed to explain age-related differences shown in a wide range of cognitive tasks. A comprehensive account of the main theories of cognitive aging follows.

2.3.2 Theories of Cognitive Aging

2.3.2.1 *Speed of Processing*

A common finding in cognitive aging research is that performance is slowed with age (e.g. Cerella, 1985; Birren & Fisher, 1995; Myerson, Adams, Hale, & Jenkins, 2003). Salthouse (1990; 1996; 2000) proposed that this 'generalised slowing' is responsible for the decrements in cognitive performance displayed by older adults. A strong body of research supports this theory. Salthouse (1996) demonstrated that approximately 86% of age-related variance on a wide variety of cognitive tasks can be explained by processing-speed.

Salthouse (1996) hypothesised that there are 2 aspects to processing speed that are pertinent to cognitive performance: limited time and simultaneity. The limited time mechanism suggests that the time taken for later operations is slowed when available time is occupied in executing earlier operations. Simultaneity works on the principle that the products of the earlier operations may be lost before the latter stages/operations are completed. Together these imply that adults are penalised when time is a factor in a cognitive task as they will be slower to perform the later operations of the task due to

engagement in the earlier stages and may not be able to keep the earlier operations in mind, to perform the later stages correctly, or even reach them.

In addition to speeded response tasks (e.g. reaction time) this theory encompasses a wide variety of cognitive tasks, which may not appear on the surface to have a speeded element. Any task that involves operations to be performed in stages would be affected due to the limited time and simultaneity mechanisms described above. Therefore older adults would differ from younger adults in their performance of both speed and accuracy. This difference would be more apparent in complex tasks, where more operations are needed (Cerella, Poon & Williams, 1980). Indeed, it has been found that older adults are often more conservative in their responses to a range of cognitive tasks, often emphasising accuracy over speed than their younger counterparts (Goethe, Kliegl & Oberauer, 2007; Glass, et al., 2000; Ratcliff, Spieler & McKoon,2000)..

This theory offers an attractive explanation for cognitive aging, however, it has been criticised. It has been argued that this account is 'too descriptive,' although it provides an account for cognitive decline in aging; it does not give an indication of why this slowing occurs (Glisky, 2007). Furthermore, research has shown that this is not a universal finding, variability has been shown across tasks, indicating that other factors may play a role (Hale & Myserson, 1996; Sülzenbrück, Hegele, Heuer & Rinkenauer, 2010). This has led researchers to propose that process-specific accounts are needed (Glisky, 2007). It has been proposed that working memory may play a role, as researchers have shown that working memory contributes to age- related variance independently of processing speed (Park et al., 1996).

Another line of reasoning is that it may be that older and younger adults are completing the tasks in a different way that results in older adults' performance being slower. For example, Bashore, van der Molen, Ridderinkhof, & Wylie, (1997) have proposed that older adults may exert more effort at performing a reaction time task, but this may not fully compensate for slowing that occurs in later processing, e.g. executing the response. It is evident that processing speed has a lot to offer as a theory for explaining the ubiquitous finding that cognitive performance declines with age. However, it is apparent that there are limitations to this theory as there are circumstances in which it does not seem to explain all the findings. It may be that other factors are working in addition to processing speed; which will now be considered.

2.3.2.2 *Working Memory/Attentional Resources*

Research using span measures consistently show that older adults typically exhibit a decreased WM capacity in complex span tasks, (Babcock & Salthouse, 1990; Verhaeghen & Basak, 2005). It has been proposed that these decrements in working memory may be responsible for the age-related decline in cognitive performance (Craik & Byrd, 1982). The theory posits that older adults have reduced processing resources at their disposal. Although there is debate in the literature as to what is meant by 'processing/attentional resources' it has been argued that this can be best be conceptualised as working memory capacity (Park & Schwarz, 2000). WMC is implicated in a wide variety of cognitive tasks, including reasoning, problem solving, memory, language comprehension and other domains (Baddeley & Hitch, 1974).

Craik and Byrd (1982) put forward the reduced processing resources framework that suggests that older adults have difficulty in engaging in 'self-initiated processing'. Therefore it was concluded that if environmental support was given to older adults then this would decrease the amount of processing required to complete the task, and therefore performance would be increased. Environmental support can be given in the way of cues or tasks that rely on recollection as opposed to recall which is highly effortful.

Various studies have supported this hypothesis. In a study by Cherry, Park, Frieske and Smith (1996), older and younger participants were required to remember a target adjective in a sentence which was either presented in addition to a corresponding image, which helped to elaborate the relationship between the sentence and image. It was found that performance was enhanced by the addition of an image, and also that age differences were reduced in this condition. It was concluded that the addition of an image reduced the amount of processing/working memory that was needed to complete the task, and therefore increased performance.

Although the speed of processing account and the reduced working memory/attentional processes theory have been put forward as separate mechanisms to explain age-related differences in cognitive performance, they are not contradictory. In fact Salthouse (1992)

proposed that the age differences in working memory are due to variation in speed of processing. Research using structural equation modelling, has found that both working memory and speed are important for explaining age-related variance in cognitive performance. Park et al. (1996) gave participants a cognitive battery of tests, which measured constructs such working memory, speed of processing and reasoning, and then tested them on free recall, cued-recall and spatial memory tasks. It was found that speed mediated a large proportion of the age-related variance, but that it operates through working memory. Additionally, it was found that working memory but not speed of processing had a direct path to cued and free recall (effortful retrieval). Therefore this study highlights the importance of both of these constructs in explaining the age-related declines in cognitive performance. It also demonstrates that the two constructs may be responsible for age-related decline in different tasks (e.g. working memory is more important in explaining age-related variance in more effortful tasks), which ties in with the theory put forward by Craik and Byrd (1982).

In a similar vein, reduced cognitive control has been put forward to account for age-related differences in cognition. Cognitive control refers to "the ability to manage one's thoughts, recollections and actions in accordance with task relevant goals" (Anderson & Craik, 2000, p411) and shares characteristics to the supervisory attentional system (SAS) (Norman & Shallice, 1986) and the central executive (CE) from Baddeley and Hitch's working memory model (1974). The concept also links with the cognitive slowing theory (Salthouse, 1996) in which the amount of information available in working memory is reduced; which could be extended to a reduction in the SAS or CE.

Proponents of this theory suggest that both cognitive slowing and a reduction in attentional resources mean that cognitive control is also reduced and therefore leads to impairments into more attention demanding tasks. This would lead to a distinction between automatic and controlled processes with automatic processes requiring little or no resources and controlled processes requiring a lot. If older adults possess less attentional resources/cognitive control then this should result in diminished performance if the task is highly demanding.

Resource theories have been criticised for lacking specificity. Constructs such as attentional resources/processing resources have been ill-defined and there seems to be a

degree of overlap between the separate constructs. For instance, Salthouse (1991) defined processing resources as encompassing working memory, attention and processing speed, and argued that performance decrements shown in cognitive aging could be due to diminished processing resources, or declines in resource allocation. Bashore, van der Molen, Ridderinkhof and Wylie (1997) proposed that multiple processing resources are needed, depending on the nature of the tasks.

2.3.2.3 *Inhibition*

Another construct that is claimed to play an important role in cognitive decline is inhibition. It has been proposed that as we age, our ability to inhibit irrelevant information is decreased and this leads to poorer cognitive performance (Hasher & Zacks, 1988). It is believed that inhibition has an effect on the efficiency of working memory. If inhibitory processes are disrupted then this would lead to irrelevant/distracting information entering working memory, and leading to lower performance. This hypothesis has been offered support by looking at performance in working memory tasks. Research conducted by May, Hasher and Kane (1999) reversed the order of administration in a WM task so that the largest trial occurred first thereby reducing the amount of proactive interference. The results showed that this greatly improved the performance of older adults so that it was comparable to that of younger adults. This shows that inhibitory processes play an important role in WM, especially in older adults who experience a decline in the efficiency of these processes (Bowles & Salthouse, 2003).

Further evidence to support the inhibitory theory is provided by studies using the directed forgetting paradigm. Studies using this paradigm involve participants attending to a list of words, which are later to be remembered or forgotten. It is shown that younger adults show superior recall for the to-be-remembered words, but that when asked to recall the words that should be forgotten they show reduced recall compared to older adults. It is proposed that younger adults are able to inhibit the irrelevant 'forget' words and therefore show superior recall when asked to remember the target words. In comparison, older adults who show less ability to inhibit the distracting information show more intrusion errors and are able to recall less of the target words (Zacks, Radvansky & Hasher, 1996).

Negative priming has also been used to investigate inhibitory processes in older adults. Negative priming describes the phenomenon that in tasks where participants are required to make a judgement between a target and distracter stimulus then responses are typically

slower when a target was a distractor in a previous trial. The reason for this is that irrelevant material which was inhibited has now become relevant, and therefore responses are slowed as this inhibition has carried over into the trial in question. Research has shown that younger adults typically exhibit a negative priming effect (Hasher, Zacks, Stoltzfus, Kane & Connelly 1996), and older adults do not (Kane, Hasher, Stoltzfus, Zack & Connelley, 1994). However, the reliability of this theory has been criticised as these effects have not been replicated in later studies (McDowd, 1997).

A recent study using multiple regression, found that inhibitory processes accounted for most of the age-related variance shown in a number of cognitive measures (Persad, Abeles, Zacks & Denburg, 2002). Speed of processing (as measured by reading speed in the current study) was shown to be a contributor to age-related variance as well, but not to the same extent as inhibitory processes. However, such studies have been criticised as reliable measures for inhibition have been difficult to establish (Park & Schwarz, 2000).

Further evidence for the inhibitory-deficit hypothesis of aging comes from studies looking into multi-tasking. Using brain imaging, Clapp, Rubens, Sabharwal and Gazzaley, (2011) conducted a study in which participants were shown a natural scene and asked to keep it in mind for 14.4 seconds. During this period an image of a face was presented and participants were asked to estimate its gender and age. Following this they were then asked to recall the scene. As expected, older adults exhibited a greater difficulty in recalling the scene. Additionally, brain scan data showed that the interruption (the display of the face) meant that people had to disengage from the network responsible for maintaining the scene, and instead allocate resources to the area responsible for face processing. Age differences were revealed; younger adults were able to reallocate resources back to the original task following the interruption, but older adults failed to do this successfully and therefore demonstrated lower recall for the scene. It is suggested that inhibition is an important factor in dual-tasking as well.

It has been proposed that inhibition acts as the mechanism responsible for the age-related differences in working memory (Hasher & Zacks, 1988). It is argued that declines in WM are not due to a smaller capacity, but instead deficient inhibitory mechanisms that regulate the contents of WM. This can lead to the contents of WM becoming overwhelmed with both relevant and irrelevant material and would therefore result in poorer performance (Persad et al., 2002).

Studies such as that of May, Hasher and Kane (1999) reported above provide support for this theory. However, Kane and Engle (2000) have argued that WMC (specifically controlled attention) drives inhibition. Evidence for this come from studies showing that low and high spans susceptibility to interference is equivalent under WM load (Rosen & Engle, 1997; Kane & Engle, 2000). If inhibition were responsible for differences in WMC/controlled attention than it should remain the same under attentional load, however the above study highlighted that higher spans ability to resist interference was negatively affected by the introduction of a secondary task. More recently, Borella, Carretti and De Beni (2008) examined the role of working memory and inhibition in older adults, and concluded that inhibition is not as an important factor as once thought in explaining working memory capacity.

Further evidence for the resource account of inhibition comes from a study conducted by Robert, Borella, Fagot, Lecerf and de Ribaupierre (2009). This study looked at whether WMC capacity is responsible for individual differences in inhibition. In line with Conway and colleagues it was proposed that if inhibition is resource demanding then individual differences in WMC should affect inhibition (Redick, Heitz & Engle, 2007).

In the study of Robert et al. (2009), WMC was defined as the performance in a reading span task and was viewed as being an indicator of both attentional/processing resources. Inhibition was also measured as some of the words that were viewed were not required for subsequent recall. The relationship between WMC and inhibition was investigated by examining the number of intrusion errors of irrelevant information in the reading span task and determining if there were age differences between young children, young adults and older adults. It was hypothesised that older adults and younger children would make more intrusion errors and recall fewer words than young adults. However this would not shed light on the nature of the deficit (inhibitory or attentional). If the expected pattern was found it could be argued that the span task was overly demanding for older adults and young children who have reduced attentional resources at their disposal, thereby leading to a reduced ability to control the contents of WM. To further test that, an additional study was conducted in which WM load was adapted to individual span measures. If attentional resources are responsible for inhibition then than by adapting the WM load to suit individual WMC should lead to less inhibition deficits and therefore less intrusion errors. The study found that as anticipated, older adults and younger children did recall fewer

words and made more intrusion errors than younger adults. However, when WM load was manipulated to coincide with WMC, inhibition was the same for all participants. This provides strong support for the resource account of inhibition.

The studies discussed above show that inhibition may play an important role in age-related decline in cognitive performance.

2.3.2.4 *Sensory Function*

Baltes and Lindenberger (1997) have put forward the 'common cause hypothesis' to explain age-related differences in cognition. They proposed that sensory function is the principal mediator of cognition. Compelling evidence for this notion comes from a study in which Baltes and Lindenberger (1997) collected data from a sample of participants aged 25-103. It was found that sensory functioning as measured by visual and auditory acuity mediated most of the age-related variance in cognitive abilities such as speed of processing, verbal fluency and memory. It is proposed that biological and structural changes in the brain due to aging are responsible for changes in sensory functioning and this also drives changes in cognitive functioning. Salthouse (1998) found that sensory processing and speed of processing share a large amount of age-related variance, suggesting that declines in visual and auditory acuity may be accounted for by declines in processing speed.

2.3.3 The Aging Brain

Aging is accompanied by structural and functional declines in neural structure (Reuter-Lorenz, 2000). With the introduction and widespread availability of neuroimaging techniques, advancements in the field of the neuropsychology of aging have been made in recent years.

Physical differences in the brain are found between younger and older adults, including a shrinkage of brain tissue (Haug & Eggers, 1991), atrophy and reduced levels of neurotransmitters, including dopamine and acetylcholine, which are implicated in learning and consolidation of memories (Woodruff-Pak, 1997) and reduction in cerebral blood flow (Madden & Hoffman, 1997). Although these changes may account for the cognitive declines displayed in older adults, there are limitations as the relationship between structure and function are not absolute. For example, cerebral regional dysfunction may not result in noticeable cognitive deficits as compensation may have taken place through

reorganisation of neural pathways, or changes in strategy. Despite this, neuropsychological studies are a valuable tool to unlocking the biological mechanisms of cognition.

2.3.3.1 *Evidence from Neuropsychology- Frontal Lobe Hypothesis*

The frontal lobes are implicated in a number of higher order cognitive functions such as the planning, coordination and execution of goal-directed behaviours and the inhibition of irrelevant behaviours (Luria, 1966). Memory processes are also linked to the frontal lobe and have been put forward as a mechanism for explaining age-related decline (Moscovitch & Winocur, 1995). Essentially, the frontal lobes are thought to reflect executive functions (see Smith & Jonides, 1999 for a review). It has been proposed that this decline in executive functions is the underlying mechanism for the cognitive deficits often displayed in older adults (West, 1996).

Evidence to support the frontal lobe hypothesis of aging has come from studying patients with frontal lobe damage. Moscovitch and Winocur (1995) have found that older adults typically displayed the same deficits in executive functions as frontal lobe patients. Memory deficits reported have included being more susceptible to false memories (Balota et al, 1999) and impaired source memory (Shimamura & Squire, 1989). Research has also shown that the frontal lobes are involved with non-declarative memory processes such as word-stem priming (Winocur, Moscovitch & Stuss, 1996). The research outlined above indicates that cognitive functions supported by the frontal lobes are more affected by aging.

The nature of this age-related deficit in tasks associated with the frontal lobes, has been the source of much debate. One theory put forward to describe the deficit, is that the frontal lobes are responsible for maintaining representations of the task by activating relevant processing pathways and inhibiting irrelevant ones. This has been supported by studies using variants of the Stroop task, as typically older adults show a greater Stroop effect (Chaippe, Hasher & Siegel, 2000; Davidson, Zacks & Williams; Speiler, Balota & Faust, 1996), which have been shown to involve the frontal lobes in particular the pre-frontal cortex (Nielson, Langenecker & Garavan, 2002).

To add further support to the relation between frontal lobe involvement and inhibitory function the spatial cueing paradigm of Posner has also been utilised. In the task, it is found that responses to stimuli are quicker when they are presented in a cued location. Results have demonstrated that older adults experience declines in tasks of voluntary spatial attention such as this (Hartley et al., 1998). These findings have been interpreted in different ways, whether it is due to failures to disengage from one stimulus to another (Greenwood & Parasuram, 1994) or allocation of attentional resources (Hartley et al., 1990) or poor encoding of visual stimuli (Folk & Hoyer, 1992); all these processes have been linked to the frontal lobes (Corbetta & Shulman, 2002).

It has also been postulated that the frontal lobes are involved with the executive functions in strategic memory processes (cognitive processes that are self-initiated). Akin to the reduced processing framework put forward by Craik and Byrd, (1982), it is proposed that older adults with low executive functioning are less able to engage in strategic processing, and age-related differences are reduced by providing cognitive support (Bunce, 2003). This finding has been supported in a variety of different tasks (Taconnat, Clarys, Vanneste, Bouazzaoui & Isingrini, 2007). Furthermore, activation of the pre-frontal cortex is associated with deeper processing and enhanced memory performance (Kapur, Craik, Tulving, Wilson, Houle & Brown (1994), abilities that may be impaired in older adults.

It is evident that there is degree of overlap between the frontal lobe hypothesis of aging with other theories put forward to describe cognitive aging. For example it has been argued that the frontal lobes play an important role in inhibition (Shimamura, 1995), which is consistent with the theoretical viewpoint of Hasher and Zacks (1988) outlined earlier. Additionally, the reduced working memory/attentional resources theories can also be viewed as harmonious. This has led to criticisms of the frontal lobe hypothesis as lacking specificity (Band, Ridderinkhof & Segalowitz, 2002).

Greenwood (2000) also challenged the frontal lobe hypothesis and has stated that it is too restrictive, as brain changes (such as neuronal loss) are evident in other areas of the brain including the temporal and parietal cortex. It has also been argued that frontal lobe measures are not always correlated and maybe sensitive to other areas of the brain as well (Burgess, 1997). It is difficult to disentangle measures of executive function from measures of attention, which may be accounted for reduced capacity/processing speed (Philips & Henry, 2005). Recently, researchers have put forward the dopamine model of

cognitive aging, suggesting that a reduction of dopamine receptors may be responsible for cognitive decline in aging (Bäckman et al., 2000; Li, Lindenberger & Sikström2001; Bäckman, Lindenberger, Li & Nyberg, 2010).   However, this is open to the same criticisms as the frontal lobe hypothesis. It may be that one factor is not enough to adequately account for cognitive aging (Band, Ridderinkhof & Segalowitz, 2002).

2.3.4   Divided Attention & Aging

Research has also shown that when older adults are asked to perform two tasks concurrently, their performance is typically worse than that of younger adults (Craik & McDowd, 1987; Li, Lindberger, Freund & Baltes, 2001). In fact, Craik (1977, p391) stated that "one of the clearest results in the experimental psychology of aging is the finding that older adults are more penalized when they must divide their attention." However, there is some controversy regarding the pattern of decline and the underlying mechanisms responsible for these deficits.

It has been proposed that task difficulty is an important factor in disproportionate age-related differences (Tsang & Shaner, 1998) with some studies showing that in-line with their single-task performance older adults do have a disproportionate deficit if the demands of a task are high, and others do not (Tun, Wingfield, Stine & Mecsas, 1992). This had led some researchers to conclude that dual-task deficits may be domain specific and not related to task difficulty. In a study by Riby, Stollery and Perfect (2004) both task difficulty and task domains (episodic and semantic memory) were examined. It was found that episodic memory but not semantic memory led to disproportionate dual-task costs in older adults, and that task difficulty did not show this age-related deficit, suggesting that it is domain rather than difficulty that leads to dual-task deficits in older adults.

A consistent finding in literature is that "the encoding process is more sensitive than retrieval to secondary task interference" (Whiting, 2003, p144). However, it is less clear whether older adults are more affected by the introduction of a secondary task during encoding than younger adults. Logie, Della Sala, MacPherson and Cooper (2007) found that in both older and younger adults dual-tasking at encoding produced significant interference in memory performance, but this was greater in older adults. This is

consistent with previous research (Park et al., 1989; Craik & McDowd, 1987). Park et al. (1989) found that older adults' memory performance at retrieval was worse when a secondary task had been introduced in the encoding stage and this was consistent across a variety of performance indicators (number of words remembered, number of categories remembered and clustering). This led Park et al. (1989) to conclude that divided attention at encoding disrupts older adults' organisational processes.

However, other studies have shown that older adults exhibit the same decrease in memory performance as younger adults (Anderson et al., 1998; Baddeley, Logie, Bressi, Della Salla & Spinnler, 1986; Park, Puglisi, Smith & Dudley, 1987).

It is evident that divided attention at encoding leads to decreased memory performance (primary task), but the extent performance is affected in the secondary task needs to be considered. Previous research has showed that both memory and secondary task performance are affected by divided attention, but secondary task costs are greater in older adults (Craik et al., 1996; Craik & McDowd, 1987). Taken as it is, this pattern of findings (that younger and older adults display equivalent divided attention costs on the primary task, but older adults exhibit greater secondary costs) does not offer compelling support for the reduction in resources hypothesis. However, it has been argued that participants may strategically 'protect' the primary task at an expense to the secondary task (Zacks, Hasher & Li, 2000). It could be argued that if older adults were unable to perform the two tasks very well, then in order to maximise performance in the more 'public' task they may sacrifice performance on the secondary task. This would therefore lead to reduced performance in the secondary task, which is a consistent finding in the literature (Craik et al., 1996; Logie et al., 2007; Naveh-Benjamin, Craik, Guez & Dori, 1998). This is an interesting concept that warrants further investigation.

There are competing theoretical explanations for the underlying causes for the age-related deficits found in dual-task performance. One of these is the generalised-slowing hypothesis put forward by Salthouse (1985) which argues that cognitive, perceptual and motor processes are slowed, which results in slowing of the component tasks and processes required to coordinate and execute the two tasks. In view of this theory results should show proportional slowing when compared to younger adults, and although some

studies have confirmed this (Somberg & Salthouse, 1982) others have not (Crossley & Hisock, 1992, Riby, Perfect & Stollery, 2004).

Another theory is that of 'specific age deficits' such as working memory that underlie this decrement in dual-task performance, which have been supported by some studies (Park, 1989). As discussed, the central executive component of working memory has been implicated as being responsible for sharing resources between storage and processing and the allocation and coordination of attentional resources (Baddeley, 1986; D'Esposito, Detre, Alsop, Shin, Atlas & Grossman 1995). Therefore if working memory is affected by aging, this would have an impact on older adults' ability to dual-task.

However, declines in working memory cannot account for all of the age-related differences in ability to dual-task as studies have also shown that there are disproportional differences in dual-task performance of older adults when working memory was not being assessed (Korteling, 1991).

In a similar vein, the concept that older adults have reduced processing resources at their disposal has been proposed to account for dual-task costs in older adults (Craik & Byrd, 1982). However, in line with the complexity hypothesis (that increased task demands lead to a decline in performance) (McDowd & Craik, 1988) this theory cannot account for why there have been large age differences found in less demanding situations that should require more resources (Korteling, 1991).

Another specific deficit that has been identified is a decline in frontal lobe functioning. This would account for the difficulties that older adults experience in maintaining and switching attention between tasks (Glass et al., 2000) In spite of this, this concept has been criticised as although it accounts for disproportionate deficits found, it cannot fully account for why in some circumstances proportionate dual-task costs are found (Glass et al., 2000).

It has been proposed that a combination of generalised slowing, process-specific slowing and the use of more cautious task coordination strategies is the source for the deficit in older adults. There is a move in the field towards a more integrative approach that can unify these theories (Band, Jolicoeur, Akyurek & Memelink, 2006).

2.3.5 Summary

It is apparent that although aging is associated with a decline in many cognitive functions, it is by no means a universal phenomenon and there are some areas of memory and attention that appear to remain unaffected. Typically, areas that have been shown to be affected by aging include, working memory, episodic memory, selective attention and divided attention. Areas that have shown no or very little age-related differences are semantic memory, sustained attention, selective attention and divided attention. It has been proposed that in aging 'crystallised' abilities are preserved, whereas more 'fluid' abilities are affected by aging (Anstey & Low, 2004).

There are a number of different theories that have been put forward to account for this cognitive decline. Current theories, include reduced speed of processing (Salthouse, 1990), a reduction in resources including WM, (Craik & Byrd, 1982), a decline in inhibition (Hasher & Zacks, 1988) and reduced sensory functioning (Baltes & Lindenberger 1997). Although all of these theories have been well supported by research, it is evident that no one theory can adequately explain the changes in cognition shown by aging.

Attentional processes also appear to be affected by aging, in particular circumstances in which older adults are required to divide their attention (Craik & McDowd, 1987). Theories proposed to account for this decline in ability seem to focus on a reduction in resources, especially working memory with the central executive being
implicated as the mechanism responsible for allocating resources between the tasks (Baddeley, 1986; D'Esposito, Detre, Alsop, Shin, Atlas & Grossman 1995).

An emerging theme in the literature is that theories of cognitive aging are not necessarily contradictory and there is a degree of overlap between them. For example, speed of processing and working memory have been shown to be closely related constructs (Salthouse, 1992; Park et al., 1996) and working memory capacity has been shown to influence inhibition in older adults (Robert et al., 2009). Evidence from neuropsychological studies also supports this perspective as the frontal lobe hypothesis draws parallels with cognitive aging theories such as reduced resources and diminished

inhibitory processes (Shimamura, 1995). It may be that a combination of these theories account for the cognitive deficits found in aging.

The literature surrounding how strategy use may increase performance in cognition (specifically memory) will now be discussed, with consideration given to how strategy use may impact dual-task performance in older adults.

2.4 Improving Memory Performance

2.4.1 Strategy use

Strategy use has been shown to be an important factor when examining memory performance. When it has been investigated, studies have often shown that people who have used a strategy performed better. Bissig and Lustig (2007) found that the top memory performers in their study used a narrative strategy or related the To-be-remembered words to their own experiences, so that it had a personal meaning to them. In contrast poor performers hardly reported any strategy use "I just used my memory" (Bissig & Lustig, 2007, p724), or used superficial strategies such as rehearsal.

Strategies can either aid the encoding or retrieval process. Encoding (the act of learning new information) may occur automatically or may need to be attended to. Strategies can facilitate the encoding process and include; paying attention, analysing the information for meaning, elaborating on the details, or using association and imagery (Folger & Stern, 1994) According to the Levels of Processing Theory (Craik & Lockhart, 1972) strategies facilitate memory performance as they may lead to deeper encoding and this has an impact on successful retrieval as the likelihood of remembering this information at a later stage is increased.

2.4.2 Working memory and strategy use

Research has been undertaken in determining whether Working Memory span or capacity can be increased following strategy training. WM span measures can be classified into two types; simple span measures and complex span measures (de Jonge & de Jong, 1996; Turner & Engle, 1989). Simple span measures assess the storage component of WM, whilst complex span measures measure the attentional resources available for both storage and processing. It is commonly accepted that these two processes interfere with one

another (Case, 1985) and require access to a common pool of resources. This capacity can be flexibly allocated to the two processes, depending on the demands of the task. Therefore, if the processing aspects of the task are more demanding then fewer resources will be available for storage, therefore reducing overall performance. This account is referred to as the Resource Sharing Hypothesis. However, it is hypothesised that individuals who use strategies, may exhibit greater performance in WM tasks, as more efficient processing occurs, freeing up resources for additional storage or other cognitive processes.

Research examining strategy use and WM capacity, has yielded mixed results. For example Engle, Cantor and Carullo (1992) tested the hypothesis that people with higher WM spans, allocate their resources more efficiently (are more strategic) than low spans, by comparing their viewing patterns in the operation span test. The results showed that there was in fact no difference between the two groups. Conversely, other research has supported the claim that higher spans are more strategic compared to their counterparts; Rosen and Engle (1997) found that high and low spans differed in how information was stored in long-term memory, with high spans utilising a clustering strategy. Kane and Engle (2000) also showed that low spans were more susceptible to proactive interference then higher spans.

Turley-Ames and Whitfield, (2003) conducted a study in which participants were asked to use different strategies and complete the operation span test (a complex span task) to see if strategies improved performance. It was found that participants, who had low spans pre-training, increased their performance in the span-test after being instructed to use a rehearsal strategy. High spans did not increase their performance post training, and some had decreased span scores. This led the researchers to conclude that the rehearsal strategy may have been the optimal strategy for low spans as it was less demanding than the other strategies and therefore had the resources available to successfully implement them. The reason high spans may not have benefited from rehearsal or the other strategies is that it was found that they more likely to be utilising a successful strategy in the pre-training WM span measure, than low span scorers and they spent longer encoding the 'to be remembered' words, (Turley-Ames & Whitfield, 2003). Additionally, it may be that a ceiling effect was occurring, as the high spans were scoring very highly to begin with, and

that the strategy training may not lead to noticeably increased scores in this group as compared to the low spans.

It is clear that more research needs to be conducted in this area to determine the role that strategy use plays in WM. It would be interesting to see if actual training, rather than instruction to use a specific strategy and 12 practice trials as in the study by Turley-Ames and Whitfield, (2003) could lead to both low spans and high spans increasing their performance. A study by McNamara and Scott (2001) found that participants increased their WM span scores after using a chaining strategy following four sessions of training on different word lists.

A study by Lee, Lu and Ko (2007) looked at the effects that existing knowledge and specific skill training had on working memory capacity. In their study, the researchers looked at specific skills such as mental abacus training and musical training had on measures of WM capacity. Their study showed that the mental abacus training led to increased performance on visual-spatial span tasks, yet not tasks that measured phonological storage or central executive aspects of working memory. The musical training, however, led to increases in not only phonological storage, but also in the spans that measured visual-spatial and central executive aspects of working memory in children. It has been suggested that the reasons the effects of music training could be extended to other areas of working memory are because they teach people cognitive, motor, memory and task-switching skills (Lee et al., 2007). It is also suggested that this enhancement may not have been as evident in adults because they have already reached an optimal skill level in these areas through experience and knowledge acquired.

 This research adds strength to the theory that training in cognitive skills can increase WM capacity, especially in areas that are closely related to that skill (domain-specific) (Ericsson & Kintsch, 1995).   Recent research investigating brain activity has demonstrated that WM training can lead to changes in brain activity and suggests that there is training-induced plasticity in the brain (Olesen, Westerberg & Klingberg, 2004).

It is evident that memory strategies may enhance WM capacity, but to what extent can it increase WM performance in older adults? A review of the literature concerning memory training for older adults will now follow.

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2.4.3 Aging and Strategy use

There are a range of different memory strategies that many people widely practice, for example using a diary or calendar to note appointments etc. However, in the last 20 years there has been a move towards developing interventions in the form of training programmes that can improve memory in older adults. Many studies have looked at whether training in memory strategies (such as imagery or rehearsal) can improve performance in memory by determining if memory performance has improved from baseline measures, following training.

Verhaeghen et al. (1992) in their meta-analysis of 33 studies examining memory training found that older adults can benefit from memory training and exhibit plasticity in the sense that they can learn new skills/techniques. This has led researchers to describe the aging process as an 'interaction of positive and negative processes' (Cavallini, Pagnin & Vecchi, 2003) as it is a period of decline, stability and growth (Baltes & Baltes, 1990). It has been proposed that older adults are able to compensate for cognitive declines and maintain levels performance in areas of everyday living (Salthouse, 1987; Baltes & Baltes, 1990).

The word 'memory-training' can encompass a wide variety of different strategies, techniques and approaches, and this is certainly reflected in the literature. Strategies are generally divided into two types, internal or external. Internal strategies emphasise mnemonic processes which rely on a person's thinking ability, and include using techniques such as elaboration, rehearsal and imagery to enhance the encoding process. External strategies focus on outside techniques, such as relying on others to remind you of something, writing on calendars, writing memo's, notes etc. A central issue to many researchers in this area is determining whether these gains are transferable to other more 'ecologically valid' tasks or novel tasks that have not been specifically practiced.

A study conducted by Cavallini et al. (2003) looked at some of these questions. Participants consisted of both older and younger adults, and were given either training in the use of the 'method of loci' (using mental imagery to associate the to-be-remembered

(TBR) material to pre-assigned destinations on a familiar place/route e.g. your house/route to work) or a variety of memory strategy techniques tailored towards the tasks (association, elaboration imagery, face-name technique etc). Also, in addition to traditional working memory laboratory tasks (digit span, common objects, word-lists etc) more everyday tasks were also used (reading a map, shopping list, matching faces to names etc). A novel-task was also introduced after training, to see any gains were transferable to an 'untrained' task.

The results showed that there was an increase in performance for all groups in the ecological tasks and the type of training received did not make a difference. However, as all of the participants were taught a form of memory training, then these results could have been from the benefit of practice and not training. This could have been eliminated by introducing a control group who did not receive any training.

The only exception to the two groups being of equal benefit was in the novel situation test. It was found that participants in the strategy group performed better. One explanation for this could be that this training focused on teaching people simple strategies that could be used in a variety of situations and may be more adaptable then loci training. In the traditional memory tasks, it was found that training had a lesser effect on the improvement in performance, and that adults performed slightly better than the older adults.

By examining the research, it is apparent that strategy training for improving older adult's memory is beneficial (for a review see Verhaghen et al., 1992) however relatively few studies have looked at whether these benefits are maintained years later. The studies that have offer mixed results, for example some researchers have found that training effects have been found 3 or 5 years later (Neely & Backman, 1993; Oswald, Gunzelmann, Rupprecht & Hagen, 2002), whereas this has not emerged for others (Scogin & Bienas, 1988).

In a recent follow-up study, Bottiroli, Cavallini and Vecchi, (2008), re-tested participants 2 years after their initial training (see Cavallini et al., 2003). Long-term effects of the training were only found on one of the tasks. Interestingly, this task was the face/name memory test, which is regarded as being highly related to everyday life. The researchers

theorise that this strategy may have been more highly practiced then others in daily life (often there are occasions where we meet new people and have to remember names), and that is why the benefit was still present two years after initial training. Furthermore, this reason has been applied to explain most of the contradictory findings on the long-term benefits of training, as the success of the training may depend on how frequently people use the learned strategies, and how similar the activities they use them for are to the tasks practiced in the memory training (Derwinger, Stigsdotter Neely & Bäckman, 2005; Bottiroli et al., 2008).

An emerging theme in the literature is the importance of examining the role of metacognitive processes in memory training programmes. It is apparent that people's beliefs about their memory performance may heavily influence the effectiveness of memory training and the ability to use these strategies efficiently.

Metacognition refers to the beliefs and knowledge that an individual has about their own thinking. Nelson and Narrens (1990) conceptualised a framework to explain metacogntive processes, in which monitoring and control are key components. The monitoring component refers to an individual's ability to "observe, reflect on and experience cognitive processes" (Schwartz & Perfect, 2002, p4) The control component alludes to the behaviours an individual engages in as a result of the monitoring process, typically these would be strategies a person adopts, such as increased allocation of time to remember something. Metacogntion in the domain of memory is called metamemory and can be defined as an "individual's knowledge about their personal attributes, memory abilities, and available memory strategies and their perception of the memory demands of various tasks and situations" (Bunnell, Baken, Richards-Ward, 1999, p24)

It has been proposed that there is an age-related decline in metamemory and as a result older adults are less able to effectively assess memory demands in certain situations. This means that older adults may allocate insufficient resources and implement ineffective strategies to achieve a task (Lachman, 1991; Hertzog, Dixon & Hultsch, 1990). Murphy, Schmitt, Caruso & Sanders, (1987) found that older adults showed better performance when they were instructed to use strategies, suggesting that there may be an age effect on metacognitive control and that this may account for the age effect on memory performance.) Research has also illustrated that younger adults are better at using and

adjusting their strategies (increased allocation of time, greater rehearsal) than older adults (Soucahy & Insingrini, 2004, Bissig & Lustig, 2007), giving further support that a deficit lies in the metacognitive control component.

An aspect of metamemory is Bandura's (1977) concept of 'self-efficacy' defined as "one's sense of competence and confidence related to specific performance in a given domain", (Mohs et al., 1998, p184), and is often used as a measure of metamemory in its own right, (Hertzog, Hultsch & Dixon, 1989). Age differences have been shown in individual's evaluation of their memory ability, with older adults perceiving theirs to be worse (Cavanaugh & Poon, 1989). Soucahy and Insingrini (2004) have suggested that these age-related differences in self-efficacy could be the reason why older adults are less able to implement effective strategies.

Research has shown that older adults commonly have more negative beliefs about their memory and therefore are more likely to attribute normal 'lapses' as being more serious than they are. (Dixon & Hultsch, 1983) Furthermore, Lachman, (2006) found that many older adults believe that these age-related declines are 'inevitable' and 'irreversible'. A study by Levy (1996) showed that older adults were more susceptible to the effects of age-negative and age-positive words when measuring actual memory performance. In this study, older adults and younger were given a memory test, and then were subliminally presented with age-positive words such as 'wisdom' and 'sage' or age-negative words 'dementia' and 'decrepit'. Following this, they were then asked to perform another memory test, the results showed that older adults performed worse following the age-negative words, with younger adults being unaffected. This study shows that implicit age-related stereotypes can have an impact on memory performance in older adults.

Further support for the notion that there are age-related differences in metamemory, come from a study conducted by Desrichard and Köpetz (2005). In their study they examined memory self-efficacy, task instructions and expectations of performance to determine how this can affect performance in older and younger adults. It was found that when an identical memory task was pitched as either assessing 'memory' or 'other cognitive functions,' performance differed in older adults, with greater scores obtained in the 'non memory' condition. In contrast, the type of task instructions made no difference to younger adult's performance. This confirms previous findings that older adults are

susceptible to stereotype threat (aging inevitably leads to cognitive decline). Lower self-efficacy and expectations were reported by older adults compared to younger adults. Furthermore, self-efficacy and expectations played a moderating role on the impact of task instruction on memory performance, with low memory self-efficacy and low expectations correlating with poorer performance in the 'memory' condition. Taken together, the findings suggest that situational/contextual factors can play a role in age-related differences in memory performance, and not solely cognitive factors are responsible.

One theory to explain these metamemory declines are that the older adults are less able to engage in self-initiated processes (Craik, 1986). This theory proposes that due to a decline in frontal lobe functioning, older adults are less able to monitor their mental processes and as a result cannot instigate some mental processes when it is necessary. It is proposed that encoding processes are particularly susceptible to aging, as it requires self-initiation of control, whereas retrieval (the act of getting information from storage into conscious thought) is more 'obligatory' (Bissig & Lustig, 2007).

It is clear that memory strategies can facilitate memory performance, but can have costs as well as benefits. It has been demonstrated that younger children exhibit a 'utilization deficiency' when it comes to strategy use, which means that although they may spontaneously use a strategy they may not derive any benefit from it even when using a comparable strategy to older children. This 'utilization deficiency' has also been extended to older adults and it has been proposed that age differences in working memory capacity may be responsible for this (Dunlosky & Hertzog, 1998; Gaultney et al., 2005). A useful line of investigation would be to see what effect memory training in specific strategies has on memory performance and the utilization of such strategies.

Research into improving memory abilities in the elderly population, have shown promising results when self-report measures of memory efficacy are included. (Cavallini et al., 2003; Mohs et al., 1998). Often, even if such studies do not show increased memory performance, self-efficacy is improved, and this finding has led some researchers to the conclusion that "exposing the elderly to methods that improve their self-efficacy or confidence in their memory are just as important as the traditional approach of teaching memory aids, strategies and mnemonic techniques," (McDougall & Balyer, 1998, p221).

It is also important to establish realistic outcomes; so that participants are not misled into believing their memories will be drastically improved following training.

Clearly, more research needs to be done in this area to ascertain in which circumstances people can improve their performance, and to determine the likelihood of whether this can be transferred to other tasks (domain general or specific). The encoding process has been emphasised as being an important target for memory training programmes (Bissig & Lustig, 2007). It may be that older adults/poor performers will benefit from more environmental support in the form of explicit training and it proposed that future research should be shaped by theory to understand the processes people engage whilst completing cognitive tasks (Bissig & Lustig).

2.4.4 Adaptivity in Strategy Use

Most of the studies looking at strategy use and memory performance outlined thus far have focused on instructed strategy use. In everyday situations it is more likely that strategies would need to be self-initiated, and selected from a repertoire of different strategies. Optimal task performance often relies on participants being able to select the most appropriate strategy for the task (Lemaire & Siegler, 1995). Strategy adaptivity has been little researched in the domain of memory performance, focusing more on the domains of decision making and mental arithmetic (Imbo & Vandierendonck, 2007; Lemaire, Arnaud & Lecacheur, 2004, Mata, 2006).

2.4.4.1 Adaptive Strategy in Older Adults

It has been proposed that older adults are unable to effectively adapt their strategy use to the demands of the situation (Lemaire et al., 2004). However, work undertaken by Mata (2006) has showed that both younger adults and older adults are adept at altering their strategy use in different situations, however there were noticeable differences in their performance. In the study, younger and older adults were asked to make decisions regarding the value of a diamond, based on various information cues. In the compensatory environment more complex strategies are favoured (people should search for more information), whereas in the non-compensatory environment the optimal strategy would be to search less information. The results showed that older adults favoured the use of simple strategies and this was greater in the appropriate non-compensatory environment.

This may indicate that older adults are in fact more adaptive in their strategy selection, however they showed poorer strategy selection in the compensatory environment; favouring simple strategies where more complex ones were more appropriate. Additionally, even when they did choose the correct strategy their performance was lower, suggesting they were making more application errors.

Strategy adaptivity has been less extensively researched in the domain of memory, but is an emerging area, especially with the keen interest in memory improvement due to the aging population. A recent study by Tournier and Postal (2011) investigated age-related differences in strategy selection in a paired-associate word task. Task characteristics were made more/less demanding by manipulating the concreteness level of the words. The word pairs consisted of unrelated nouns that either had a high concrete level (e.g. lettuce/hammer), a middle level (e.g. childhood/apparatus) or an abstract level (e.g. regret/instinct). Previous research has shown that different strategies yield better performance at different levels of concreteness; an imagery strategy is superior for high concrete words; yet a sentence strategy is better for abstract words (Dunlosky & Hertzog, 1998; 2001; Richardson, 1998). However, due to a decline in cognitive resources and typically superior verbal skills/vocabulary it has been found that older adults show a preference for using the sentence strategy rather than imagery (Hulicka & Grossman, 1967).

The results revealed that older adults used less imagery than younger adults, but used the sentence strategy to the same level. This shows a partial decrease in strategy adaptivity as in the concrete level the imagery strategy is superior. Although both older and younger adults showed good strategy selection, as they both used more imagery for concrete pairs and sentence for abstract pairs; younger adults used more imagery than older adults, which decreased recall in the concrete level. For the middle level (where no strategy was said to be better) older adults used the sentence strategy more than younger adults, whereas younger adults used both strategies to the same extent. This ties in with what previous research has found, namely that older adults when not given specific strategy instructions tend to adopt a sentence strategy (Hertzog & Dunlosky, 2004).

The results of Tournier and Postal (2011) also revealed that older adults are as efficient as younger adults in strategy use, but only with the sentence strategy and not the imagery strategy. It may be explained by cognitive effort involved, in that older adults (who exhibit cognitive decline) may find implementing the imagery strategy difficult and are more able to use the sentence strategy. This is supported by research suggesting that older adults exhibit a decline in using an imagery strategy (Craik & Dirkx, 1992). Another suggestion is that it may be that older adults prefer to use a sentence strategy as they typically have a greater level of vocabulary (Verhaeghen, 2003).

These findings have been supported by a recent study by Hertzog et al. (2012). This study revealed that when older adults were given a choice of strategy to use after a period of supervised strategy use, they typically picked the more superficial strategy (repetition) in a paired-associate task, whereas younger adults adopted the more effective strategy (imagery). This shows that although older adults learned through task experience that imagery was a superior strategy, they still persisted in using repetition, which requires less effort. One possible explanation for age-related differences found in strategy selection and execution is that older adults have reduced processing resources (Lemaire, 2010). Indeed, research exploring strategy use in a number of cognitive domains has implicated executive functions (Taconnat et al., 2009), processing speed (Lemaire, 2004) and working memory (Mata, 2006).

 Research investigating whether cognitive resources, notably WMC has an impact on strategy selection/execution has yielded some interesting results. In the Mata (2006) study it was hypothesised that in the compensatory condition (where more intensive search strategies are favoured) WMC will influence strategy selection, as those with lower WMC will be penalised as they will not be able to implement the appropriate higher resource-demanding strategies. In the non-compensatory condition, WMC should play less of a role as both those with high and low WMC should be able to choose and implement the simple strategies. The results showed that in the compensatory condition those with higher WMC typically used more sophisticated strategies. The results were mixed in the non-compensatory environment suggesting that individual differences in cognitive capacity play a larger role in a compensatory environment. Overall, the results indicated that individual differences in cognitive capacity are a determinant of strategy use (at least in the compensatory environment).

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This pattern of results was different in the older adult group. It was predicted that cognitive abilities should play a role in the compensatory environment (where intensive strategies are favoured) but not in the non-compensatory environment. However, it was shown that it was evident in both environments. Additionally, specific cognitive facets such as reasoning speed and knowledge were associated with the use of more demanding strategies, suggesting that if older adults had these resources at their disposal then they were likely to use more complex strategies, irrespective of environment.

This study highlights the importance of examining strategy selection in older adults, as it may be that differing task demands have an impact on which strategies will be used. As older adults are believed to have reduced cognitive resources, it would be useful to determine whether this has an impact on strategy use as well.

2.4.5 Summary

It is evident that there is a link between WMC and strategy use, with people with a higher WMC often outperforming those with a lower WMC (Rosen & Engle, 1997; McNamara, 2001; Turley-Ames & Whitfield, 2003; Bissig & Lustig, 2007), however this finding has not been replicated in some studies (Engle, Cantor & Curullo, 1992). This has an implication for older adults who are theorised to have a reduced WMC.

Examination of the literature regarding older adult's memory strategy use does reveal differences when compared to younger adults. For example, research has shown that older adults are less likely than younger adults to spontaneously employ the use of strategies (Perlmutter & Mitchell, 1982) or sometimes even when older adults use strategies, they may be ineffective due to a utilization deficiency, or not being able to choose the appropriate/effective strategy (Gaultney et al., 2005; Murphy, Schmitt, Caruso & Sanders, 1982). Different theories have been put forward to account for why these differences may occur, including deficits in metamemory, or an inability to exhibit self-initiated processes due to a reduction in working memory resources (Craik & Byrd, 1982).

When older adults are encouraged or trained to use strategies, the research paints a more promising picture, namely that older adults are able to benefit from the use of strategies (Verhaeghen et al., 1992; Cavillini et al., 2003).

Looking at the above points, it is clear that there are many different research avenues to explore re: aging and strategy use. However, an area that is often overlooked is whether strategy use could benefit older adults when they are performing two concurrent tasks, when one is in the domain of working memory? It is hypothesised that strategy use may play a role in performance in dual-task performance, for example if people employ the use of a strategy would this lead to increased performance? It may be that that strategy use may make the memory task easier and more automatic, and therefore offers more resources/capacity for the other task. Conversely, it may be for people with reduced working memory capacity, implementing a strategy may lead to decreased performance as it may overstretch already limited resources. There are many questions relating to strategy use, working memory capacity and the role these have to play in aging that have not been explored in very much detail, and will form the basis of the current research.

Firstly, it is important to have a look at the literature regarding strategy use in older adults in dual-tasks and how the current research expands upon this.

2.5   Divided Attention and Strategy use

Recently, Naveh-Benjamin et al. (2005) conducted a study that examined the use of memory strategies in dual-task performance. Their findings showed that when instructed to use a elaborate encoding strategy (association/imagery) both older adults and younger adults increased their memory performance, yet in older adults this was accompanied with higher secondary task costs, suggesting that effectively using these strategies requires additional attentional resources. According to Craik and Byrd (1982), as older adults have reduced attentional resources at their disposal this would mean that "the ability to engage in demanding mnemonic strategies either at encoding or retrieval is compromised by age" (Naveh-Benjamin et al., 2005, p521). Naveh-Benjamin et al. concluded that there is an age-related deficit in strategy use, as both older and younger adult's benefitted from strategy instruction, yet this was at a cost to the older adults.

However, the above study merely instructed participants to adopt a particular strategy and not actually train them in the use of a strategy. If training was provided then it may be that memory performance would be increased and secondary task costs decreased as a result of the strategies becoming more familiar and less resource demanding.

Whiting (2003) conducted a study that looked at the effects of an elaboration strategy on performance whilst attention was divided between two tasks. This research showed primary performance was affected more by the introduction of a secondary task at encoding rather than retrieval. However, divided attention at retrieval led to higher secondary task costs. Surprisingly, when asked to use an elaboration strategy, older adults benefitted to the same extent as younger adults and exhibited little DA costs (either to primary or secondary task). It was hypothesised that elaboration strategies would lead to increased DA costs as it would require more resources than just reading the words. However, it is proposed that generating words was a form of environmental support as words were generated from word fragments with a semantically related cue. In the read condition this cue is not present and therefore any strategies used would have to be 'self-initiated'. This would mean that less resources are needed at encoding in the generate condition than in the read condition and therefore would result in less DA costs (as seen in the study). As older adults are proposed to perform better when environmental support is given due to a deficit in controlled processing (Craik & Jennings, 1992) this would mean that older adults would benefit from this as well. Previous research looking at age-differences in memory recall when processing demands are manipulated has confirmed this- e.g. Eysenck (1974) found that when asked to self-initiate an imagery strategy age differences increased, with older adults performing worse than younger adults.

Although this finding is promising as it shows that there are elaborative strategies that older adults can adopt without at a cost to their performance- it is likely that in 'real-life' situations, older adults will have to self-initiate strategy use therefore it is important to determine what effect self-initiating strategies has on performance when attention is divided- and to see if training can improve performance.

2.6 Current Research

The overarching aim of this research is to expand upon previous work, which has produced an inconsistent pattern of results, leaving uncertainty over whether an encoding

deficit exists, particularly in dual tasks, and whether strategies might help to overcome this deficit in aged people.

A number of studies are planned in order to investigate this. Firstly, the effects of strategy training in single and dual-task performance will be examined, with older and younger adults to see whether performance can be improved. Cognitive resources such as working memory capacity will also be assessed so that the relationship between WM and strategy use can be examined. The methodology employed will allow the contributions of both working memory and aging to be considered which is often overlooked in studies of cognitive aging (Borella, Ludwig, Fagot & De Ribaupiere, 2011).

Other studies will focus on how performance is affected by specific strategies, and whether there are age-related differences in strategy selection and exploitation. The research aims have naturally developed and evolved as the research progressed in order to fully explore this topic and answer any questions that were generated from the results obtained.

The following questions will be addressed by the current research:

- To examine whether training in a normatively effective strategy (imagery/association) can directly improve performance in a single task, and to ascertain whether such beneficial effects transfer to dual tasks? Are there age-related differences in performance? (Study 1, 2 and 3). Can this benefit transfer to other complex tasks (e.g. WM tasks)? (Study 4)

- If memory training leads to increased performance in the memory task (primary task) then does it lead to decreased or increased secondary task costs? (Study 1, 2 and 3)

- To determine which memory strategies are effective/ineffective in single-task and dual-task activities. (Study 2 and 3)

- In single and dual-task conditions do people spontaneously adopt normatively effective strategies, and if so, do they out-perform people who have been identified as not using these strategies (Study 2 and 3)

- To investigate adaptivity/ flexibility in strategy use, do people adapt their strategy depending on task demands? Is this the same in younger and older adults? (Study 2 and 3)

3   Methodological Overview

3.1   Aims of Study

As previously discussed, empirical findings have shown that a relationship exists between working memory capacity and strategy use and that this is influenced by aging. However, whether this relationship holds for dual-task performance has been less extensively examined.

The current research aims to explore these topics in a number of studies as described below:

Study one (Chapter 4, p74) will focus on looking at whether a brief strategy training session can improve memory performance in older and younger adults. More importantly, this study will determine whether strategies are effective for dual tasks, and whether there are age-differences in performance.

Having established whether an imagery/association strategy is effective, study 2 (Chapter 5, p103) and 3 (Chapter 6, p168) will examine more closely which strategies participants adopt in the tasks, and whether there are age-related differences in strategy selection and execution.

Finally, a study on transfer (Chapter 7, p208) will be conducted to determine whether strategies can be applied to 'untrained' tasks. A central theme in all studies will be to assess how processing resources, such as working memory capacity, processing speed and executive functioning impact on the utilisation of strategies and performance.

3.2   Rationale/Justification of Method

In order to explore these aims, a suitable methodology had to be devised. The focus of this chapter is to provide a rationale for the methods chosen, and to provide some background of how these decisions were made. The general development of the methodology is outlined below, with more specific information given and description of the measures and procedures given in the methods sections of the individual studies.

3.2.1 Cross sectional vs Longitudinal Design

One methodological issue apparent in the cognitive aging literature is whether cross-sectional or longitudinal methods should be used in research. Cross-sectional methods involve testing two groups of participants of different ages (young/old) at a particular time and comparing the results to determine the effect of age. Longitudinal studies test the same participants but over intervals of time (typically years). Both methods have strengths, but also have limitations to consider.

The merits of conducting cross-sectional research mainly focus on practical issues, e.g. it is less time consuming, and therefore less expensive to conduct research using this technique, and studies are quicker. However, difficulties arise in the interpretation of the results, as they can only be inferred as reflecting age-related changes in a given time, as if they are thought to genuinely reflect changes over time then assumptions are made that the younger and older adults resemble each other in the past/future, which is not possible (Salthouse, 2000). Another concern is cohort effects (Schaie, Maitland, Willis & Intrieri, 1998) in which unique experiences/circumstances can be applied to a generation of participants but not another (e.g. war) which may have an effect on the results, masking real age effects (Salthouse, 2004). Nevertheless, cross sectional research has been heralded as being an invaluable way of providing "insights into relationships among variables and how they change across the lifespan, and they have been used to generate a wealth of valuable normative data and hypotheses" (Graf, 2004, p. 305)

Longitudinal research is often yielded as superior to cross-sectional research for studying developmental changes (Hultsch et al., 1992), as they allow for the investigation of intra-individual variation. However, in addition to being time intensive there are still other limitations that need to be taken into consideration. For example, longitudinal studies are vulnerable to time-of-measurement effects, defined as being changes occurring during the time of testing. For example a major socio-historical event could have an impact on the findings, which may not necessarily be present if the study were repeated in a different time period. In addition, variations in the experimental protocol at different testing sessions could also have an impact on results (e.g. different researcher used). Another issue may be reactivity effects, as participants are measured repeatedly over periods of

time, then prior exposure to the methodology may have an impact, such as practice effects (Unger, van Belle & Hayman, 1999; Salthouse, 2004).

Retention of participants may also difficult, and attrition could be an issue; especially in aging studies, where older participants may die in-between testing sessions. Selective attrition is a concern for researchers using longitudinal methods, as it has been found that lower performing participants withdraw from the study more frequently than those with greater cognitive abilities, therefore making it harder to detect age-related changes (Hultsch et al., 1992).

When the two methods are compared, it is often found that the results converge, but the magnitude of age-related changes may be inflated in cross-sectional studies (Wilkie, Eisdorfer & Nowlin, 1976). However, the opposite finding has also been reported (Zelinksi & Burnight, 1997). In fact recent research has demonstrated that similar age trends are associated with within-age cohort effects (longitudinal analysis) and between-age cohort effects (cross-sectional), and these effects may not be a critical factor in some cognitive abilities (Salthouse, 2014). With this in mind, a cross-sectional design was chosen for the current research.

3.2.2 Dual-task Method

As all of the studies were employing a dual-task methodology, a number of issues should be addressed in order to ensure that the measures were appropriate considering the aims of the research. Studies examining age-differences in dual-task abilities have yielded mixed results, however this is hardly surprising considering the disparity of methodologies involved (De Ribaupierre & Ludwig, 2003; Riby, Perfect & Stollery, 2004a). To examine whether strategy training can increase performance in the primary or secondary task in a dual-task situation, there needs to be a divided attention effect present prior to strategy training.

An initial question that arose was whether attention would be divided at encoding, retrieval or at both. A consistent finding in the literature is that "the encoding process is more sensitive than retrieval to secondary task interference" (Whiting, 2003, pg 144) so it was felt that dividing attention at the encoding process would be sufficient. Therefore most of the previous literature on dual-task studies discussed focus on dual- task

performance when attention is divided at the encoding stage. Many studies have reported an age-related deficit in dual-task performance, but the exact nature of this deficit may be dependent on the experimental situations (McDowd, Vercruyssen, & Birren, 1991; Albinet, Tomporowski & Beasman, 2006). This view has been supported by a study conducted by de Ribaupierre and Ludwig (2003), who examined the dual-task performance of young and older adults on nine different tasks. Results showed that age-related differences were only evident in four of the nine tasks, which suggested to the authors that the degree of interference experienced when performing dual-tasks is dependent on certain task characteristics.

There is debate in the literature under which circumstances age-related differences manifest, however there have been a number of meta-analytic studies that have been conducted to determine which factors are most important. Kieley, 1991 (cited in Hartley, 1992) found that older adults are particularly disadvantaged when the tasks are difficult or when a motor/memory component is present. This has been lent support by subsequent studies that have shown that the complexity of the task may be a contributing factor in whether age-differences will be found in dual-task studies. Anderson et al. (1998) found that when a memory task was coupled with a tracking task both older adults and younger adults' performance was affected to the same degree. However, compared to other studies that found an age-related difference in dual-task performance the choice of secondary task was less demanding. In their meta-analysis; Riby, Perfect and Stollery, (2004a) looked at a range of task characteristics in their meta-analysis and found that domain was critical to whether age-related differences are apparent in dual-tasking. The findings showed that tasks involving controlled processing resulted in age differences in dual-task performance, whereas tasks relying on automatic processing resulted in an absence of age differences. This pattern has been replicated in other studies; Riby, Stollery and Perfect (2004b) found that in an n-back task comparing semantic and episodic memory, age differences where only found in the episodic task which relies on controlled processing.

The current studies focus on examining age-related differences in dual-task performance when a memory task (episodic) is coupled with an auditory discrimination task. These tasks where chosen as they are similar to methodologies used by previous research in which age-differences have been found (Park et al., 1989). In this way it could be determined if age differences are prevalent where both tasks rely on controlled processing.

Another reason for choosing these two tests was so they could easily be converted to more ecologically valid tasks- e.g. the words could be changed to be a shopping list (although this makes it easier as linked semantically) and the auditory discrimination task could be changed to train announcements. This is important, as this has been stated as a reason why traditional lab-based experiments do not transfer to 'real-life' situations (Mohs et al., 1998).

A further issue that needs to be taken into consideration when examining age-differences in dual-task performance is the method used to calculate dual-task costs. There are a number of methods used to calculate dual-task costs each with different justifications. Absolute costs have often been used whereby dual task scores are subtracted from the single-task score. This has received criticism in the literature because absolute costs fail to consider the differences in baseline performance. As older adults are more likely to perform worse at baseline this can lead to inflated dual-task costs. A better method is to control for these differences by using relative scoring as advocated by Somberg and Salthouse (1982). Relative scores are calculated by dividing the absolute scores by single-task performance. Relative scores are typically more conservative than absolute costs and therefore are more likely to reflect genuine costs (Riby, Perfect & Stollery, 2004b). However, it has been found that both of these methods of scoring can reveal similar results (Whiting, 2003; Naveh-Benjamin et al., 2005). To be comparable to the literature both of these methods were employed in the present study, and where there are converging results only relative scores will be reported.

3.2.3   Processing Resource Measures

A main component of this thesis is to examine the contribution of various processing resources to strategy implementation and memory performance, and to establish whether they are affected by aging. Therefore different measures will be used to assess a variety of different processes including memory, speed of processing and executive functioning. The issues surrounding measurement of these facets and the reasoning behind the choices of measures/administration of tasks will now be outlined.

3.2.3.1 *Working Memory Measures*

There are a wide range of tasks that are commonly used to assess working memory capacity. These tasks differ from short-term memory measures as they not only assess an individual's ability to store information, but also the ability to actively process the information (Baddeley, 1986). These complex tasks are sometimes referred to as dual-tasks in the sense that they are comprised of both a storage and processing aspect. The storage aspect taken on its own can be viewed as a short-term memory task, in which participants are usually required to recall a string of digits/words. The processing element of the task requires this information to be manipulated in some way (Turner & Engle, 1989).

Research investigating whether strategy use impacts on working memory capacity, typically use variations of the reading span measure (Conway & Kane 2005). The reading span (Daneman & Carpenter, 1980) requires participants to read a number of sentences, and made a decision as to whether they are logical or not whilst remembering the last word of each sentence for later recall. Other commonly used measures include the operation span (Turner & Engle, 1986), in which participants have to solve simple arithmetic problems whilst remembering words for subsequent recall, and the counting span (Case, Kurland & Goldberg, 1982) which requires participants to count shapes and remember these for later recall. Overall these tasks work on the underlying principle of WMC "to force storage in the face of processing (distraction) in order to engage executive attention processes" (Conway et al., 2005, pg 773).

In the original version of the span tasks conceptualised by Daneman and Carpenter (1980) although deemed important, the accuracy of the processing element of the task (verifying the sentences) was not monitored, therefore making it susceptible to participants sacrificing their performance on the processing task in order to do better on the storage element (remembering the words). Therefore in subsequent versions of the span task it is now typical that the processing component is monitored so for an individual's score to be deemed valid, accuracy must be at least 85%. Earlier versions of the task also used an ascending trial format, so that smaller trials were presented first, which allowed participants to anticipate how many words they would be required to remember. Engle at al. (1992) changed the format in their version of the operation span so that the set size was

randomised, this is beneficial as it avoids the build-up of proactive interference and participants developing specific strategies that are related to prior knowledge of set size. Although randomised set sizes are more typical in the current literature, ascending trials are still used. Recently St Clair-Thompson (2012) examined the differences in ascending versus randomised set sizes, and found that randomised set sizes were superior in predicting complex cognition.

Another important factor to take into consideration is how the tasks are administered, as it has been found that these may have a bearing on the results obtained. Traditionally working memory span tasks were self-paced with participants able to control how long they read the sentences/words for. However, this has been criticised as participants may take longer thereby enhancing their ability to use strategies, as delaying the stimulus presentation decreases the degree to which the processing component interferes with utilising strategies such as rehearsal. This is important, as with the introduction of strategies, working memory measures lose their ability to predict higher order cognition (comprehension, arithmetic etc) (Friedman & Miyake, 2004), and thus may no longer be a pure measure of WMC, but rather a STM measure (Conway et al., 2005). This has been supported by St-Clair Thompson, (2007) who found when tasks were participant-paced as opposed to experimenter-paced, memory span scores increased; however the relationship between them and higher order cognition was decreased.

An alternative to using self-paced tasks is to use experimenter-paced tasks, in which the experimenter controls the timing of the task. Although the experimenter must wait until the processing element has been read by the participant before moving onto the next one; the time between the trials is minimised. Recently, there has been a move toward computer paced span tasks, in which the timing of the stimulus presentation is pre-set. The timing of these has varied considerably, but about 4-6 seconds for the processing task and 1-2 seconds for storage is typical. Bailey (2012) examined the difference between these methods (experimenter-paced versus computer paced) and found that the computer tasks were a viable alternative to experimenter tasks in that the reliability and validity of these tasks was comparable. They also offer added benefits such as being able to be administered in a group setting and may eliminate anxiety due to an experimenter being present. However, without an experimenter present, it is hard to monitor participant's

attention to ensure they are engaging with the task, and it is difficult to equate processing time for all participants.

One way to address this is to use automated span tasks instead in which the processing time is tailored to an individual by examining their score on practice trials and, adding 2.s.d's (Unsworth, Heitz, Schrock & Engle, 2005). These measures have received support in the literature, and are widely used; however they are still subject to the criticisms of computer administered tasks, in that they do not allow experimenters to ensure that participants are fully engaging with the task. Research has shown that even when following the recommended procedures (randomised set sizes, computer paced), working memory measures are still subject to the influence of strategy use (Dunlosky & Kane, 2007, McCabe, 2010).

Therefore it was felt that the backwards digit span task may give a purer measure of WMC as it is less susceptible to strategy use, or at least the type of strategies commonly employed in verbal span measures (Logie et al., 2007). It is also a widely used measure in the field and has been standardised on both young children and older adults (Park et al., 1989). It has also been found to correlate well with other WM measures, for example correlations between backwards digit span task and the reading span task have ranged from .46 and .62 (Park, et al., 2002; Oberuaer, Lange & Engle, 2004). In some cases non-verbal span tasks such as backwards digit span yield stronger correlations with working memory measures such as N-back tasks (Redick & Lindsey, 2013).

Therefore, the current research will use a variety of different tasks to measure WMC, including measures that are not thought to be as affected by strategy use, such as backwards digit span. Where span tasks are used they will be administered via computer but closely monitored to ensure that participants are engaging with the task in the required manner.

Another issue that requires consideration, is the method used to score the WM task. There are many different methods prevalent in the literature, which will briefly be discussed. Traditionally working memory tasks were administered until participant's accuracy fell below an appointed threshold, and the set size of the last list is the person's WM span

score. However, this absolute span score method has been discredited for not being sensitive enough to detect individual differences, as a lot of information is discarded (Oberauer & Süβ, 2000). Another method is to score a participant for each item they correctly recall, and whether it is remembered in the correct serial position or not. Additionally, the set size can also be taken into account by assigning weight to the items in order to reflect that remembering 5 items is harder than remembering 3 items. As all items are supposed to be measuring the same construct weighting is not usually used (Conway et al., 2005). The different methods of scoring a WM span tasks were investigated by Conway et al. (2005), who looked at partial credit scoring (items which are partly correct are granted credit), all or nothing scoring (only those in the correct serial order are scored), unit scoring (proportion of items are scored) or loading scoring (all correctly recalled elements are scored, regardless of set size). It was revealed that partial-credit scoring (unit-weighted rather than load scoring) was superior in terms of internal consistency. This was also advocated as all items are supposed to be measuring the same construct so weighting does not need to be taken into consideration. (Conway et al., 2005).

3.2.3.2 *Processing Speed*

Research has shown that a large amount of age-related variance shown in cognitive tasks can be explained by processing speed (Salthouse, 1994; 1996). It has also been shown that age-related declines in WMC are closely related to declines in processing speed (Park et al., 1996). Conversely, a recent study demonstrated that WMC, and executive functioning explained more age-related variance than processing speed in an episodic memory task (McCabe, Roediger, McDaniel, Bolata & Hambrick, 2010).

It has also been proposed that process-specific factors (such as strategy use) can also contribute to age-related variance (Madden & Gotlob, 1997). Processing speed has been identified as a mechanism that influences strategy use, for example Verhaeghen and Marcoen (1994) found that age-differences in strategy choice was related to age-differences in processing speed, namely that older adults were less likely to engage in elaborative encoding strategies. In their study examining children's strategy use in

arithmetic, Imbo and Vandierendonck (2007) found that faster processing speed was associated with utilisation of a more efficient strategy.

However, other findings have demonstrated that speed of processing is not associated with strategy implementation. Dunlosky and Hertzog (1998) failed to show that speed of processing was a strong predictor of strategy use or age-related differences in a paired-associate task. This finding was supported in a study conducted by Bryan et al. (1999) who found that although speed of processing was associated with recall, it was not associated with strategy use during encoding. Instead, working memory and executive functioning were associated with strategy use.

It is evident that speed of processing may be an important factor to consider when examining age-differences in memory performance and strategy use, therefore this will be assessed in the initial study.

3.2.3.3 *Computerised Test Batteries*

In addition to traditional pen and paper measures of cognitive functions; this research will also utilise computerised measures. Although less widely used; with advancements being made in the assessment of cognitive abilities, a range of computerised batteries have been developed. These typically employ the use of technology such as touch screens to enable easy administration and accessible to a wide range of participants. One such assessment battery is the Cambridge Neuropsychological Test Automated Battery (CANTAB), which assesses facets of working memory, attention, planning and executive functioning. A brief evaluation of the CANTAB will now be given.

The CANTAB was chosen as it was originally developed for the assessment of cognitive function in older adults (Robbins et al., 1994), and is therefore well suited to assess this population. It has also been widely used in research since the 1990's, with an established track-record of over 700 journal articles published (Wild & Musser, 2014). The CANTAB offers an advantage over traditional measures in a number of ways. Firstly; it may be more cost-effective, as typically the tests are quicker and easier to administer in comparison to traditional tests. Secondly, as the tests are graded with difficulty they minimise both floor and ceiling effects and therefore are suitable in testing a wide range of abilities and ages.

Other strengths of the CANTAB are that it relies solely on non-verbal abilities, has a large normative database, standardised administration and can give instant feedback.

However, it does have some limitations as well. Although the tests were developed using traditional tests and existing paradigms (for example the Stockings of Cambridge task has been heavily influenced by the Tower of London task), there is concern that they are not comparable (Buchanan, 2002) owing to differences in communication, presentation of stimuli/materials and responses (Wild & Musser, 2014). Additionally, there have been mixed findings in reported test-retest reliability. Lowe and Rabbit (1998) found that some tests are more consistent than others, for example the tasks assessing memory yielded greater reliability than those assessing executive functions. However, this has been attributed to executive functioning tasks requiring novelty; which may be difficult to achieve with repeated testing, as they will lose their impact. A further limitation is that as this battery has non-verbal tasks, it may not be directly comparable with traditional 'verbal' measurements.

Due to its computerised nature older adults may be at a disadvantage, as are often less familiar with using computers (Wild, Howieson, Webbe, Seelye & Kaye, 2008) and exhibit greater computer anxiety (Laguna & Babcock, 1997). As test anxiety has been shown to negatively affect test performance (Kausler, 1990), than age-differences shown in cognitive tasks may be in part attributed to differences in computer anxiety. However, research directly examining this has revealed that although older adults typically report higher levels of computer anxiety, it only impacted when performance was measured by speed of response rather than accuracy (Laguna & Babcock, 1997). Furthermore, when older adults are given adequate instruction and reassurance, it has been reported that computerised tests are favoured over their paper-pen counterparts (Wild et al., 2008).

Overall, the CANTAB provides a versatile and useful way in which to measure cognitive functioning. As it has been shown to be sensitive to detecting age-differences in a range of different facets, including memory, attention and executive functioning (Wild & Musser, 2014) it is an ideal candidate for use in this research. However, participant's interactions will be monitored closely to ensure that they are comfortable in using it (especially with older adults).

3.2.4 Strategy Training

An integral part of this research is assessing strategy use in memory tasks and training participants on how to use various strategies. Although the methodology changes from study to study, the reasoning for choosing certain strategies and the theoretical framework adopted is consistent across the research.

Giving older adults memory strategy training has led to successful gains (for a review see Verhaeghen et al., 1992). However, there are variations to the degree of success exhibited and to the type of strategy training given. It is apparent that some strategies are more successful than others in specific tasks; for example when remembering faces and names an association strategy is better than a strategy such as the method of loci (for a comprehensive review see Poon, Walsh-Sweeney & Fozard, 1980). For the current research, memory strategy training included a range of strategies including a mixture of 'global' (rehearsal, imagery, association) and more 'specific' strategies (chunking, face-name association). As opposed to previous research in this area, strategy instructions were not given to participants so that a particular strategy had to be chosen for the tasks as it was felt that in a real-life situation these prompts would not be given to participants. Additionally it was felt that part of being an effective strategy user was being able to self-initiate an appropriate strategy for the task.

The choice of strategies included in the training is also guided by previous research into this area. It was decided that the memory strategy should focus on the normally effective strategies such as imagery and association that are relatively easy to learn and implement, (Dunlosky & Kane, 2007; Hertzog, McGuire & Lineweaver, 1998). Other strategies such as the method of loci and variations on the peg-word system were considered as these have shown success in previous studies (see Cavallini et al., 2003) but were rejected as research suggests that these methods are very time-consuming and effortful. For older adults (who may have reduced resources at their disposal) such strategies may be detrimental to performance as they are too resource-demanding and therefore may reduce performance rather than enhancing it (Mcpherson, 2007).

Previous research has shown that strategies such as verbal association/elaboration that are based on verbal skills require less effort for older adults compared to other more complex

strategies (West, 1995), presumably because these are skills that are preserved in aging. In fact, most studies have reported that older adults exhibit higher vocabulary scores than younger adults (Bailey, Dunlosky & Hertzog, 2009) which may have an impact on how these verbal strategies are implemented, although this is something that has not been extensively researched in the literature (McNamara & Scott, 2001). Therefore it was felt that these should be included in the memory strategy training.

Another aspect that needs to be considered is the working memory capacity of individuals. As outlined in the previous chapter, older adults typically exhibit lower working memory capacity on a variety of span tasks (Salthouse, 1994). This is important as this may have a bearing on strategy use, although the exact relationship between working memory capacity and strategy use is still unclear. Some researchers have theorised that high working memory capacity leads to strategy use, as these people have the necessary resources to implement a strategy. However, others have purported that it is effective strategy use that lead to high working memory capacities; these two theories have been appropriately dubbed the strategy-as-effect hypothesis and the strategy- as-cause hypothesis to describe the relationship between working memory capacity and strategy use (Dunlosky & Kane, 2007; Bailey, Dunlosky & Kane, 2008).

It may be that both of these contribute to the relationship between span scores and strategy use, however in recent years the strategy- as-effect hypothesis has gathered more support. For example Dunlosky and Theide, (2004) found that people identified with possessing a higher working memory capacity used more effective strategies than people identified with lower working memory capacities when instructed to do so. Additionally Turley-Ames & Whitfield (2003) found that low spans were not able to use more demanding strategies and only marginally improved their scores following training, whereas although high spans also did not improve their performance following training they were performing optimally at pre-test. However, McNamara & Scott, (2001) argue against this hypothesis, stating that a 'capacity account cannot explain why less strategic individuals were able to learn strategies, which increased their WM span" (pg 15).

This has an impact on memory intervention programmes for older adults, as according to the strategy-as- effect theory it may not be worth teaching older adults memory strategies

as typically they exhibit lower working memory capacity scores and therefore would not be able to implement them. This will explored in the current research.

Another important element to consider regarding the nature of the strategy training would be how the training is administered. A prevalent format for memory training in the literature is that of a seminar. Typically training will consist of a slideshow presentation, in which various memory strategies will be introduced in which participants will have a chance to practice these strategies. These are often conducted in a group session, to promote discussion; however this has been criticised as it "may not be conducive to strategy mastery. Trainees may need more direct-instruction, and more opportunities for individual mastery-ordered practice," Yassuda (1999, pg 92). Based on the recommendation of Yassuda (1999) the majority of strategy training will be completed in one-to-one sessions, or small groups (2-3 people).

Time given to implement strategies is also an important factor to consider when assessing memory performance. Dunlosky and Kane (2007) found that only 30% of participants reported using a strategy in the operation span task, as participants found implementing a strategy difficult due to the task being fast-paced. St-Clair Thompson (2007) found that when participants had control over the timing of a memory span task, they typically took longer and their performance was improved. It was concluded that this extra time allowed participants to utilise effective strategies.

To remain consistent with methods used in similar research, equivalent/similar times for encoding TBR information were used (Bailey, Dunlosky & Kane, 2008; Unsworth, 2009) Anecdotal feedback from the pilot study indicated that the timing was adequate for participants to use strategies, although it did prove difficult.

Another methodological concern was that of how to assess strategy use. A widely- used method is that of self-reports, although the way in which strategy use has been reported has differed considerably. Some researchers have asked open-ended questions asking participants to describe how they used strategies to learn the items (Martin, Boersma & Cox, 1965), whereas other researchers have asked participants to select the strategy they used from a list of possible strategies (Richardson, 1998; Dunlosky & Hertzog, 2001).

These methods are used for a number of reasons; they provide a rich account about the strategies and how they are used (especially true for the open-ended questions), all possible strategies are examined. However, as with most self-report data, this method has limitations. It may be that participants are responding the way they feel the experimenter wants them to, by reporting the strategies they think they should be using, rather than what strategies they actually did use. This may be especially valid for participants who have taken part in training, as they may feel more of an obligation to report using the trained strategies, rather than the strategies of their choosing.

A further issue concerning the use of self-reports is whether they should be completed retrospectively or during the task itself. Asking participants to report their strategy after the task has been completed is a common method employed (Friedman & Miyake, 2004; McNamara & Scott, 2001; Turley-Ames & Whitfield, 2003). However, this is vulnerable to people forgetting which strategies they adopted throughout the task, or making generalisations based on strategy use on a couple of trials. Although eliminating these concerns, adopting the alternative method by reporting strategy use during the task, also has weaknesses. By concurrently reporting the strategies used, participants may be influenced by this and therefore it may alter subsequent strategy use (Dunlosky & Hertzog, 2001).

Research has also shown that task times are often increased when participants are asked to verbalise their thoughts whilst completing a complex cognitive task (Bowles & Leow, 2005; Deffner, 1980; Yoshida, 2008). This may not be important if the variable measured is number of items recalled, but would have an impact on timed data. In the current research, the reaction time is the dependent variable for the secondary task, so verbalisation of a strategy may lead to inflated secondary task costs.

Another aspect concerning concurrent verbalisation of the strategy is that it may be resource-demanding and therefore impact on the implementation and the efficacy of the strategies being used. This is proposed to be especially salient when participants are engaged in the dual-tasks (Goo, 2010; Jourdenais, 2001). Individual differences in WMC may play an important role in this situation. Goo (2010) hypothesised that those who have a high WMC would be better at verbalising their thoughts during a task, as it would involve attentional control to simultaneously process information related to the task and

verbalise thoughts. In fact the opposite pattern was found; that those with a lower WMC performed better whilst 'thinking aloud.' It was theorised that the advantage of having a higher WMC was negated by the verbalisation demand, thus increasing their susceptibility to interference; those with a low WMC showed equivalent performance as they exhibited a lower ability to withstand interference initially. Overall, it is felt that verbalising the strategy used during the completion of the cognitive tasks, would not be a good method to use for the current research as it introduces an additional variable that may affect the results unnecessarily.

A way around this is to utilise the use of set-by-set retrospective reports, as advocated by Dunlosky and Kane (2007). As opposed to general retrospective reports, participants are presented with the set list and asked to indicate which strategy they used for that particular set. Although both the general report and the set-by-set reports were useful in providing information about strategy use, namely that people use a range of strategies and often favour the use of non-effective ones; the set-by-set reports allowed for a greater examination of the findings. In contrast to the general reports, set-by-set reports showed that individual differences in effective strategy use correlated with individual differences in performance.

Other methods commonly utilised to examine strategy use are clustering techniques. Typically these are employed in free recall tasks, where participants are asked to record the words they have remembered from a list in any order. The order of the words is taken to indicate whether a particular strategy has been used. For example if the list was comprised of words pertaining to a number of different categories that were interspersed, than usually participants would use a strategy in which they group the words from a category together. This would be reflected in their responses, as words from the same category would be recorded consecutively more than would due to chance alone (Bousfield, 1953). This method is useful as it avoids the inherent limitations in relying on self-report data; however it also has weaknesses, such as not being able to accommodate all possible encoding strategies. For example a clustering analysis may be useful for assessing an association strategy; however it may not be helpful for assessing a strategy such as imagery. Such clustering techniques may also fail to capture true strategy use, as it may be that clustering may occur when participants are using a different strategy.

Although there are strengths and weaknesses for each of the methods used in the previous research, it was felt that for the current research, where strategy use is assessed it should be by retrospective self-reports. This was deemed to be a superior method for the following reasons: (1) As a wide-range of strategies are included in the training, self-reports would allow for more strategies to be assessed than would be achievable using a clustering approach. (2) Retrospective self-reports will not have an impact on how the strategy is utilised in the tasks. (3) Recently, it has been shown that making strategy reports retrospectively seems to be minimally effected by forgetting. Also when concurrent and retrospective self-report methods have been directly compared, they have yielded similar results (Dunlosky & Kane, 2007; Gero & Tang, 2001). Additionally, when the task is divided into sets (e.g. working memory span tasks with trials) than retrospective set-by-set strategy reports will be used as these allow for a closer examination of the strategies used as opposed to a general report (Dunlosky & Kane, 2007).

4 Study 1: Effects of age and memory strategy use on performance in single and dual-tasks

4.1 Introduction

Studies in the aging literature consistently report that there are declines in areas of memory and attention (for a review see Salthouse, 2010). A prominent theory in the cognitive aging literature to account for these changes in cognition is the processing resource hypothesis (Park et al., 1996), which posits that cognitive processing resources decline as we age. The exact processing resource responsible has been the source of much debate, but several mechanisms have been put forward including reductions in speed of processing (Salthouse, 1994; 1996), working memory (Craik & Byrd, 1982; Park & Schwartz, 2000, Bopp & Verhaeghen, 2005), attentional resources (Anderson & Craik, 2000) and inhibitory processes (Hasher & Zacks, 1988). Although there is no real consensus regarding the mechanisms which underlie cognitive aging, ways to mitigate cognitive decline and promote successful aging is a topic of great importance to researchers in the field.

An area that has received considerable attention is whether performance can be enhanced through the use of memory strategies. According to the levels of processing principle (Craik & Lockhart, 1972), by elaborating on material that needs to be remembered through the formation of strategies such as imagery/association, deeper encoding will occur and thus lead to greater recall. This has been widely supported with findings demonstrating that when memory strategies (such as mental imagery/association) are utilised at the encoding stage in various cognitive tasks, they typically yield superior performance (Bissig & Lustig, 2007; Cokely et al., 2006). In light of cognitive aging, of particular interest is whether older adults are able to benefit from using a memory strategy.

Typically research has reported positive effects. For example, Verhaeghen et al. (1992) in their meta-analysis found that older adults could improve their performance when instructed to use a strategy. Numerous studies conducted since then have supported this finding (Cavillni et al., 2003; Carretti et al., 2007; Carretti, Borella, Zavagnin & De Beni, 2010; Fairchild & Scogin, 2010, Gross & Rebok, 2011). It has been hypothesised that

elaborative strategies may also act as a type of environmental support (Caretti et al., 2007). This would benefit older adults, who are able to capitalise when the environment offers more support (cues, strategy instructions), as they are believed to experience a deficit in the use of self-initiated processes (Craik, 1986).

However, not all research has revealed positive findings. For example research has found that imagery strategy use does not improve performance in older adults (Isingrini, Fontaine, Metras & Bonneau, 1994). Other studies have shown that when instructed to use an optimal strategy, not only do age differences fail to diminish but are actually increased (Verhaghen et al., 1992), demonstrating that older adults may not benefit to the same degree as younger adults (Dunlosky & Hertzog, 1998). In line with the processing resource hypothesis it has been proposed that older adults lack the necessary resources to effectively use demanding strategies such as imagery and association (Bryan et al., 1999; Lemaire, 2010; Soucahy & Insingrini, 2004); however this has been disputed as when instructed to use a strategy older adults have been found to benefit to the same extent as younger adults (Light, 1991; Carretti et al., 2007).

Moreover, older adults are less likely to engage in spontaneous strategy use as compared to younger adults (Hulicka & Grossman, 1967; Dunlosky & Hertzog, 1998), and may not consistently employ effective strategies even when instructed to do so (Hertzog & Dunlosky, 2004, Taconnat et al., 2009, Verhagehen & Marcoen, 1996). Recently; the notion that poor metacognitive knowledge/strategy use coupled with a reduction in cognitive resources leads to impairment in cognitive tasks has received merit. Bender and Raz, (2012) in their study used structural equation modelling to determine which variables could explain age-related variance in memory performance. It was found that both belief in inefficient strategies such as rehearsal (indicative of shallow encoding) and reduced processing resources (working memory) were independently associated with reduced memory performance.

Given the debate in the literature about whether older adults possess the cognitive resources to implement and effectively use strategies; one insightful line of research would be to investigate how strategy use is affected by increased task demands. One way of doing this would be to introduce another cognitive task at the encoding stage. So called dual tasks represent a more challenging feat than performing tasks singly, because

attentional resources have to be divided between the tasks which is typically reflected by reduced performance in one or both of the tasks. As resource theories of cognitive aging emphasise a reduction in the amount of available cognitive resources available to older adults, then age-related differences in performance in effortful and demanding tasks (such as dual tasks) should manifest.

Indeed, there is evidence to suggest that dual tasks have more of a negative effect on older adult's memory performance more than their younger counterparts (Logie et al., 2007; Park et al., 1989). However, this finding has not been demonstrated in some studies, which have found that performing a concurrent task at encoding leads to reduced memory performance in older and younger adults to the same extent (Anderson et al., 1998; Baddeley, Logie, Bressi, Della Salla & Spinnler, 1986; Park et al., 1987). In regards to the secondary task, research has typically found that older adults exhibit greater secondary task costs in relation to younger adults (Anderson, et al., 1998; Craik & McDowd, 1987). As secondary task costs are thought to reflect the attentional demands of the memory task, then these findings suggest that older adults find dual tasking more demanding than younger adults owing to reduced attentional resources. Looking at this pattern of findings, it is unclear how strategy use may impact on dual-tasking; it may be that utilising these effortful strategies in these taxing conditions may be too demanding for older adults, who are believed to have limited attentional resources (Guttentag, 1985; Shaw & Craik, 1989). On the other hand, it may be that using an encoding strategy may alleviate some of the dual-task demands (Logie, et al., 2007).

Surprisingly, with the interest in strategy training in older adults and age differences in dual tasking, few studies have focused on examining whether using a strategy can improve performance in highly demanding situations such as dual-tasks. Naveh-Benjamin et al. (2005) examined the effects of strategy use on divided attention, and found that older and younger adults benefited from using an imagery/association strategy. However this was accompanied by a decrement to the secondary task only for older adults. Whiting (2003) found that older adults were able to utilise an elaborate encoding strategy (generating words) to improve their performance, and this came at no cost to the secondary task. However, it may be that the generation of words is not as demanding as using other strategies such as imagery/association as it relies on generating words from a

fragment using semantic cues so does offer a degree of environmental support (Whiting, 2003).

A limitation in previous studies is that they instructed participants to use a particular strategy rather than training them. As strategies are effortful and require resources (Dunlosky & Hertzog, 1998; Palladino & De Beni, 2003) then offering information about the effectiveness of strategies and allowing practice with them may lead to greater improvements. Indeed, a recent study has shown that when participants are given information regarding the use of strategies (applicability and effectiveness) this can enhance performance in a memory task compared to when given just strategy training alone (Cavillini et al., 2010). In a recent meta-analysis Gross et al. (2012) found that the type of memory strategy and duration of the training did not make a difference but that teaching more strategies might be advantageous. It is believed that with increased knowledge about and a broader repertoire of strategies, older adults are not only more likely to apply them in cognitive tasks and thus improve their performance (Troyer, 2001) but also utilise them in everyday life (Hertzog, Kramer, Wilson & Lindenberger, 2008; Gross & Rebok, 2011).

The main goal of the current study is therefore to establish whether memory strategy training in imagery and association can improve performance in single and dual-tasks in younger and older adults. The training will focus on imagery and association strategies, as previous research has shown these to be effective strategies in free recall tasks (Bailey, Dunlosky & Hertzog, 2009; Carretti et al., 2007; 2010) and are commonly employed in strategy training (Gross et al., 2012). Knowing whether older adults can utilise such strategies effectively in these conditions will expand our current understanding of this topic, and can guide future memory training,

In line with previous research it was hypothesised that both younger and older adults will increase their memory performance following strategy training in single tasks. Moreover it was predicted that younger adults would benefit from utilisation of a strategy in the dual task. Due to the mixed findings in the literature, it was less clear whether older adults will be able to exploit the use of strategies in a dual-task, and if they could, whether this increase in memory performance would be accompanied by greater dual task costs. Irrespective of whether any benefits of strategy use are found in older adults, in

accordance with cognitive aging theories; it was predicted that age-related differences in performance will persist following training.

As reduced processing resources are offered as an explanation to account for age-related differences in memory performance; another goal of this study was to examine the relationship between age, performance, working memory and processing speed. In line with previous research, it was expected that working memory performance would be negatively correlated with age, with older adults performing worse than younger adults. Similarly, the same was expected for processing speed; older adults were expected to be slower than their younger counterparts. In regards to performance, it was anticipated that both working memory and processing speed would be correlated to the performance measures, with processing speed being associated more with secondary task performance (Reaction times) and working memory span with word recall measures. To examine whether processing resources are required to implement a strategy; the correlation between performance and processing resources prior to strategy training and following strategy training will also be compared.

4.2   Methods

4.2.1   Participants

Thirty-six participants took part in this study; 18 younger adults (aged 19-25, 15 female) and 18 older adults (aged 66-82, 14 female). The majority of younger adults were recruited from the University of Greenwich through the research participation scheme and received course credits for their participation. Others were recruited through local organisations. The older adults were recruited from the local community through organisations such as University of the Third Age and social clubs. No participants received monetary compensation. The mean age for the younger adults was 21.67; (SD = 2.63), and the older adults was 73.94 (SD = 4.30). Participants were excluded if they did not have good command of the English language, a history of neurological illness, were taking any medication liable to affect their thinking ability, or had an uncorrected hearing or visual impairment. Each age-group was randomly divided into two groups (the control and experimental groups) and participant characteristics are presented in Table 4.1.

There were no significant differences in age or educational levels between the experimental and control groups in the older and younger adult group respectively, (smallest $p=.27$) Although older adults had an overall lower educational level than younger adults, this difference was not significant in either the experimental or the control group

Table 4.1 Characteristics of Participants in Each Group

		Younger			Older		
	Group	*M*	*S.D*	*n*	*M*	*S.D*	*n*
Age (years)	Experimental	21.56	2.88	9	72.78	5.21	9
	Control	21.78	2.54	9	75.11	2.98	9
	p	.864			.265		
Education (years)	Experimental	14.00	1.58	9	12.25	3.41	9
	Control	13.67	0.71	9	11.88	2.23	9
	p	.572			.799		

4.2.2 Materials

Working Memory Test- The Backwards Digit Span Test from the WAIS- III (Wechsler, 1997) was administered to participants to assess WMC. It comprises of ascending trials of digit strings (2 to 10 digits long). Participants are required to listen to the digits and then repeat them in the reverse order. The test is terminated when participants fail both trials of a digit string.

Processing Speed Measure- The Digit-Symbol Coding test from the WAIS-III (Wechsler, 1997) was used as a measure of processing speed. Nine digit-symbol pairings are detailed in a key, and participants are required to use the key to write down the corresponding symbols next to the letters that are presented. The number of symbols that are accurately completed in 120secs is taken as the score.

Word Lists (Primary Task) – Word lists were constructed of 18 high frequency, high imagery words taken from the MRC Psycholinguistic

Database (Coltheart, 1981). All words were between 5-7 letters. Four different word lists were constructed for the four different tasks; the pre-training single and dual-tasks, and the post-training single and dual tasks.

Auditory Discrimination Task (Secondary Task)– All tones were constructed using the Audacity software. Two different tones were used that were either 440Hz or 990Hz in frequency (low or high tone). Four different lists were constructed for tones (18) that each had 3 occasions when three of the same tone (either 440 Hz or 990 Hz) were presented consecutively.

4.2.3   Procedure

Participants were asked to complete the study in two sessions. The 1st session lasted approx1 hour, and the second 45 minutes. The second session was completed 5-7 days after the initial session.

First Session: All participants were tested individually or in a small group (2-3) in a quiet room. Participants were first instructed to read and sign the information and consent form. (see Appendix A). Once this was completed they filled out the demographic form (Appendix B). Following this the Backwards Digit-span subtest from the WAIS III was administered to give an indication of working memory capacity. The backwards digit span test required participants to repeat a string of digits that the researcher had orally recited, but in the reverse order. Digits were spoken at a rate of 1 per second and the task was discontinued once a participant had failed to recall the digits correctly for both trials at that length. Participants then completed the single and dual-tasks presented using the Super Lab software (version 4.07) on a laptop computer (OS Windows XP).

Participants were informed that they would be asked to memorise a list of words presented or on the screen, or listen for tones; whilst sometimes also engaging in another task. All instructions were presented on the screen before the test started, which also gave an opportunity for participants to ask the researcher to clarify any issues. The word test was comprised of a word list being presented at a rate of one word every 3 seconds. After 18 words had been presented, participants were asked to record all the words they could recall (in any order). There was no time limit for this, but participants typically spent between 1 and 5 minutes on this task. The tone test comprised of 18 tones being

presented (which were either high or low in frequency). Participants had to indicate by pressing the space bar when they had heard 3 identical tones in a row. The dual-task consisted of participants completing the word and tone task simultaneously. The duration of the tone/word would be 3 seconds followed immediately by the next word/tone. This procedure was repeated after memory training which is outlined below.

Strategy Training

Participants were randomly assigned to the experimental condition who received strategy training (n=18, 9 older adults and 9 younger adults) or the control condition who received no strategy training (n=18, 9 older adults and 9 younger adults). Strategy training was completed in individual sessions and lasted approximately 45 minutes. The training took the following format; first an overview of memory was given, outlining the role of working memory and how strategies may benefit the encoding process. Next, participants were given examples of different strategies that can be employed in everyday situations and the effectiveness of these strategies was given in reference to the literature. Participants were given an opportunity to practice these strategies and encouraged to practice them when they were able to. The strategies focused around using imagery and association to link words together and form an image in your 'mind's eye'. Concepts such as vividness and plausibility of the images were addressed, with personal preference being encouraged (see Appendix C).

Second Session: Those who had attended the training were given a short-recap (lasting about 15 mins). All participants were asked to complete the single and dual-tasks again. Different word and tone lists were constructed for the re-tests. Those who had attended the strategy training session were encouraged to use the strategies taught. At the end of the sessions participants were thanked for their time and fully debriefed (debriefing sheet is provided in Appendix D).

4.3 Results

4.3.1 Data screening[5]

Outliers were screened for by examining boxplots and standardised scores (z-scores). Inspection of the z-scores did not reveal any that exceeded 3.29, which is considered a potential outlier (Tabachnick & Fidell, 2007). However, inspection of boxplots revealed an extreme outlier for one participant on the number of words recalled at dual-task 1. Therefore this was winsorised to the next highest score to reduce the influence of this. This method ameliorates the disproportionate influence of the extreme value on the standard error while maintaining the value in the dataset as the highest score. Histograms and Q-Q plots were visually inspected for normality, and revealed a possible deviation from normality in some of the dependent variables. Given the central limit theorem (Howell 2007) and the sample size (N>30), this deviation should not present a problem to reliability of the significance values. This was checked by applying Log and square root transformations to the dependent variables [6] and re-running analyses. Similar patterns emerged so untransformed variables were retained.

4.3.2 Analysis

Data were analysed using 2x2x2 Mixed ANOVA, with group (no strategy /strategy) and age (young/old) as between-subjects IVs and time (pre/post) as a within subjects IV. Four separate ANOVAs were conducted for each DV, which are detailed below. To adjust for the multiple tests, and to reduce the risk of making a Type I error; the Dubey/Armitage-Parmar (Sankoh, Huque & Dubey, 1997) correction was applied. This procedure takes into account the correlated nature of the dependent variables[7], and was conducted using Uitenbroek's (1997) SISA programme online. This resulted in a corrected alpha threshold of 0.04 for the primary tasks (word recall), and 0.03 for the secondary tasks (RT).

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[5]As there are 2 between- subjects groups all data were screened in their respective groups: younger adults-control, younger adults- experimental, older adults- control, older adults- experimental.

[6]Word recall (single task) was found to be negatively skewed at time 1, so this was reflected and transformed. The other dependent variable was Tones- RT (single task) at time 2- which was positively skewed.

[7]The average correlation between the dependent variables for the primary task (word recall) was 0.81, and for the secondary tasks (RT) was 0.61

4.3.2.1 *Primary Task: Word Recall (single task)*

Mean number of words recalled by age (younger/older) and group (experimental/control) for pre and post task are presented in Table 4.2. The ANOVA of number of words recalled (single task) with age, group and time as IV's revealed a main effect of Age $F(1, 32)=$ 13.34, $p<.001$, $\eta^2_p = .30$, with younger adults ($M=10.06$, $SD= 2.71$) scoring significantly higher at time 1 and time 2 than older adults ($M=6.61$, $SD= 3.64$). The main effect for Group ($F[1, 32]= 2.53$, $p =.12$, $\eta^2_p= .07$) or Time ($F[1, 32]=3.64$, $p =.07$, $\eta^2_p = .10$) was not significant.

Table 4.2 Means and standard deviations for number of words recalled at time 1 and time 2

Age	Group	Time 1 (pre strategy training)		Time 2 (post strategy training)	
		M	*S.D*	*M*	*S.D*
Young	Control	9.44	1.42	8.56	2.93
	Experimental	9.67	2.60	12.56	2.56
Old	Control	5.67	3.81	6.67	3.04
	Experimental	6.78	3.23	7.33	4.61

The Time*Group*Age Group Interaction was also significant at the adjusted alpha level ($F[1, 32] = 5.13$, $p= .03$, $\eta^2_p = .14$. To further deconstruct this interaction follow-up t-tests were conducted where appropriate. A bonferroni correction was applied, resulting in an alpha level of .001. Inspection of the data (as shown in Figure 4.1) suggest that older adults (regardless of in the experimental and control condition) did improve from time 1 to time 2, however this was not significant ($t[17]= 1.43$, $p=.72$). For the younger adults at time1 there is little difference in mean scores between the two groups (experimental/control) ($t[16]= 0.23$, $p = .825$), yet at time 2 those in the experimental group recall more words than at time 1 ($t[8]=2.83$, $p= .022$) and more than those in the control group ($t[16]=3.067$, $p= .007$) who recall slightly less than at time 1 ($t[8]=0.819$, $p=.437$). All other interactions were not significant (All F's $\geq$ .81, although the Time* Age*Group interaction was marginally significant ($p = .057$). The results therefore indicate that strategy training improves performance in the single task for younger adults only.
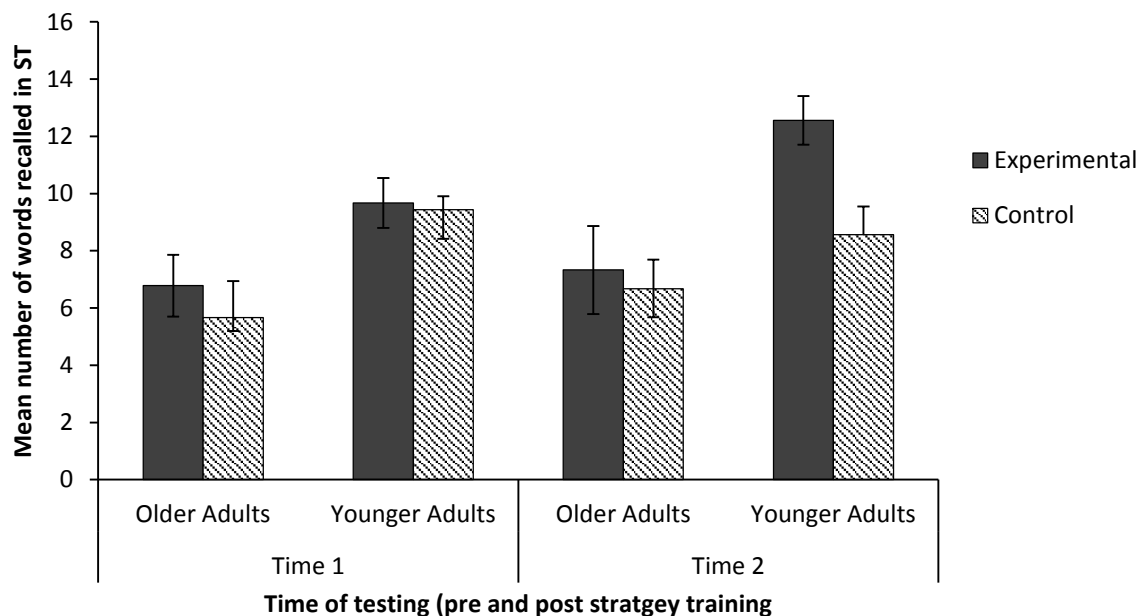
Figure 4.1. Younger and older adults' word recall (single task) by group (experimental/control). Error bars represent standard errors

4.3.2.2 *Primary Task: Word Recall (dual task)*

The ANOVA revealed a main effect for Time ($F[1, 32]= 16.40$, p<.001, $\eta^2_p= .34$) with participants scoring significantly lower at time 1 ($M= 4.89$, $SD= 2.25$) than at time 2 ($M= 6.44$, $SD= 3.24$). A main effect for Age was also found ($F[1, 32]= 11.50$, p= .002, $\eta^2_p=. 26$) revealing that younger adults recalled more words than older adults. The main effect of Group was also significant ($F[1, 32]=5.48$, p=.02, $\eta^2_p=.15$) showing that those who were in the experimental group ($M= 6.47$, $SD= 2.99$) scored significantly higher than those in the control group ($M= 4.86$, $SD= 2.25$).

The interaction between group and time, and all of the other interactions were not significant ($p>.07$). Closer inspection of the data (see Table 4.3 for means by age and group) reveal that the lack of interaction between group and time may have been attributable to the performance of the younger adults, as there were significant differences between the experimental and control groups at pre-test, $t (16) = 3.40$, $p = .006$; whereas

scores for both groups of older adults were roughly equivalent in the pre-test, $t(16) = .971$, $p = .346$.

Table 4.3 Means and standard deviations for number of words recalled at time 1 and time 2

		Time 1 (pre strategy training)		Time 2 (post strategy training)	
Age	Group	M	S.D	M	S.D
Young	Control	4.34	1.12	6.56	2.92
	Experimental	7.33	2.40	9.11	2.76
	Overall	5.83	2.38	7.83	3.05
Old	Control	4.33	2.06	4.22	2.49
	Experimental	3.56	1.24	5.89	3.10
	Overall	3.94	1.70	5.06	2.86

When the data for the older adults were analysed independently it was found that the trained group performed better than the control group only at post-test, as demonstrated by the significant Time*Group interaction ($F[1,16]=6.25$, $p= .024$, $\eta^2_p= .28$) (shown in Figure 4.2). To summarise, it was revealed that in dual tasks strategy training can improve older adult's memory performance, but this was not evident for younger adults.
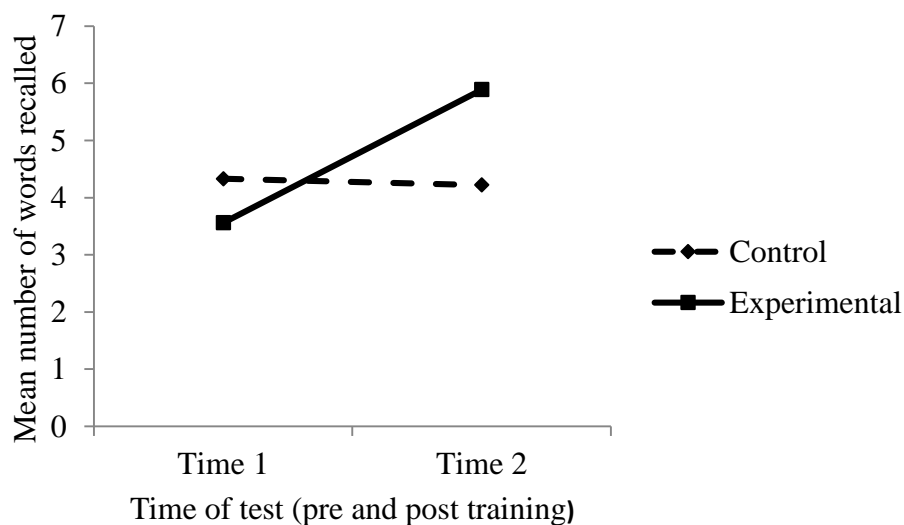
Figure 4.2 Older adults' word recall (dual task) by group (experimental/control)

4.3.2.3 *Secondary Task: Tones- RT (single task)*

Mean RT for correct responses in the secondary task performed singly by age group and group (experimental/control) are detailed in Table 4.4.

Table 4.4 Means and standard deviations for Tones (RT in ms) at time 1 and time 2

		Time 1 (pre strategy training)		Time 2 (post strategy training)	
Age	Group	*M*	*S.D*	*M*	*S.D*
Young	Control	845.10	366.70	708.26	265.17
	Experimental	888.48	343.16	614.07	244.03
Old	Control	977.73	320.88	1030.28	340.81
	Experimental	1009.38	234.10	739.42	199.84

ANOVA revealed a main effect of Time ($F[1,31]=9.85$, $p =.004$, $\eta^2_p= .24$) showing that Reaction time decreased from time 1 (*M*= 932.81, *SD*-=311.44 ms) to time 2 (*M*= 773.01, *SD*= 302.18 ms). The main effect for age was not significant ($F[1,31]= 3.78$, $p = .061$, $\eta^2_p = .11$) but was approaching significance. There was a significant interaction between Time and Group ($F[1, 31]= 6.11$, $p= .019$, $\eta^2_p =.17$) suggesting that at Time 1 those in the experimental group (*M* =948.93, *SD*= 292.02 ms) were marginally slower than those in the control group (*M*= 915.74, *SD*= 338.98 ms); following training, those in the experimental group (*M*= 676.75, *SD*= 225.78 ms) were quicker compared to those in the control group (*M*=869.27, *SD*= 339.72 ms) (see Figure 4.3). All other interactions were not significant (All *F*'s <1).
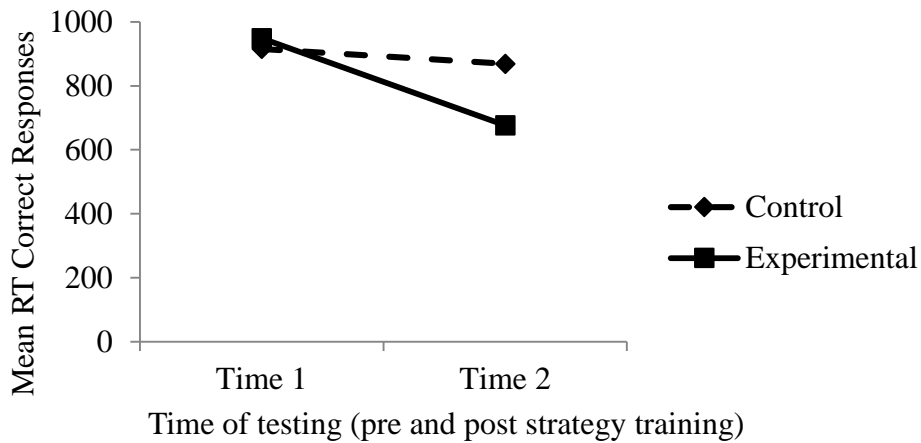
Figure 4.3 Reaction time for Tones pre and post strategy training by group

4.3.2.4   *Secondary Task- RT Tones (dual-task)*

Mean RT for correct responses of participants in the dual task condition by Age (Younger/Older) and Group (Experimental/Control) are outlined in Table 4.5.

Table 4.5 Means and standard deviations for Tones (RT in ms) at time 1 and time 2

Age	Group	Time 1 (pre strategy training)		Time 2 (post strategy training)	
		M	*S.D*	*M*	*S.D*
Young	Control	713.41	231.25	684.50	321.56
	Experimental	905.24	375.18	866.56	396.30
Old	Control	1076.44	335.32	926.12	289.87
	Experimental	1036.99	375.82	773.33	213.01

Looking at the means, it is evident that younger adults have quicker RT's than older adults in all conditions apart from the experimental group at time 2, and that participants decreased their RT from time 1 to time 2. However, ANOVA revealed no main effects/interactions (all *F*'s $\leq$ 3.63) although the main effect for Age was approaching significance (*p*=.067).

To establish whether there was a speed/accuracy trade-off, error data were analysed in a 2x2x2 Mixed ANOVA with group (no strategy training- control/strategy training- experimental) and age (young/old) as between-subjects IVs and time (pre/post) as a within subjects IV.

4.3.2.5 *Number of errors- Single task*

The results showed that participants made very few errors in this task (see Table 4.6 for means), with the range being 0-5, but with most participants (75% at time 1 and 83% at time 2) making no errors. As the findings from the RT data showed that in single-task performance a main effect of time was found, with faster RT at time 2, it would be expected that if a speed/accuracy trade-off was occurring then higher error rates would be found at time 2. Examination of the means shows slightly elevated error frequencies at time 2 for younger adults at least (M= 0.12, SD= 0.34 M= 0.18, SD= 0.40 at time 1 and time 2 respectively) but not for older adults who show less errors at time 2 (M= 0.28, SD= 0.67) than at time 1 (M= 0.78, SD=1.39). This finding was irrespective of whether participants completed strategy training or not. This is reflected in the ANOVA results which yielded no main effect for Time (F[1, 32]= 1.40, p=.25, η^2_p =.043), Age (F[1, 32]=2.78, p =.11, η^2_p =.08) or Group (F[1, 32]= .87, p=.11, η^2_p =.03). No interactions were found (all F's $\leq$ 2.3). Comparing this data to that seen in the RT data, it does not suggest that participants are sacrificing their accuracy on the task for speed.

Table 4.6 Means and standard deviations for number of errors produced at time 1 and time 2 – Single task

Age	Group	Time 1 (pre strategy training)		Time 2 (post strategy training)	
		M	*S.D*	*M*	*S.D*
Young	Control	0.13	0.36	0.25	0.46
	Experimental	0.11	0.33	0.11	0.71
Old	Control	0.44	1.01	0.11	0.33
	Experimental	1.11	1.77	0.44	1.01

4.3.2.6 _Number of errors- Dual task_

Again, inspection of the means (shown in Table 4.7) reveals a relatively low error rate, with the majority of participants (72% at time 1, and 55% at time 2 respectively) scoring 0 errors. In the correct response latency data, no main effects or interactions were found; but examination of the means showed that participants did decrease their RT at time 2. It would therefore be expected that if participants were sacrificing their accuracy in favour of speed, than more errors would be made at time 2, and this was confirmed by a significant main effect of time ($F[1, 32]= 4.68$, $p= .03$, $\eta^2_p =.127$). However, all other main effects and interactions were not significant (All F's ≤ 1.17) suggesting that this was not an age-related or group effect.

Table 4.7 Means and standard deviation for number of errors produced at time 1 and time 2 - Dual task

		Time 1		Time 2	
		(pre strategy training)		(post strategy training)	
Age	Group	_M_	_S.D_	_M_	_S.D_
Young	Control	0.22	0.44	0.56	0.73
	Experimental	0.11	0.33	0.67	0.50
Old	Control	0.44	0.53	0.56	0.88
	Experimental	0.33	0.50	1.11	2.08

4.3.3 Secondary Analysis

4.3.3.1 _Dual Task Costs_

Dual task costs were calculated to determine how performance was affected by the introduction of another task. Relative costs were calculated as advocated by Somberg & Salthouse (1982) by calculating the absolute cost (single task- dual task) and then dividing this by single task performance. This method was used as it takes into account baseline performance which may be reduced in older adults. This therefore provides more conservative results and avoids the risk of having inflated dual-task costs due to age-

related differences at base-line. Relative costs are thought to reflect the amount of attentional demand needed to complete the task with higher dual-task costs indicating greater attentional resources are required. The means and standard deviations subdivided by age and group are presented in Table 4.8.

4.3.3.1.1 Primary Task- Word Recall

Table 4.8 Means and standard deviations for dual-task costs on the primary (memory task)

Age	Group	Time 1 (pre strategy training)		Time 2 (post strategy training)	
		M	*S.D*	*M*	*S.D*
Young	Control	.54	.11	.23	.30
	Experimental	.23	.20	.26	.23
Old	Control	.12	.30	.40	.31
	Experimental	.42	.22	.03	.50

The results of the ANOVA revealed that there was not a main effect of Time, Age or Group (All F's $\leq$ 2.4). However the Time*Age*Group interaction was significant (F[1, 32]= 15.68, $p<.001$, η^2_p = .33). Figure 4.4 shows that at time 1, younger adults in the control condition have the highest dual task costs, and at time 2 they have lower dual-task costs than in the experimental condition. For older adults, the opposite pattern emerges (as shown in Figure 4.5) with higher costs for the experimental group at time 1, and lower costs (close to 0) than the control group at time 2.
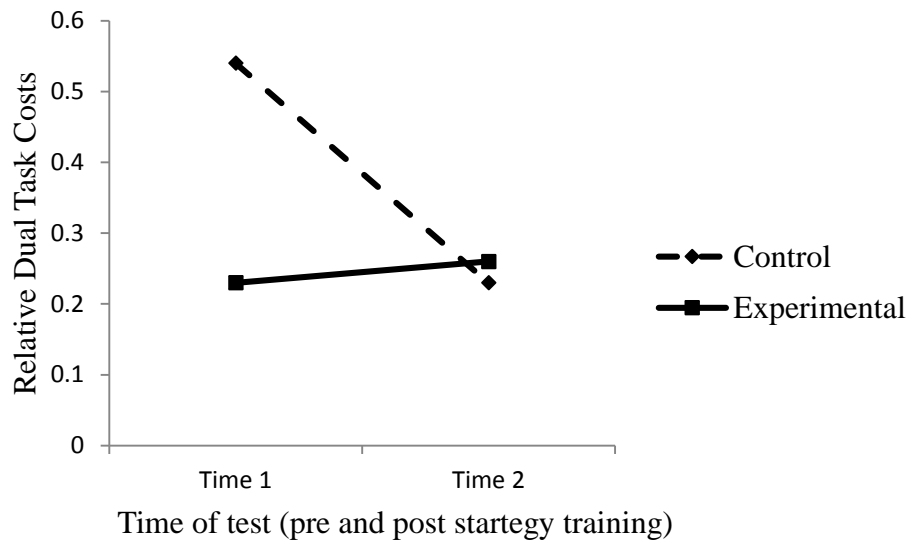
Figure 4.4 Younger adults' dual task costs for primary task (word recall) at time 1 and time 2
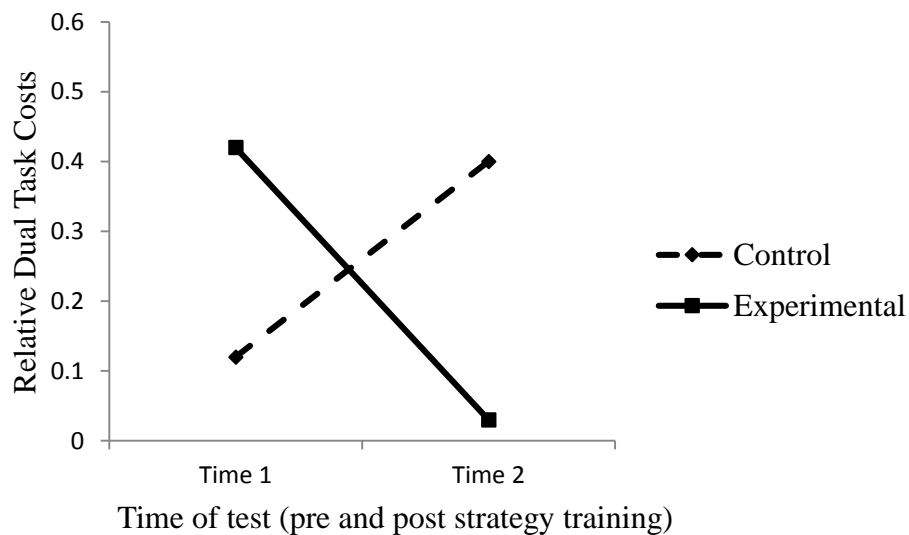
Figure 4.5 Older adults' dual task costs for primary task (word recall) at time 1 and time 2

Secondary Task- RT Tones

The means and standard deviations by group/age are given below (Table 4.9). Reaction time was used to measure the dual-task costs as there was little evidence of a speed/accuracy trade-off occurring. Negative values indicate greater dual-task costs, with positive values meaning that participants performed better in the dual-task condition as opposed to the single-task condition.

Table 4.9 Means and standard deviations for dual-task costs on the secondary task (RT)

Age	Group	Time 1 (pre strategy training)		Time 2 (post strategy training)	
		M	*S.D*	*M*	*S.D*
Young	Control	.11	.30	-0.5	.62
	Experimental	-.07	.35	-.54	.95
Old	Control	-.16	.30	.07	.20
	Experimental	-.03	.32	-.11	.39

Looking at the means, those in the experimental group do appear to have marginally greater costs after strategy training; however the main effect for Group was not significant (F[1,31]=1.98, p= 0.17, η^2_p = .06). The main effect for Age was also not significant,(F<1) showing that older and younger adults displayed equivalent dual-task costs. No significant interactions were found (All F's ≤3.4), although the Time * Age interaction was marginally significant (p = .07).

4.3.3.2 *The Contribution of Processing Resources*

Although not the primary focus of this study, measures of working memory and processing speed were taken prior to testing to determine if these had any influence on strategy use and performance. Differences between the experimental and control groups working memory and processing speed were checked with independent t-tests and are reported below. As can be seen from Table 4.10, WMC and processing speed were equivalent for most groups; although as expected there were significant differences between older and younger adults in processing speed, with younger adults being quicker, but only for the experimental group. In addition, there were differences between the control and experimental group in younger adults in processing speed, with the experimental group being slower than the control group. Surprisingly there were no significant differences between older and younger adults in WMC.

Table 4.10 Processing resources of participants in each group

	Group	Older			Younger		
		M	*S.D*		*M*	*S.D*	*T*
Backwards Digit	Experimental	6.67	2.35		6.56	1.94	0.11
Span	Control	5.11	1.45		6.22	1.86	1.42
	t	1.69			0.37		
Digit-Symbol	Experimental	37.62	10.35		55.00	9.84	3.55**
Coding	Control	43.22	9.48		44.67	7.76	0.35
	t	1.16			2.47*		

*Significant at .05 level, ** significant at the .01 level

Correlational Analysis

Correlations were conducted to determine the relationship between working memory, processing speed and performance in the single and dual tasks. Age was also included to see how this was related to performance and processing resources, with negative correlations indicating worse performance for older adults. [8] The full correlation matrix is presented in Table 4.11.

Working Memory Capacity

It was expected that working memory capacity would be positively correlated with performance in the word recall tasks. A significant positive correlation was found for the single tasks and for the dual task at time 2, but not for word recall in the dual task condition at time 1. Surprisingly, WMC was not found to significantly correlate with age; although the correlation was in the expected direction, with increased age relating to decreased working memory span.

To look more closely at the data, correlations were conducted separately for older and younger adults. This revealed that working memory capacity was only significantly positively correlated with word recall performance in older adults, and not younger adults,

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[8]With the exception of RT variables (secondary task performance) where a positive correlation would demonstrate worse performance for older adults.

suggesting that older adults may rely more on their working memory resources when performing these tasks. Correlations were stronger at time 2, (single task word recall- $r=$ .63 at time 1, $r=$ .75 at time 2; dual task word recall, $r=$ .23 at time 1, $r=$ .70 at time 2). Notably, these correlations were driven by the performance of the experimental group, as when analysed by age x group; the correlations were only significant for the experimental group (single task word recall $r =$ .68, $p =$ .043 at time 1, $r =$ .90, p $<$ .001 at time 2; dual task word recall, r = .20, $p =$ .61 ns at time 1, r = .75, $p=$ .02 at time 2), indicating that implementing a strategy requires more resources. Using Fisher's r-z transformation, it was found that the difference between the two correlations at single task approached significance (z = - 1.67, $p=$ 0.09, two-tailed) but was not significant at dual task.

Processing Speed

A significant positive correlation was found between processing speed and word recall in the dual task at time 1, and both word recall in the single and dual task conditions at time 2. In relation to reaction time measures; processing speed was significantly negatively correlated with tones at time 1 for both the single and the dual tasks; but not at time 2. Age was significantly negatively correlated with processing speed; as expected increased age was associated with slower reaction times. Although positively correlated; the relationship between processing speed and working memory was not significant, contrary to expectations.

Age

It was found that the results mainly supported the hypothesis that increased age would be associated with lower task performance and processing resources. Age was significantly negatively correlated with processing speed, indicating that as age increased processing speed decreased. However; although working memory was negatively correlated with age, this was a weak correlation and not significant. In relation to performance it was found that word recall was significantly negatively correlated to age on single task measures at time 1 and time 2. For tone performance positive correlations were revealed, which is in line with expectations that age is associated with increased and therefore slower reaction times. However, this was only significant in the dual task condition at time 1 and the single task measure at time 2.

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Table 4.11 Pearson Correlations between age, processing resources and dependent variables

	Age	Working Memory	Processing Speed	Word Recall (ST1)	Word Recall (DT1)	Word Recall (ST2)	Word Recall (DT2)	Tones (ST1)	Tones (DT1)	Tones (ST2)
Working Memory	-.14									
Processing Speed	-.45*	.32								
Word Recall (ST1)	-.54**	.41*	.22							
Word Recall (DT1)	-.44**	.28	.53**	.60***						
Word Recall (ST2)	-.48**	.56***	.41*	.67***	.68***					
Word Recall (DT2)	-.48**	.42*	.43*	.59***	.67***	.79***				
Tones (ST1)	.25	.13	-.35*	-.01	-.26	-.08	-.21			
Tones (DT1)	.40*	-.01	-.34*	-.23	-.29	-.19	-.25	.64**		
Tones (ST2)	.40*	-.21	-.21	-.26	-.37*	-.38*	-.47**	.50**	.42*	
Tones (DT2)	.16	-.06	.17	.066	.087	0.65	-.11	.19	.29	.43**

* p <0.5 ** p < .01 *** p <.001

4.4 Discussion

The study investigated the effects of age and strategy training on memory performance in single and dual tasks. Age-related differences were found in the primary task, with younger adults recalling more words overall than older adults pre and post strategy training, in both the single and dual tasks. This was not entirely unexpected, previous research examining strategy use in memory performance has found that age differences in performance do persist following training (Caretti et al., 2007; Cavillini et al., 2003; Dahlin, Nyberg, Bäckman & Sttigsdotter Neely, 2008). Of greater interest to the current study, however, was whether strategies could improve memory performance, and whether this was influenced by age.

It was hypothesised that strategy training would lead to improved recall in single tasks for younger adults, and older adults. Based on the existing literature, it was more an open question of whether these findings would be found in older adults in the dual-task. If the training was successful then a Time*Group interaction would be expected, with differences between the control and experimental groups only displayed post-training.

The results revealed differential effects for younger and older adults in single tasks. Younger adults exhibited improved performance following strategy training, (the group*time interaction approached significance), whereas older adults showed no improvement. For the dual tasks a different pattern emerged, with both younger and older adults demonstrating an improvement in memory recall at post-test. However, the time*group interaction was marginally significant for the older group only. In regards to the secondary task, there was no decrease in performance for those in the experimental group at post-test, suggesting that using a strategy was not associated with increased attentional costs, even for older adults.

These findings confirm the outcomes of previous research which found that training in imagery strategies can improve performance in a word recall task for younger adults (Bissig & Lustig, 2007; Cavillini et al., 2003, Turley-Ames & Whitfield, 2003). However, this benefit was not extended to older adults in the single task. This finding is in support of Isingrini, Fontaine, Metras and Bonneau, (1994) who found that older

adults did not improve their performance when utilising an imagery strategy. However, it is in contrast with numerous studies that have demonstrated that older adults are able to improve their performance in a free recall task by making effective use of an imagery strategy (Borella, Carretti, Riboldi & De Beni, 2010; Bailey, Dunlosky & Hertzog, 2009). Taken on its own, it could be argued that this finding provides support for the hypothesis that older adults experience a production deficiency in strategy use (Hertzog et al., 1998, 2001), but this notion is undermined by the findings showing that older adults were able to use a strategy to improve performance in the dual task condition. This is surprising, given that older adults did not show significant improvements following strategy training in the single tasks, which are less cognitively demanding.

A possible explanation for the unexpected findings is that there is an utilisation deficiency taking place, in which older adults are unable to derive the same benefit as younger adults when using a strategy (Dunlosky & Hertzog, 1998; Gaultney et al., 2005). This is supported by the Age*Group*Time interaction found, demonstrating that younger adults who had participated in the strategy training improved their performance more than older adults who had completed the training. However, this cannot wholly explain the findings, as this pattern did not emerge in the dual-task condition. In the single-task, it may be that older adult's performance was quite high anyway, and engagement in an imagery strategy only lead to minimal improvement. However, in the dual-tasks; as performance was quite low for older adults, utilising a strategy led to marked differences. Support for this thesis, comes from the finding that age-differences still persisted following strategy training; it has been argued that older adults should benefit more from strategy training/instruction as it offers a form of environmental support (Craik & Jennings, 1992; Bissig & Lustig, 2007).

Metacognitive differences could also account for the results. It could be argued that the nature of the word recall task in that it uses high imagery words lends itself to utilisation of an imagery strategy (it is hard not to imagine a clown when hearing the word clown), and therefore encourages spontaneous strategy use (Kuhlman & Touron, 2012). It may be that both younger and older participants were already using a form of strategy at time 1, but that at time 2 younger adults were able to make more

effective use of the strategy. Although older adults are typically believed to engage in less spontaneous strategy use (Hulicka & Grossman, 1967; Dunlosky & Hertzog, 1998) findings have shown equivalent spontaneous strategy use in younger and older adults (Kuhlman & Touron, 2012). In the dual-task, as it represented a more demanding situation, participants may be less likely to use a strategy at pre-task. However, when specifically instructed that an imagery strategy could be applied in dual-tasks, than it may have benefitted older adults more, as typically older adults are more penalised in these circumstances (Park et al., 1989). It has been suggested that older adults can use strategies, but have more difficulty in identifying when strategies can be applied (Cavillini et al., 2010), so with specific instruction they could capitalise. Of course, as the current research did not directly examine strategy use than this is a speculative argument at present, but anecdotal evidence suggests that some participants used an encoding strategy on the task at pre-test.

In future research it would be beneficial to measure strategy use in order to test this notion. Not only may participants be using a strategy at pre-test, it may be that the participants are not implementing the specified strategy at post-test. Dunlosky & Hertzog (2001) indicated that compliance to strategy instruction is typically about 60-80%. It may be that a different strategy is being implemented, or more than one is being used in synergy. If there are age differences in compliance to strategy use, then this could impact on the findings. However, previous research has shown that compliance to imagery instructions in equivalent for younger and older adults (Dunlosky & Hertzog, 1998; Kuhlman & Touron, 2012).

Surprisingly, there were no age-related differences in working memory capacity as measured by backwards digit span. Although unexpected this may be due to sampling issues (which will be discussed shortly) or may be due to the measure used. Backwards digit span was chosen as it is quick and easy to administer, has validated norms and also because it is less amenable to encoding strategies that are being investigated in this research than substitute measures such as the Reading Span (Cowan et al., 2005). However in previous research age-related differences are not always found, (Lamar & Resnick, 2004) and it has been criticised for being age-insensitive and loading more onto short-term rather than working memory (Park et al.,

2002; St-Clair Thompson, 2010). If it is more of a short-term memory measure, then this could account for why age-related differences were not found, as typically short-term measures are less sensitive to aging than working memory measures (Rabbit, 2005). In future research, it may be beneficial to utilise a different measure of working memory capacity or use a composite measure.

Inspection of the correlations between backwards digit span (a measure of WMC) and recall performance in the single and dual tasks showed that these were only significant for older adults, suggesting that word recall performance relies more heavily on working memory capacity in this group than for younger adults. This is in line with previous research which has demonstrated that stronger correlations between processing resources and episodic memory are typically found in older adults (Bouazzaoui, Angel, Fay, Taconnat, Charlotte & Isingrini, 2013). Of particular interest is that the correlations are only significant in the experimental group, and are stronger post-strategy training, indicating that more resources are required by older adults when utilising a strategy. However, as with any correlational data, this has to be interpreted with caution and as the sample size was very small, the ability to make any conclusions is very limited. Nevertheless this finding is interesting, and it would be useful for future studies to examine the role of processing resources in more depth and allow them to differentiate between the theories of age-related decline.

Although the correlations indicate that older adults may rely more heavily on their processing resources than younger adults; examination of the dual-task costs revealed that older adults did not show greater costs of dividing attention than younger adults, for both the primary and secondary task. In regards to the primary task, this confirms previous research showing that older adults' memory performance is not more disrupted by the introduction of a secondary task (Anderson et al., 1998; Naveh-Benjamin et al., 2005) (but see Park et al., 1989 and Salthouse, Rogan & Prill, 1984, for divergent results). It has been argued that tasks that are amenable to mnemonic encoding strategies such as free recall (used in the present study) may account for why dual-task demands are not found as these strategies may mask the age-related effects, (Logie et al., 2007). However, the finding that older adults could benefit from using an imagery strategy without incurring secondary task costs is novel. Previous

work, has demonstrated that when instructed to use an imagery strategy in dual-tasks older adults can increase their performance, but at a cost to the secondary task, (Naveh-Benjamin et al., 2005). It is argued that the strategies are more resource demanding for older adults to use, and thus led to differences in memory performance, in line with the inefficient strategy use hypothesis (Shaw & Craik, 1989). However, the results of the current study do not support this finding, as secondary task costs were equivalent in younger and older adults. It may be that strategy training rather than instruction can account for this finding, as the training may had meant that the strategies were more familiar to the participants and therefore less resource demanding.

Differences in the tasks used could be a defining factor for the incongruous results found. An auditory discrimination task was chosen for the secondary task because it is deemed suitable for use with older and younger adults as it has a high processing load, yet yields low error rates, traits which are considered ideal for a secondary task (Morris, Gick & Craik, 1988), and has been used successfully in past research (Park et al., 1989). It could be argued that this secondary task is less demanding than others used in previous research, i.e. the tracking task used in the study by Naveh-Benjamin et al. (2005), and therefore this may have been why increased attentional costs were not found in older adults. Although an attractive explanation, as it accounts for the low costs seen at pre and post-test, it is undermined by the finding that Park et al. (1989) found greater secondary costs for older adults in their study, and the digit monitoring task is generally regarded as being more demanding than a perceptual tracking task (Naveh-Bejamin et al., 2005).

Another important methodological factor may be the training itself. There is a great deal of variability regarding the nature of strategy training in the literature; including its duration and content. For the present study careful consideration was given to the strategy training to ensure that it was methodologically sound, and followed recommendations in the literature. However, one aspect that may be an issue is the duration, as it was only an hour. Gross et al. (2012) in their recent meta-analysis found that the mean duration for memory strategy training was 12.8 hours, but varied from 30 minutes to 42 hours. The duration of the training in this study was chosen as

a shorter duration (mean 90mins) has been advocated, as it is felt that longer durations increase the chance of fatigue (Verhaeghen et al., 1992) and that overall it has been found not to be an important factor in the effectiveness of the training (Owen et al., 2010; Gross et al., 2012). However, it may be argued that the duration was not sufficiently long enough for participants to gain enough practice and familiarity to be confident in using the strategies at post-test. This could be particularly true for older adults who may need more exposure with the strategies, and may contribute to the age-related differences found in the present study. However, this explanation seems to be unlikely given that strategies benefitted older adults in the dual-task condition.

The sample used could account for some of the discrepancies found between this study and others. Older adults were recruited from the community, and often were highly motivated and involved in activities or clubs that were interested in furthering knowledge (e.g. University of the Third age). It has been suggested that recruitment practices may have a factor in the differing results found in aging studies; "recruitment methods that place high demands on older people, such as volunteering to come to a university for testing, might over represent the higher performing older adults," (Hedden & Gabrieli, 2004, pg 88). However, despite the limitations this method of recruitment is commonly employed in cognitive aging research (Kuhlman & Touron, 2012), and has been argued as being preferable as it allows for a more homogenous sample (Schaie, 1987)

Additionally, it has been postulated that older adults who seek out and have an interest in challenging activities are more likely to benefit from strategic training (Caretti et al., 2011) and intellectual engagement is related to cognitive performance (Fairchild & Scogin, 2010; Hertzog, Hultsch & Dixon, 1989; Stine-Morrow, Parisi, Morrow & Park, 2008). This adds credence to the hypothesis that the older adults in the current study may have been quite high in their cognitive functioning, indeed age-differences in working memory capacity were not found. Therefore it may be more likely that older adults were utilising a strategy at pre-test in the single task.

Overall, this research has found that performance can be enhanced by utilising an imagery strategy; however there were some differences between older and younger

adults. Older adults were shown to benefit more from strategy instruction in dual-tasks than single tasks, and younger adults benefitted from using a strategy only in single-tasks. It is posited that spontaneous strategy use at pre-test could account for the results found; i.e. strategy use benefitting older adults in dual task, and younger adults only benefitting at single task. However as this research did not monitor strategy use, further research is warranted to substantiate this claim. For older adults, this increase in memory performance came at no cost to the secondary task, indicating that adopting a strategy in dual tasks did not place greater demands on attentional resources, contrary to prior research (Naveh-Benjamin et al., 2005). This is promising, as it demonstrates that older adults are able to effectively use strategies even in cognitively demanding situations, and at no cost to the secondary task.

5   Study 2: Aging and adaptive strategy use in memory performance in single and dual tasks; the role of processing resources.

5.1   Introduction

The results of experiment 1 showed that using a memory strategy led to increased recall in single-task and dual task conditions. However there were differential age effects with younger adults showing improvement in single tasks, and older adults benefitting from strategy use in the dual tasks. One possible explanation for these results is that younger and older adults differed in their strategy adoption. However, as older adults were shown to improve following strategy information this shows that even in cognitively demanding situations (dual-task conditions) an effortful strategy could be executed.

As study 1 did not directly monitor strategy use, it is possible that individuals may not have been utilising the strategies that were trained, and were using strategies at pre-test. To this end, the current study was devised to address some of these gaps in knowledge and attempt to uncover possible reasons to explain the pattern of observed results in study 1. Furthermore, the study was designed to examine adaptive strategy use in younger and older adults. It may be that when given a choice, older and younger adults would opt to use different strategies dependent on task demands and/or cognitive resources.

Research has found that individuals use a variety of different strategies to complete cognitive tasks (Salthouse, 1991). For example, when remembering word lists, strategies such as imagery, association, repetition and sentence generation have been reported (Dunlosky & Hertzog, 1998). Previous research has demonstrated that a number of factors can influence strategy use including age (Lemaire & Seigler, 1995; task demands (Tournier & Postal, 2011; and cognitive resources such as working memory capacity (Dunlosky & Kane, 2007) inhibition (Coyle, 2001) and executive functions (Bouazzaoui et al., 2010; Taconnat et al., 2009)

5.1.1   Age-related Differences in Adaptivity

The ability to shift behaviour in relation to changes in the environment in order to increase performance is very important, and has been described as a "hallmark for human cognition" (Lemaire et al., 2004, pg 248). Age-related differences in adaptive strategy use have been well documented in children, but less established in older adults. Previous research examining the effect of aging on adaptivity have revealed that although older adults are able to change their strategy in order to increase performance, usually age-related differences do persist (Lemaire et al). In their study looking at computational estimation strategies, it was found that both older and younger adults were able to adaptively choose the optimal strategy for the situation. However, older adults chose the optimal strategies less than younger adults. Performance was also worse for older adults, especially when using the more complex strategies. Reduced processing resources could account for these results, as the tasks themselves are resource-demanding, and this could lead to less complex strategies being chosen, or not being used as efficiently (Lemaire et al., 2004). This finding has also been replicated in the domain of decision-making (Mata, 2006).

As individuals can use a variety of different strategies to complete cognitive tasks, by examining strategy choice it can give a measure of an individual's strategy repertoire (which strategies individuals can employ in the task) which may be different for older and younger adults. By manipulating characteristics of the task such as difficulty, adaptivity can also be examined by seeing if people change their strategy in different environments. However, studies using these methods do not allow for the investigation of an individual's effectiveness of using specific strategies (e.g imagery in a free recall task) if the individual favours a different strategy (e.g. sentence generation). Therefore studies in which participants are free to choose a strategy, and then are asked to use a particular strategy are a more useful way of investigating age-related differences in strategy use.

Gandini, Lemaire and Dafu (2008) used such a method in their research looking at strategy use and age-related differences in approximate quantification in a dot collection task. In their research, two studies were conducted; one which focused on examining which strategies participants used in the task (strategy selection), and the

other to see the effectiveness of a specific strategies (strategy execution). The first study required participants to make verbal trial by trial strategy reports and revealed that individuals use multiple strategies to solve a task, and that strategy selection is dependent on age and the difficulty of the task. Older adults typically favoured an exact counting strategy, whereas younger adults preferred to use approximate counting more. The second study gave participants specific instructions to use one of two strategies (an anchoring or benchmark strategy) in order to determine strategy effectiveness. Results showed that younger adults performed better in both conditions; however the tasks involved mainly relied on visuo-spatial processes, which are shown to be reduced in aging (Jenkins, Myerson, Joerding& Hale, 2000). Overall, the study shows that although older and younger adults both have the same repertoire of strategies, there are age-related differences in strategy selection and execution. Furthermore, it highlights the importance of examining age-related differences in strategy selection and execution independently to know which strategies individual's use when free to choose, how differences in the task may affect this choice and how effectively they are able to use specific strategies.

Another method which has been advocated is the choice/no choice method. It has been proposed that if people are free to use a strategy then although it would measure strategy selection, it would not give an indication of strategy efficiency as efficiency is based on selection (Siegler & Lemaire, 1997). This is similar to the method used by Gandini et al. (2008), but differs as strategy selection and execution can be examined in the same study in which there are certain trials in which participants are able to choose a strategy (choice trail) and then trials where participants are instructed to use a specific strategy (no choice trial). This method has been applied mainly in studies in the mental arithmetic domain, (Lemaire et al., 2004; Imbo & Vandierendonck, 2007; Siegler & Lemaire, 1997), but has been suggested as a useful methodology to use in investigating memory strategy use (Kulhmann & Touron, 2012).

5.1.2   Strategy Adaptivity and Memory Performance

Previous research investigating strategy adaptivity has typically focused on the arithmetic and decision making domain. However, with the surge of interest in cognitive aging due to the aging population, adaptivity in memory strategy use is a developing area of research. In one such study, Bailey et al. (2009) looked at whether age-related differences in performance in memory tasks could be accounted for by differential strategy use. It was hypothesised that older adults would use less effective strategies than younger adults and this would lead to differences in performance. Findings did not confirm the hypothesis; older adults used effective strategies to the same extent as younger adults, although their performance was decreased. It was also found that with increasing set size participants changed their strategy use, with less effective strategies used at larger set size. More interestingly, this strategic behaviour was found for both older and younger adults. However, research has shown that at higher set sizes older adults who use an effective strategy have benefited more than younger adults (Touron, Oransky, Meier & Hines, 2010).

In a similar study, Tournier and Postal (2011) looked at age-related differences in strategy behaviour in a paired-associate task. The concreteness of the words was modified, so that the optimal strategy would be different dependent on the concreteness level. It was found that with strategy information, older and younger adults adapted their strategy use accordingly; an imagery strategy was used more frequently when the word pair was high concrete level, and a sentence generation strategy was used more in a low concrete level (abstract). However, younger adults used imagery more than older adults who relied more on sentence generation at all levels. As sentence generation was not the optimal strategy in the high and middle concrete level conditions, older adults performed worse. This reflects a partial decrease in adaptivity for older adults, as although older adults modified their strategy use; they did not modify it to the same level as younger adults. These findings are consistent with the results found in other domains.

5.1.3 Cognitive Resources and Strategy Use

It may be that older adults are limited by their cognitive resources, and this could be the underlying reason for why older adults may use different strategies in tasks and exhibit less adaptivity. For example, in the Tournier and Postal (2011) study the preferred strategy for older adults was sentence generation, whereas for younger adults it was imagery, which is a more demanding strategy. Similarly, Hertzog et al. (2012) found that after older and younger adults had been instructed about the effectiveness of different strategies, older adults still typically used a more superficial strategy (repetition) for remembering a word list, whereas younger adults favoured the optimal strategy (imagery) which was more demanding. It may be that age-related differences in strategy use are only exhibited when the strategies used require cognitive resources such as working memory capacity and executive functions which are thought to be reduced in aging.

5.1.4 Working Memory

Turning to working memory specifically, research has found that individuals possessing a higher working memory capacity perform better in cognitive tasks (Bissig & Lustig, 2007, Turley-Ames, 2003). It has been hypothesised that it is advantageous to have a greater working capacity as this allows you to exploit the use of memory strategies, especially if implementing the strategy is cognitively demanding (Dunlosky & Kane, 2007). Several studies offer compelling evidence to support this notion. For example, McNamara and Scott (2001) found that high spans used more effective and demanding strategies such as imagery and chaining than their lower span counterparts. This finding has been replicated by Dunlosky and Kane (2007) who found that on an OPSAN task (a commonly used measure for assessing WMC), individuals who reported using a normatively effective strategy (imagery, sentence generation and grouping) fared significantly better than individuals using less effective strategies such as reading and rehearsal.

In a study examining strategy instruction, Turley-Ames and Whitfield, (2003) found that low spans were able to increase their performance following instruction, whereas high spans did not, as it was believed they were performing optimally prior to

instruction. However, low spans only improved when using a rehearsal strategy, suggesting that the more demanding strategies such as imagery or chaining taxed their resources, and thus could not be implemented as effectively. Research examining study time has found that those with a higher WMC typically allocate their study time more strategically than those with low WMC (Dunlosky & Thiedes, 2004).

Working memory capacity has also been directly investigated in studies on strategy adaptivity. Hinze et al. (2009) examined adaptive strategy use in a study looking at cognitive skill acquisition (CSA). It was found that an individual's selection of resource-allocation strategy was influenced by WMC and cognitive load. Individuals who are using more of their available cognitive resources (either due to a low WMC or a highly demanding task) reduced the cognitive load by using a simple strategy - relying on help or responding quickly at the expense of accuracy. Those who had more cognitive resources at their disposal, due to less demanding task demands or a higher WMC typically used more complex reasoning strategies. This suggests adaptability, as individuals are able to adapt their strategy selection depending on their environment. However, there are limitations to this study, which will be discussed now.

As it was an independent groups design, participants were allocated to load and no-load condition randomly, however, it was found that there was a high percentage (70.6%) of participants who used the ineffective/simple strategies (relying almost exclusively on help) in the load condition. This may have an additive effect, as these 'help- abusers' also had a lower than average WMC as well. A better method may have been to use a repeated design in order to ascertain whether people with low WMC are able to use more effective strategies in a no-load environment. This way it could be determined it the same individual adapted their strategy use in different situations.

As findings suggest that working memory capacity is important for the exploitation of strategies then as suggested earlier reductions in processing resources such as working memory capacity may be the mechanism responsible for the age-related differences seen in strategy selection, execution and repertoire (Lemaire, 2010).

5.1.5 Executive Functioning

In line with the frontal hypothesis of age-related memory decline (West, 1996), it has been argued that functions that are linked to the pre-frontal cortex such as executive functioning are particularly sensitive to aging, and may account for declines in memory (Braver & West, 2008; Moscovitch & Winocur 1992, Parkin, 1997; Philips & Henry, 2005; Raz, 2000). It is proposed that executive functions are involved in the strategic elements of memory performance such as the execution of encoding strategies, (Moscovitch & Winocur, 1992). Consistent with this notion is the finding that older adults possessing higher levels of exective functioning typically display greater memory performance, which has been interpreted as being due to these individuals using memory strategies to their advantage (Taconnat, et al., 2009). Indeed, studies have shown that executive functions are associated with internal memory strategy use (Bouazzaoui et al., 2010) such as clustering (Taconnat et al., 2009) and association (Bryan et al., 1999). Therefore, although executive functions are reduced with advancing age; preservation of these abilities means that strategies can be utilised to increase memory performance and compensate for age-related decline (Bouazzaoui et al., 2013).

Another important construct of executive functioning is cognitive flexibility; the ability to adapt behaviour to the changing demands of the task in order to optimise performance (Miyake et al., 2000). Research examining aging and cognitive flexibility has found that older adults are less flexible than younger adults, and show more preservative behaviour (failure to shift behaviour in response to changing task demands). This has been taken as a measure of how well individuals adapt their strategy use to changes in the environment (Taconnat et al., 2009). As older adults are proposed to be less adaptive in their memory strategy use (Bailey, Dunlosky & Hertzog, 2009; Lemaire, 2010), then it would be useful to empirically examine the role of executive functions (particularly cognitive flexibility) in adaptive strategy use.

5.1.6   Strategy Use in Dual-Tasking

It is evident that cognitive resources may have an impact on strategy selection and execution; however this has been less assessed in dual-task situations. Imbo and Vandierendonck (2007) looked at the role WM plays in strategy selection in children when applied to arithmetic, using a dual-task methodology.   There are many strategies that people can choose when performing simple mental arithmetic tasks, including; direct memory retrieval (e.g. knowing that 8+5=13), Transformation (e.g. 8+6= 8+2+4= 10+4) and counting (e.g. 4+3= 4…5…6…7).   This study assessed which strategies were the most efficient and the most used.   The study adopted the choice/ no choice methodology advocated by Siegler and Lemaire, (1997) so that both strategy selection and efficiency could be assessed. It was hypothesised that as WM resources are needed less as arithmetic knowledge is stored (Ackerman, 1988) older children would perform better than younger children. It was also hypothesised that as memory retrieval requires fewer WM resources then non-retrieval strategies this should 'free-up' resources for the secondary task and result in better performance. As participants were able to choose their strategy at some stages then strategy selection could also be assessed.

The results found a clear effect of age on strategy selection and efficiency, with older children performing better and using the retrieval strategy more often. Older children were more efficient in using the retrieval strategy evidenced by quicker reaction times (RT's).   This increase in efficiency reduced the need for WM resources, thereby reducing the negative impact of an executive load (secondary task).   No effects of load on strategy selection were observed. Although this may seem unexpected as it could be hypothesised that as WM load is taxed people should adopt less-demanding strategies, a closer inspection of the results revealed that retrieval was found to be both the most efficient and least demanding strategy and therefore was more likely to be adopted across both load conditions. This has been supported by previous research showing that the retrieval strategy is the dominant strategy when solving simple arithmetic problems (Ashcraft & Kirk, 2001; Hecht, 2002). Additionally, previous research has shown that environment and WM may have more of an impact at initial stages of skill acquisition (Ackerman, 1988), but as the skill develops then these may

play less of a role. As arithmetic is a skill that is practiced and developed as children age, then the effects of WM load on strategy selection may not be apparent.

In a similar study, Imbo, Duverne and Lemaire, (2007) assessed the impact of WM load on strategy selection and execution. Adopting a choice/no-choice method, 72 participants were asked to give an estimate for complex arithmetic problems e.g 78 x 42. Previous research has shown that there are a variety of different strategies that people may adopt when solving arithmetic problems, however two seem to be the most dominant in computational estimation; rounding up and rounding down to the closest decade. Rounding down is a simpler strategy than rounding up, and as such requires fewer WM resources. Working memory load was obtained by introducing a secondary task, in this case a Choice Reaction Time (CRT) task in which participants had to identify whether a tone was high or low. It was hypothesised that as fewer WM resources would be available when under WM load, a simpler strategy would be used more often. As with the Imbo and Vandierendonck (2007) study, a choice/no-choice method was implemented to determine both strategy selection and efficiency; in the choice condition participants were free to choose either the simple (rounding down) or complex (rounding up) strategy; in the no-choice condition they were instructed which strategy (complex or simple) to use.

Results showed that participants chose the simpler strategy more often under WM load. Interestingly, the most adaptive strategy was not always chosen, suggesting that choosing an appropriate strategy requires WM resources. The researchers concluded that "speculatively, it is possible that when a cognitive task is not accompanied by a massively dominating strategy (like retrieval in simple arithmetic), strategy selection requires working memory resources" (Imbo & Vandierendonck, 2007; pg 1259). It would be interesting to see how the addition of a secondary task would affect the strategy selection and efficiency in a memory task, where there are many different strategies to choose from (Dunlsoky & Hertzog, 1998).

5.1.7   Overview of the Present Study

Study 2 will examine in more depth strategy use in older and younger adults, with an overall aim of determining whether older adults are able to utilise the same strategies as younger adults.   The strategies which older and younger adults use both spontaneously and following training/instruction will be examined to determine if there are any age-related differences in strategy selection and execution. Although participants will be able to use any strategy they wish, they will be asked to identify their strategy from a list of commonly used strategies (Dunlosky & Kane, 2007). Strategy execution will also be assessed independently from strategy selection by asking participants to use a specific strategy (imagery or rehearsal) on certain trials. These strategies were chosen as they are widely used in word recall tasks, and have previously been investigated in similar research (Bailey, Dunlosky & Hertzog, 2014). How strategy selection and execution are affected by task demands will also be examined, by determining whether participants adapt their strategy use in single and dual tasks. The role of cognitive resources such as working memory capacity, and executive functions will also be investigated to determine how these are related to strategy use and performance.

A similar design to study 1 will be used. However, to assess strategy selection and efficiency the choice/no choice method will be used (Siegler & Lemaire, 1997). Environment (single/dual-task) will be manipulated as in study 1 to see the effect of this. This will give an indication of adaptavity as it can be determined if people resort to simpler strategies when the environment is demanding (dual-task conditions). As opposed to the study conducted by Hinze et al. (2009), this study will employ a repeated measures design which will enable strategy use to be examined across different environments. This way, it can be determined if the same individual adapted their strategy use in different situations. This does however pose issues with reactivity, namely that by asking participants to use a particular strategy on certain trials, it will increase the likelihood of that strategy being implemented. For example, research has found that compliance to using a rehearsal strategy is often lower when it is followed by instructions to use an imagery strategy (Hertzog, Price, Burpee, Frentzel, Feldstein & Dunlosky, 2009). However, this method is necessary in order to get a clearer picture of strategy selection and execution.

In addition to compliance issues, sequential difficulty effects have also been found in strategy execution. Uittenhove and Lemaire (2012) looked at solution latencies when executing a rounding up, rounding down or a mixed rounding strategy when solving two-digit multiplication problems. It was found that performance (as measured by solution latency) on a given trial was worse when a harder strategy (rounding up/mixed) as opposed to an easier strategy (rounding down) had preceded it, regardless of which strategy was used. It was hypothesised that this was due to working memory resources being taxed or depleted during execution of the difficult strategy and therefore leaving less resources available, or the resources needing to be remobilised for the next problem and subsequent strategy execution. Whether this will be an issue for tasks in which the performance measure is not latencies is less known, but is worth taking into consideration. In order to try and mitigate against effects of reactivity and sequential difficulty the order of strategy instructions will be counter-balanced among participants, and a blocked design will be used.

5.1.8 Research Questions and Hypotheses:

1) Which strategies do younger and older adults spontaneously employ on a word recall task in single and dual task situations? Are there age-related differences in strategy selection and execution? How is secondary task performance affected?

   It is anticipated that prior to strategy training/instruction, younger adults will choose more effective strategies (imagery/association) and perform better than older adults in both the single and dual tasks. In line with the results of study 1, no age-related differences in secondary task costs will be found.

2) Following strategy training do younger and older adults choose more effective strategies in the tasks? Are there age-related differences in strategy selection and their execution?

   It is expected that both older and younger adults will choose more effective strategies. However, it may be that younger adults are

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**better able to exploit these strategies and thus display greater
performance**

3) When asked to use a certain strategy (no-choice conditions) are there age-
related differences in their execution?

> **It is anticipated that there will be no age-related differences in the
> rehearsal strategy, but that older adults will perform worse than
> younger adults when asked to use a more demanding imagery
> strategy.**

4) Do participants adapt their strategy use depending on environment/task
demands? For example are different strategies chosen in single/dual tasks?
Which strategies are most efficient? Is this pattern the same for younger and
older adults?

> **It is hypothesised that in single-task conditions participants will
> use more effective strategies (such as imagery)more than in the
> dual tasks, and that this will prove to be the most efficient.
> However, it is less clear whether this benefit will transfer to the
> dual-task condition. It may be that a more simple strategy (such as
> rehearsal)may prove to be more effective, as the environment is
> more demanding in these situations due to attention needing to be
> divided across two tasks. No specific predictions are made for
> whether there will be differences between older and younger
> adults.**

5) Do individual differences in processing resources such as executive functioning
and WMC account for strategy use and performance? Do older adults have
reduced cognitive resources?

> **It is expected that individuals possessing higher EF and WMC are
> more likely to utilise better strategies and exhibit greater
> performance in the single and dual tasks. It is hypothesised that
> older adults do have reduced cognitive resources and as such there
> will be age-related differences in performance of these tasks.**

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5.2   Methodology

In order to fully address the research questions, the methodology from study 1 was expanded upon. In order to assess strategy selection and efficiency the Choice/No Choice Method will be utilised, whereby participants will be free to choose a strategy on some trials, and be restricted to using a specified strategy on the other trials. In this study two different strategies will be used- repetition and imagery. Previous research has shown that imagery is a more effective strategy than rote-repetition when recalling unrelated words, however it is more demanding (Richardson, 1998). Performance will be assessed by examining the number of words recalled using these two strategies. All participants will receive similar strategy training as used in study 1, however this will be adapted to be more in line with the Tournier & Postal (2011) study and include more information about the specific strategies used in this study and the cost-benefit of each.

5.2.1   Participants

Thirty-six participants took part in this study, 18 younger adults (aged 18-30, 13 females) and 18 older adults (aged 64-81, 13 females). The subsample of younger adults consisted mainly of undergraduate students recruited through the departmental research participation scheme who received course credits in return for their participation. The remainder were recruited from the local community. The older adults were recruited through organisations such as University of the Third Age and local social clubs. Participants did not receive any monetary compensation. The mean age for the younger adults was 20.06 ($SD = 3.02$), and the older adults was 70.44 ($SD = 5.59$). Older adults showed an overall lower educational level ($M = 12.33$) than younger adults ($M = 13.5$), however this difference was not significant, $t(34) = 1.68$, p = .10 (two-tailed). There was no indication of cognitive impairment in the older group, with Mini-Mental State Examination (MMSE) (Folstein, Folstein & McHugh, 1975) scores ranging from 28-30).

Inclusion criteria was identical to that of study 1 and consisted of having a good command of the English language, no history of neurological illness, not currently taking any medication liable to affect thinking/concentration and not having an uncorrected hearing or visual impairment.

5.2.2   Materials

5.2.2.1   *Word lists (Primary Task)*

Word lists were constructed using the MRC Psycholinguistic database (Coltheart, 1981). Each list comprised of 15 middle imagery words, each between 5-7 letters long. In contrast to study 1 which used high imagery words instead middle imagery words were chosen, to avoid participants favouring an imagery strategy at pre-test, and thus making other strategies harder to implement (Kuhlman & Touron, 2012; Luwel, Onghena, Torbeyns, Schillemans & Verschaffel, 2009). Twelve word lists were constructed (for the different trails) the order of which was counterbalanced among participants using a Latin-square design.

5.2.2.2   *Auditory Discrimination Task (Secondary Task).*

All tones were constructed using the Audacity software. Two different tones were used that were either 440Hz or 990Hz in frequency (low or high tone). 12 different lists were constructed for tones (15) that each had 3 occasions when three of the same tone (either 440 Hz or 990 Hz) were presented consecutively.

5.2.2.3   *Measures of Cognitive Functioning*

Measures were taken from the Cambridge Neuropsychological Automated Test Battery (CANTAB). For the rationale of including these measures please see chapter 3: Methodological Overview.

Executive Functioning Measures

Intra-Extra Dimensional Shift- IED

In this task two shapes are displayed on the computer- one is correct, and the other is incorrect. Participants learn through feedback which shape is the correct one, and apply this rule to subsequent trials. After a certain number of trials the rule changes and a different shape is correct. In later stages, lines appear with the shapes adding another dimension, in which a shift in response set will need to occur so that the participant focuses on the previously irrelevant dimension (lines instead of shapes). In

stages 1-7 shifts to the correct stimulus are intra-dimensional (shape) and stages 8-9 are extra-dimensional (lines). The test is terminated if participants fail to select the correct shape after 50 trials on any stage. Therefore the outcome measures are adjusted to account for this (as individuals who complete fewer trials will have less opportunity to make errors). The total number of errors (adjusted) is reported as it is thought to best reflect cognitive flexibility (Janssen et al., 2013).

Stockings of Cambridge

This is based on the Tower of London task and assesses planning ability, and to a lesser extent working memory and inhibition (Shallice, 1982). On the screen two displays of coloured balls suspended in socks/stockings are presented one above the other. Participants are required to move the coloured balls in the bottom display so it matches the top display. Initially, it is only necessary to move one ball, but this gradually increases so that number of moves required to complete the trial is five. The number of problems solved in the minimum amount of moves was taken as a measure of planning ability (executive/frontal lobe functioning).

Working Memory

Spatial Working Memory

This task assesses an individual's ability to store and manipulate spatial information in working memory. An array of coloured boxes are presented on the screen; participants are required to search through these to find a hidden blue token. Once found, these tokens are then used to fill up an empty 'home' column on the right hand side of the screen. Participants then have to find another token in the boxes; however the token will not be the same box that previously had the blue token in. Therefore to perform well in this task participants have to remember which boxes previously held a blue token. This procedure is repeated until all of the boxes have had a blue token inside them. The number of boxes gradually increases from three to eight boxes. The number of between errors (the number of times a participant revisits a box where a blue token was previously found) was used as a DV. Additionally, because older adults may perform worse at larger trial lengths (e.g. at the 8 box stage as opposed to 4), the number of errors made at each stage was also examined. Strategy use denotes

the number of times the participant started the search with a different box, which according to Owen et al. (1990) is not an efficient strategy (the optimal strategy requires following a predetermined sequence always starting with the same box). A higher score reflects poorer strategy use.

5.2.3 Procedure

Participants were asked to complete the study in two sessions. The 1st session lasted approximately an hour and a half, and the second up to an hour. The second session was completed 5-7 days after the initial session.

5.2.3.1 *First Session.*

Participants were tested individually in a quiet room. Prior to starting the experimental tests, participants were first instructed to fill out the consent and demographic form. Older adults were screened for dementia, using the MMSE with individuals scoring lower than 27 excluded. The tasks from the CANTAB were then administered, with verbal instructions given as stated in the CANTAB manual. Participants then completed the single and dual-tasks presented using the Super Lab software (version 5.0) on a laptop computer (OS Windows 7), manual responses were collected using a Cedrus RB-730response pad. The procedure for the single and dual-tasks was identical to experiment 1, with the exception of the word lists (which had 15 items, and were comprised of middle imagery words). Additionally, strategy use was monitored following each word list by asking participants to indicate which strategy they had used by key press. The same protocol as Dunlosky and Kane (2007) was used, with the following appearing on the screen:

1= read each word as it appeared
2= repeated the words as much as possible
3= used a sentence to link the words together
4= developed mental images of the words
5= grouped the words in a meaningful way
6= did something else

Strategy training was very similar to study 1, albeit slightly modified to include more information about the costs and benefits of the different strategies. For example, imagery was described as a very effective strategy but also very effortful and demanding, whereas a rehearsal strategy was deemed less effective (but better than none) and less effortful. Strategy information was given in individual sessions and lasted approximately 45 minutes.

5.2.3.2 *Second Session*

Participants were asked to complete the single and dual-tasks again first in the choice condition (free to use a strategy) and then twice in the no-choice condition (instructed to use a particular strategy). In the choice condition, they were asked to complete the task to the best of their ability using any strategy they wished. Following this, participants were asked to repeat the tasks, but this time they were asked to use either a rehearsal (mentally repeating the words) or an imagery strategy (constructing mental images of the words); the order of which was counterbalanced among participants. In line with other studies using the choice/no-choice methodology, the free condition was always presented first to prevent strategy instructions having a reactive effect on strategy selection (Siegler & Lemaire, 1997; Imbo & Vandierendonck, 2007). Different word and tone lists were constructed for the re-tests. At the end of the sessions participants were thanked for their time and fully debriefed.

5.3 Results and Discussion

5.3.1 Data Screening

The data were screened and assumptions checked prior to analysis. Firstly, outliers were identified by examining z-scores and boxplots. Following the recommendation of Tabachnick and Fidell, (2007) any z-scores over 3.29 and extreme values from the boxplots were considered outliers. Using this method four data points were identified as being extreme, and were subsequently winsorised to the next highest score to reduce their impact in the data, but to retain their high/low ranking in the data. Histograms were visually inspected for normality and revealed a potential deviation from normality in some of the variables. This was confirmed with the results of the

Shapiro-Wilk test. The data was therefore transformed using the Log and square root transformations, however these did not normalise the data or make a difference to any of the results found. Therefore the untransformed data was retained and used in all subsequent analysis.

5.3.2 Preliminary Analysis; Manipulation Checks

Prior to the main analysis, some preliminary checks were performed on the data. Firstly, by examining memory performance in the choice conditions at time 1 (pre-strategy training) and time 2 (post-strategy training) it was possible to ascertain whether strategy training led to increased performance (irrespective of which strategies individuals adopted), and whether there were any age-differences in performance. Although this was not the main focus of this study, it was required to make direct comparisons to study 1, and establish whether the training was effective when overall performance was examined. Therefore a mixed ANOVA was conducted on single task and dual task performance separately, with time as a within subjects factor, and age as a between groups factor.

5.3.2.1 *Performance Pre and Post Strategy Training*

Single Task

A main effect of age was found with younger adults (*M*= 8.75, *S.D*= 1.31) performing better than older adults (*M*= 6.69, *S.D*=2.93). The main effect for time was not significant with only a slightly elevated mean at time 2 (*M*= 7.92, *S.D*=2.42) compared to time 1 (*M*= 7.53, *S.D*=2.32). The Age x Time Interaction was approaching significance ($F[1, 34]=3.87$, $p = .057$, $\eta^2_p = .10$), with older adults improving from time 1 to time 2 and younger adults performance slightly decreasing from time 1 to time 2 (see Figure 5.1).
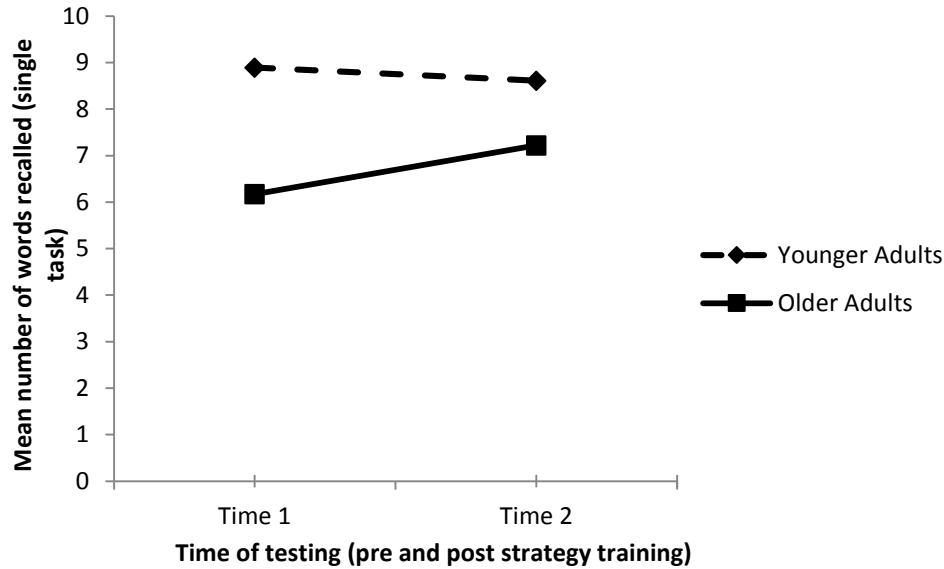
Figure 5.1 Mean number of words recalled by older and younger adults' pre and post strategy training in choice/single task conditions

Dual Task

Only the main effect of age was significant, which younger adults performing better than older adults (*M*= 6.31, *S.D*= 2.61 and *M* =4.39, *S.D*= 2.83 respectively). The main effect for time, and the Age x Time interaction were not significant (all *F*'s ≤ 1.19).

It is surprising that there was not a significant effect of time, as it was expected that the strategy training would lead to improvements in performance (as found in study 1). As this analysis did not take strategy use into account, it may be that these results can be explained by differential strategy use. This will therefore be investigated in the main analysis. As strategy use was reported (unlike in study 1) a greater exploration into which strategies people were using and how this effected performance can be established. Another possible reason for the differing results to study 1 is the use of a different level of imagery-rating of the TBR words. This study used middle imagery words which have been found to be less amenable to strategy use (Marston & Young, 1974) and therefore could account for these findings (this is fully discussed later).

Another important factor to consider is whether participants were actually complying with the strategy instructions given in the no-choice conditions, as if they were not using the strategies at post-test than this could be a reason for the results shown.

5.3.2.2 *Compliance with Strategy Instructions*

To ascertain compliance, data were coded as '1' if participants reported using the correct strategy and '2' if they did not use the correct strategy. For example if a participant was asked to use an imagery strategy but instead used a grouping strategy they would be categorised as non-compliant and given a '2'. Percentages of correct reported strategy use were then calculated and are presented in Table 5.1, both the overall compliance rates and when divided by age group are given.

Table 5.1 Percentages of correct strategy use by strategy type and age

	Overall		Younger		Older	
	Imagery	Rehearsal	Imagery	Rehearsal	Imagery	Rehearsal
ST	80.6%	94.4%	94.4%	100%	66.7%	88.9%
DT	77.7%	80.6%	88.9%	88.9%	66.7%	72.2%

ST =single task, DT =dual task

From looking at Table 5.1 it is evident that older adults had lower levels of compliance than younger adults in all conditions. To determine if these were statistically significant Chi- square analyses were undertaken for imagery and rehearsal separately. As some of the expected cell frequencies were less than 5, Fishers Exact Test is reported instead. This revealed that there was only a significant difference between older and younger adult's compliance in the imagery condition at single task, with older adults complying less with strategy instructions than younger adults χ^2 (1, N= 36)= 4.43, *p*= .044, one-tailed, φ_c =.351(All other *p*'s $\geq$.09).

Additionally, examination of Table 5.1 reveals that compliance rates are higher in the rehearsal than the imagery condition. To determine if these differences were significant a McNemar analysis was performed, as the data examined were repeated-measures. This showed that there was no significant difference between the

compliance rates in the imagery and rehearsal conditions for both single task (*N*= 36, *p*= .125) and dual task. (*N*= 36, *p* = .99). It is important to establish if there were any age differences as it may be that due to reduced cognitive resources older adults may be less likely to be able to implement a more demanding strategy like imagery resulting in reduced compliance. However, no difference in compliance rates were found when younger and older adults were analysed separately (all *p*'s ≥.99)

Another important factor to consider is whether compliance to instructions is different in the single/dual task conditions. Inspection of the compliance rates shows that there is generally greater compliance in the single task than the dual task conditions for both the imagery and rehearsal conditions. However a McNemar test revealed that this difference was not significant in the imagery condition (N= 36, p= .99). In the rehearsal condition, it was marginally significant (N= 36, p= .06, φ = .494). Furthermore, when analysis was conducted by age group there were no significant differences in all conditions (all p's ≥ .25)

Overall, the compliance rates in this study are comparable to previous research, which typically fall between 60-80% for single task conditions (Dunlosky & Hertzog, 2001; Hertzog, Price & Dunlosky, 2008). In fact, when considering the rehearsal strategy, compliance rates are higher than those reported in the literature. Examination of the compliance rates showed that older adults did have lower levels of compliance in imagery use in the single task condition, which may have an influence on the results obtained. This is in-line with previous findings which show that older adults typically display lower levels of compliance than younger adults for demanding strategies (Kulhman & Touron, 2012).

5.3.3 Main Analysis

To fully answer the research questions of the study, analysis is divided into addressing the separate research questions, with different subsections where needed to aid clarity.

5.3.3.1 *Research Question 1: Spontaneous Strategy use.*

Which strategies do people spontaneously use? Are there age-related differences in strategy use?

In order to get an overall picture of which strategies individuals elected to use when given a choice, the strategies reported in the tasks at time 1 and time 2 are reported in Table 5.2.

Table 5.2 Percentage of strategy use for each condition (single and dual task), pre and post strategy training, as a function of age

Strategy Type	Overall				Younger Adults				Older Adults			
	ST1	DT1	ST2	DT2	ST1	DT1	ST2	DT2	ST1	DT1	ST2	DT2
Read	19.40	38.90	8.30	16.70	5.60	27.80	5.60	16.70	33.30	50.00	11.10	16.70
Repetition	38.90	33.30	19.40	25.00	44.40	33.30	16.70	22.20	33.30	33.30	22.20	27.80
Sentence	13.90	13.90	38.90	16.70	11.10	16.70	33.30	16.70	16.70	11.10	44.40	16.70
Imagery	19.40	5.60	25.00	19.40	27.80	11.10	38.90	27.80	11.10	0.00	11.10	11.10
Grouping	5.60	8.30	8.30	13.90	5.60	11.10	5.60	11.10	5.60	5.60	11.10	16.70
Other	2.80	0.00	0.00	5.60	5.60	0.00	0.00	5.60	0.00	0.00	0.00	5.60

ST1= Single task1, DT= Dual-task1, ST2= Single task2, DT2= Dual-task 2.

As can been seen from Table 5.2; participants report using a variety of strategies in the tasks. It appears that at time 1 (spontaneous strategy use) overall participants prefer to use a rehearsal strategy in the single tasks. Older adults are just as likely to report not using a strategy as they are using a rehearsal strategy in single tasks. Younger adults also report using imagery more than older adults. For dual tasks, younger adults report a higher use of rehearsal strategy than no strategy, but older adults report the opposite.

To ascertain whether there were differences in spontaneous strategy use between the two age groups the reported strategies used at time 1 were subjected to a Chi-square analysis. As there were a number of cell frequencies of strategy use that fell below 5, they were collapsed into groups of normally 'effective' and less effective' strategies. An a priori method was used to determine which strategies were classified as normally effective and less effective based on previous research findings, and validated by empirical research (see Bailey, Dunlosky & Hertzog, 2009). According to this method; imagery, association and sentence generation were classified as 'effective strategies' and 'reading' and 'repetition' classed as 'less effective strategies.' These were coded as 1 and 2 respectively and used as a between subjects factor in analysis. Those who indicated the 'other' strategy were not included in the analysis, as it could not be determined whether the strategy was effective or not effective. Therefore in subsequent analyses examining effective strategy use the *N* and *df* reported may vary.

Table 5.3 Percentage of effective/less effective strategy use reported by all (overall), older and younger participants

	Overall		Younger		Older	
	Effective	Less Effective	Effective	Less Effective	Effective	Less Effective
ST 1	41.70	58.30	50.00	50.00	33.30	66.70
DT 1	25.70	74.30	38.90	61.10	11.80	88.20

ST1= Single task 1, DT1= Dual task 1

To determine whether there were age-group differences between effective and less effective strategy use Chi-square analyses[9] were run on the single and dual task. Although younger adults showed a greater use of effective strategies (see Table 5.3), it was revealed that these differences were not significant (all p's $\geq .121$).

Spontaneous Strategy Use- Performance: To ascertain whether strategy selection had an impact on performance, and if there were any age-related differences, a 2 (age; older, younger) x 2 (strategy; effective, less effective) ANOVA was performed. Results are presented in Table 5.4.

Effective/Less Effective Strategy-Single task: As can be seen from Table 5.4, younger adults recalled more words than older adults. Surprisingly, using an effective strategy did not yield a significant advantage over a less effective strategy.

Effective/Less Effective Strategy - Dual task

In the dual task conditions, those opting to use an effective strategy outperformed those who did not use an effective strategy. Interestingly, no significant age- related differences in performance were found, and the age x strategy interaction was also not significant. Older adults performed similarly to younger adults when using the same strategy.

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[9] Expected counts where less than 5 in one of the analyses (dual task 1) so in this case Fisher's Exact was used instead.

Table 5.4 Means, standard deviations and Analysis of Variance (ANOVA) results given by strategy and age for each condition (choice data - T1)

Condition	Variable(s)	Mean (SD)		ANOVA Results	Effect Size (η^2_p)
Single Task	Age	Younger Adults	8.89 (1.75)	$F(1, 32)= 9.48, p=.004$	.23
		Older Adults	6.17 (2.90)		
	Strategy	Effective	8.33 (2.53)	$F(1, 32)= 1.30, p=.26$	.04
		Less Effective	6.96 (2.78)		
	Age x Strategy	Younger Adults- Effective	9.33 (1.58)	$F(1, 32)= .01, p=.95$	.01
		Younger Adults- Less Effective	8.44 (1.88)		
		Older Adults- Effective	6.83 (3.06)		
		Older Adults- Less Effective	5.83 (2.89)		
Dual Task	Age	Younger Adults	6.28 (2.44)	$F(1, 32)= 1.95, p=.17$	.06
		Older Adults	3.94 (2.44)		
	Strategy	Effective	7.40 (1.90)	$F(1, 32)= 12.24, p=.001$	.28
		Less Effective	4.23 (2.42)		
	Age x Strategy	Younger Adults- Effective	7.43 (1.99)	$F(1, 32)= 1.65, p=.21$	.05
		Younger Adults- Less Effective	5.55 (2.50)		
		Older Adults- Effective	7.33 (2.08)		
		Older Adults- Less Effective	3.27 (1.91)		

The analysis was repeated including only those who reported utilising a strategy in the tasks,[10] in order to make the results more directly comparable with those examining hypothesis 4 (age differences in strategy execution- no choice conditions).

Table 5.5 Means and standard deviations for number of words recalled in the single and dual tasks as a function of age and strategy type

Age	Condition	Strategy type			
		Imagery/ Association		Rehearsal	
		M	*S.D*	*M*	*S.D*
Younger	Single task	9.38	1.69	8.38	2.00
	Dual task	7.43	1.99	5.17	2.40
Older	Single task	7.40	3.05	7.50	2.50
	Dual task	7.33	2.08	3.67	1.63

Imagery/Rehearsal Strategy- Single task

The age difference obtained in the previous analysis (effective/ less effective) disappeared when examining only those who reported using an imagery or rehearsal strategy. Inspection of the means (Table 5.5) reveals that this was mainly due to the exclusion of those reporting using no strategies (predominantly older adults). Although older adults performed less well than younger adults when those who reported no strategy were excluded from the analysis, this difference was less pronounced than in the prior analysis. In line with the results found in the prior analysis, no other significant differences or interaction was obtained (all *F*'s <2.60).

Imagery/Rehearsal Strategy- Dual task

At dual task; the same pattern of results was obtained as when effective/less effective strategy use was assessed. There was no main effect of age (*F*< 1). The main effect for strategy was significant, with those using an imagery/association strategy recalling

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[10] The less effective strategy category included those using 'no strategy'. To increase sample size and as some participants indicated using an imagery and association strategy in conjunction, it was deemed that people who reported using a sentence, imagery or grouping strategy were grouped as using imagery/association. As there was less ambiguity with the rehearsal strategy; this was not grouped with any others

more words than those using a rehearsal strategy ($F[1, 18]=10.48$, $p=.005$, $\eta^2_p = .368$). The Age x Strategy interaction was not significant ($F< 1$)

Secondary Task Performance

In order to maintain performance in the primary task, it is possible that participants may be sacrificing their performance in the secondary task. This may be different depending on which strategy used, or by age. To investigate whether this is occurring, a 2 (Strategy, Imagery/Association vs Rehearsal- between subjects) x 2 (Condition, single vs dual- within subjects) x 2 (Age, older vs younger adults- between subjects) mixed ANOVAs was conducted. These were conducted for both reaction time and errors made to rule out the possibility of any speed-accuracy trade-off.

For RT, no main effects or interactions were found (all F's ≤ 1.15). When the analysis was repeated for the number of errors, the main effect of condition was approaching significance ($F[1, 18]=.3.50$, $p=.08$, $\eta^2_p = .16$), with more errors being made in the dual task ($M= 0.24$, $SD= 0.49$) compared to the single task condition ($M=0.00$, $SD= 0.00$). All other main effects and interactions were not significant (all F's ≤ 1.48).

Overall the findings demonstrate that older and younger adults spontaneously use a variety of different strategies when completing the tasks. Although younger adults did report using effective strategies more than older adults, this difference was not statistically significant. When specific strategies were assessed (imagery/association vs rehearsal) there were not a significant age- difference for performance in both the single task and dual task conditions. Conversely, when comparing the performance of those using effective strategies and less effective strategies age-related differences in performance were found in the single-task. As expected younger adults recalled more words than older adults. These divergent results may appear on first glance contradictory, however in the latter example participants who were not using any strategy and reported that they 'just read the words,' were included in the analysis. This distinction is important, as older adults reported using no strategy more than younger adults (e.g. 33.3% compared to just 5.6% of younger adults in ST1), and could account for the age-related differences in this circumstance.

Effective strategies (such as imagery and association) were shown to be better than less effective strategies (rehearsal, or no strategy) in dual tasks however this was not evident in the single tasks. The lack of an age x strategy interaction suggests that both older and younger adults' performance is affected by strategy use in the same way, namely that both are spontaneously able to utilise an effective strategy in order to increase performance. Importantly this was not at the cost of secondary task performance. The lack of a strategy effect in the single-task is perplexing, one possible explanation may be that the more demanding strategies were not being utilised effectively. In the dual task it may be that due to the task demands even if the strategies were not being executed well it was still superior to using an ineffective strategy.

5.3.3.2   *Research Question 2: Adaptive Strategy use*

Following strategy training do younger and older adults choose more effective strategies in the tasks? Are there age-related differences in strategy selection and their execution? How is secondary task performance affected?

Adaptive Strategy Use- Strategy Selection

To determine whether participants were adaptive and changed their strategy use following strategy training (e.g. moving from a less-effective to an effective strategy) a McNemar test was conducted. Again, this was performed on the grouped strategy data at time 1 and at time 2 where participants were able to choose a strategy, and was conducted overall and then separately for younger and older adults. Findings revealed that for single-task conditions there was a shift in effective strategy use, with more participants choosing an effective strategy at time 2 (71.4%) than at time 1 (40%) ($p = .007$, $\varphi = .258$). When examining the differences in effective strategy use for older and younger adults separately, it is clear that in both groups participants chose to adopt a more effective strategy at time 2, (77.8% compared to 50% at time 1 for younger adults and 64.7% compared to 29.4% for older adults). For older adults this difference was marginally significant ($n= 17$, $p =.07$, $\varphi = .207$), whereas for younger adults it was not significant ($n =18$, $p= .12$).

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A similar pattern was obtained for the dual task conditions, participants tended to choose a more effective strategy following strategy training (51.5%) than before (24.2%) (N = 33, p =.049, φ = .017). When this was examined by age, it was found that older adults and younger adults both opted to utilise an effective strategy more at time 2 (40% for older adults[11], 61.1% of younger adults) than at time 1 (6.7% for older adults, 38.9% for younger adults). However, these differences were not significant for both age groups (p's ≥.125).

Strategy Execution

Although it is promising that both older and younger adults shifted their strategy use and used more effective ones following training, it is important to establish that they actually were more effective. To that end, separate 2x2 ANOVAs were run for the number of words recalled in single and dual tasks, with strategy use (effective, less effective) and age (older and younger) as between groups factors[12]. The results are reported in Table 5.6.

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[11] The percentages of effective strategy use differ from those reported in Table 5.3, as only 15 of the 18 older adults were included in the McNemar analysis. As the variables here are a within subjects factor, data can only be analysed from participants who have reported using an effective/less effective strategy at time 1 and time 2. In this case 3 older adults reported using the 'other' strategy at time 1 or time 2.

[12] Although the most optimal way to examine this would be to use a repeated measures ANOVA to determine how performance changed from time 1 to time 2; as strategy use could change, it could not be included as a within subjects factor.

Table 5.6 Means, standard deviations and Analysis of Variance (ANOVA) results given by strategy and age for each condition (choice data - T2)

Condition	Variable(s)	Mean (SD)		ANOVA Results	Effect Size (η^2_p)
Single Task	Age	Younger Adults	8.61 (1.88)	$F(1, 32)= 4.09$, $p=.051$	.11
		Older Adults	7.22 (2.96)		
	Strategy	Effective	8.65 (2.21)	$F(1, 32)= 7.99$, $p=.008$	.20
		Less Effective	6.00 (2.45)		
	Age x Strategy	Younger Adults- Effective	8.86 (1.83)	$F(1, 32)= 2.23$, $p=.15$	.07
		Younger Adults- Less Effective	7.75 (2.06)		
		Older Adults- Effective	8.42 (2.64)		
		Older Adults- Less Effective	4.83 (2.04)		
Dual Task	Age	Younger Adults	6.33 (2.77)	$F(1, 32)= 1.19$, $p=.28$	.04
		Older Adults	4.94 (3.29)		
	Strategy	Effective	6.74 (2.98)	$F(1, 32)= 4.92$, $p=.034$	.14
		Less Effective	4.38 (2.73)		
	Age x Strategy	Younger Adults- Effective	7.18 (3.03)	$F(1, 32)= .01$, $p=.098$	.01
		Younger Adults- Less Effective	5.00 (1.73)		
		Older Adults- Effective	6.13 (3.00)		
		Older Adults- Less Effective	4.38 (2.73)		

Time 2- Single task

The main effect of age was approaching significance ($p= .051$), with younger adults recalling more words on average than older adults. There was also a significant main effect of strategy, with those using an effective strategy recalling more words than those using a less effective strategy. Looking at Figure 5.2, it does appear as though the age effect may be driven by an interaction between age and strategy, as there is little difference between recall for older and younger adults when using an effective strategy, but when examining performance when using the less effective strategy it looks as though younger adults recall more words than older adults. However, the interaction was not significant.
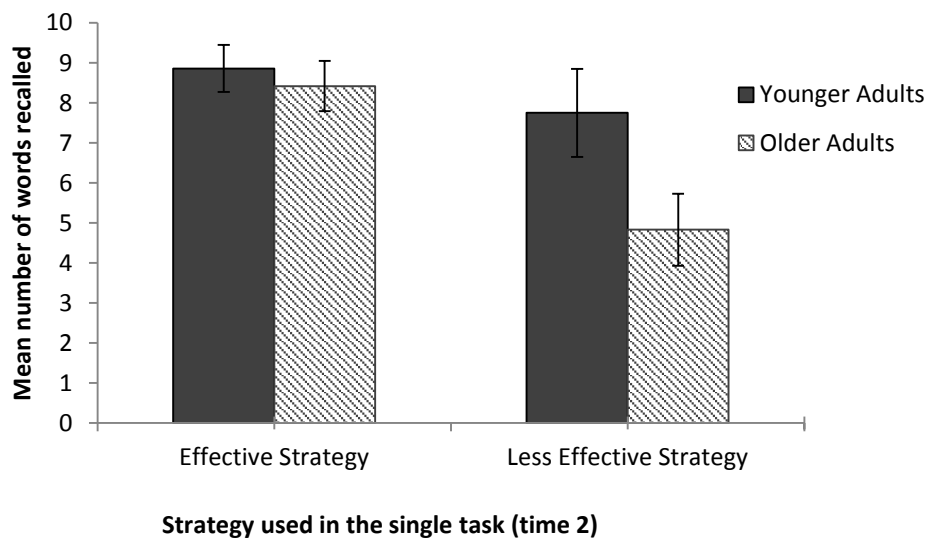
Figure 5.2 Number of words recalled by older and younger adults using an effective or less effective strategy in the single task at time 2. Error bars represent one standard error above and below the mean

Time 2- Dual task

Although younger adults did perform better than older adults, the main effect of age was not significant. Those using a more effective strategy outperformed those who were using a less effective strategy. The Age x Strategy interaction was also not significant.

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Imagery/Association vs Rehearsal

When the analysis was re-run with only those using a strategy (imagery/association vs rehearsal), the results were the same as above- with only a significant effect of strategy being found in single task and dual tasks ($F[1, 29]= 5.85$, $p=.022$, $\eta^2_p = .168$, and $F[1, 23]=.505$, $p= .035$, $\eta^2_p = .18$, respectively). (All other F's <1.03).

Secondary task performance

To investigate how strategy use affected secondary task performance in the dual task conditions, strategy use and age were included as between subjects factors. As with the analysis conducted in the primary task, only participants who used the strategies of imagery/association and rehearsal were included in the analysis[13], thereby resulting in a reduced sample size.

For the RT data it was found that there were no main effects present for age or strategy type and there was no Age x Strategy interaction (all F's ≤ 1.01). When examining the number of errors made; the ANOVA revealed a significant main effect of strategy, showing that fewer errors were made when using the imagery/association ($M=0.25$) strategy compared with the rehearsal strategy ($M= 0.75$). The main effect of Age and the Age x Strategy interaction were not significant (all F's ≤ 1.11).

To determine how the secondary task performance measures (RT and errors) were influenced by the type of strategy used, working memory load (the addition of a secondary task) and age, a 2 (Strategy, Imagery/Association vs Rehearsal- between subjects) x 2 (Condition, single vs dual- within subjects) x 2 (Age, older vs younger adults- between subjects) mixed ANOVAs was conducted.

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[13] As some participants indicated using an imagery and association strategy in conjunction, it was deemed that people who reported using a sentence, imagery or grouping strategy were grouped as using imagery/association. As there was less ambiguity with the rehearsal strategy; this was not grouped with any others.

For RT, no main effects were significant (all F's ≤ 1.27). However the interaction for Age x Condition was approaching significance ($F[1, 20]=3.62$, $p =.07$, $\eta^2_p = .15$). Figure 5.3 shows that younger adults displayed quicker RT's than older adults at single task; yet at dual task conditions, the opposite pattern was found, with older adults responding to the tones quicker than younger adults. All other interactions were not significant (all F's ≤ 1.27)
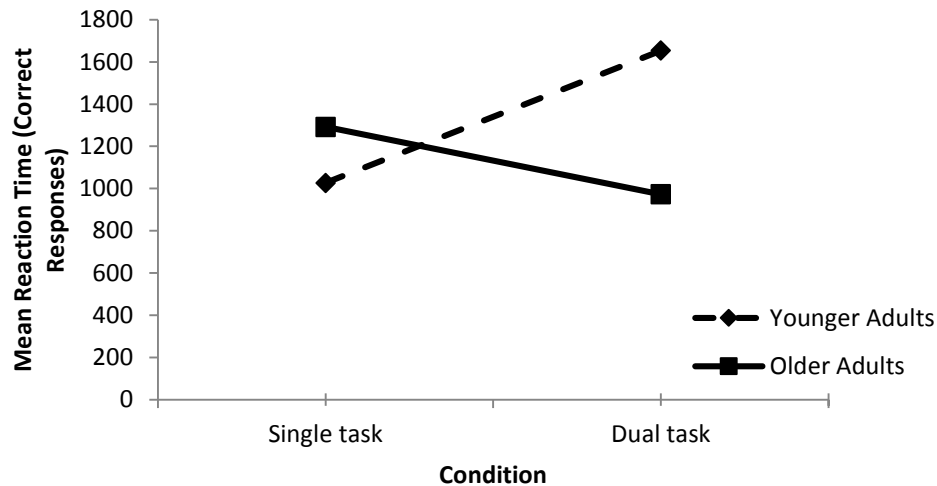
Figure 5.3 Mean reaction time of older and younger adults in the tones task (single task and dual task conditions)

For error data, a main effect of condition was found ($F[1, 20]= 17.44$, $p<.001$, $\eta^2_p = .47$), with a higher amount of errors being made in the dual task ($M=0.50$) as compared to the single task ($M= 0.03$). Furthermore a significant Condition x Strategy interaction ($F[1, 20]=6.28$, $p=.02$, $\eta^2_p = .24$) was found. As can be seen from Figure 5.4, in single task conditions there is not that much difference in the error rate for those who use an imagery or rehearsal strategy, but at dual task, those who use a rehearsal strategy make more errors at dual task.[14] All other interactions were not significant (all F's ≤ 2.44).

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[14] Of course this interaction has to be interpreted with caution- the strategy variable was taken from the strategy used in the dual task- a memory strategy used in the primary task would not affect RT in the secondary task in single task conditions.
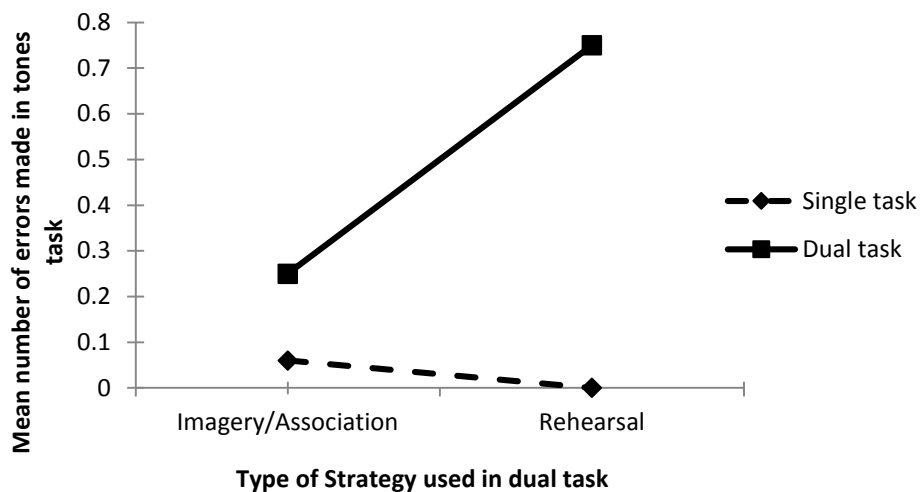
Figure 5.4 Mean number of errors made in the tones task by stategy used in the dual task (single task and dual task condition)

Age-differences in Strategy Selection?

Since previous research has suggested that older adults may prefer to use a sentence strategy and younger adults an imagery strategy (Tournier & Postal, 2011) this was investigated in the current study. When the frequency of strategy use was examined in single-task conditions (see table 5.2) it was revealed that following strategy training younger adults increase their use of imagery use (38.9% compared to 27.8%), however older adult's use of imagery remained the same (11.1% at both times). Regarding sentence generation, younger adults did again increase their use of the strategy (33.3% compared to 11.1%), similarly older adults also increased their use of this strategy (16.7% at time 1 and 44.4% at time 2).

As it is evident that older adults opted to use a sentence generation strategy more following training and younger adults favoured an imagery strategy, it is important to establish how this affects performance and whether this choice is adaptive. Participants who reported using either an imagery or sentence generation strategy were included in the analysis, which accounted for 55.5% of older adults and 72.2% of younger adults. Examination of the means revealed that following strategy training younger adults fared slightly better when using an imagery strategy (*M*= 8.80) as

compared to a sentence strategy (*M*= 8.00). In contrast older adults performed better using a sentence strategy as opposed to an imagery strategy (*M*= 11.00 compared to *M*= 6.50 respectively).

To determine whether this was a significant interaction a 2 Strategy (imagery vs sentence generation) x 2 Age (younger vs older) ANOVA was conducted on memory performance. No main effects of Age or Strategy were found (all *F*'s $\leq$ 1.92), but the interaction of Age x Strategy was trending towards significance ($F[1, 8]=3.93$, $p=$ .083, $\eta^2_p = .33$)- see Figure 5.5.
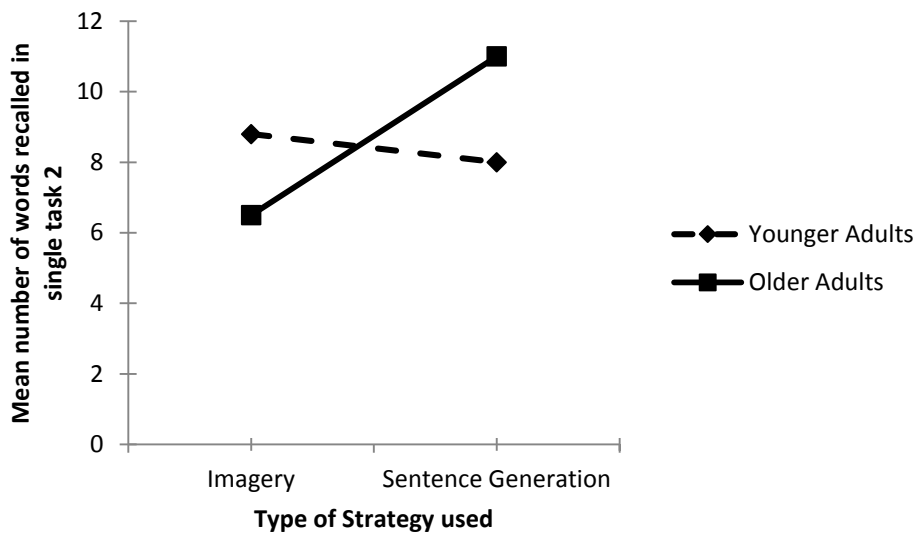
Figure 5.5 Number of words recalled by older and younger adults using a sentence generation or imagery strategy in the single task at time 2

In summary, it was found that strategy instruction/training promoted a greater use of effective strategies, with both younger and older adults shifting their strategy use from less effective strategies to more effective ones. These strategies were shown to be advantegeous, as all participants were found to perform better when using an effective strategy in the single and dual tasks. In constrast to the results found at time 1, no age-differences manisfested (although in the single task condition the age effect was marginally significant) showing that older and younger had equivalent performance when using either an effective or less effective startegy. Interestingly, there did appear to be age-differences in effective strategy selection. Older adults showed a

preference for using a sentence generation stratey and younger adults an imagery strategy. This finding is in line with previous research looking at memory strategy selection (Tournier & Postal, 2011). This increase in using a sentence generation strategy for older adults has been considered a compensatory behaviour owing to older adult's higher vocabulary skills (Tournier & Postal), however as this was not directly assessed in the current study it is hard to comment, but does provide an attractive explanation. Conversely, in their study, using an imagery strategy still offered an advantage over a sentence strategy, meaning that behaviour was less adaptive. In the current study, this was not the case for older adults; in fact sentence generation was shown to increase performance more than imagery. For younger adults, the opposite finding was found, leading to a strategy * age interaction that was approaching significance. This shows that older adults are able to utilise a demanding strategy in single task conditions to boost their performance to the same extent as younger adults, albeit a different one.

Promisingly, using an effective strategy was not accompanied by a decrement in secondary task performance. In fact, more errors in the auditory discrimination task were made when using a less effective strategy (rehearsal) than a more effective strategy (imagery) in the primary task.

5.3.3.3 *Research Question 3: Strategy Execution- No-choice Conditions*

When asked to use a certain strategy (no-choice conditions) are there age-related differences in their execution? How is secondary task performance affected?

No-choice

ANOVAs were performed in the no-choice condition with a 2 (condition: single vs dual) x 2 (age, younger vs older) mixed design with condition being a within and age a between-subjects factor on imagery and rehearsal conditions separately. This was conducted for both the primary and secondary task data, in order to assess whether performance in the secondary task was influenced by performance in the primary task. To determine whether a speed-trade-off may have been occurring, analysis of secondary task performance is reported for both RT and error rates.

Only data from participants who self-reported as being compliant with the strategy instructions were included in the analysis. This therefore resulted in uneven cell sizes as younger adults were more compliant in using both the imagery and the rehearsal strategy. To deal with the issue of unequal cell sizes, type III sum of squares ANOVAs were conducted (the default in SPSS) and estimated marginal means are reported to give the unweighted means (Keppel, 1991).

Table 5.7 Means, standard deviations and Analysis of Variance (ANOVA) results given by condition and age for each strategy (no choice data)

Strategy Type	Variable(s)	Mean (SD)		ANOVA Results	Effect Size (η^2_p)
Imagery	Age	Younger Adults	7.78 (2.84)	$F(1, 24)= 3.83,\ p=.06$	.14
		Older Adults	6.00 (2.08)		
	Condition	Single task	8.11 (2.50)	$F(1, 24)= 17.88,\ p<.001$	.43
		Dual task	6.08 (2.87)		
	Age x Condition	Younger Adults- Single task	8.63 (2.73)	$F(1, 24)= 0.81,\ p=.38$	.03
		Younger Adults- Dual task	6.94 (2.96)		
		Older Adults- Single task	7.30 (1.95)		
		Older Adults- Dual task	4.70 (2.21)		
Rehearsal	Age	Younger Adults	6.56 (1.69)	$F(1, 27)= 6.87,\ p=.01$	.20
		Older Adults	4.65 (2.53)		
	Condition	Single task	5.72 (2.23)	$F(1, 27)= 0.03,\ p=.86$	.01
		Dual task	5.69 (2.33)		
	Age x Condition	Younger Adults- Single task	6.50 (1.59)	$F(1, 27)= 0.36,\ p=.55$	.01
		Younger Adults- Dual task	6.63 (1.78)		
		Older Adults- Single task	4.77 (2.59)		
		Older Adults- Dual task	4.54 (2.47)		

Imagery- Primary task (word recall)

As can be seen from Table 5.7, in line with expectations participants experienced a dual task deficit and recalled more words in the single task condition than in the dual task condition. Younger adults recalled more words than older adults, although this was only marginally significant. There was no age x condition interaction.

Imagery – Secondary task (RT and Errors)

For the imagery condition with RT as the DV both main effects and the interaction were not significant (all *F*'s < 1). Repeating the analysis with the number of errors made as the DV, the results revealed the same pattern of no main effects or interactions (all *F*'s<1). For means see Table 5.8.

Table 5.8 Mean reaction time and error rates in the tone task when using an imagery strategy divided by condition and age

	Mean reaction time			Mean number of errors made		
	Overall	Younger	Older	Overall	Younger	Older
ST	790.72	862.98	718.46	0.10	0.07	0.13
DT	982.08	997.43	966.72	0.20	0.14	0.25

ST= Single task, DT = Dual task

Rehearsal- Primary task (word recall)

Participants were shown to recall a similar amount of words in the single task and the dual-task condition when using a rehearsal strategy. The main effect of age was significant (with younger adults recalling more words than older adults), however the interaction between age and condition was not significant.

Rehearsal- Secondary task (RT and number of errors)

The ANOVA for the RT showed no significant main effects or an interaction (all F's < 1). When the analysis was run with error data as the DV, it was found that there was a main effect of condition (F[1, 24]=8.25, p=.008, η^2_p = .27) with more errors produced in the dual task (M=.55, SD= .56) compared to in the single task condition (M=.20, SD= .49). The main effect of age was approaching significance (F[1, 24]= 3.35, p=.08, η^2_p = .12), with younger adults committing more errors (M=.53, SD=.55)

compared with older adults ($M=.21$, $SD=.51$). The interaction between Age and Condition was also significant ($F[1, 24]= 12.63$, $p=.002$, $\eta^2_p = .24$). Looking at Figure 5.6 below, it is evident that older adults have a slightly increased error rate in the single task condition, but in the dual task condition younger adults make more errors than older adults.
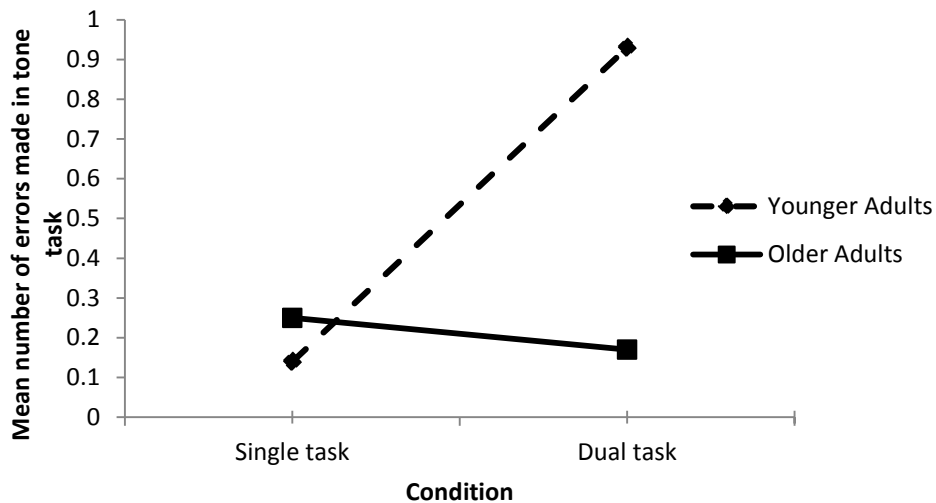
Figure 5.6 Number of errors made by older and younger adults using a rehearsal strategy in the tones task (single and dual task condition)

No-choice

Within Strategy Type

As participants completed both imagery and rehearsal conditions then a repeated measures analysis could be conducted to determine if there were age-differences in the single task and dual tasks separately. To that end a mixed ANOVA was conducted with type of strategy used as a within subjects factor and age as a between subjects variable. Again this was only run on compliant individuals, thereby reducing the sample size.

Single Task

A main effect of strategy type was found, with participants recalling more words when asked to use an imagery strategy as opposed to a rehearsal strategy ($F[1, 26] =12.41$, $p = .002$, $\eta^2_p = .32$). Although younger adults scored higher than older adults

this was only marginally significant (F[1, 22]= 2.94, *p*= .09, η^2_p = .10). The interaction between strategy and age was not significant (F<1).
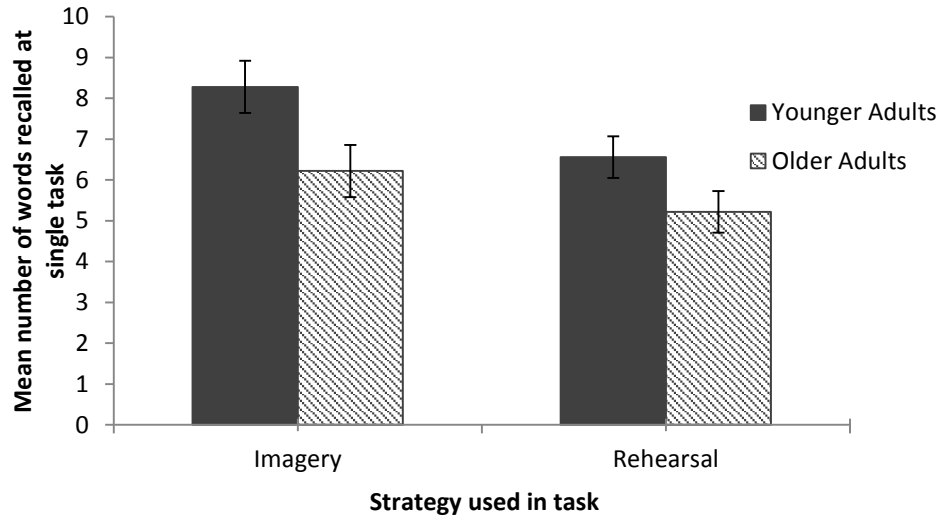
Figure 5.7 Number of words recalled by older and younger adults when using an imagery and rehearsal strategy in the single task condition. Error bars represent one standard error above and below the mean

Dual Task

The main effect of strategy type was not found, participants recalled an equivalent amount of words when using an imagery or rehearsal strategy (F[1, 21]= .009, *p* =.93). The main effect of age was significant (F[1, 21]= 5.31, *p*= .03, η^2_p = .20), with younger adults scoring higher than older adults. The interaction between strategy and age was not significant (F[1, 34]= .227, *p*= .64).
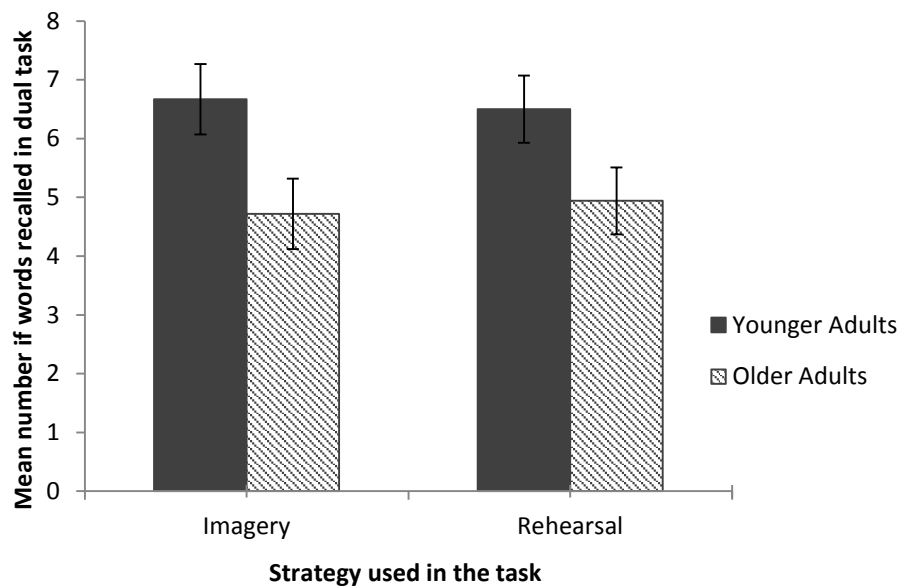
Figure 5.8 Number of words recalled by older and younger adults when using an imagery and rehearsal strategy in the dual task condition. Error bars represent one standard error above and below the mean

Secondary task performance

Reaction time

The analysis was repeated to determine whether performance in the secondary task differed as a function of the strategy used in the primary task (imagery or rehearsal) or age. Results revealed that there was no main effect of strategy ($F[1, 18]$=.64, p =.43), Age ($F[1, 18]$=.54, p= .47) and no interaction between Strategy and Age ($F[1, 18]$= 1.01, p= .33).

Error Data

In addition to seeing it there were differences in Reaction time data, the number of errors made was also analysed. This revealed that the main effect for Strategy and Age were not significant (all F's $\leq$ 1.38), but the Age x Strategy interaction was ($F[1, 18]$=7.68, p=.013, η^2_p = .29. The data revealed that younger adults made more errors in the rehearsal condition, whereas older adults made more errors in the imagery condition (see Figure 5.9).

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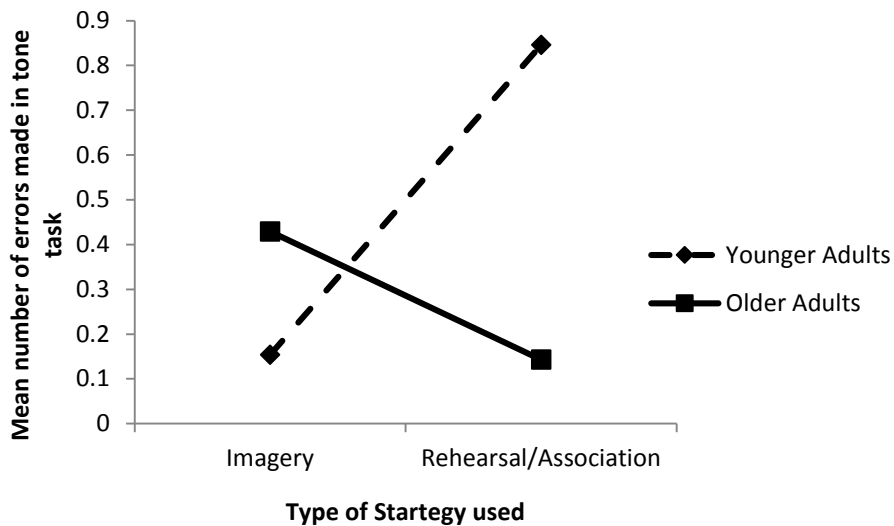
Figure 5.9 Number of errors made by older and younger adults using an imagery or rehearsal strategy in the tones task (dual task condition)

In the no-choice conditions it is apparent that there are age-related differences in execution of the strategies.The advantage of younger adults when using an imagery strategy was not unexpected, and is consistent with previous research (Dunlosky & Hertzog, 1998), although it was only marginally significant. It has been argued that these age-related differences may be due to strategy effectiveness rather than production. Explanations put forward to account for these differences include the differential quality hypothesis which argues that older adults produce lower quality mediators when using an imagery strategy, or they may simply require more time to generate images than younger adults (Robinson, Hertzog & Dunlosky, 2006).Considering the 5 sec time limit for each word in the current study, this may well be a factor. Older adults have also been more likely to report that they unsuccessfully tried to implement the strategy (Price, 2008).

The data from the secondary tasks revealed that when using an imagery strategy younger and older adults performed similarly (RT and errors). This is encouraging as it suggests that older adults are not more penalised than younger adults when using a demanding strategy like imagery in dual tasks, contrary to previous research (Naveh-Benjamin et al., 2005).

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Younger adults also performed significantly better when using a rehearsal strategy in both the single task and dual tasks. Unexpectedly, the age effect was greater in this condition than in the imagery condition. This is surprising as it is generally regarded as a less demanding strategy reliant on short-term memory which has been shown to be less affected by aging (Bopp & Verhaeghen, 2005). However, using a rehearsal startegy is thought to reflect primary memory ability which has been shown to be impaired in older adults (Salthouse, 1991). Poorer performance of older adults in using rehearsal has also been attributed to a slower rehearsal rate (Salthouse, 1980; Maylor, 1999), a tendency to rehearse a fewer amount of total words, and differences in distribution, focusing more on words presented at the start of a list (Ward & Maylor, 2005).

One possible explanation for the unexpected finding is that imagery is not as effective when recalling a middle imagery list as opposed to a high imagery list. Indeed, previous research has shown that recall levels when using medium- imagery lists are similar to those found in low-imagery lists (Marston & Young, 1974). It would of interest to see if age-related differences are more pronounced when high imagery level lists are used. As older adults have been shown to be less susceptible than younger adults to the 'concreteness effect', where higher imagery words are typically recalled more than lower imagery ones (Dirkx & Craik, 1992; Eye, Dixon & Krampen, 1989; Huang, Meyer & Federmeier, 2012; Peters & Daum, 2008), it would be expected.

The finding that when younger adults used a rehearsal strategy in the word recall task they committed more errors in the secondary task than older adults is surprising. As rehearsal is deemed to be a less demanding strategy than imagery, it should tax cognitive resources less than an imagery strategy and therefore not lead to reductions in performance in the secondary task. Coupled with the assumption that younger adults possess more cognitive resources than older adults, this is unexpected. However, considering the advantage that rehearsal offered younger adults, it may be effective exploitation of the rehearsal strategy led to worse performance in the secondary task.

5.3.3.4 *Research Question 4: Do participants adapt their strategy use depending on task/environment demands?*

Do participants adapt their strategy use depending on environment/task demands? For example are different strategies chosen in single/dual tasks? Which strategies are most efficient? Is this pattern the same for younger and older adults? How is secondary task performance effected by strategy use and age?

From looking at Table 5.3 it is evident that there is a higher rate of effective strategy use in single task conditions than in dual task conditions. Therefore a Chi-square test[15] was conducted to determine whether there were differences in effective strategy use for single and dual tasks which revealed that this was not significant at time 1, χ^2 (1, $N= 35$)= .432, or at time 2 χ^2 (1, $N= 34$)=.99. When this analysis was conducted by age-group, these differences were also not significant (all p's $\geq$ .432).

Choice Conditions

To establish whether using a normatively effective strategy in the tasks was actually more efficient, performance was assessed. This was conducted for single and dual tasks in the choice conditions to ascertain whether this was adaptive, and reflected the optimal strategy choice. As outlined earlier, a repeated measures analysis could not be used due to participants being able to change their strategy choice from time 1 to time 2.

Time 1: The ANOVA results are reported in Table 5.4. The results show that in the single tasks there was no significant advantage in using an effective strategy (although performance was increased). However for the dual task there was a significant effect of strategy, showing that an optimal strategy was imagery/association compared to rehearsal or 'just reading the words.'

Time 2: The ANOVA results are reported in Table 5.6 .It was found that following strategy training, there was an effect of strategy in both the single and dual tasks, with

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[15] The expected count was less than 5 in one of the cells, therefore a Fischer Exact test is reported.

an effective strategy being the optimal strategy regardless of how strategy use was assessed (effective/less effective or imagery/rehearsal).

No-choice conditions

To determine whether this pattern was the same in the no-choice conditions, performance data was analysed from compliant participants. The analysis is reported in Table 5.7.

Results revealed that in single-tasks, an imagery/association strategy was superior to a rehearsal strategy. However, in the dual task condition it was found that there was not an effect of strategy, a normatively effective strategy did not offer any benefit over a normatively less effective strategy. This finding was confirmed when performance was analysed by strategy type, as there was a clear advantage of using an imagery strategy in single tasks, but not in dual tasks. This is surprising given that there was an effect in dual tasks in choice conditions. It could be that the ability to use a strategy is affected by whether it was self- elected or a forced choice.

In both choice and no-choice conditions no interactions were found between strategy and age, demonstrating that the pattern was the same for older and younger adults.

5.3.3.5 *Research Question 5: Do individual differences in processing resources such as EF and WMC account for strategy use and performance?*

Do individual differences in processing resources such as executive functioning and WMC account for strategy use and performance? Do older adults have reduced cognitive resources?

To examine how processing resources may impact strategy use, the data were subjected to a series of two-way ANOVAs with the different processing resources (executive functioning as measured by the IED and SOC tasks and working memory as measured by the SWM task) as the DVs and Age (younger vs older adults) and strategy (effective vs not effective) as between subject's factors. As these resulted in unequal cell sizes, again, type III sum of squares ANOVAs were conducted and estimated marginal means are reported.

The strategies participants reported (effective, less effective) using in the word recall tasks at time 1 were used for the strategy condition to address the question of whether people who possess greater cognitive resources are more likely to self-initiate effective strategies than those having fewer resources (Lemaire, 2010). Separate analyses were run using the strategies used by participants in the word recall tasks for single task conditions, and dual task conditions.

Also of importance is whether there is any age-related differences; as older adults typically show less self-initiated strategy use (Craik & Byrd, 1982), or use less effective strategies (Hertzog, Price & Dunlosky, 2012) which has been attributed to structural changes in the frontal lobes resulting in lower executive functioning/ working memory ability (Kirchhoff, Anderson, Barch & Jacoby, 2011).

The main results are summarised in Table 5.9, showing whether there were any main effects/interactions for each variable. Where there are any significant results, they are briefly discussed.

Table 5.9 Summary of ANOVA results for processing resources, given by strategy and age (significant results are highlighted in bold)

Task	Strategy used in word recall task (single task)		Strategy used in word recall task (dual task)	
(DV)	Summary Results	ANOVA Results	Summary Results	ANOVA Results
IED-	No main effect of Age	$F(1,32)=0.49$, $p= .49$, $\eta^2_p =.02$	No main effect of Age	$F(1, 32)=0.01$, $p=.94$, $\eta^2_p =.01$
TE(A)	**Main effect of Strategy**	$F(1,32)=4.23$, $p= .04$, $\eta^2_p = 12$	**Marginal main effect of Strategy**	$F(1,32) =3.67$, $p =.06$, $\eta^2_p = .11$
	No Age x Strategy Interaction	$F(1,32) = 0.02$, $p =.88$, $\eta^2_p .01$	No Age x Strategy Interaction	$F(1, 32)=0.35$, $p=.56$, $\eta^2_p =.01$
SWM-	No main effect of Age	$F (1,31)=1.90$, $p =.18$, $\eta^2_p .06$	No main effect of Age	$F(1, 31)=1.17$, $p=.29$, $\eta^2_p =.04$
BE	**Main effect of Strategy**	$F(1,31)=7.04$, $p=.01$, $\eta^2_p = .18$	No main effect of Strategy	$F(1, 31) =2.50$, $p=.12$, $\eta^2_p =.08$
	No Age x Strategy Interaction	$F(1, 31)=0.18$, $p=.68$, $\eta^2_p =.01$	No Age x Strategy Interaction	$F(1, 31)=0.04$, $p=.84$, $\eta^2_p =.01$
SWM,	**Main effect of Stage**	$F(*)=60.45$, $p<.001$, $\eta^2_p =.74$	**Main effect of Stage**	$F(**)=30.48$, $p< .001$, $\eta^2_p = .50$
4,6,8	No main effect of Age	$F(1, 31)=0.85$, $p=.36$, $\eta^2_p =.03$	No main effect of Age	$F(1, 30)=0.51$, $p=.48$, $\eta^2_p =.02$
	Main effect of Strategy	$F(1,31)=11.09$, $p<.001$, $\eta^2_p= 26$	No Main effect of Strategy	$F(1, 30)=1.15$, $p=.29$, $\eta^2_p =.04$
	Significant Stage x Strategy	$F(1,62) =7.12$, $p<.01$, $\eta^2_p =.19$	No Stage x Strategy Interaction	$F(1, 60)= 0.63$, $p=.53$, $\eta^2_p =.02$
	No Stage x Age Interaction	$F(1,62)=0.36$, $p=.70$, $\eta^2_p =.02$	No Stage X Age Interaction	$F(1, 60)=0.22$, $p=.80$, $\eta^2_p =.01$
	No Stage x Age x Strategy	F(1, 62)=1.04, $p=.36$, $\eta^2_p =.03$	No Stage x Age x Strategy	$F(1, 60)=0.24$, $p=.79$, $\eta^2_p =.01$

SWM-S	No main effect of Age	$F(1,31)=0.35, p=.56, \eta^2_p=.01$	No main effect of Age	$F(1, 30)=0.58, p=.45, \eta^2_p=.02$
	Main effect of Strategy	**$F(1,31)= 5.39, p=.03, \eta^2_p= .15$**	No main effect of Strategy	$F(1, 30)=1.41, p=.24, \eta^2_p=.05$
	No Age X Strategy Interaction	$F(1,31)= 1.24, p=.28, \eta^2_p=.04$	No Age x Strategy Interaction	$F(1, 30)=1.49, p=.23, \eta^2_p=.05$
SOC-Min	No main effect of Age	$F(1,32)= .489, p = .49, \eta^2_p .05$	No main effect of Age	$F(1, 31)=1.90, p=.18, \eta^2_p=.06$
	Main effect of Strategy	**$F(1,32) =4.23, p= .04, \eta^2_p = 12$**	No main effect of Strategy	$F (1, 31)=0.78, p=.39, \eta^2_p=.02$
	No Age x Strategy Interaction	$F[1, 32] =.02, p =.88, \eta^2_p = .01$	No Age x Strategy Interaction	$F(1, 31)=0.26, p=.61, \eta^2_p=.01$

IED-TE(A) Intra-extra Dimensional task-Total errors (adjusted), SWM- BE= Spatial Working Memory task between errors, SWM-4,6,8= Spatial Working Memory, 4 box, 6 box and 8 box problems, SWM= Spatial Working Memory task Strategy, SOC-Min= Stockings of Cambridge task minimum amount of moves.

*$F(1.33, 41.26)$ ** $F(1.28, 38.51)$- Greenhouse-Geisser corrected.

The role of cognitive flexibility on self-initiated effective strategy use was assessed using the total adjusted errors as the DV.

Strategy used in single task: Looking at Figure 5.10, it is evident that younger adults commit fewer errors than older adults, but this was shown not to be significant. There was a significant main effect for strategy, showing that those who used an effective strategy committed less total errors then those who used non effective strategies.
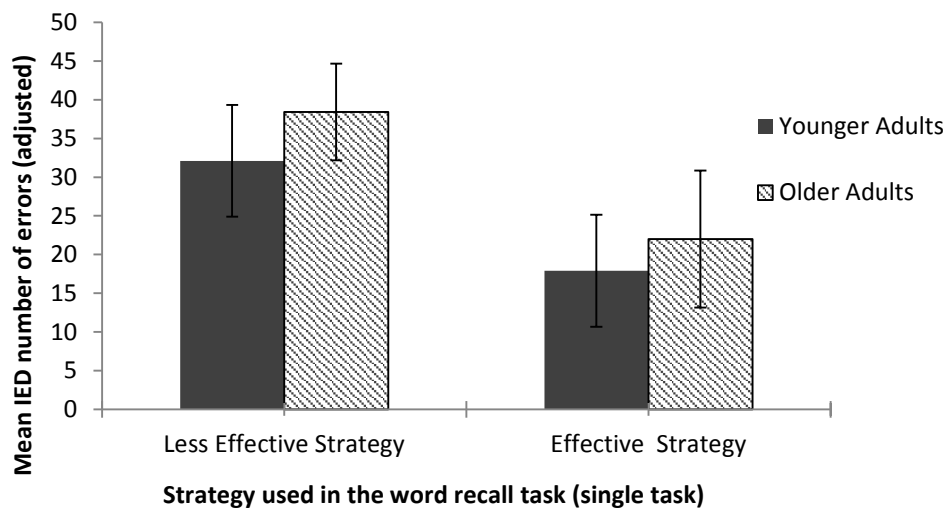
Figure 5.10 Mean number of IED adjusted errors made by younger and older adults when using an effective or less effective strategy. Error bars represent one standard error above and below the mean

Strategy used in dual task: The same pattern of results was obtained for the dual-task condition, with no main effect of age or interaction found. However, the main effect for strategy was only approaching significance, with those using a less effective strategy committing more errors (*M*= 33.38, *SD* =23.28) than those using an effective strategy (*M*= 14.50, *SD*= 14.12).

Between errors

Strategy used in single task: This revealed that there was no main effect for age, although as can be seen from Figure 5.11 older adults did produce more errors than younger adults. The main effect for strategy was significant, with those who used effective strategies making fewer errors than those who used a less effective strategy. There was no interaction found between strategy use and age ($F<1$).
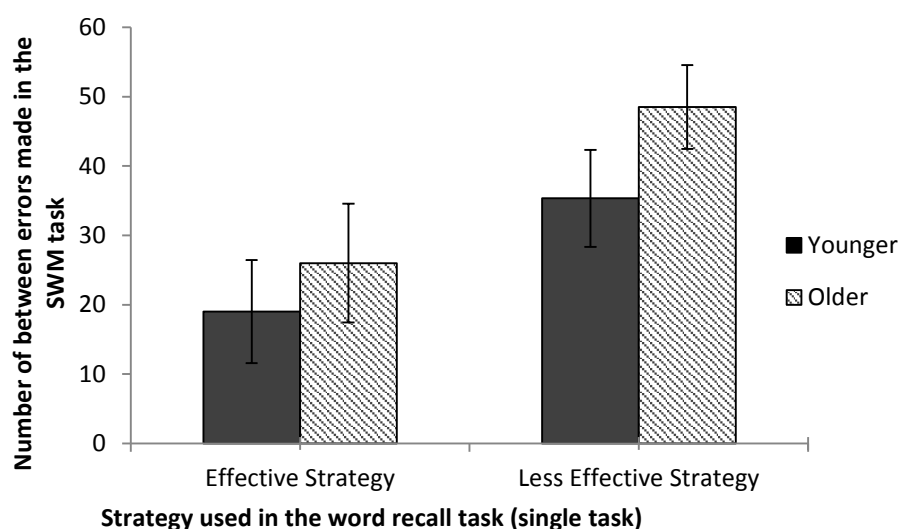
Figure 5.11 Mean number of errors made in the SWM task for younger and older adults using an effective or less effective strategy. Error bars represent one standard error above and below the mean

Strategy used in dual task:

A similar pattern of results was found when using the IV of strategy reported in the word recall task in the dual task condition. The main effects of age and the interaction were not significant (all F's ≤ 1.17), although older adults made more errors than younger adults ($M= 36.87$, $SD= 20.02$ $M= 26.07$, $SD=18.22$ respectively). However,

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[16] There was a power cut during testing for one of the younger adults, which resulted in some of their data for the SWM task not being recorded from the CANTAB. The data for this task is therefore missing and excluded from analysis. All other variable data for this participant is included analyses.

unlike when the single task strategy IV was used, the main effect for strategy was also not significant.

Stages

Again, it may be that age-related differences are only present at the later stages of the task. Therefore the number of errors made per stage was examined to determine if this was the case. A 3x2x2 ANOVA with stage as within subjects and age and strategy as between subjects was conducted in order to determine if any differences in errors were a function of stage, age, strategy used in the word recall test or a combination of these. As there were three levels for the different stages (the total number of between errors for 4 box, 6 box and 8 box problems) this was tested for spheriticy.

Strategy used in single task: Maulchy's test revealed that it did violate the assumption of sphericity, $\chi^2(2) = 20.97$, therefore Greenhouse-Geisser corrections were applied ($\varepsilon=.67$) in order to reduce the degrees of freedom. The main effect for stage was significant. Post hoc tests revealed that there were significant differences between all levels of the IV (all p values <001), with more errors made the more boxes there were. There was no main effect for age, but there was a main effect for strategy. The Stage x Strategy interaction was also significant, although the three way interaction between Stage, Strategy and Age was not. As can be seen in Figure 5.12, at earlier stages of the task there was not much difference in the number of errors made between participants who self-initiated an effective or a less effective strategy in the word recall task at single task. This difference steadily increased as the task difficulty increased; with those who used a less effective strategy in the word recall task (single task) committing more errors than those who used an effective strategy at 6 boxes and at 8 boxes.
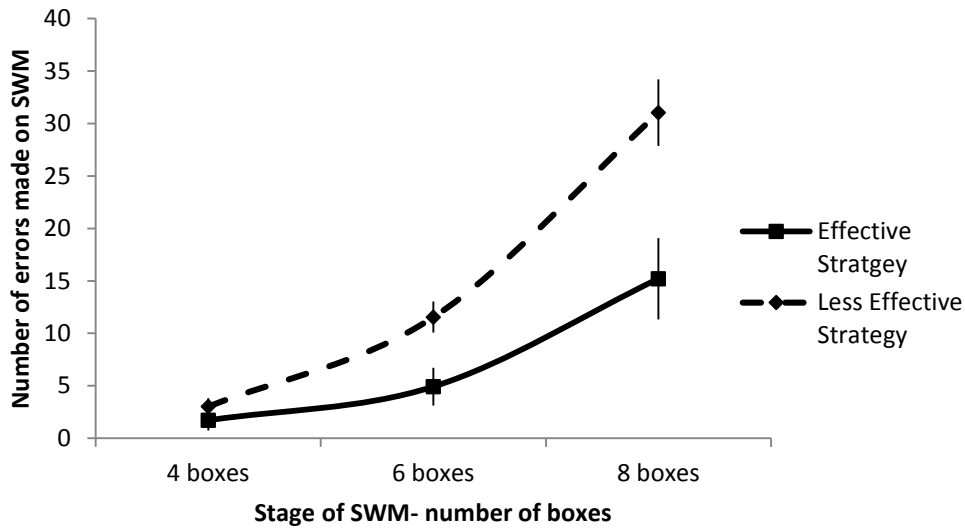
Figure 5.12 Mean number of errors made in the SWM task at 4, 6 and 8 box problems when using an effective or less effective strategy in the single task word recall task. Error bars represent one standard error above and below the mean

Strategy used in dual task: When the analysis was repeated using the strategy used in the word recall task at dual task; only the main effect of stage was significant, with more errors made as the number of boxes increased (see Figure 5.13). The Greenhouse-Geisser correction was applied as it violated the assumption of sphericity, $\chi^2(2) = 23.68$, p< .001. All other main effects and interactions were not significant.
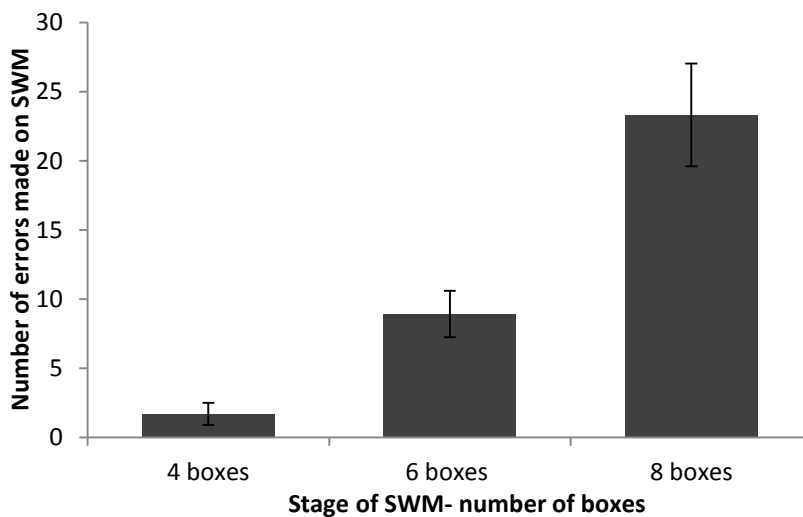
Figure 5.13 Mean number of errors made in the SWM task at 4, 6 and 8 problems. Error bars represent one standard error above and below the mean

Strategy Score

In addition to the stages of the task, participant's strategy score on the SWM was also calculated and subjected to a 2x2x2 ANOVA. A higher strategy score indicates poorer strategy use (i.e. not using a pre-determined search sequence).

Strategy used in single task: There was a main effect for strategy, with those who used an effective strategy in the word recall task using a more effective strategy in the SWM task (scoring a lower score, *M*= 31.56, *SD*= 6.35) and those who used a less effective strategy in the word recall task, opting to use a poorer strategy in the SWM task (scoring a higher score, *M* =36.85, *SD*= 6.01). The main effect for age was not significant, showing that older adults and younger adults score similar scores for strategy (*M*= 34.88, *SD*=3.75 *M* = 33.54, *SD*= 8.61 respectively). The Age x Strategy interaction was also not significant.

Strategy used in dual task: Main effects and interaction were not significant.

SOC

The amount of problems solved in the minimum number of moves was used to examine participants planning ability (indicative of frontal lobe/executive functioning).

Strategy used in single-task:. By looking at Figure 5.14, it is apparent that older and younger adults who used an effective strategy in the word recall task complete a comparable number of problems in the minimum amount moves. However; for those who used a less effective strategy in the word recall task; younger adults completed slightly more problems in the minimum amount of moves than older adults, suggesting that an interaction may be taking place. However, no interaction between age and strategy was found, just a main effect of strategy.
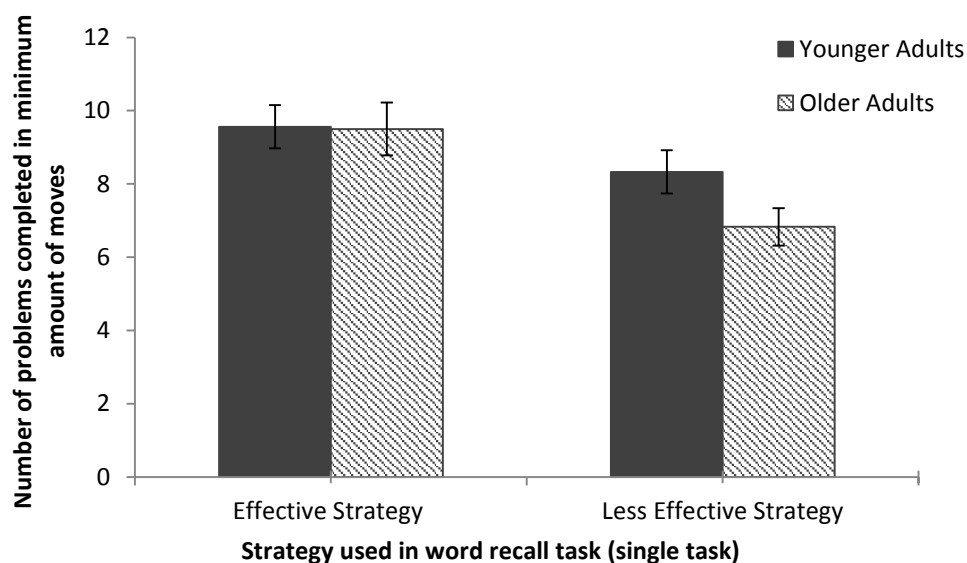
Figure 5.14 Mean number of problems completed in the minimum amount of moves for older and younger adults when using an effective/less effective strategy. Error bars represent one standard error above and below the mean

Strategy used in dual-task: No significant results were obtained.

Cognitive Flexibility and Adaptivity

In order to examine the hypothesis that participants possessing higher cognitive flexibility are more adaptive in their strategy use; a new variable 'Effective strategy change' was created. Participants who changed from a less effective strategy at time 1 to a more effective strategy at time 2 were classified as demonstrating effective strategy change and were given a score of 1. Participants who did not change their strategy use from a less effective one were given a score of 2. Participants who reported using an effective strategy at both times were not included in the analysis. This resulted in the following subsample sizes for younger and older adults, n = 10 younger adults, n = 13 older adults.

2 (Age, older vs younger) x 2 (Strategy, change vs no change) was run with the DV being the total number of errors on the IED. There was no main effect of Age (F[1, 19] = .54, p =.47) or Strategy (F [1, 19] = 1.19, p =.29). There was also no Age x Strategy interaction (F [1, 19]= .37, p = .55, η^2_p = .02).

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Processing Resources and Performance

In addition to determining whether cognitive resources could account for effective strategy use; the relationship between cognitive resources and performance in the single and dual tasks at time 1 were also examined. As the variables are continuous, correlations were run as opposed to dichotomising the variables via median splits in order to compare groups. This method was chosen in order to avoid the possible negative consequences of performing median splits such as discarding important information about individual differences in the data, loss of statistical power, and obtaining spurious results (MacCallum, Zhang, Preacher, & Rucker, 2002). Age was also included to see how this was related to performance and processing resources, with positive correlations indicating worse performance for older adults in most of the variables, as these represented error data, with fewer errors reflecting better performance.[17]

For cognitive resources only the main outcome variables of each measure are reported unless the results are particularly interesting/unexpected for other outcome measures; in any case, the full correlation matrix is displayed in Table 5.10.

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[17] Except for the following variables; number of words recalled single-task, number of words recalled dual-task, stages completed IED and the number of problems solved in minimum amount of moves in the SOC, where negative correlations indicate worse performance by older adults.

Table 5.10 Full correlation matrix for single and dual tasks at time 1 and tasks assessing processing resources

	Age	Word Recall (ST1)	Word Recall (DT1)	SWM Between Errors	SWM Strategy	SWM 4 Box Errors	SWM 6 Box Errors	SWM 8 Box Errors	IED Total Errors Adjusted
Word Recall (ST1)	-.54**								
Word Recall (DT1)	-.49**	.47**							
SWM Between Errors	.32	-.28	-.30						
SWM Strategy	.10	-.07	-.18	.55**					
4 Box Errors	.40*	-.39*	-.36*	.59***	.15				
6 Box Errors	.07	-.04	-.15	.74***	.45**	.47**			
8 Box Errors	.23	-.19	-.13	.86***	.34*	.46**	.56***		
IED Total errors Adjusted	.21	-.19	-.59***	.48**	.18	.37*	.52**	.49**	
Minimum Moves	-.29	.50**	.11	-.39*	-.27	-.22	-.29	-.35*	-.20

* p <0.5 ** p < .01 *** p <.001

Working Memory Capacity (SWM)- Between errors

As expected, this was negatively correlated with performance in the single and dual task; however this was non-significant at single task ($r= -.28$, $p= .11$) and marginally significant at dual task ($r= -.30$, $p=.09$), indicating that as performance in the single and dual tasks increased the number of errors made decreased. Not surprisingly; the number of errors significantly positively correlated with the other outcome variables of this task; with high correlations found with number of errors made in 4 box ($r=.59$, $p< .001$) 6 box ($r=.74$, $p< .001$) and 8 box problems ($r= .86$, $p<.001$), and strategy ($r=.55$, $p<.01$).

This variable was also significantly correlated with the other measures of cognitive resources, such as cognitive flexibility- reflected by the total amount of errors made on the IED ($r= .48$, $p<.01$) and planning ability measured by the amount of problems solved in the minimum amount of moves on the Stockings of Cambridge task ($r= -.39$, $p= .02$) suggesting that those who perform well in the working memory task tend to perform well in other cognitive tasks, namely those measuring executive function.

Age was positively correlated with the number of errors made on the working memory task indicating that increased age was associated with more errors made on the task; however this was only modestly correlated and only marginally significant ($r = .32$, $p = .06$)

Cognitive Flexibility (IED)- Total Errors (adjusted)

The number of words recalled at single and dual task were negatively correlated with the number of errors made on the IED task, suggesting that greater cognitive flexibility leads to increased performance on the word recall tasks; however, this was only significant in the dual task ($r= -.59$, $p<.001$) and not the single task which only showed a weak correlation ($r= -.19$, $p=.29$)

As expected, total errors were positively correlated with the number of errors made on the task both prior to ($r= .48$, $p< .01$) and post extra-dimensional shift ($r= .53$, $p<.01$) and also negatively correlated to the number of stages completed ($r= -.54$, $p<.01$) Poorer cognitive flexibility was also associated with more errors made on the working memory task ($r= .48$, $p<.01$). However, it was not significantly correlated with performance on the SOC task, contrary to expectations. Surprisingly the number of errors made was only weakly positively correlated with age, and was not significant ($r= .21$, $p = .21$)

Planning Ability (SOC)- Number of problems solved in minimum moves

Increased performance in this task (reflecting greater frontal lobe/executive functioning) was correlated to increased performance in the word recall task at single task ($r = .50$, $p< .01$) however it was not significantly related to performance in the dual task ($r= .12$, $p = .51$) When examined in relation to the other cognitive measures, planning ability was significantly correlated with working memory (between errors) ($r= -.38$, $p= .02$), and the IED only when the number of stages completed was analysed and not the number of errors made ($r= -.46$, $p<.01$). Although in the expected direction, the correlation between age and performance on the SOC was not significant ($r= -.26$, $p =.21$).

Age

As predicted, age was significantly negatively correlated to performance in the single ($r= -.54$, $p<.01$) and dual tasks ($r = -.49$, $p< .01$), with increased age being associated with decreased performance in the tasks. Surprisingly; age was not significantly correlated with any of the main outcome measures of working memory, cognitive flexibility or executive functioning. However, age was significantly positively correlated with the number of pre-ED errors made on the IED task ($r= .34$, $p = .046$); and the total amount of errors made on the 4 box problems of the SWM ($r= .40$, $p= .02$) indicating that older adults may only make more errors than younger adults at the initial stages of these tasks, but when overall performance is considered (e.g. total number of errors made on the task) age differences do not manifest.

In summary, cognitive resources were shown to be important for strategy use. It was found that those who spontaneously used a more effective strategy in the word recall tasks possessed higher processing resources than those who were not using an effective strategy. This finding is consistent with previous research, demonstrating that higher rates of spontaneous strategy use are associated with higher levels of cognitive resources such as working memory capacity (Dunlosky & Kane, 2007; Turley-Ames & Whitfield, 2003) and executive functioning (Bouazzaoui et al., 2010).

In line with predictions, higher cognitive resources were related to increased performance in the tasks. Interestingly, different facets of cognition were related to performance in the single and dual tasks. Planning ability (as measured by the SOC task) was related to performance in the single task and cognitive flexibility in the dual task, indicating that the executive

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functions and the frontal lobes are important for recall and implicated in strategy use (Tacconat et al., 2009; Bouazzaoui, et al., 2010). The finding that performance on the IED was correlated with performance on the dual task ties in with previous research suggesting that the ability to coordinate two separate tasks is linked to the central executive and the DLPFC (Baddeley, 1996). The hypothesis that greater cognitive flexibility would be associated with adaptive strategy use, (the ability to shift strategy use from a less effective to a more effective strategy) was not supported by the current study. However, this may lie with problems inherent in the analysis rather than reflecting that there is no relationship between the two. This is because only those participants who were using a less effective strategy at pre-test were included in the analysis, however this would exclude those with higher cognitive flexibility, as an effect of strategy was found in IED performance, with those using an effective strategy at pre-test making less errors than those using a less effective strategy.

Surprisingly, although older adults generally performed worse in the tasks than younger adults, this difference was not significant. However, age was found to be negatively correlated to performance in the word recall tasks, suggesting that the age-related differences exhibited in the word recall task were not due to differences in processing resources.

5.4   General Discussion

This study investigated strategy use in older and younger adults when completing single and dual tasks, using a choice/no-choice methodology. In the no-choice conditions, it was found that there were age differences in performance following strategy information, with younger adults faring significantly better when using a rehearsal strategy. Younger adults also showed an advantage when using an imagery strategy, although this difference was only approaching significance. Conversely; when participants were given a choice in which strategy to use; age-related differences failed to manifest when examining performance using the rehearsal or imagery strategy, suggesting that younger and older adults could utilise these strategies to the same extent. These results show that examining strategy use is important, as when overall performance was considered (irrespective of strategy use) age-related differences were evident at both single and dual-task conditions in choice conditions, with younger adults showing higher performance.

As age-related differences were evident in the no-choice conditions, it could be argued that participants were not using the appropriate strategies. However; this appears unlikely as age differences in compliance rates were not found in most of the tasks. A lower level of compliance in using an imagery strategy for older adults was found which may have contributed to the age-differences in the single task, but does not offer an explanation for the results of the dual task, or those in the rehearsal condition.

Taken on its own, the reduced cognitive resources theory offers compelling evidence to account for the age-related differences found in the no-choice condition. However, when examining the choice conditions a different pattern of results emerged. When participants were using specific strategies such as imagery/association and rehearsal, age-related differences were not found; but there was an effect of strategy, suggesting that when both older and younger adults were using effective strategies such as imagery/association their performance was equivalent. The lack of an age x strategy interaction suggests that both older and younger adults' performance is affected by strategy use in the same way, namely that both are able to utilise an effective strategy in order to increase performance. However, when comparing the performance of those using effective strategies and less effective strategies in choice conditions; age-related differences in performance were found, with younger adults recalling more words. These diverging results may appear contradictory; but in the latter example participants who were not using any strategy and reported that they 'just read the words,' were included in the analysis. This is important; as older adults reported using no strategy more than younger adults (e.g. 33.3% compared to just 5.6% of younger adults in ST1), and could account for the age-related differences in this circumstance.

As the current study revealed that older adults prefer to use a sentence generation strategy in the word recall tasks, then it is not all too surprising that in the no-choice condition when asked to use an imagery strategy they are not performing as well as younger adults. Previous research has demonstrated that when individuals are restricted to use a specific strategy then pre-existing ability differences are often increased, particularly age differences (Lustig & Flegal, 2008). Similarly, Hertzog, Price and Dunlosky (2008) found that when participants were given a choice, strategy use reflected individual preferences and abilities to use the different strategies, suggesting that for some individuals the strategies chosen may be different from the ones given in the no-choice condition and may therefore result in reduced performance.

As this study used middle imagery words, it would be interesting to see if the same pattern of results would be found if using high imagery words. As previously mentioned, research has revealed that an imagery strategy may not be effective when mid-level imagery words are used. This could account for the results found in the no-choice conditions (age-related differences in performance more pronounced in the rehearsal condition) or when overall performance was assessed (irrespective of strategy use) in which participants were not found to significantly increase their performance following strategy training, in contrast to the results found in Study 1 (however see Kulhman & Touron, 2012 for conflicting results). As the older adults in this study opted to use a sentence generation more in the choice conditions; reflecting strategic behaviour, it would be useful to examine if this was observed when the words were of high imagery level.

5.4.1 Adaptive Strategy Use

One of the main goals of the current study was to assess whether participants where adaptive in their strategy selection, and whether this was effected by age. In order to determine this, it is important to establish which strategies are the most efficient in certain conditions. The hypothesis that demanding strategies (such as imagery/association) would be more advantageous in single tasks was supported by the study, as in both the choice and no-choice conditions utilising these strategies did lead to higher recall. This advantage was not extended to the dual task, at least not when strategy choice was enforced, as both imagery and rehearsal yielded equivalent performance, suggesting that maybe in this situation the strategy cannot be executed as effectively. Only when participants were given a choice over their strategy use, did differences become apparent, with imagery/association leading to greater performance than rehearsal. At first glance these results may appear contradictory, but as discussed earlier it may be due to different preferences in strategy selection that are not necessarily reflected in the strategy choices offered in the no-choice condition.

The assertion that older adults are less adaptive in their strategy use (Lemaire, 2010) was not supported by the current study. Although younger adults did choose effective strategies more than older adults at pre and post strategy training, these differences were not significant, and both older and younger adults were shown to shift their strategy use in favour of a more effective strategy following strategy training/instruction in the single and dual tasks. In

contrast to Lemaire, Arnaud and Lecacheur, (2004) no age-related differences in performance were found; older adult's performance when using a demanding strategy was comparable to younger adults. As previously stated, there were age differences in strategy selection, with older adults favouring a sentence generation strategy and younger adults an imagery strategy. However, unlike in the study of Tournier and Postal (2011) switching to a sentence generation strategy appeared to be the optimal choice for older adults, and thus was considered adaptive. Although these findings are in contrast with Dunlosky and Price (2012) who demonstrated that older adults typically stuck to their preferred strategy of rehearsal following training, they are consistent with the findings of Bailey Dunlosky and Hertzog, (2009) who found that older adults used effective strategies to the same extent as younger adults.

5.4.2 Secondary task Performance

Although not a primary aim of this study; it is nonetheless important to determine whether performance on the secondary task was affected by strategy use, and if there were any age-related differences. When using an imagery strategy, secondary task performance (as measured by RT) was found not be affected by age or the addition of a secondary task in both the choice and no-choice conditions. This is especially encouraging in the no-choice condition as it suggests that older adults are able to utilise a demanding strategy without cost to their secondary task performance. Additionally it suggests that the process of choosing and implementing an effective memory strategy does not tax cognitive resources, which has been demonstrated in studies of arithmetic strategies (Imbo & Vandierendonck, 2007).

5.4.3 Individual Differences in Cognitive Resources

In order to address the notion that the age-related differences found in the no-choice conditions could be accounted for by reduced cognitive resources; executive functioning, working memory and planning were measured. Although older adults were typically shown to perform less well on the tasks than younger adults, the difference in task performance was not significant. This is contrary to expectations as age-related differences in constructs such as working memory, inhibition, and executive functioning are widely reported in the literature (Braver & West, 2007; Glisky, 2007).It could be argued that differences may be due to differences in the measures used and the method of administration. In this study the CANTAB was used, which is not as commonly used as more traditional 'pen and paper' tests

in the field, therefore it could be argued that they were either not measuring the same constructs, or were not sensitive enough to detect age differences. However the CANTAB has both proven validity and reliability, and has been extensively tested in older adults (De Luca et al., 2003; Robbins et al., 1994. Simpson et al., 2005). Previous research using the CANTAB has also revealed age-differences in the SWM, SOC and IED test (Robbins et al., 1998), although not always (see Rabbitt & Lowe, 2000). Computerised tests have also been shown to be an equally valid method of assessing cognitive function, and may hold advantages such as being less likely to elicit distress in older participants (Collerton et al., 2007).

It is therefore unlikely that the methods used had an impact on the results obtained; instead, a more plausible explanation may be that the older adults in this sample were high functioning. Support for this comes from comparing older adults' performance in the SWM, SOC and IED tests in the current study to those found by Robbins et al., (1998). In the majority of cases the older adults in the current study performed better than the older adults in the Robbins study. For example, in the SWM task, older adults (aged 65 or over) had a mean score of approximately 52, whereas in the current study it was 37.25. However, the study of Robbins did have a considerably larger sample of older adults (n= 162, compared to n=18) which may have accounted for the differences shown. Another consideration to take into account is the sample, the older adults were recruited from the community via organisations such as university of the third age, thereby representing a highly motivated and presumably a high functioning group.

Younger adults are often credited with higher rates of spontaneous strategy use (Dunlosky & Hertzog, 2001, Tacconat, 2009), which has been attributed to greater cognitive resources 'affording' the use of these strategies (Dunlosky & Kane, 2007; Turley-Ames & Whitfield, 2003). However, although younger adults were more likely to spontaneously use an effective strategy in the single and dual tasks, this difference was not found to be significant. Furthermore, as age-related differences were not apparent in the majority of the cognitive resource measures, but effective strategy use was; this indicates that cognitive resources were necessary for the execution of spontaneous strategy use in the tasks, but that this was not as a function of age.

5.4.4 Summary and Conclusions

In summary, the results show that when older adults are able to choose a strategy, their performance is equivalent to younger adults. However, when participants are asked to use a particular strategy; younger adults typically perform better than older adults, consistent with the literature (Caretti et al., 2007). Importantly, these age-related differences do not seem to be due to a strategy production deficiency, as would be suggested if less demanding/effective strategies were being utilised by older adults, but instead by different strategies being employed. Following strategy training/instruction, older adults showed a preference for using a sentence generation strategy rather than an imagery strategy. Promisingly; older adults are also able to utilise these strategies in dual task conditions. In fact, it was younger adult's secondary task performance which decreased, especially in the rehearsal condition.

Furthermore, this research demonstrates that older adults are adaptive in their strategy use, and can shift their strategy use so that they are using an optimal strategy. Although cognitive resources such as working memory capacity and executive functioning where shown to be important in spontaneous effective strategy use; age-related differences were generally not found; suggesting that a reduction in cognitive resources is unlikely to be the mechanism responsible for the age-related differences found in the no-choice conditions. This has implications for memory strategy training, as the findings suggest that by enabling older adults a variety of strategies to choose from, instead of instructing them to use a particular strategy they can perform better (Lustig & Flegal, 2008). Additionally, equipping older adults with a repertoire of strategies to choose may be a key element in promoting transfer to untrained/everyday tasks, an essential goal of memory strategy training (McDaniel & Bugg, 2012).

6 Study 3- Aging and adaptive strategy use in memory performance in single and dual tasks; the role of processing resources (high imagery words)

6.1 Introduction

The previous study (study 2) investigated whether there were any age –related differences in the selection and execution of memory strategies in single and dual tasks. The study found that younger adults performed better than older adults when they were asked to use a certain memory strategy (imagery or rehearsal). However, when participants were free to choose a strategy, age-related differences failed to manifest. Further examination revealed that this may have been due to differences in strategy selection as older adults chose to use a sentence generation strategy to a greater extent than younger adults. The study also found that when overall performance was examined (irrespective of which strategy was used) participant's single and dual task performance did not improve following strategy training. This was surprising given that in study 1 performance was increased following strategy training/instruction.

Although the training itself was slightly modified from that used in study 1, it seems unlikely to have been the reason for the results, given the enduring positive effect of strategy training seen across a variety of different methodologies (see Gross & Rebok, 2011for a review). Instead, it may be due to the difference in the imagery level of the words. As is typical in memory strategy studies, study 1 utilised high imagery words. However, study 2 used mid-level imagery words. Since previous research has revealed that an imagery strategy may not be as effective in these conditions (Marston & Young, 1974), than it could explain the pattern of results. For example, older adults may be less able to utilise an imagery strategy in these conditions, and therefore could be the underlying reason why they chose to use a sentence generation strategy (consistent with Tournier & Postal, 2011). This would account for why age –related differences were only found in the no-choice conditions, where participants were 'forced' to use an imagery strategy. It may also partially explain why strategy training did not lead to a significant increase in performance. The strategy billed as being the most effective (imagery) in the training/instructions may not actually be the most effective, (this seemed to be the case for older adults at least). Therefore, it would be of interest to determine how participants perform when the imagery level is increased. It is anticipated that

if more participants utilise imagery at time 2, this would be prove to be more fruitful and lead to an improvement from time 1.

In order to establish whether imagery level did account for the results obtained in study 2, the study will be replicated using high level imagery words. The overall goal of the study is to determine whether the findings from study 2 are able to generalise across to high imagery words, or whether the results are dependent on the imagery level of the words. If we can establish that imagery level is the critical component of strategy effectiveness, then this can help when developing strategy training programmes for older adults, as it may be that different strategies are favoured dependent on imagery level. Additionally, this study (unlike study 2) will have a control group who do not take part in the strategy training, to determine if strategy training or task experience lead to greater strategy use when participants are free to choose a strategy. To avoid issues of reactivity, only those in the experimental group will complete the tasks in the no-choice conditions.

The aims of the study were identical to that of study 2. However, it was anticipated that the imagery strategy would offer more of an advantage in the word recall tasks, and would result in improved performance from time 1 to time 2. Additionally, it was expected that older adults would use an imagery strategy more than a sentence generation strategy. As there were no age-related differences in performance in the choice conditions in study 2, it is expected that older adults would benefit as much as younger adults from using an imagery strategy in the current study.

6.2   Method

6.2.1   Participants

A total of forty participants took part in this study; 22 younger adults (aged 18-30, 18 female) and 18 older adults (aged 64-87, 13 female). Younger adults were recruited from the University of Greenwich and were offered course credit in return for their participation. The older adults were mainly recruited from local sheltered accommodation schemes, and were tested in their community hall. The mean age for the younger adults was 20.95 (SD =3.85), and the older adults was 76.11 (SD =8.04). Older and younger adults were then randomly allocated into an experimental and control group. The participant demographics for each group are provided in Table 6.1.

As in the previous studies- participants were required to have a good command of the English language, no history of neurological illness, no visual or auditory impairments and not be taking any medication liable to affect thinking/concentration.

Table 6.1 Participant demographic information

	Group	Younger			Older		
		M	*S.D*	*n*	*M*	*S.D*	*n*
Age	Experimental	21.82	4.40	11	75.22	7.38	9
(years)	Control	20.09	2.34	11	77.00	9.00	9
	p	.26			.65		
Education	Experimental	13.55	1.04	11	10.33	1.58	9
(years)	Control	13.18	0.40	11	11.11	2.03	9
	p	.30			.38		

As can be seen from Table 6.1, no age differences or educational differences were apparent in the experimental and control conditions (when categorised by age). There was a difference in educational levels between the younger and older adults, with younger adults having significantly more years of education (*M*= 13.36) than older adults (*M*= 10.72) (*t*[38]=5.76, *p*<.001).

6.2.2 Materials

The same materials as in Study 2 were used, with the exception of the word lists. Word lists were constructed using the MRC Psycholinguistic database (Coltheart, 1981). As in study 1, high imagery words were used, each word being 5-7 letters long. Twelve different lists were constructed each with 15 words, which were counterbalanced using a Latin-square design.

6.2.3 Procedure

The procedure was identical to that of study 2 (please see chapter 5 for details). However, only those in the experimental group took part in the strategy training and the imagery and rehearsal re-tests (all participants completed the choice tasks at time 2).

6.3 Results and Discussion

6.3.1 Data Screening

Prior to analysis the data were screened for outliers using boxplots. A number of outliers were identified and were winsorised to the next highest score to ameliorate their influence. Variables where then visually inspected for normality using histograms, Q-Q plots. Although a few variables looked as though they may potentially deviate slightly from normal, examination of the skewness and kurtosis scores showed these were in an acceptable range (+/- 1.5). Therefore untransformed data were used in this analysis.

6.3.2 Preliminary Analysis- Manipulation Checks

To ensure that participants were adhering to the strategy instructions in the no-choice conditions, compliance rates were checked. The procedure was identical to that of study 2- participants scored a '1' if they used the strategy asked, and a '2' if they did not. The dichotomised variable was then used in a Chi-square analysis to ascertain if there were any age differences in compliance, to rule out the possibility that any age-related differences in performance may actually be due to compliance differences. Compliance rates are outlined in Table 6.2:

Table 6.2 Percentage of participants complying with strategy instructions in Single Task (ST) and Dual Task (DT) conditions

	Overall		Younger		Older	
	Imagery	Rehearsal	Imagery	Rehearsal	Imagery	Rehearsal
ST	85.0%	100%	90.9%	100%	77.8%	100%
DT	75.0%	95.0%	72.7%	90.9%	77.8%	100%

Compliance rates are overall higher than those from previous studies, which are typically between 60-80% (ref). As can be seen from Table 6.2, the compliance rates were greater in rehearsal than in the imagery strategy which is consistent with the results found in study 1. However using a McNemar analysis this was not significant for single or dual tasks (all p's $\geq$ .13).

Although younger adults did comply more with strategy instructions in the imagery condition at single task than older adults, this pattern was the opposite in dual tasks. Given that dual

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tasks are more demanding than single tasks, and an imagery strategy is effortful, it would be expected that older adults would comply less with instructions than younger adults in these circumstances (as found in study 2- although not significant). Of course, compliance and successful execution may be markedly different, so this will be examined in the main analysis. To determine whether there were any significant age-differences in compliance to strategy instructions Chi-square analyses were conducted. These revealed that there were no significant age-differences in compliance. (all p's $\geq$ .56).

To get an indication of whether the strategy training improved performance, a repeated measures ANOVA was conducted with time as a within factor (pre and post strategy training) with age (younger and older adults) and group (experimental and control) as a between factor The results are single task and dual task are presented in Table 6.3, and Table 6.4 respectively.

Table 6.3 Means, standard deviations and Analysis of Variance (ANOVA) results given by age, group and time - single task

Condition	Variable(s)		Mean (S.D)	ANOVA results	Effect Size (η^2_p)
Single Task	Age	Younger Adults	9.32 (3.00)	$F(1, 36)=29.54, p<.001$	.45
		Older Adults	5.45 (1.85)		
	Time	Pre strategy training	7.26 (2.57)	$F(1, 36)=0.32, p=.57$	.01
		Post strategy training	7.50 (2.29)		
	Group	Experimental	7.85 (2.71)	$F(1, 36)= 0.74, p= .40$	.02
		Control	7.30 (3.74)		
	Age x Time	Younger Adults (pre)	8.64 (3.09)	$F(1, 36)= 7.13, p=.01$	.21
		Younger Adults (post)	10.00 (2.92)		
		Older adults (pre)	5.89 (2.05)		
		Older adults (post)	5.01 (1.66)		
	Group x Time	Experimental (pre)	7.35 (2.23)	$F(1, 36)= 2.31, p= .14$	.06
		Experimental (post)	8.35 (3.18)		
		Control (pre)	7.45 (3.69)		
		Control (post)	7.15 (3.79)		
	Group x Age	Experimental Younger	9.32 (2.55)	$F (1, 36)= 0.74, p=.40$	.02
		Experimental Older	6.05 (1.51)		
		Control Younger	9.32 (3.46)		
		Control Older	4.84 (2.20)		
	Age x Time x Group	Younger Adults (pre) –C	9.00 (3.77)	$F (1, 36)= .04, p=.84$	.01
		Younger Adults (post) C	9.64 (3.14)		
		Younger Adults (pre) –E	8.27 (2.41)		
		Younger Adults (post)- E	10.36 (2.69)		
		Older Adults (pre)- C	5.56 (2.70)		
		Older Adults (post) –C	4.11 (1.69)		
		Older Adults (pre)- E	6.22 (1.39)		
		Older Adults (post)- E	5.89 (1.62)		

Table 6.4 Means, standard deviations and Analysis of Variance (ANOVA) results given by age, group and time - dual task

Condition	Variable(s)		Mean (S.D)	ANOVA results	Effect Size (η^2_p)
Dual Task	Age	Younger Adults	7.32 (2.40)	$F(1, 36)=38.46, p<.001$	.53
		Older Adults	3.56 (1.88)		
	Time	Pre strategy training	4.65 (1.79)	$F(1, 36)=13.38, p=.001$	.28
		Post strategy training	6.23 (2.49)		
	Group	Experimental	5.31 (2.30)	$F(1, 36)= 0.19, p= .67$	.01
		Control	5.57 (1.98)		
	Age x Time	Younger Adults (pre)	6.52 (1.81)	$F(1, 36)= 0.03, p=.96$	.01
		Younger Adults (post)	8.12 (2.99)		
		Older adults (pre)	2.78 (1.78)		
		Older adults (post)	4.34 (1.98)		
	Group x Time	Experimental (pre)	4.00 (1.51)	$F(1, 36)= 5.73, p= .02$	.14
		Experimental (post)	6.61 (3.10)		
		Control (pre)	5.30 (2.08)		
		Control (post)	5.85 (1.88)		
	Group x Age	Experimental Younger	6.78 (2.26)	$F (1, 36)= 1.83, p=.19$	.05
		Experimental Older	3.84 (2.34)		
		Control Younger	7.87 (2.54)		
		Control Older	3.28 (1.42)		
	Age x Time x Group	Younger Adults (pre) –C	7.82 (2.52)	$F (1, 36)= .04, p=.84$	.01
		Younger Adults (post) C	7.91 (2.55)		
		Younger Adults (pre) E	5.22 (1.09)		
		Younger Adults (post)- E	8.33 (3.43)		
		Older Adults (pre)- C	2.78 (1.39)		
		Older Adults (post)- C	3.78 (1.20)		
		Older Adults (pre)- E	2.78 (1.92)		
		Older Adults (post)- E	4.89 (2.76)		

As this study used high imagery words, it was anticipated that this would be more amenable to an imagery strategy and therefore would result in an increase in performance from time 1 to time 2. Looking at the means it can be seen that in the single task condition, both younger adults in the control and experimental did improve their performance from time 1 to time 2. . In contrast older adults recalled slightly less words, yielding a marginally significant interaction of Age x Time. Younger adults were also shown to recall more words than older adults at time 1 and time 2, reflected by the main effect of age. The main effect of time, or the Age x Group x Time were not significant.

In the dual tasks a main effect of age was found, with younger adults recalling more words than older adults. A main effect of time was also found, demonstrating that participants did improve their performance from time 1 to time 2. Inspection of the means revealed that this was the case for both younger and older adults. The Time x Group interaction was significant, showing that those in the experimental group significantly improved their performance, whereas those in the control group did not.

Overall, the findings suggest that strategy training did not really benefit participants in the single task; although younger adults did improve their performance, this was true for both the control and experimental groups. In the dual tasks, both younger and older adults benefitted from strategy instruction. Of course, as the words are of a high imagery level it may be that participants were more likely to already be using an effective strategy at pre-test. This question will be examined in the main analysis.

6.3.3   Main Analysis

6.3.3.1   Research Question 1: Spontaneous Strategy Use

Table 6.5 Percentage of overall strategy use, and as a function of age - experimental group

Strategy Type	Overall				Younger Adults				Older Adults			
	ST1	DT1	ST2	DT2	ST1	DT1	ST2	DT2	ST1	DT1	ST2	DT2
Read	15.00	30.00	5.00	25.00	0.00	20.00	0.00	9.10	33.30	44.40	11.10	44.40
Repetition	45.00	50.00	25.00	30.00	72.70	60.00	27.30	27.30	11.10	44.40	22.20	33.30
Sentence	10.00	0.00	30.00	10.00	0.00	0.00	45.50	18.20	22.20	0.00	11.10	0.00
Imagery	20.00	5.00	35.00	35.00	27.30	10.00	27.30	45.50	11.10	0.00	44.40	22.20
Grouping	0.00	5.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	11.10	11.10	0.00
Other	10.00	5.00	0.00	0.00	0.00	10.00	0.00	0.00	22.20	0.00	0.00	0.00

Table 6.6 Percentage of overall strategy use, and as a function of age - control group

Strategy Type	Overall				Younger Adults				Older Adults			
	ST1	DT1	ST2	DT2	ST1	DT1	ST2	DT2	ST1	DT1	ST2	DT2
Read	20.00	20.00	20.00	20.00	18.20	9.10	18.20	18.20	22.20	33.30	25.00	25.00
Repetition	25.00	40.00	30.00	30.00	18.20	45.50	18.20	9.10	33.30	33.30	50.00	62.50
Sentence	15.00	10.00	20.00	20.00	18.20	18.20	18.20	27.30	11.10	0.00	25.00	12.50
Imagery	30.00	20.00	20.00	25.00	45.50	27.30	36.40	45.50	11.10	11.10	0.00	0.00
Grouping	10.00	10.00	5.00	0.00	0.00	0.00	9.10	0.00	0.00	22.20	0.00	0.00
Other	0.00	0.00	0.00	0.00	0.00	9.10	0.00	0.00	22.20	0.00	0.00	0.00

ST1- Single task1, DT1- Dual task1, ST2-Single task2, DT2- Dual task2

Table 6.5 and Table 6.6 show that a number of strategies are reported when completing the tasks. Looking at spontaneous strategy use (T1), the distribution of strategy use does seem to differ between younger and older adults. Older adults are more likely to report 'just reading the words', compared to younger adults. Younger adults reported using imagery more, and also used repetition to a greater extent in both single and dual tasks. Additionally, despite random allocation to groups, there does seem to be some differences in the strategies reported in the experimental and control condition at time 1. Those in the experimental group reported using rehearsal more than those in the control group.

To determine if any of these differences were significant, Chi-square analyses were performed. Using the same method as study 2, reported strategies were collapsed into groups ('normatively effective' and 'less effective') to maximise numbers in each cell.[18]

Table 6.7 Percentage of reported effective and less effective strategy use in T1 tasks

	Experimental					
	Overall		Younger		Older	
	Effective	Less Effective	Effective	Less Effective	Effective	Less Effective
ST 1	30.00	60.00	27.30	72.70	42.90	57.10
DT 1	10.00	80.00	11.10	88.90	11.10	88.90
	Control					
	Overall		Younger		Older	
	Effective	Less Effective	Effective	Less Effective	Effective	Less effective
ST1	45.00	45.00	63.60	36.40	28.60	71.40
DT1	40.00	60.00	45.50	54.50	33.30	66.70

ST1- Single task 1, DT1- Dual task 1

As can be seen from Table 6.7, there does seem to be some differences in effective strategy use between the control and experimental group. Overall, those in the control group seem to have a higher percentage of effective strategy use in the single and dual tasks. A Chi-square[19] analysis found that this was significant in the dual tasks χ^2 (1, N= 38)= 4.07, p= .048, one-

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[18] Those who reported using the 'other' strategy were excluded from the analysis. Therefore some of the percentages reported in Table 6.7 do not add up to 100%, and the N and df differ.

[19] As some expected frequencies were below 5, Fisher's exact is reported instead.

tailed, φ_c =.33. A higher level of less effective strategy use was reported in the dual tasks, compared to the single tasks. Surprisingly, younger adults reported using a less effective strategy more than older adults in the single task, in the experimental group. However, this was not significant. No age differences were found (all p's $\geq$.17).

A 2 (Age- older, younger) x 2 (Strategy- effective, less effective) x 2 (Group, experimental, Control) ANOVA was performed to ascertain whether it was advantageous to use an effective strategy in the tasks, and whether there were age or group differences in performance.

Single task- A main effect of age was found, with younger adults performing better than older adults (F[1, 28]= 7.13, p=.01, η^2_p=.20). A main effect of strategy was also found, with those using an effective strategy outperforming those using a less effective strategy. (F[1, 28]= 21.72, p=<.001,η^2_p=.44). The main effect of Group was not significant (F<1). There was however a marginally significant interaction between Group and Strategy, with those in the experimental group scoring less than those in the control group when using an effective strategy, but more when using a less effective strategy.(F[1, 28]=3.13, p=.09, η^2_p =.10. No other interactions were significant (all $F's$ <1).
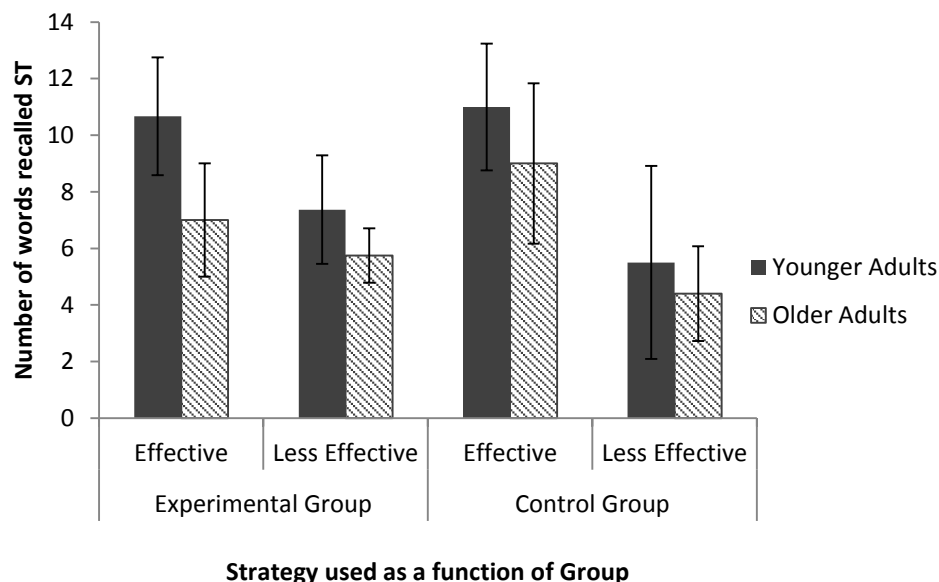
Figure 6.1 Number of words recalled by older and younger adults in the control and experimental group when using an effective or less effective strategy in the single task

Dual task – Younger adults were shown to recall more words than older adults ($F[1, 29]=$ 19.73, $p< .001$, $\eta^2_p =.41$). Additionally those opting to use an effective strategy outperformed those using a less effective strategy, which was the case for both older and younger adults However, as can be seen from Figure 6.2, younger adults in the control condition scored considerably higher than those in the experimental condition, whereas older adults scored marginally better in the experimental condition. This was reflected by a significant Age x Group interaction ($F[1, 29]= 4.65$, $p= .40$, $\eta^2_p =.14$). This is not too surprising, given that younger adults in the control condition did report using effective strategies more than those experimental condition. However, these results do need to be interpreted with caution, owing to the fact that very few participants reported using an effective strategy in the dual task condition.
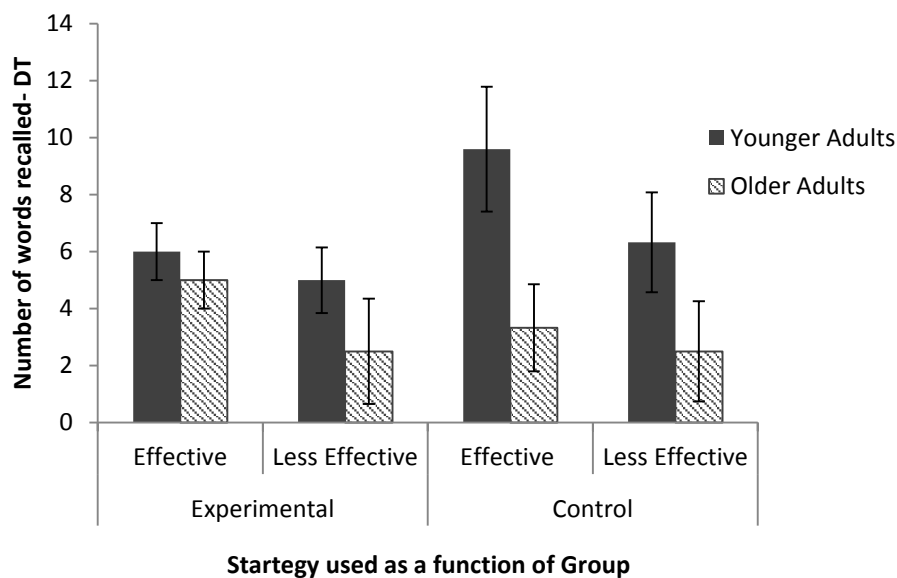
Figure 6.2 Number of words recalled by older and younger adults in the control and experimental group when using an effective or less effective strategy in the dual task

Imagery/Association vs Rehearsal

The analysis was repeated removing participants who reported 'just reading the words' (no strategy) to get a clearer indication of whether those opting to use an imagery/association performed better than those using a rehearsal strategy. To that end, 2 x 2 x2 ANOVAs were conducted with age (younger, older), strategy (imagery/association, rehearsal) and group (experimental, control) as between subject variables and the amount of words recalled as the DV.

Single task- The same pattern of results was found, however this time the main effect of age was only marginally significant ($p= .08$), and the interaction between Group and strategy was significant ($F[1, 21]= 6.33$, $p=.02$, $\eta^2_p=.23$).

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Dual task- The main effect of age was significant, with younger adults recalling a greater number of words than older adults. ($F[1, 16]= 11.94$, $p= .003$, $\eta^2_p =.43$). All other main effects and interactions were not significant. Of course, as participants who reported 'no strategy' were excluded from the analysis this resulted in a reduced sample size, which could be a contributing factor for the lack of results found.

Secondary Task data

To determine how secondary task performance was affected by the use of an effective or less effective strategy in the primary task, the analysis was repeated using the secondary task as the DV. As stated earlier, it could be that as implementing an effective strategy is thought to require more cognitive resources compared to a less effective one, this may manifest as decreased performance in the secondary task (increased RT). Of course a better method would be to directly compare the same people and see if their RT increases/decreases when using a different strategy, but this is not possible when examining spontaneous strategy use. This is examined in no-choice conditions, which is detailed later on in the results section.

A 2 (age, younger/older) x 2 (Strategy, effective/less effective) x 2 (Group, experimental/ control) ANOVA was performed with the DV of Reaction time in dual task1. The results revealed that although using an effective strategy culminated in an increased RT ($M=1805.34$, $SD= 921.38$ ms) compared to when utilising a less effective strategy ($M= 1430.76$, $SD= 737.01$ ms), this was not significant ($p= .32$). Contrary to expectations, older adults were quicker at responding to the tones in the dual task condition than younger adults ($M=1359.41$, $SD= 1012.11$ and $M=1876.69$, $SD= 939.09$ ms, respectively), however this was also not significant ($p= .17$). The Group x Age interaction was marginally significant, demonstrating that younger adults in the experimental group had slower reaction times ($M=2310.95$, $SD=1009.35$ ms) than those in the control group, ($M=1442.42$, $SD=1027.29$ ms) whereas older adults displayed the opposite pattern (experimental group- $M=1140.30$, $SD= 683.31$ ms, control $1578. 52$, $SD= 207.14$ ms), ($F[1, 28=3.12$, $p=.09$, $\eta^2_p=.10$).

When this analysis was repeated with the number of errors made in the tone task as the DV, no significant results emerged (all p's ≥ .15).

6.3.3.2 *Research Question 2: Adaptive Strategy Use*

To address the issue of whether participants increased their use of effective strategy use from time to time 2 a McNemar analysis was performed. Firstly this was conducted on all participants and revealed that in single tasks at time 2 participants reported using an effective strategy more than at time 1 (61.11% and 41.67% respectively), however this increase was only marginally significant ($N=36$, $p = .09$, $\varphi = .33$).

Of course, it was expected that only those participants who undertook strategy training should increase their use of effective strategies. Therefore, the analysis was repeated for those in the experimental and control condition separately. It was found that those in the experimental group did significantly increase their effective strategy use from 33.33% at time 1 to 72.22% at time 2 ($n= 18$, $p= .02$, $\varphi = .44$). Participants in the control condition did not increase their effective strategy use, despite having an initial higher level of effective strategy use; it remained at 50% for both times.

When this was further examined by age, it was found that although both younger adults and older adults in the experimental group increased their effective strategy use, however this difference was only marginally significant for younger adults (27.27% at time 1 and 72.73% at time 2, n= 11, p= .06, $\varphi = .38$).

A different pattern emerged in the dual tasks. When all of the participants were examined, it was found that although there was an increase in effective strategy use from time 1 (27.00%) to time 2 (43.20%) this was not significant ($p= .21$). As with the single tasks, it was expected that only those in the experimental group should increase their effective strategy use in the dual tasks. Although effective strategy use was elevated at time 2 (38.9%) compared to time 1 (11.1%) this was not significant ($p= .13$). There was less of an increased difference in the control group, however their effective strategy use was higher than that of the experimental group at both times (42.11% at time 1, and 47.70% at time 2).

A marginal increase in effective strategy use was found in younger adults compared to older adults, regardless of what group they were in. Younger adults showed an overall increase (30% at time 1 and 65% at time 2), whereas older adults showed a slight decrease in effective strategy use (23.5% and 17.6% respectively). Further examination of the data revealed that this decrease was mainly due to the older adults in the control group who yielded a non-significant decrease in their effective strategy use from 37.50% at time 1 to 12.5% at time 2.

It was important to establish whether using an effective strategy was actually beneficial for performance. Therefore 2 x 2 x 2 ANOVAs were undertaken with Age (younger and older). Strategy (Effective and Less effective) and Group (Experimental and Control) as IVs and number of words recalled as the DV for single and dual tasks separately.

Single task- A main effect of age was found with younger adults recalling more words than older adults ($F[1, 31]=29.10$, $p<.001$, $\eta^2_p= .48$). The main effect for strategy was also significant ($F[1, 31]= 7.41$, $p= .01$, $\eta^2_p=.19$), with those using a more effective strategy outperforming those with using a less effective strategy. This was irrespective of which condition the participants were in. All other main effects and interactions were not significant (all p's $\geq .17$).
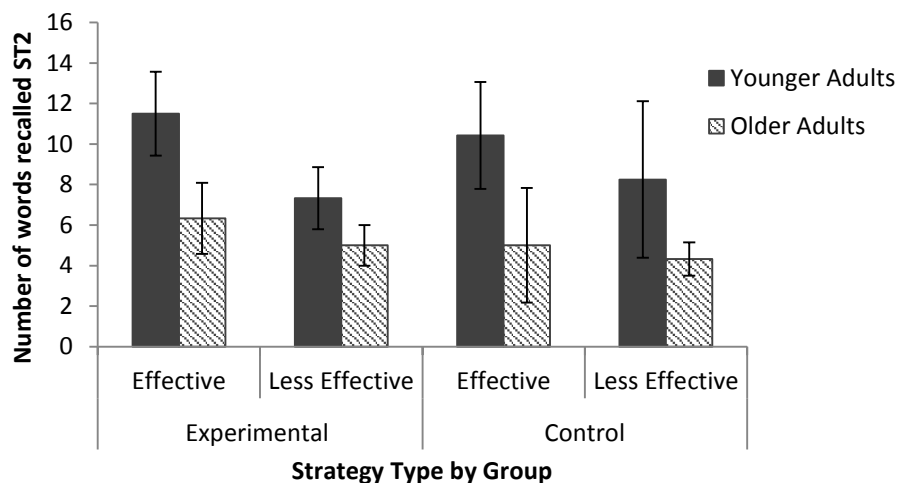
Figure 6.3 Mean number of words recalled by younger and older adults in the experimental and control group using an effective or less effective strategy in the single task T2

Dual task- Younger adults recalled more words than older adults (M= 7.35, SD= 2.39 M= 5.13, SD= 2.95 respectively, F[1,31]= 5.31, p=.03, η^2_p =.15). The main effect of strategy was significant, with those using an effective strategy (M= 7.81, SD=3.86) outperforming those using a less effective strategy (M =4.67, SD= 1.71), (F[1, 31]= 10.57, p= .01, η^2_p= .26). Despite a slight advantage in recall for those in the experimental group (M= 6.48, SD= 3.38) compared to the control group (M=6.00, SD= 1.63) the main effect of strategy was not significant (F< 1). No significant interactions were found (all $F's$ <1).

Imagery/Association vs Rehearsal

When the analysis was repeated excluding those who reported not using a strategy, the pattern of results was identical for the single tasks. For the dual tasks, only the main effect of strategy was significant, age differences failed to manifest (p= .11)

Secondary task data

A 2 (age, younger/older) x 2 (Strategy, effective/Less effective) x2 (Group, Experimental/Control) ANOVA was performed to ascertain how the secondary task was affected by the implementation of a strategy in the primary task when both were performed concurrently. In contrast to the results obtained at time 1 and in light with expectations, younger adults were shown to have faster RT times than older adults (M=1121.57, SD=747.71ms, M= 1628.88, SD= 499.85, respectively). This difference was found not to be significant (p=.11). Oddly, utilisation of an effective strategy resulted in quicker RT's in the secondary task, but this was not significant (p=.13). There was however, a main effect of group, with those in the experimental group exhibiting quicker reaction times than those in the control group (M= 1044.96, SD= 321.31 ms compared to M= 1705.49, SD = 1068.39 ms). There was also no evidence of any interactions occurring (all $p's \geq$ .21).

6.3.3.3 _Research Question 3: Strategy Execution- No-choice Conditions_

To assess strategy execution, participant's performance was examined when they were asked to use a specific strategy (imagery or rehearsal). As the same type of strategy was used in both single and dual tasks, then how word recall performance was affected by the introduction of a dual task for each strategy could be determined. Typically, individuals perform worse in dual task conditions then single task performance, referred to as a dual task

deficit. (Ref). As dual task conditions require additional resources, whether they will manifest when utilising a less demanding strategy like rehearsal is not known.

 The impact of age will also be examined in order to ascertain if there are age-differences in strategy execution or whether there is any condition x age interactions.   To that end separate 2 x2 ANOVA s were run for the imagery and rehearsal strategy, with age as a between groups factor and condition as a within groups factor. These were conducted on only on the participants who reported complying to strategy instructions to avoid confounding the data with other strategies.

The results of the ANOVAs are presented in Table 6.8.

Table 6.8 Means, standard deviations and ANOVA results as a function of age and task condition when using an imagery and rehearsal strategy

Strategy Type	Variable(s)		Mean (SD)	ANOVA Results	Effect Size (η^2_p)
Imagery	Age	Younger Adults	9.57 (2.90)	$F(1, 13)= 11.28$, $p= .005$	.47
		Older Adults	5.86 (1.37)		
	Condition	Single task	8.87 (3.31)	$F(1, 13)= 17.14$, $p=.001$	.57
		Dual task	6.80 (3.36)		
	Age x Condition	Younger Adults- Single task	10.25 (2.49)	$F (1, 13)= 2.10$, $p=.17$	.14
		Younger Adults- Dual task	8.88 (3.31)		
		Older Adults- Single task	7.29 (1.68)		
		Older Adults- Dual task	4.43 (1.13)		
Rehearsal	Age	Younger Adults	6.65 (1.56)	$F (1, 17)=25.43$, $p<.001$	.60
		Older Adults	4.11 (1.31)		
	Condition	Single task	5.53(1.58)	$F (1, 17)= 0.11$, $p=.75$	.01
		Dual task	5.37 (2.31)		
	Age x Condition	Younger Adults- Single task	6.70 (1.16)	$F (1, 17)= 0.15$, $p=.90$	.01
		Younger Adults- Dual task	6.60 (1.96)		
		Older Adults- Single task	4.22 (0.67)		
		Older Adults- Dual task	4.00 (1.94)		

Looking at Table 6.8, it is evident that younger adults performed better than older adults in both conditions, this was reflected by a main effect of age. Additionally, participants also experienced a dual task deficit and recalled more words in the single task condition, than in the dual task condition. This pattern was the same for older and younger adults, as no age x condition interaction was found.

The results were markedly different in the rehearsal condition. Although age differences were present with younger adults recalling a greater number of words than older adults, the main effect of condition was not. Both older and younger adults recalled a similar amount of words in the single and dual tasks.

Secondary tasks

To understand how secondary task performance was affected by the different strategies the analysis was repeated using RT as the DV in the single and dual tasks. Firstly, it can be assessed if the secondary task is susceptible to dual task interference by seeing if the RT in the auditory discrimination task is increased in the dual task as compared to the single task. Secondly, it can be determined whether there are differences in the secondary task performance when an imagery strategy is used in the primary task, or a rehearsal strategy is used in the primary task. Additionally, it allows for comparison to the results in the primary task and to give an indication of whether participants are sacrificing performance in one task in order to boost performance in the other.

Two 2 x 2 ANOVAs were run with condition (single, dual) as a within subjects factor and age (younger, older) as a between groups factor, for the imagery and rehearsal condition separately.

Imagery- Results revealed that there was no effect of condition, participants responded similarly in the single and dual tasks. The main effect of age was significant, with older adults responding slower than younger adults, (F[1, 12]= 4.87, p=.048, η^2_p =.29) . The age x condition interaction was also significant (F[1, 12]=8.66, p=.01, η^2_p= .42). As depicted in Figure 6.4, younger adults displayed a classic dual

task deficit, with increased RT in the dual task compared to the single task. Older adults exhibited the opposite pattern, with quicker reaction times in the dual task.
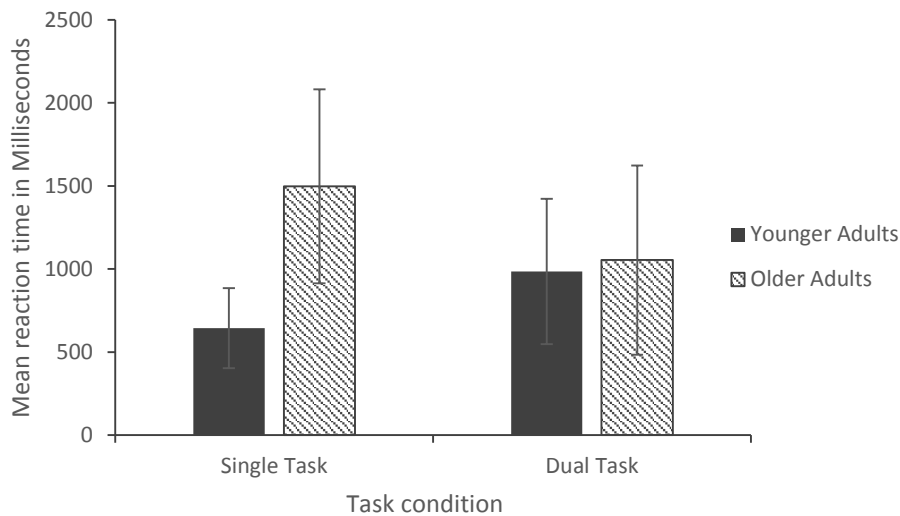
Figure 6.4 Secondary task performance of older and younger adults when performing the task singly or concurrently when using an imagery strategy in the primary task

Rehearsal – As with the imagery condition, participant's RTs were similar in the single and dual task (*M*=751.96, *SD*= 521.56 ms and *M*=787.98, *SD*= 326.99 ms), *p*= .81. Although older adults exhibited greater RTs (*M*=943.01, *SD*=530.73 ms) in comparison to younger adults (*M*=666.14, *SD*=284.76 ms), this difference was not significant (*p*= .15). Identical to the imagery condition, younger adults had quicker RTs in the single task compared to the dual task condition, and older adults had quicker RTs in the dual task condition. However, the Condition x Age interaction was only marginally significant (*F*[1, 14]=3.82, *p*= .07, η^2_p=.21).

Within Task

Being that this study used high imagery words, it was anticipated that the imagery strategy would be far superior to a rehearsal strategy. Whether this advantage would transfer to a dual task condition was more speculative. To answer these questions, a mixed 2 x2 ANOVA was conducted for the single and dual tasks individually, with age (younger vs older) as a between factors variable and type of strategy used (imagery vs rehearsal) as a within subjects variable.

Single task: As can be seen by Figure 6.5, it was revealed that when participants used an imagery strategy they recalled more words than when using a rehearsal strategy (F[1, 15]=28.41, p<.001, η^2_p= .65). The main effect of age was also significant; a greater number of words was recalled by younger adults in comparison to older adults (F[1, 15]=14.97, p=.002, η^2_p=.50). The results revealed that no Age x Strategy interaction was taking place.
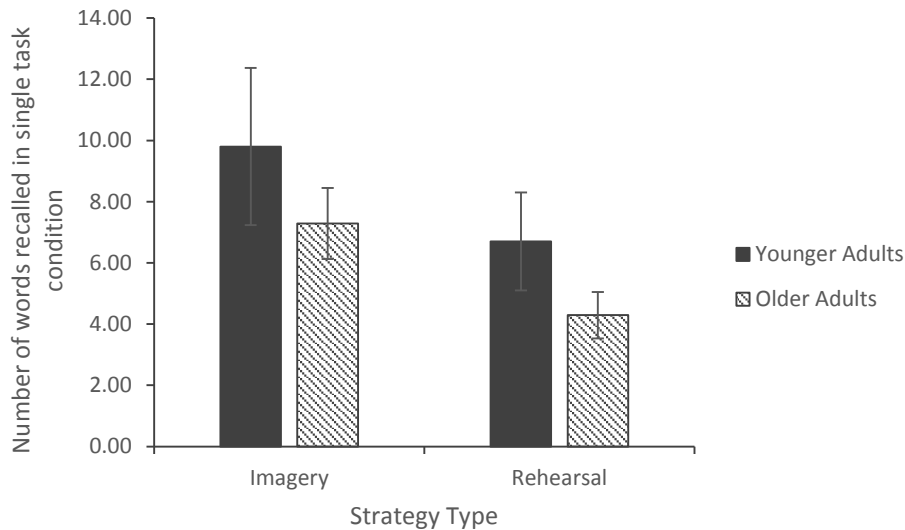
Figure 6.5 Mean number of words recalled by older and younger adults when using an imagery or rehearsal strategy

Dual task: In contrast to the findings in the single task condition, the main effect of strategy was not significant (p= .20). There was no significant advantage in using an imagery strategy (*M*= 6.65, *SD* =2.22) compared to a rehearsal strategy (*M*= 5.65, *SD*= 2.04). The main effect of age was significant, with younger adults outperforming older adults, (F[1, 13]=13.38, p=.003, η^2_p= .51). There was no age x strategy interaction (*p*= .20).

Secondary task performance.

Secondary task performance was examined to see whether implementing a more effortful strategy such as imagery would require additional resources, and manifest as increased RT in this condition in comparison to the rehearsal condition. Although this should only be apparent in the dual task (as the strategy used in the primary task will only affect performance when both tasks are performed concurrently), single task

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performance was also examined in order to establish if there were any baseline differences.

Single task- As expected, there were no differences in performance of the secondary task when an imagery strategy was used in the primary task, or a rehearsal strategy was used (*M*= 921.54, *SD*= 427.85 ms, compared to *M*= 822.72, *SD* = 626.38 ms, *p*= .32). There was an effect of age, older adults had greater RTs than younger adults (*M*= 1301.09, *SD*= 722.51 ms and *M*= 571.87, *SD*= 204.34 ms, respectively), $F(1, 15)$ =11.28, *p*=.004, $\eta^2_{p=}$ .43. There was no evidence of an age x strategy interaction (*F*<1).

Dual task- A different pattern of results was obtained for the dual task conditions. As can be seen in Figure 6.6, an imagery strategy in the primary task was accompanied by greater RTs in the secondary task when compared to using a rehearsal strategy although this was only marginally significant, $F(1, 10)=3.64$, *p*=.09, $\eta^2_{p=}$ .27). Although younger adults were shown to have quicker RTs than older adults (*M*= 926.78, *SD*= 423.83 ms, compared to *M*= 971.23, *SD*= 440.12 ms), this difference was not significant (*F*<1). Inspection of Figure 6.6 reveals that that older adults had quicker reaction times than younger adults in the rehearsal condition, but slower reaction times in the imagery condition. However the age x strategy interaction was not significant (*p*= .27).
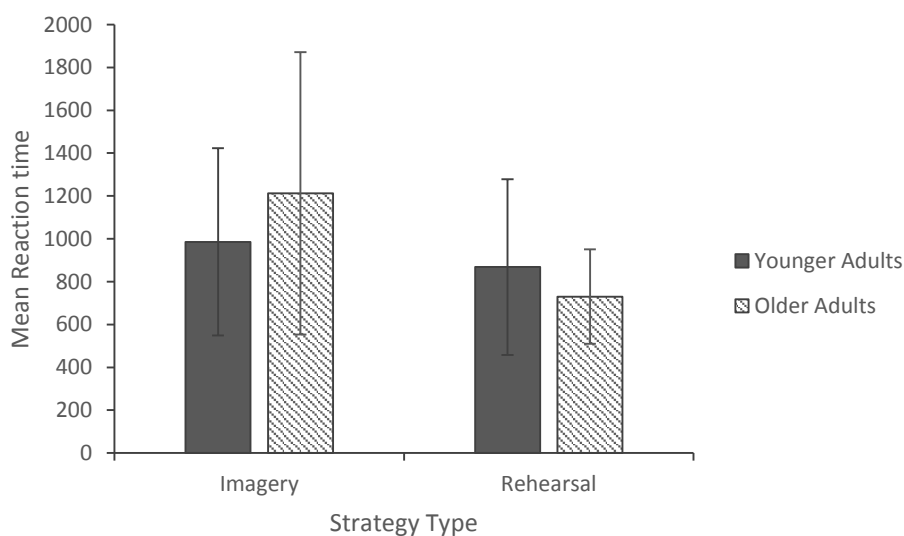
Figure 6.6 Mean reaction time of older and younger adults in the secondary task when using an imagery or rehearsal strategy in the primary task

6.3.3.4 Research Question 4: Are different strategies used for single task and dual task conditions?

Choice Condition

Time 1-The ANOVA results are reported in section 6.3.3.1. For both the single and dual tasks a main effect of strategy was found, with those utilising an effective strategy scoring higher than those using a less effective strategy. This pattern was the same for both older and younger adults.

Time 2- Post strategy training, a main effect of strategy was found in both the single and dual task condition in the expected direction (see section 6.3.3.2 for ANOVA results). This was the case for older and younger adults.

No-choice conditions

Taken together with the analysis conducted both between and within strategy type (see section 6.3.3.3) an imagery strategy was shown to be a superior strategy in single tasks. However in dual tasks, the imagery and rehearsal strategy were shown to produce equivalent performance. The absence of any age x strategy interactions indicates that this pattern applied to both older and younger adults.

6.3.3.5 Research Question 5: Cognitive Resources

To determine if cognitive resources (such as working memory and cognitive flexibility) were important for strategy use and performance in the single and dual tasks, the data were subjected to a series of ANOVAs. Strategy use (effective vs less effective), Group (experimental, control) and Age (younger, older) were between groups independent variables and the cognitive resource measures were the dependent variables. The results are reported in Table 6.9, and significant and marginally significant results are highlighted in bold.

Table 6.9 Summary of ANOVA results for processing resources given by strategy group and age (significant results highlighted in bold)

Task DV	Strategy used in word recall task (single task)		Strategy used in word recall task (dual task)	
	Summary Results	ANOVA Results	Summary Results	ANOVA Results
IED-TEA	**Main effect of Age**	**$F(1,28)= 10.07, p=.004, \eta^2_p =.27$**	No main effect of Age	$F(1,30)=2.30, p=.14, \eta^2_p=.07$
	Marginal effect of Strategy	**$F(1, 28)=3.03, p=.09, \eta^2_p =. 10$**	No effect of Strategy	$F(1,30)=1.57, p=.09, \eta^2_p = .05$
	No main effect of Group	$F(1, 28)=0.32, p=.86, \eta^2_p=.01$	No main effect of Group	$F(1, 30)=1.27, p=.27, \eta^2p =.04$
	Marginal Age x Strategy	**$F(1,28)=3.31, p=.14, \eta^2_p = .16$**	No Age x Strategy	$F(1, 30)=1.00, p=.33, \eta^2p =.03$
	No Age x Group	$F(1, 28)=2.28, p=.14, \eta^2_p =.08$	No Age x Group	$F(1, 30)=0.94, p=.76, \eta^2_p =.01$
	No Group x Strategy	$F(1, 28)=2.13, p=.16, \eta^2_p =. 07$	No Group x Strategy	$F(1, 30)=0.00, p=.10, \eta^2p <.01$
	No Group x Strategy x Age	$F(1, 28)=.01, p=.93, \eta^2_p =. 01$	No Group x Strategy x Age	$F(1, 30)=0.13, p=.72, \eta^2p <.01$
SWM-BE	**Main effect of Age**	**$F(1,28)=29.71, p<.001 \; \eta^2_p =.52$**	**Main effect of Age**	**$F(1,30)=13.38 \; p<.001, \eta^2_p .38$**
	No main effect of Strategy	$F(1,28)=0.36, p=.53, \eta^2_p =.01$	No main effect of Strategy	$F(1, 30) =0.11, p=.75, \eta^2_p <.01$
	No main effect of Group	$F(1, 28)=0.09, p=.92, \eta^2_p =.01$	No main effect of Group	$F(1, 30)=1.15, p=.29, \eta^2p =.04$
	No Age x Strategy	$F(1, 28)=0.40, p=.28, \eta^2_p =.01$	**Age x Strategy**	**$F(1, 30)=8.50, p=.007, \eta^2p =.35$**
	No Age x Group	$F(1, 28)=1.10, p=.30, \eta^2_p =. 04$	No Age x Group	$F(1, 30)=0.86, p=.36, \eta^2_p=.03$
	No Group x Strategy	$F(1, 28)=0.40, p=.53, \eta^2_p =. 01$	No Group x Strategy	$F(1,30)=0.61, p=.44, \eta^2_p= .02$
	No Group x Strategy x Age	$F(1, 28)=1.13, p=.30, \eta^2_p =. 04$	No Group x Strategy x Age	$F(1, 30)=1.35, p=.25, \eta^2_p .04$
SWM 4,6,8	**Main effect of Stage**	**$F(2,54)=186.00, p<.001, \eta^2_p =.88$**	**Main effect of Stage**	**$F(2,58)=98.38, p<.001, \eta^2_p=.77$**
	Main effect of Age	**$F(1, 27)=51.38, p=.001, \eta^2_p =.65$**	**Marginal main effect of Age**	**$F(1, 29)=21.53 \; p<.001, \eta^2_p =.23$**
	No main effect of Group	$F(1, 27)=0. 46, p=.50, \eta^2_p= .02$	No Main effect of Group	**$F(1, 29)=0.63, p=.44, \eta^2_p =.04$**
	No main effect of Strategy	$F(1, 27) =0.00, p=.98, \eta^2_p <.01$	No Main effect of Strategy	$F(1, 29)=0.88, p=.36, \eta^2_p =.03$

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	Stage x Age	$F(2,54)=30.95, p<.001, \eta^2_p =.53$	**Stage x Age**	$F(2, 58)=10.00, p<.001, \eta^2_p =.26$
	Marginal Stage x Strategy	$F(2, 54)=2.87, p=.07, \eta^2_p =.10$	No Stage x Strategy	$F(2, 58)=0.54, p=.59, \eta^2_p =.02$
	No Stage x Group	$F(2, 54)=0.41, p=.67, \eta^2_p =.02$	No Stage x Group	$F(2, 58)=0.18, p=.84, \eta^2_p <.01$
	No Age x Group	$F(1, 27)=0.04, p=.55, \eta^2_p =.01$	No Age x Group	$F(1, 29)=2.25, p=.14, \eta^2_p =.07$
	No Age x Strategy	$F(1, 27)=1.99, p=.17, \eta^2_p =.07$	No Age x Strategy	$F(1, 29)=8.24, p=.008, \eta^2_p =.21$
	No Group x Strategy	$F(1, 27)= 0.02, p=.91, \eta^2_p =.01$	No Group x Strategy	$F(1, 29)=0.23, p=.64, \eta^2_p =.15$
	No Stage x Age x Group	$F(1, 54)=0.96, p=.39, \eta^2_p =.03$	No Stage x Age x Group	$F(2, 58)=1.24, p=.30, \eta^2_p =.04$
	No Stage x Age x Strategy	$F(1, 54)=1.12, p=.33, \eta^2_p =.04$	**Stage x Age x Strategy**	$F(2, 58)=4.18, p=.02, \eta^2_p =.13$
	No Stage x Group x Strategy	$F(1, 54)=0.29, p=.75, \eta^2_p =.01$	No Stage x Group x Strategy	$F(2, 58)=0.04, p=.96, \eta^2_p < .01$
	No Age x Group x Strategy	$F(1, 27)=0.22, p= .65, \eta^2_p =.01$	**Marginal Age x Group x Strategy**	$F(1, 29)=3.20, p=.08, \eta^2_p =.10$
	No Stage x Age x Group x Strategy	$F(1, 54)=0.10, p=.90, \eta^2_p =.01$	No Stage x Age x Group x Strategy	$F(2, 58)=1.31, p=.29, \eta^2_p =.04$
SWM-S	**Main effect of Age**	$F(1,28)=23.41, p<.001, \eta^2_p =.46$	**Main effect of Age**	$F(1,30)=11.79, p=.002, \eta^2_p =.28$
	No main effect of Strategy	$F(1,28)= 0.20, p=.66, \eta^2_p= .01$	No main effect of Strategy	$F(1, 30)=0.77, p=.78, \eta^2_p <.01$
	No main effect of Group	$F(1, 28)=1.08, p=.31, \eta^2_p =.04$	No main effect of Group	$F(1, 30)=2.95, p=.10, \eta^2_p =.09$
	No Age x Strategy	$F(1,28)= 0.80, p=.33, \eta^2_p =.03$	**Age x Strategy**	$F(1, 30)=7.33, p=.01, \eta^2_p =.20$
	No Age x Group	$F(1, 28)=3.12, p=.09, \eta^2_p =.10$	No Age x Group	$F(1, 30)=0.40, p=.54, \eta^2_p =.01$
	No Group x Strategy	$F(1, 28)=0.01, p>.99, \eta^2_p =.01$	No Group x Strategy	$F(1, 30)=0.12, p=.73, \eta^2_p <.01$
	No Group x Strategy x Age	$F(1, 28)=0.01, p =.97, \eta^2_p =.01$	No Group x Strategy x Age	$F(1, 30)-0.61, p=.44, \eta^2_p =.02$
SOC-Min	**Main effect of Age**	$F(1, 28)=4.25, p= .049, \eta^2_p =.13$	No main effect of Age	$F(1, 30)=1.00, p=.34, \eta^2_p =.03$
	No main effect of Strategy	$F(1, 28)=1.54, p= .23, \eta^2_p = .05$	No main effect of Strategy	$F(1,30)=2.62, p=.12, \eta^2_p =.08$

No main effect of Group	$F_{(1,28)} = 0.31$, $p = .83$, $\eta^2_p = .01$	No main effect of Group	$F_{(1, 30)} = 0.11$, $p = .74$, $\eta^2_p < .01$
No Age x Strategy	$F_{(1, 28)} = 0.82$, $p = .37$, $\eta^2_p = .03.$	No Age x Strategy	$F_{(1, 30)} = 1.92$, $p = .18$, $\eta^2_p = .06$
No Age x Group	$F_{(1, 28)} = 0.19$, $p = .89$, $\eta^2_p = .01$	No Age x Group	$F_{(1, 30)} = 2.54$, $p = .12$, $\eta^2_p = .08$
No Group x Strategy	$F_{(1, 28)} = 1.76$, $p = .20$, $\eta^2_p = .06$	No Group x Strategy	$F_{(1, 30)} = 1.72$, $p = .20$, $\eta^2_p = .06$
No Group x Strategy x Age	$F_{(1, 28)} = 1.67$, $p = .21$, $\eta^2_p = .06$	**Group x Strategy x Age**	$\mathbf{F_{(1, 30)} = 8.59}$, $\mathbf{p < .01}$, $\boldsymbol{\eta^2_p = .22}$

IED-TE(A) Intra-extra Dimensional Task-Total errors (adjusted), , SWM- BE= Spatial Working Memory task between errors, SWM-4,6,8= Spatial Working Memory, 4 box, 6 box and 8 box problems, SWM= Spatial Working Memory task Strategy, SOC-Min= Stockings of Cambridge task minimum amount of moves.

The role of cognitive flexibility on self-initiated effective strategy use was assessed using the total adjusted errors as the DV.

Strategy used in single task: The results showed that younger adults committed fewer errors than older adults. There was also a significant main effect for strategy, showing that those who used an effective strategy committed less total errors then those who used a less effective strategy. However, this effect may be in part driven by the strategy x Age interaction depicted in Figure 6.7. Older adults using a less effective strategy made more errors than those using an effective strategy. Younger adults had comparable performance when using an effective or less effective strategy.
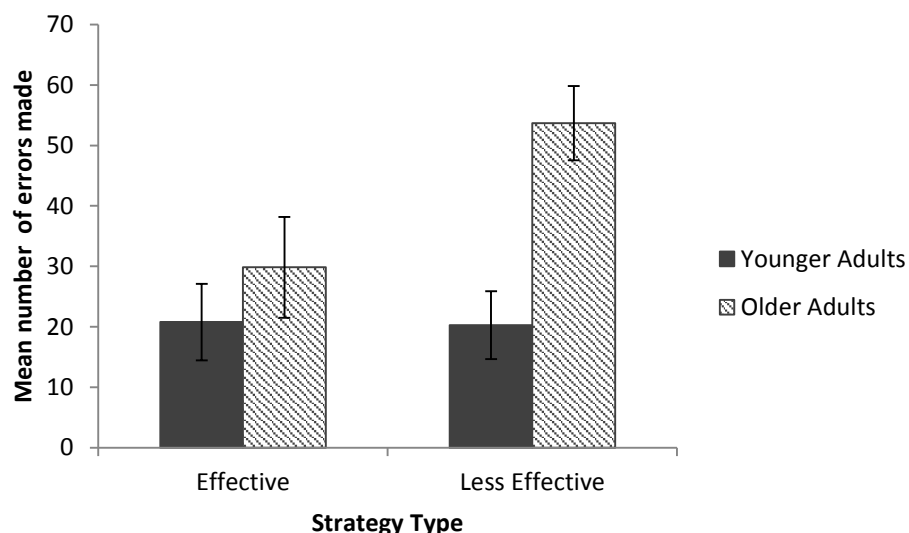
Figure 6.7 Mean number of IED adjusted errors made by younger and older adults when using an effective or less effective strategy. Error bars represent one standard error above and below the mean

Strategy used in dual task: No main effects or interactions were found.

SWM-*Between Errors*

Strategy used in single task: A main effect of age was found, with older adults scoring more errors (*M*= 51.09, *SD*= 16.44) than younger adults (*M*= 19.34, *SD*= 14.00). No other main effects or interactions were found.

Strategy used in the dual task: As in the single task, a main effect of age found, with older adults performing worse than younger adults. However, there was a Age x Strategy Interaction. Older adults using a less effective strategy committed more errors than those using a more effective strategy. For younger adults, the opposite pattern was found (see Figure 6.8).
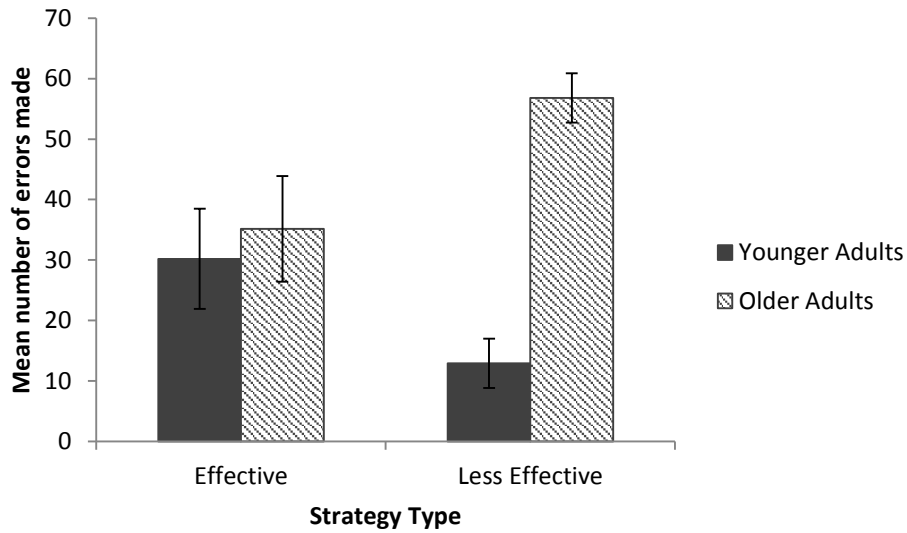
Figure 6.8 Mean number of SWM-Between Errors made by younger and older adults when using an effective or less effective strategy. Error bars represent one standard error above and below the mean

SWM- *4, 6, 8 Boxes*

Strategy used in the single task: In line with expectations, there was a main effect of stage- with more errors being made at a higher level of difficulty (8 boxes). Older adults were also shown to make more errors than younger adults. This was reflected by a Stage x Age interaction, with older adults performing alot worse than younger adults at each stage of the task (see Figure 6.9). There was also a marginal Stage x Strategy interaction, with those using an effective strategy perfroming better (fewer errors) at stages 4 and 6, but making slighlty more errors at stage 8.
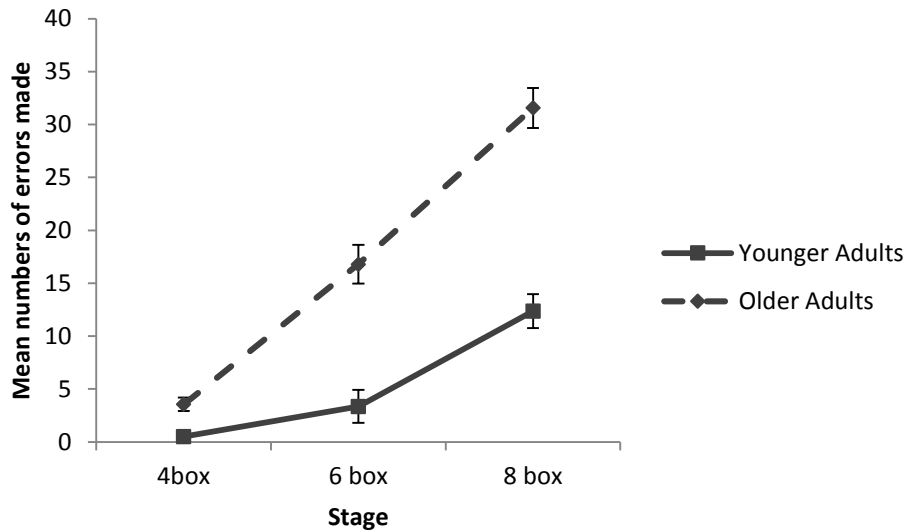
Figure 6.9 Mean number of SWM-Between Errors made by younger and older adults at each stage of the task. Error bars represent one standard error above and below the mean

Strategy used in the dual task: A similar pattern of results was obtained when the strategy used in the dual task was examined. As the number of boxes increased so did the number of errrors made, reflected by a main effect of stage. Older adults were also found to perform worse than younger adults. Identical to the single task, the Age x Stage interaction was also significant. The three way interaction between Stage, Age and Strategy was also significant. Contrary to what was expected, younger adults using a less effective strategy performed better than those using a less effective strategy at each stage of the task. More in line with expectations, older adults exhibited the opposite pattern, with those using an effective strategy outperforming those using a less effective strategy at each stage of the task. The Age x Group x Strategy interaction was approaching significance. Older adults using an effective strategy in the dual task performed differently on the task depending whether they were in the experiemntal or control group. Those in the control group scored worse (*M*= 16.33, *SD* = 3.18) than those in the experimental group, (*M*= 7.33, *SD*= 2.98). For younger adults this difference was not so pronounced (*M*= 10.33, *SD*= 3.23 - experimental) (*M*=6.33, *SD*= 4.59- control).

<u>SWM-</u> *Strategy*

Strategy used in the single task: Only the main effect of age was significant, with younger adults making fewer errors than older adults.

Strategy used in dual task: The main effect of age was also significant, with older adults having a higher strategy score (indicative of a worse strategy) than younger adults. Additionally the Age x Strategy interaction was significant, when older and younger adults were using an effective startegy in the word recall task, they obtained a similar strategy score in the SWM task. When they were using a less effective strategy in the dual task, older adults performed considerably worse than younger adults (see Figure 6.10).
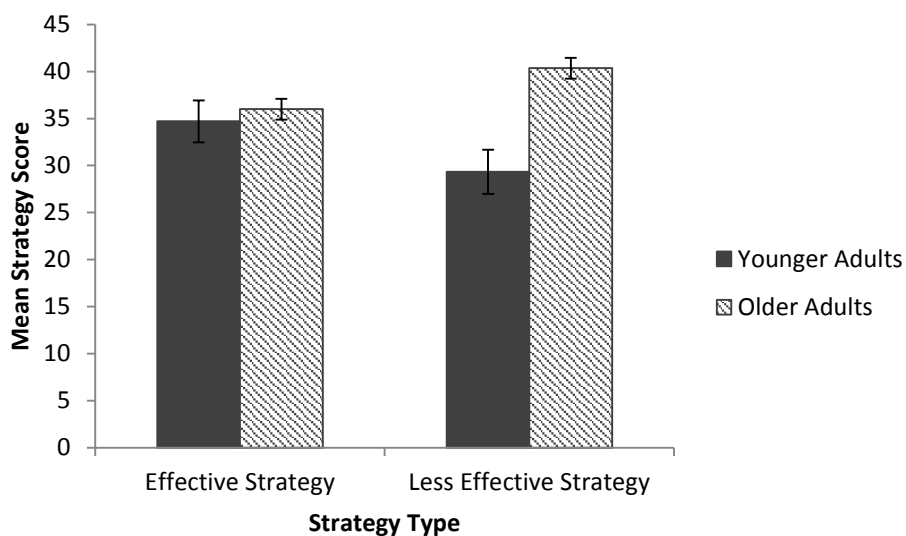
Figure 6.10 Mean SWM strategy score of younger and older adults when using an effective or less effective strategy in the word recall dual task. Error bars represent one standard error above and below the mean

<u>SOC-</u> *Minimun number of moves*

Strategy used in the single task: Only a main effect of age was found, with younger adults completing more trials with the minimum number of moves (*M*=8.52) than older adults (*M*=7.11).

Strategy used in the dual task: Only the three way interaction between Group, Strategy and Age was significant. As can be seen from Figure 6.11 below younger adults in the experimental group performed alot worse than younger adults in any other condition. Older adults in the experimental group using an effective strategy perform better than those not using an effective strategy. However, those in the control group using an effective strategy score slightly less than those using a less effective strategy in either group.
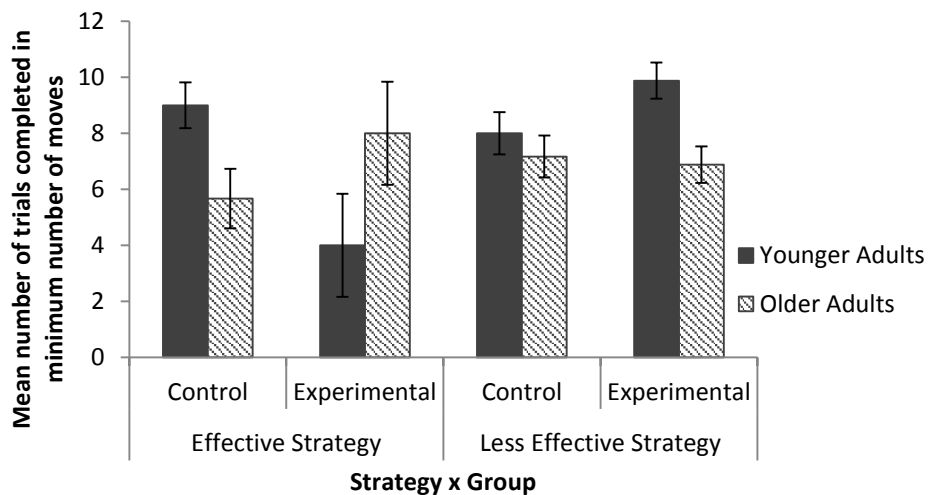
Figure 6.11 Minimum number of moves made by younger and older adults in the experimental or control group when using an effective or less effective strategy. Error bars represent one standard error above and below the mean

It was anticipated that participants who used effective strategies in the single and dual tasks would possess higher cognitive resources, but this was not reflected in the results. An effect of strategy was only found in the IED task, with those using a more effective strategy in the single task scoring fewer errors in the task of cognitive flexibility. In contrast with the results found in study 2, a main effect of age was prevalent in all of the tasks, with older adults performing worse than younger adults in measures of working memory (SWM) and cognitive flexibility (IED) and planning (SOC).

Additionally, there appeared to be a number of interactions taking place. Older adults who used an effective strategy performed better than older adults using a less effective strategy, in the SWM, and IED task. As older and younger adults were randomly assigned to the control and experimental groups, it was anticipated that there would

not be differences in performance between them (prior to strategy training). This was partially reflected in the results, as a main effect of group was not found in any of the measures of cognitive resources. However, when looking at the dual task results, Age x Group x Strategy interactions were evident in the SWM and SOC task. These results were unexpected, but need to be interpreted with caution as very few participants reported using an effective strategy, especially in the dual tasks.

Pearson correlations were run on the cognitive resource measures to see how they related to each other and to age and performance in the single and dual tasks. It was anticipated that increased age would be significantly correlated with worse performance on the cognitive resource measures, and performance in the single and dual tasks. The full correlation matrix is presented in Table 6.10.

Table 6.10 Correlation matrix for processing resources and word recall task at time 1

	Age	Word Recall (ST1)	Word Recall (DT1)	SWM Between Errors	SWM Strategy	SWM 4 Box Errors	SWM 6 Box Errors	SWM 8 Box Errors	IED Total Errors Adjusted
Word Recall (ST1)	-.49***								
Word Recall (DT1)	-.72***	.56***							
SWM Between Errors	.77***	-.50**	-.55***						
SWM Strategy	.67***	-.26	-.31	.84***					
4 Box Errors	.66***	-.33*	-.60***	.82***	.58***				
6 Box Errors	.74***	-.47**	-.68***	.95***	.73***	.78***			
8 Box Errors	.86***	-.43**	-.60***	.95***	.86***	.69***	.81***		
IED Total errors Adjusted	.40**	-.27	-.59***	.52**	.50**	.51**	.68***	.42**	
Minimum Moves	-.47**	.31	.34*	-.67***	-.60***	-.54***	-.67***	-.67***	-.36*

Working Memory Capacity (SWM)- Between errors

Performance in this task was shown to be negatively correlated with performance in the single and dual task; ($r= -.50$, $p=.001$) ($r= -.55$, $p<.001$), demonstrating that as performance in the single and dual tasks increased the number of errors made decreased. As expected the number of errors significantly positively correlated with the other outcome variables of this task; with high correlations found with number of errors made in 4 box ($r=.82$, $p< .001$) 6 box ($r=.95$, $p< .001$) and 8 box problems ($r= .95$, $p<.001$), and strategy ($r=.84$, $p<.001$).

This variable was also significantly correlated with the other measures of cognitive resources, such as cognitive flexibility- reflected by the total amount of errors made on the IED ($r= .52$, $p<.001$) and planning ability measured by the amount of problems solved in the minimum amount of moves on the Stockings of Cambridge task ($r=-.69$, $p<.001$). This suggests that participants who perform well in the working memory task also performed well in other cognitive tasks, namely those measuring planning and executive function.

Age was strongly positively correlated with the number of errors made on the working memory task indicating that increased age was associated with more errors made on the task ($r= .77$, $p< .001$).

Cognitive Flexibility (IED)- Total Errors (adjusted)

Greater cognitive flexibility was associated with increased performance only on the word recall task in the dual task condition ($r=-.45$, $p=.004$). Although negatively correlated, it was not significant in the single task condition ($r=-.27$, $p=.10$).

Poorer cognitive flexibility was also associated with more errors made on the working memory task ($r= .52$, $p=.001$) and poorer strategy use ($r= .36$, $p=.02$) Planning ability was also shown to negatively correlate with performance on the IED task, with higher error rate on the IED task associated with less trials being completed in the minimum amount of moves ($r=.36$, $p=.02$).

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Cognitive flexibility was found to be positively correlated to age, with the number of errors made on the task increasing as age increased (r=.40, p=.01).

Planning Ability (SOC)- Number of problems solved in minimum moves

Increased performance in this task (reflecting an individual's planning ability/frontal lobe/executive functioning) was correlated to increased performance in the word recall task, but only at dual task (r= .50 , p< .01). Planning ability was shown to be significantly correlated with other cognitive resources such as working memory (between errors) (r= -.69, p< .001), and the IED (r= -.36, p=.02). The relationship between performance on the SOC and age was negatively correlated (r= -.47, p<.01), which greater age being associated with worse planning ability.

Age

In line with expectations, age was shown to significantly negatively correlated to performance in the single (r= -.49, p=.001) and dual tasks (r = -.72, p< .001), with increased age being associated with decreased performance in the tasks.

In contrast to the results shown in study 2, age was significantly correlated with all of measures of working memory, cognitive flexibility and executive functioning. Advancing age was associated with poorer performance in all of the tasks.

Dual Task Costs

Relative dual task costs were also calculated, and are reported in Appendix E.

6.4   Discussion

The aim of this study was to determine whether the findings from study 2 could be replicated when the imagery level of the words was changed. This study differed from study 2, in that it featured a control group so that the effectiveness of the strategy training could be ascertained.   Overall, findings mainly confirmed those found in study 2, albeit with some differences.

As this study used high imagery words, it was expected that both older and younger adults would benefit from strategy training (which advocated the use of

imagery/association strategies) and this would be reflected in an increase in performance from time1 (pre strategy training) to time 2 (post strategy training). As this study utilised a control group, it was expected that only those in the experimental group (who took part in the training) would improve, which would be reflected by a group x time interaction. The findings revealed that regardless of strategy use, overall performance in the single task did not improve from time 1 to time 2 for either the experimental or control group. There was however, a time x age interaction, showing that the performance of younger adults did improve (in both groups), yet older adults did not. The lack of a group x time interaction is disappointing and at first glance suggests that the strategy training is not effective. This finding could reflect differences in strategy use present at time 1 between the control and experimental group. Inspection of the frequencies of reported strategy use show that the control group did use a higher proportion of effective strategies in the single task at time 1 than those in the experimental group, which may be masking any group effects in performance. In the dual task, those in the experimental group were shown to increase their performance, whilst those in the control group did not. In line with expectations, age-related differences in performance were found, with younger adults performing better than older adults.

6.4.1 Choice Conditions

When strategy use was examined, it was found that participants who utilised an effective strategy spontaneously were shown to perform better in both the single and dual tasks than those who used a less effective strategy. Although as expected there were no direct group differences in performance pre-strategy training, there were some interactions involving the group. In the single task, those in the control group who were using an effective strategy performed better than those in the experimental group using an effective strategy. A similar pattern of results was obtained in the dual task, but instead younger adults were shown to recall more words in the control group then the experimental group. This adds strength to the argument that there may have been differences between the groups prior to strategy training, which may account for the lack of group effects post strategy training. Consistent with the findings from study 2, age differences were apparent, with older adults recalling less words than younger adults in both the single and dual tasks.

Following strategy training, these age differences did persist, with older adults recalling fewer words than younger adults in both the single and dual task condition. As in study 2, it was important to establish whether these age-related differences could be attributed to a greater number of older adults reporting not using any form of strategy. The results did not support this premise, at least not in the single task condition which still showed a main effect of age. In the dual task condition, age differences failed to manifest, suggesting that older and younger adults who utilised a strategy performed similarly.

The fact that age differences were found in the single task is surprisingly, given that they were not found in study 2 when the imagery level was only medium compared to high. It was expected that with the increase in imagery level, effective strategies such as imagery/association would be easier to implement and thus lead to decreased age differences. On the contrary it may be that by altering the imagery level, and making it more amenable to imagery/association strategies, younger adults are more able to capitalise, leading to exacerbated age differences. Indeed this has been widely reported in the memory strategy training literature (Verhaeghen & Marcoen, 1996). Another alternative explanation is that older adults in study 2 relied on a sentence generation strategy more in single tasks to enhance their performance. Inspection of the frequencies of reported strategy use does not indicate that older adults were following this inclination for this study, consistent with the findings of Tournier and Postal (2011). Both of these are intriguing propositions that warrant further investigation. Another possibility is that it may be due to differences in the samples used and recruitment method. This will be discussed fully in the general discussion chapter.

Contrary to expectations no group effects were found, the experimental group (who undertook training) did not recall more words than those in the control group. Again, this absence of an effect may be due to the differences in effective strategy use, but nonetheless is surprising. Instead participants using an effective strategy (regardless of which group they were in) outperformed those using a less effective strategy. This was still the case when those who reported not using a strategy were excluded from

the analysis. This demonstrates the importance of measuring strategy use when examining memory performance, as it indicates that effective strategy use is a key contributing factor for increased performance.

6.4.2 No-choice Conditions

The findings of the no-choice conditions mimic those found in study 2. Firstly, an imagery strategy was shown to be superior to a rehearsal strategy in the single task condition. This was expected, and is in line with what was found in study 2. Due to the nature of imagery level of the words, it was tentatively anticipated that unlike in study 2, the dual task may benefit more from an imagery strategy. This however was not reflected in the results, using an effective strategy such as imagery did not offer any advantage over using a normatively less effective strategy such as rehearsal. Consistent with the results in study 2, age differences were prevalent in both the single and dual tasks, with older adults remembering fewer words than younger adults.

This study also confirms the findings from study 2, regarding the distinction between choice and no-choice conditions. As with study 2, this study showed that in the dual task condition, when participants were given a choice, opting to use an effective strategy was advantageous. In the no-choice condition, no such advantage was evident. As aforementioned in chapter 5, this provides a valid claim for advocating choice in memory strategy regimens (Derwinger, Stigsdotter & Bäckman, 2005).

6.4.3 Adaptive Strategy Use

It is apparent that the strategy training did promote the use of effective strategies in the single task, reflected by the increase of effective strategy use in the experimental, compared to the control group. However, this greater use of effective strategies following training was not evident in the dual task condition. This differs from the results found in study 2, which found that all participants increased their strategy use from time 1 to time 2. This is surprising given that the imagery level was higher in this study, therefore making it more amenable to an imagery strategy. Of course, it may be that this leads to increased use of effective strategies at time 1, and although this was certainly the case for younger adults in the control condition, the overall rates

were comparable to those exhibited in study 2 pre-test (27% in study 2, 24% in study 2).

Although younger adults did exhibit higher effective strategy use than older adults prior to and after strategy training, these differences were found not to be significant, consistent with the findings of Kulhman and Touron (2012). Both older and younger adults were shown to shift their strategy use in the single task condition. This shows that older adults are able to adapt their strategy use in order to increase their performance, in contrast to findings presented by Lemaire (2010). However unlike study 2, age differences still manifested, suggesting that despite use of an effective was advantageous for both groups (reflected by the main effect of strategy) older and younger adults were not performing at the same level. This is in line with the findings of Lemaire, Arnaud and Lecacheur, (2004), and may suggest that older adults are experiencing an utilisation deficiency (Gaultney et al., 2005).

6.4.4 Secondary Task Performance

As previous research has suggested that effortful strategies used in the primary task effect older adults secondary task performance (Naveh-Benjamin et al., 2005) this was assessed. Overall the results did not support this finding. Although older adults were shown to be slower in a number of the single tasks, they were not shown to be more penalised than younger adults in the dual tasks. In fact, older adults exhibited quicker reaction times than younger adults in both the imagery and rehearsal condition dual tasks.

6.4.5 The Contribution of Cognitive Resources

In stark contrast with the findings presented thus far in the thesis, older adults were shown to have poorer cognitive resources[20]. Age differences were found in all of the tasks for working memory capacity and executive functioning, specifically cognitive flexibility and planning abilities. Although different to the previous studies in this body of research, this is consistent with the literature (Craik, 1996; Glisky, 2007). Coupled with the findings that age related differences were found in memory word recall, this finding offers support to cognitive aging theories emphasising a reduction

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[20] An explanation of why this may have occurred (due to differences in the recruitment strategy/sample) is detailed in the general discussion chapter.

in resources, be it working memory capacity (Park et al., 1989; Hara & Naveh-Benjamin, 2014) executive functioning (Bouazzaoui et al., 2010) or a reduction in processes relying on the frontal lobes Moscovitch & Winocur, 1995).

The hypothesis that participants opting to use an effective strategy spontaneously (at time 1) would possess greater cognitive resources was not supported by the present study. The only effect of strategy was found for the IED task measuring cognitive flexibility, showing that those who utilised an effective strategy in the single task condition made fewer errors on the task. Correlational data run on overall performance in the single and dual tasks did show a relationship between cognitive resources and performance, suggesting that resources are implicated in successful task performance (irrespective of strategy use). Mimicking the results found in study 2, cognitive flexibility was only significantly correlated with performance in the dual task, highlighting its importance with the ability to dual task (Baddeley, 1996).

6.4.6   Summary and Conclusions

Overall this study did not provide that much support that training in strategies can increase performance in memory performance. However, this may be due to difficulties in equating effective strategy use in control and experimental groups at pre-test. This study did show that strategy training does at least promote the use of effective memory strategies in both older and younger adults, at least in single tasks. Furthermore this study provides support that there is disparity in results when participants are allowed to choose their strategy compared to when they are asked to use a specific strategy. As in study 2, age differences were not found when participants were asked to choose a strategy in the dual task post strategy training, whereas when instructed to use an effective one in the no-choice condition older adults were shown to not perform as well as younger adults.

The findings also provided support for the theory that older adults may experience an utilisation deficiency in memory strategy use, as when older adults were using an effective strategy they were shown not to benefit as much younger adults. Unlike the previous studies presented in this thesis, it does appear as though poorer performance by older adults could be due to a reduction in cognitive resources.

7 Study 4: Strategy training and transfer in older and younger adults.

7.1 Introduction

As a wider objective of memory strategy training is to enhance memory and improve everyday functioning of older adults, it is important to establish whether the benefits of memory training can be extended to other tasks as this will show more real-life applications (Cornoldi & De Beni, 1995). Therefore the focus of this study will be to determine whether the training used in the other studies can be successfully utilised in other 'untrained' tasks. If the training leads to improvements in untrained/novel tasks then the training is said to show transfer. Dependent on how similar the novel tasks are to the trained one they are described as demonstrating near transfer (if very similar) or far transfer (dissimilar). Research examining cognitive training and transfer can be divided into two streams; one takes the form of teaching specific encoding strategies (such as imagery) and the other focuses on WM training, often involving extended practice on a complex WM task. The two avenues of research have been extensively researched and will be outlined below.

7.1.1 Training Specific Encoding Strategies

Training on specific encoding strategies has taken numerous guises. Strategies such as the method of loci technique (Rebok & Balcerak, 1989); imagery and association (Cavillini et al., 2003) and the name-face technique (Yesavage & Rose, 1984) have all been at the focus of research studies. In addition to the type of strategy trained; other factors such as duration and whether supplementary information (e.g. about memory processes) is provided also vary. Typically research looking at strategy training shows that there are improvements to the trained task, but transfer to other tasks has yielded inconsistent results. For example it has been found that teaching an imagery strategy to older and younger adults lead to increased performance in not only the trained task (free recall of a word list) but also a complex working memory task (Caretti, Borella, and De Beni, 2007: Carretti et al., 2011).

Bailey, Dunlosky and Hertzog (2014) recently investigated the concept of transfer by training younger and older adults in the use of encoding strategies such as interactive imagery and sentence generation on a list-learning task. A complex working memory strategy task (RSPAN) was used as the outcome task to determine if strategies could improve performance. To examine transfer, a paired-associate recall task was used to evidence near transfer and the self-ordered pointing task (SOPT) was used to demonstrate far transfer. It was hypothesised that the strategies would not be beneficial to the SOPT which is an executive function measure which involves choosing from an array of abstract shapes. In contrast it was expected that if the strategy training generalised to other tasks, then it should transfer to the paired-associate task as the tasks are quite similar.

The results found that after strategy training participants increased their use of effective strategies in the RSPAN task which led to increased performance. Expectedly this benefit of training was not extended to the far transfer task, in fact the training group performed worse than those in the control group suggesting that trying to apply the strategies had a negative impact as they were not applicable to the task. Surprisingly; trained participants did not outperform participants in the control group on a paired associate task, even though they reported using greater strategy use. One possible explanation is that although on first glance the strategies trained (and used by the participants) may appear to be beneficial for the paired-associate task they are actually not. For free-recall and working memory tasks it is necessary to integrate the unrelated words into a sentence or image, whereas for paired-associate tasks a mediator is often utilised to make a link between the two words which then need to be effectively decoded in order to retrieve the target words. These subtle differences have been put forward as an explanation why transfer did not occur in this task (Bailey et al., 2014). Additionally the paired-associate task and the SOPT were not administered pre-training so there could be group differences present at pre-test.

In regards to showing far transfer; the effects of encoding strategy training are less established. One such study conducted by Lustig and Flegal (2008), focused on teaching participants strategies to encourage deeper encoding by either thinking about the meaning of the words but with no explicit strategy instructions (strategy choice) or

making sentences with the words (sentence generation).   It was found that training led to improvements in not only the trained task; but also in the Trail Making Task B, which involves connecting a series of numbers/letters by alternating between them and is considered a measure of executive function. It has been hypothesised that far transfer may have occurred due to the type of training used in this study which took the form of recollection training (Jennings & Jacoby, 2003). This procedure involves asking participants to study a number of different word lists and then instructing them to discriminate between the studied words and lures. The difficulty of the recognition task is increased as the lures are repeated so that they are highly familiar therefore making it harder to differentiate between the studied words and lures. It is proposed that this type of training is reliant on attentional control (Bailey, Dagenbach & Jennings, 2011), and may have led to improvements in working memory and/or executive processes. Therefore it is hard to generalise to other studies using more traditional training procedures and using more demanding free-recall tasks. Overall, evidence of far transfer in memory strategy training studies is not a very robust finding; and generally strategy training is limited to improvements on the trained task, or just near transfer (Rebok, Carlson & Langubaum, 2007; Zelinski, 2009).

It has been suggested that training older adults may not be enough to promote transfer as participants may fail to recognise that the strategies can be applied to other tasks (Cavillini et al., 2010; Hertzog & Dunlosky, 2012). Instead, it has been recommended that in addition to teaching specific encoding strategies; researchers should also equip participants with appraisal skills so that tasks can be analysed and the most appropriate strategy selected. (Bottiroli, Cavillini, Dunlosky, Vecchi & Hertzog, 2013). In their study Bottiroli et al. (2013) directly compared strategy training to strategy-adaptation training. Although both groups received training on encoding strategies (including imagery/association) and information about transfer, crucially they differed on instruction on how to analyse the tasks and adapt strategies to them. It was found that those who were in the strategy adaptation group and had been directed to ask specific questions about the task (e.g." how can you adapt sentences and imagery to help you meaningfully process the to-be learned materials" pg 207), showed greater transfer. In fact, the strategy adaptation group have been credited as demonstrating 'far transfer', as they showed improvements in a face-name task which

differs from the trained tasks (list recall). However, defining what constitutes 'near' and 'far' transfer is very difficult, as the concept of similarity has been ill-defined, (Barnett & Ceci, 2002). Therefore whether a face-name task is actually different enough from the trained task to be an example of 'far transfer' is open to debate.

7.1.2   Domain General Working Memory Training

It is assumed that WM is a domain-general resource which may underlie performance in a wide variety of tasks. As working memory and other higher order cognitive abilities appear to be highly related (St-Clair Thompson, 2007; Unsworth, Redick, Heitz, Broadway & Engle, 2009); there is a lot of interest in determining whether training in working memory can improve capacity and performance in other abilities such as fluid intelligence. These studies generally involve extended practice with a variety of tasks that target working memory, attention and inhibition processes. Findings have typically illustrated that although working memory training may lead to improvements in working memory tasks and transfer in younger adults; the vast majority fail to show far transfer in older adults (Morrison & Chein, 2011). However this prevailing finding has been challenged, especially in studies that focus on adaptive working memory training. In their study; Borella et al. (2010) trained older adults (n=20) on an adaptive working memory procedure, which involved remembering a list of words whilst tapping the table when an animal noun (e.g. dog) was presented. This was modified to promote transfer by manipulating the difficulty and progression according to individual performance. The findings were quite positive in that they found that training lead to improvements in the trained WM task and digit span tasks demonstrating near transfer; but also in the Cattell task and Pattern Comparison task which measure fluid intelligence and processing speed and therefore evidence far transfer. However; the study did not include a group of younger adults so therefore age-related differences cannot be examined and the group consisted of 'younger' older adults (65-75) who typically benefit more from training (Dahlin et al., 2008).

Although this finding is promising; a recent study focusing on an adaptive training WM program failed to show any far transfer effects (Harrison et al., 2013). This study trained participants (n=21) using an adaptive complex span procedure which

again tailored the level of difficulty to individual performance. Following 20 sessions of training, improvements were made in other complex span tasks using different stimuli and 'keeping track' tasks which are thought to reflect WM constructs. However; there was no evidence that the training had generalised to measures of fluid intelligence (far transfer). Taken with the finding that the training led to improvements on a free recall task it has been proposed that adaptive training may only improve specific facets of working memory such as the secondary memory component (Harrison et al., 2013). This refers to the items that are held outside the focus of attention and therefore cannot be due to active maintenance in primary memory. Retrieval of items from secondary memory is shown to be highly dependent on encoding, and is amenable to effective strategy use (Bailey, Dunlosky & Kane, 2011). Therefore it may be that teaching encoding strategies may be a more suitable avenue of research.

In summary, it is hard to draw firm conclusions and the interpretation of findings is challenging because of variations in the methodology used. It is also difficult to decipher which type of training is most beneficial; on the one hand studies that train a specific encoding strategy such as imagery may show limited transfer effects as the specific strategies may enhance performance only in tasks that 'afford' the same strategy (Dunlosky & Kane, 2008). On the other hand, working memory training has been criticised as lacking ecological validity (Morrison & Chein, 2011) and it may be that a more "realistic goal" of training may be to focus on specific strategies "important to other aspects of cognition" (Harrison et al., 2013 pg 2418). Crucially, it may be that training is only beneficial when it impacts on everyday functioning (McDaniel & Bugg, 2012), and there is evidence to suggest that memory strategy training can have a positive influence on everyday memory strategy use (Flustig & Lustig, 2008; Rebok & Gross, 2011).

7.1.3 The Present Study

The current study aims to extend previous research in the field by examining whether the memory training developed during this project will transfer to similar or dissimilar untrained tasks. The training procedure was identical to that used in Studies 2 and 3, which taught participants about a variety of strategies including imagery and

association. Similar to Bailey al. (2014) this study will examine near transfer using the working memory measure of RSPAN, and will directly evaluate whether the strategies are adopted by using set-by-set strategy reports (Dunlosky & Kane, 2007). However unlike Bailey et al. (2014) this study will be able to determine if there are differences between the groups present at pre-test by administering the transfer tasks pre and post strategy training. In line with Lustig and Flegal, (2008) the Trial Making B task was used to assess far transfer as it is measures executive function/fluid intelligence, and differs vastly from free recall or verbal working memory tasks. Therefore this task will also be able to evaluate whether Lustig and Flegal's (2008) finding of far transfer can be replicated using a more traditional method of memory strategy training.

Although research has demonstrated that older adults may benefit more if they are encouraged to think about how strategies could be implemented in the untrained tasks (Cavillini et al., 2010); to be considered a true example of transfer the decision to use the strategy for the novel task must be spontaneous (Detterman, 1993). Therefore, although the training did emphasise the importance of appraising tasks and thinking about whether these strategies would be useful in other tasks, no specific mention of this or hints to use a strategy were given when the transfer tasks were administered.

In line with previous research it was expected that untrained tasks that 'afforded' the same strategies would be improved following strategy training (Bailey et al., 2014; Caretti et al., 2011). Therefore it was hypothesised that the experimental group would perform better than the control group in the RSPAN task following strategy training. In contrast, it is unclear how an elaborative verbal encoding strategy would benefit performance in the Trail Making B task, which is more reliant on set-switching abilities. For that reason, it was anticipated that the experimental group would gain no advantage in utilising the trained strategies and consequently there would be no difference between the groups post strategy training.

In regards to age differences, in line with previous research evidenced in this thesis and from the literature, it was expected that these would persist following strategy training, with younger adults performing better than older adults in all tasks.

7.2 Methodology

7.2.1 Participants

The same participants were used as in experiment 2.1. The sample is described in chapter 6.

7.2.2 Materials

7.2.2.1 *Near Transfer Task*

RSPAN

A modified version of the Reading span task was used in this experiment to assess near transfer. A sentence was presented on the screen (e.g. Isabella went to the library to return some books) and participants were required to make a judgement about whether it made sense or not. Once this decision was made (via key press) an unrelated word was presented on the screen for 2 secs. Immediately after this another sentence would appear followed by another word. After the final presentation of the sentence-word pair in the trial a prompt was displayed asking participants to write down the words that were presented in the correct order. Following from this participants were asked to indicate how they remembered the words in the trial, choosing from six options (reading, repetition, sentence generation, imagery, grouping and other) using the same protocol described in experiment 2 and devised by Dunloksy and Kane (2007). Trial length ranged from three to seven sentence word-pairs and there were 1 practice trail and 15 experimental trails in total. The trials were initially randomised and then subsequent participants took the test in the same order. The partial credit scoring system was used for this in accordance with Conway et al. (2005) and Bailey et al. (2014) (for a discussion on scoring procedures please see Chapter 3).

7.2.2.2 *Far Transfer Task*

Trail-Making Task B

This was used to assess far transfer and is used as a measure of executive functioning/cognitive flexibility. The task consists of a number of circles which are either labelled numerically (1-13) or alphabetically (A-L). The participant must draw lines as quickly as possible to connect the circles alternating between letters and numbers. The time taken to complete the task is taken as a participants score.

7.2.3   Procedure

As participants completed this study at the same time as completing the measure for study 2.1, only measures that pertain to this study will be reported in full, details of study 2.1 can be found in chapter 6.

Participants were asked to complete the study in two sessions. Each session lasted approximately 2 hours. The second session was completed approximately 7 days after the initial session.

First Session. All participants were tested individually in a quiet room. Firstly participants read the information form and were briefed on the nature of the experiment. Participants were encouraged to ask questions, and once these were answered they were instructed to fill out the consent and demographic form. Older adults were screened for dementia, using the MMSE (Folstein, Folstein & McHugh, 1975), with individuals scoring lower than 27 excluded. The tasks from the CANTAB were then administered and participants completed the single and dual-tasks (these tasks form part of experiment 2.1, and are therefore not reported here, but in chapter 6). Participants then performed the RSPAN task, the order of which was counterbalanced for each participant. Once these were completed, participants completed the Trial-Making A and B task.

Strategy Training. Strategy training was the same as in studies 2 and 2.1, and focused on imagery/association strategies and the merits of each. Strategy information was given in individual sessions and lasted approximately 45 minutes.

Second Session: Participants were asked to complete the single and dual-tasks again and are reported in the preceding chapter. Following this, participants completed the

RSPAN with different stimuli (sentences/words or operations/letters) used at time 2. Participants then completed the Trial Making A and B task and at the end of the session participants were thanked for their time and fully debriefed.

7.2.4   Results

7.2.4.1   *Data Screening*

Data were screened following the same procedures reported in study 2.1, and outliers were dealt with as stated in chapter 6. In addition to the variables used in study 2.1, RSPAN and the Trial Making variables needed to be checked to ensure they did not violate the assumptions of parametric data. Visual inspections of the boxplots histograms, Q-Q plots and skewness and kurtosis values revealed that all data were shown to be approximately normally distributed, with the exception of the Trial Making B task, where one older adult in the control group was identified as an extreme outlier. This was winsorised to the next highest value, which then corrected the violation.

Single and Dual task performance- These are not the focus of this study and are reported in full in chapter 6.

7.2.4.2   *Main Analysis*

RSPAN- To determine whether strategy training led to improvements in an untrained but similar task, a 2 (Age, younger, older adults) x 2 (Time, pre and post-strategy training) x 2 Group (experimental, control) mixed ANOVA was conducted on performance in the RSPAN task.

The main effect of age was significant, with younger adults performing better than older adults (F[1, 36]= 13.36, p=.001, η^2_p =.27). There was a marginal main effect of time, with elevated performance at time 2 compared to time 1 (F[1, 36]= 3.98, p=.054, η^2_p =.10). The Time x Age interaction was also significant, with older adults showing more of an increase in performance from time 1 to time 2, compared to younger adults, whose performance was identical at both age times, (F[1, 36]=4.17, p=.048, η^2_p =.10).   The three way interaction between Age x Group x Time was

marginally significant ($F[1, 36]=2.94$, $p= .095$, $\eta^2_p =.10$). As can be seen from Figure 7.1, it revealed that younger adults in the experimental condition did increase their performance following strategy training compared to those in the control group. Older adults showed an increase, regardless of which group they were in; however surprisingly this was more pronounced in the control condition.
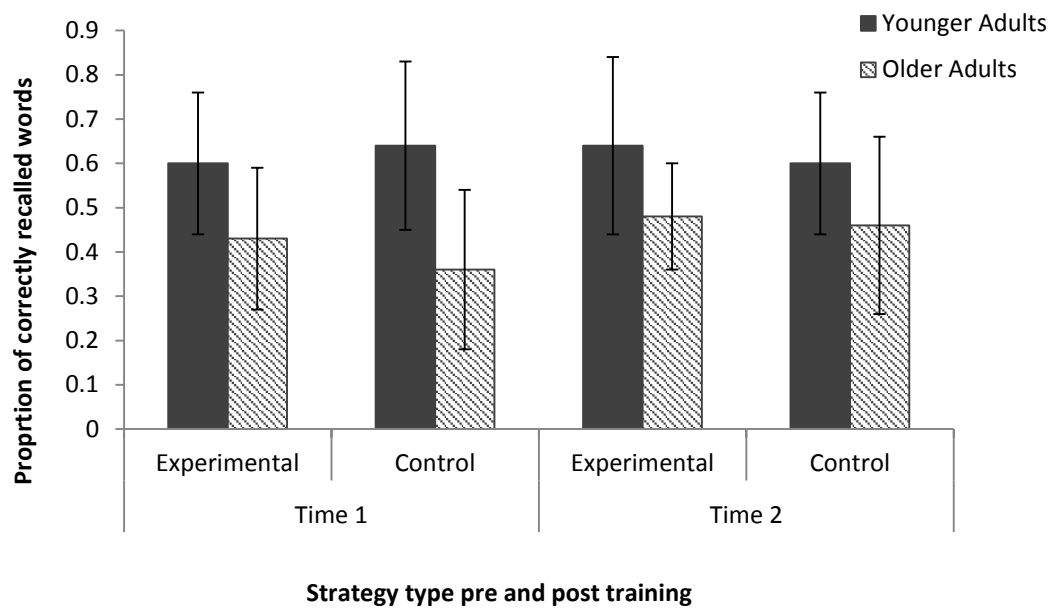
Figure 7.1 RSPAN Performance of younger and older adults given as a function of group and time. Error bars represent one standard error above and below the mean

To investigate these interactions further, 2 (Group) x (Time) mixed ANOVA's were performed separately on older and younger adults data. These failed to establish an effect of training, the 2-way interaction between time x group for younger adults was not significant ($p=.13$), neither was it for older adults ($F<1$). For older adults only the main effect of time was significant ($F[1, 16]=6.43$, $p=.02$, $\eta^2_p =.29$), confirming that older adults in both the experimental and control group increased their performance at time 2.

Effective Strategy Use: To ascertain whether those in the experimental group used the strategies covered in the training, the total proportion of trials that effective strategies were used on were calculated for older and younger adults separately in each group.

Normatively effective strategies were considered as imagery, sentence generation and grouping. Rehearsal and no strategy were classed as normatively less effective strategies (for a justification for this please see chapter 5). The means for each group are provided in Table 7.1.

Table 7.1 The mean proportion of trials where older and younger adults in the control and experimental groups reported using an effective strategy

Age Group	Experimental		Control	
	Time 1	Time 2	Time 1	Time 2
Younger Adults	0.56 (0.29)	0.80 (0.39)	0.60 (0.33)	0.37 (0.34)
Older Adults	0.28 (0.37)	0.35 (0.35)	0.07 (0.16)	0.13 (0.23)

As can be seen from Table 7.1, both younger and older adults in the experimental group increase their use of effective strategies following strategy training. For the control group, older adults are shown to increase their use of effective strategies in the RSPAN task, whereas younger adults actually decrease their use of effective strategies.

This was subjected to a 2 (Age) x 2 (Group) x 2 (Time) Mixed ANOVA, to determine whether any of these trends in the data were significant. It was found that the main effect of age, (F[1, 33]=20.01, $p<.001$, $\eta^2_p =.38$), and group were significant (F[1, 33]=5.97, $p=.020$ $\eta^2_p =.15$), with younger adults, and those in the experimental group using more effective strategies respectively. The time x group interaction was approaching significance (F[1, 33]=3.83, $p=.059$, $\eta^2_p =.10$), with those in the experimental group using more effective strategies at time 2, compared to time 1. The three way interaction between time x age and group. (F[1, 33]=3.58, $p=.067$, $\eta^2_p=.10$), was also approaching significance.

To find out if this increased use of effective strategy use, actually had an impact on performance, the correlation between the change in RSPAN performance from time 1 to time 2 and the change in the proportion of effective strategy use from time 1 to time 2 was calculated. A significant positive correlation was obtained ($r=.37$, $p=.03$, two-tailed) between the two variables, and is depicted in Figure 7.2.
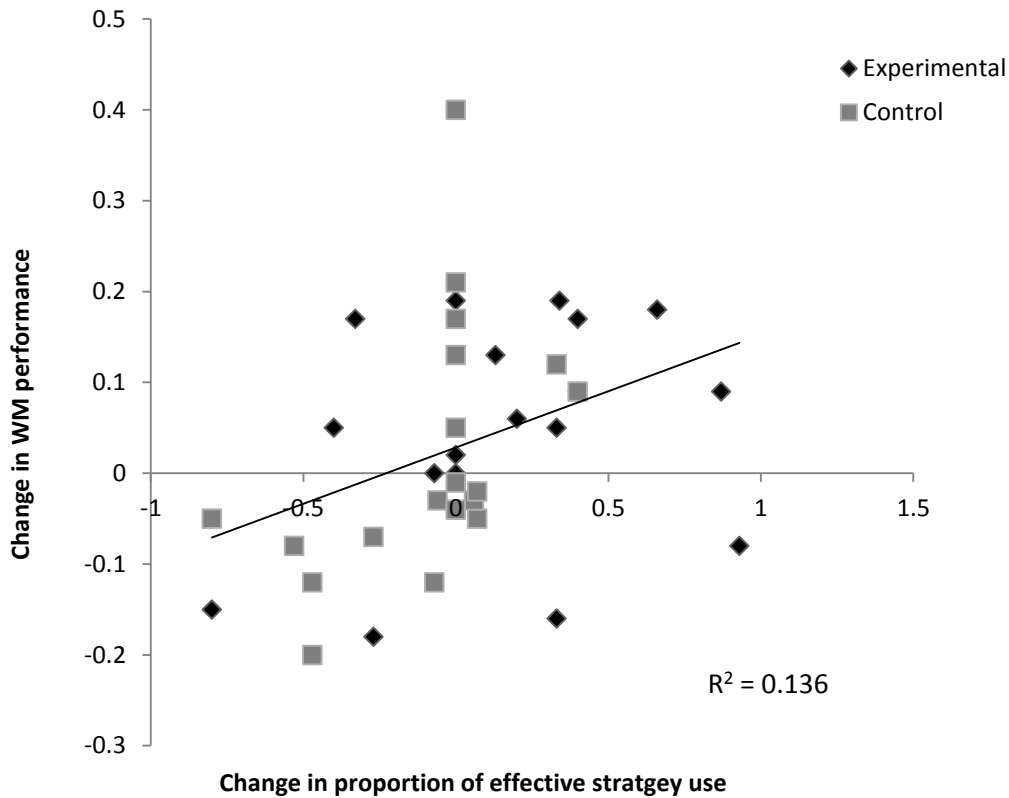
Figure 7.2 Scatterplot depicting the relationship between the change in effective strategies and the change in WM performance as measured by the RSPAN task for the experimental and control group

Far Transfer

To assess far transfer the Trial Making A and B tasks were administered pre and post strategy training. It was anticipated that the encoding strategies covered in the strategy training would not be beneficial in this tasks, the experimental group would not perform better than the control group.

As with the RSPAN task, a 2 (Age, younger/older) x 2 (Group, experimental/control) x 2 Time (pre/post strategy training) mixed ANOVA was conducted on the trail making A and B tasks.

Trial Making A: A main effect of age was found, with younger adults performing better (*M*=23.38, *SD*= 6.33 secs) than older adults (*M*=33.67, *SD*= 12.20 secs), $F(1, 30)$=10.88, *p*= .003, η^2_p =.27. Participants were also shown to be quicker at time 2

(*M*=26.85, *SD*= 9.60 secs) than at time 1 (*M*= 30.19, *SD*= 8.93 secs), *F*(1, 30)=7.15, *p*=. 012, η²$_p$ =.19). All other effects/interactions were not significant (all *p*'s >.13).

Trial Making B: Only a main effect of age was found, with younger adults performing quicker (*M*= 41.99, *SD*= 11.16 secs) than older adults (*M*= 70.14, *SD*= 22.96 secs), *F*(1, 30)=23.08, *p*<.001, η²$_p$ =.44. Although participants were slightly quicker post strategy training (*M*=54.95, *SD*= 17.30 secs) than pre strategy training (*M*=57.18, *SD*= 16.74 secs), this difference was not significant (*F*<1).

7.3   Discussion

The aims of this study were to determine whether training in memory encoding strategies such as imagery and association could transfer to untrained tasks, which are believed to either 'afford' the use of similar strategies such as the RSPAN task (near transfer) or do not, such as the trial making tasks (far transfer). Another goal of this study was to see if strategy training increased the use of effective strategies in the RSPAN task. Overall the results failed to show reliable transfer on any of the tasks, but did show that strategy training does promote effective encoding strategies such as imagery and association.

 In the RSPAN task, although younger adults in the experimental group did make improvements in the task post strategy training (evidenced by a 3-way time, group, age interaction), follow-up tests failed to support this effect. Older adults were shown to improve their performance regardless of whether they had received strategy training or not. This finding is in contrast with that of Bailey et al., (2014) who found that both younger and older adults were able to improve their performance following strategy training. This is surprising given that the RSPAN task adopted was very similar.

The finding that the strategies trained did not lead to improvements in the single and dual tasks (presented in chapter 6), may demonstrate that the strategy training in itself was flawed. The duration may not have been long enough, or participants may not have been particularly engaged with it. Although methodological differences in the memory strategy training could be a factor, it is unlikely given that the protocol was

very alike to that conducted by Bailey et al. (2014), in fact the duration in the current study was longer.

One factor could be that due to differences in the sample. In their study Bailey et al. (2014) did not find any age-differences in performance on the RSPAN task, whereas this study did. A comparison of the means of the older adults at pre-test in this study to those exhibited by Bailey et al. (2014) shows reduced WM performance (0.39 to 0.54). As outlined in chapter 6, the sample used in this study did appear to be lower educated and lower functioning than those who completed the prior studies, which used similar recruitment methods to Bailey et al. (2014).

As the older adults were shown to have a lower WMC than the younger adults in this task pre and post strategy training, it may be that the strategies were too hard to implement in this task. The RSPAN task places demands on the central executive (Engle, Tulhoski, Laughlin & Conway, 1999) and involves controlled processing (Kane & Engle, 2003), which are resources thought to be effected by aging. It may be that fast-paced nature of the task make it too hard for older adults to use strategies in this instance. This could explain the much lower use of effective strategy use by the older adults in the RSPAN task. The disparity between older and younger adults effective strategy use was surprising, given that previous research has found similar rates between older and younger adults (Bailey, Dunlosky & Hertzog, 2009).

This may offer an explanation to why older adults did not improve their performance following strategy training, but does not explain the lack of reliable transfer found for younger adults. One possible reason may be that for younger adults rehearsal was an effective strategy, and switching to another one such as association/imagery would not necessarily lead to vast improvements. Owing to the fact that trial length did not exceed seven words and typical working memory capacity is 4-7 items, it may be that sub-vocal rehearsal allowed these words to be maintained in working memory and recalled adequately. This explanation however, is not conducive with the finding that the change in effective strategy use was correlated with greater performance, and is inconsistent with the literature. For example, Dunlosky & Kane (2008) found that younger adults performed better on the RSPAN task when an effective strategy was used, as opposed to a less effective one (.60 as compared to .49).

Even though strategy training was not found to directly boost performance in the RPSAN task, it was found to increase rates of effective strategy use. It was found that those in the experimental compared to the control group did increase their use of effective strategy use post strategy training (although only marginally). However, this seemed to be more apparent in the younger group then the older adults. Encouragingly, this change in effective strategy use was also shown to improve performance (as demonstrated by the positive correlation between the two). This shows that if training can promote the use of these strategies, then this should lead to improvements. Why this was not found in the correct study is open to debate, but perhaps the gains made were not big enough to detect.

No evidence of far transfer was found in the current study, although both younger and older adults showed improvements in the Trial Making A task, this was for both the experimental and control group, suggesting that practice rather than strategy training was responsible for this increase. Only an effect of age was found for the Trial Making B task, with younger adults completing it in a faster time than older adults. If the strategy affordance hypothesis is accepted, than this lack of far transfer is hardly surprising. It would be difficult to reconcile how specific encoding strategies such as imagery and association would improve performance in task testing executive functioning, specifically the ability to switch between letters and numbers. This lack of transfer finding is in line with Bailey et al. (2014) and the wider literature (Zelinski, 2009). However, it does contradict the findings of Lustig and Flegal (2008), who reported an increase in performance of the Trial Making B task post strategy training. The training employed in their study did have a recollection repetition element which may have enhanced ability on the task making B task through activation of similar brain regions (left pre-frontal cortex) (Lustig & Flegal, 2008). By the same token, participants in this study had also completed some dual tasks (as part of study 3), which are thought to engage the central executive component of working memory, the executive functions, (namely cognitive flexibility) and activate the prefrontal cortex regions (Ohsugi, Ohgi, Shigemori & Schneider, 2013), however no such transfer effects were shown. Of course unlike the study of Lustig and Flegal the dual tasking element did not feature in the training so it may be that more exposure and direct training is required before performance can be improved.

Overall, this study failed to show that strategy training led to near or far transfer in younger and older adults. Although the findings of not demonstrating far transfer are consistent with the literature, the inability to find evidence of near transfer on an RSPAN is not. Differences in the sample for older adults may account for some of the results shown, but are unlikely to account for why this effect was not found in younger adults. Promisingly, strategy training was shown to boost the use of effective strategies in the RSPAN task, which in turn was related to increased performance in the sample.

8 General Discussion

This final chapter will summarise and integrate the results and conclusions from the four experimental chapters. The overall aim of this thesis was to build on the existing body of knowledge of memory strategy training in older adults, but expanding this to look more closely at whether any benefits from training could apply to dual task conditions. A central theme of this research was to examine the role of cognitive resources in strategy use and performance, with a specific focus on assessing whether a reduction in cognitive resources can account for age-related differences in performance. The theoretical and practical implications of the research presented in this thesis will be discussed, in addition to the limitations of the research. Finally, how this research can be developed in for future studies will be considered.

8.1 Overview of Findings

8.1.1 Strategy Training

The results from study 1 showed that strategy training can enhance performance in memory tasks; however younger adults were shown to only improve in single tasks, and older adults in dual tasks. As strategy use was not actually recorded in this study it was postulated that the effect could be due to differential strategy use at pre-test. To address this, study 2 looked more in depth at which strategies participants were using at pre and post strategy training. It was found that although younger adults exhibited a higher rate of spontaneous effective strategy use than older adults (Dunlosky & Hertzog, 2001; Tacconat, 2009), this difference was shown not to be statistically significant (Kulhman & Touron, 2012). Importantly, this study revealed that older and younger adults relied on different strategies to boost performance in the single task. In accordance with previous research, it was found that when the imagery level of the words was medium, younger adults relied more on an imagery strategy, whilst older adults chose a sentence generation strategy more, (Tournier & Postal, 2011).

As study 1 and 2 used a different imagery level for the word tasks, study 3 was designed to examine which strategies individuals used pre and post strategy training when the imagery level was high (as in study 1). When overall performance was assessed (irrespective of strategy use) the results differed slightly from those found in

studies 1 and 2, showing no improvements in the single task. This was surprising given that the imagery level was modified in favour of eliciting the use of effective strategies (such as imagery). The study did show improvements in both older and younger adults in the dual task condition. Although the beneficial effect of strategy training has been extensively reported, very few studies have shown that strategy training can enhance performance in dual task situations. This research represents (to the researcher's knowledge) the first study which attempts to uncover which strategies are used when performing a dual task, before and after training.

The findings of study 2 and 3, also confirmed the findings of Tournier and Postal (2011) who found that when presented with mid-level imagery items, older adults opted to use a sentence generation strategy more than younger adults, whereas when the imagery level of the words was high, this preference no longer manifested. In contrast to Tournier and Postal (2011) this was shown to be an adaptive behaviour as when using an effective strategy, both older and younger adults exhibited similar performance. In study 3, however, following strategy training, age-differences in the choice condition were still apparent. When older adults used an effective strategy, their performance was still lower than that of younger adults. This offers support for the notion that although older adults can select an effective strategy they may not be able to execute it as well as younger adults, thus exhibiting an utilisation deficiency (Gaultney et al., 2005). It also shows that older adults are able to compensate for this when the benefit of using an imagery strategy is not so obviously apparent (middle imagery level words), by choosing to use a sentence generation strategy to enhance performance.

Overall, the findings contribute to a growing body of research, suggesting that a short duration of memory training can be beneficial to enhancing performance in memory tasks (Gross et al., 2012). For younger adults this benefit was shown predominantly in single tasks (study 1) but also in dual tasks (study 3). For older adults, this benefit seems to be more prevalent in dual tasks (study 1 and 3), but also was seen in single task conditions when the imagery level was lower (study 2). Although there were slight methodological and sampling differences between the studies, one line of reasoning to account for the unexpected finding of older adults benefitting from a

strategy at dual task is to do with their baseline performance. Older adults typically performed a lot worse than their younger counterparts in the tasks, pre strategy training (sometimes at floor level). Therefore they had more capacity than younger adults to improve in the dual task. Younger adults, on the other hand, reported higher use of effective strategy use in the dual tasks (albeit this was non-significant) and although generally increased their performance, it may not have been enough to detect a statistical difference.

Through the novel use of the choice-no choice methodology utilised in this thesis, both strategy execution and strategy exploitation could be assessed independently of each other. The results were illuminating in a number of ways. Firstly, it was found that strategy training does lead to an increased use of effective strategies; participants were shown to report using more effective strategies following strategy training, not only in free recall tasks (studies 2 and 3), but also in an RSPAN task (study 4). Secondly, it was revealed that following strategy training, there were differences in strategy effectiveness between the choice and no-choice conditions. A typically effective strategy (imagery/association) was shown to be more advantageous than using a rehearsal strategy or no strategy in both the choice and no-choice conditions when the word recall task was performed on its own. However, when it was performed concurrently with another task (dual task condition), the benefit of using an effective strategy was only found in the choice condition and not in the no-choice condition. It suggests that allowing individuals the freedom to choose their strategy may be preferable to asking them to use a particular one. This has practical implications for training which will be discussed later.

8.1.2 Cognitive Resources

There is compelling evidence in the literature to suggest that individuals with more cognitive resources at their disposal (e.g. higher working memory capacity, greater executive functioning) perform better in cognitive tasks. A central premise to this is that those with higher abilities are better able to exploit the use of strategies (Turley-Ames & Whitfield, 2003). There is persuasive support for this notion from most of the studies outlined in this thesis. In study 1, there was a positive correlation between working memory capacity and performance in the word recall tasks. Although, this

on its own cannot be taken for support as actual strategy use was not measured, the findings from study 2 strengthen this theory. Study 2 reported strategy use and found that those who spontaneously used an effective strategy to encode the words in the free recall task (single task) performed significantly better than those using 'no strategy' or 'rehearsal' in tasks of cognitive flexibility, working memory, and planning ability.

When this was repeated using the strategy (effective, less effective) used in the dual task condition, only cognitive flexibility was shown to be affected, with those using an effective strategy in the dual task committing less errors on a task of cognitive flexibility. This finding was confirmed in Study 3 as well. This taken together with the finding that performance on the IED task significantly correlated with performance in the dual task, provides persuasive evidence that executive functioning (specifically cognitive flexibility) is important for effective dual tasking, consistent with the wider literature (Holtzer, Stern & Rakitin, 2005).

The executive functions (especially cognitive flexibility) have not only been implicated in dual tasking and strategy use (Bouazzaoui, et al., 2010), but also in the ability to shift strategy use (Taconnat, 2009). Study 2 examined this by looking at whether those who moved from a less effective strategy pre training, to a more effective strategy post strategy training, had greater cognitive flexibility. Although this study did not find evidence to support this tenet, owing to the findings outlined above it may be difficult to detect this effect (as most individuals with high cognitive flexibility use an effective strategy pre strategy training). Therefore this cannot be ruled out, and should be explored in future research.

8.1.3   Theories of Cognitive Aging

8.1.3.1   *Reduced Resources*

A prevailing theme in the cognitive aging literature is that older adults perform worse on a number of memory tasks because they lack the necessary cognitive resources to accomplish the task (Craik & Byrd, 1982). Reduced cognitive resources have been proposed to be responsible for older adult's poorer strategy use (Bailey, Dunlosky & Hertzog, 2009), reduced adaptivity, (Lemaire, 2010) and greater dual task costs

(Naveh-Benjamin et al., 2005). The research outlined in this thesis, provided a good opportunity to explore these ideas, as it assessed performance in free recall tasks, including in dual task conditions which are believed to be very effortful and resource demanding.

Overall the current research offered little support in view of older adults possessing reduced cognitive resources. In study 1, it was hypothesised that working memory strategy use (as assessed by backwards digit span) would be significantly lower for older adults. Despite age differences in memory performance in the word recall task, there was no significant difference in working memory capacity between younger and older adults. Study 2 further examined the role of cognitive resources using measures of working memory capacity, executive functioning (cognitive flexibility) and planning using the CANTAB. As with study 1, although younger adults were often credited with significantly higher performance in the word recall tasks, there were no age differences present in the cognitive resource measures. Only study 3, offered evidence to the contrary and did show age effects in both working memory capacity and executive functioning (planning and cognitive flexibility). Additionally, in contrast to study 2, older adults were also shown to perform worse than younger adults post strategy training in the single task, choice condition. However, as stated earlier in the discussion sections of the experimental chapters, the samples used in these studies could be a factor for why age-differences were generally not found[21]

A consistent finding in the studies was the absence of age-related differences in dual task costs. That older adults did not exhibit disproportionate costs compared to younger adults in the primary task (memory performance) is in line with some findings (Anderson et al., 1998; Park et al., 1987, but for contradictory results see Craik, et al., 1996). However, the finding that older adults did not show higher costs in the secondary task, compared to younger adults was unexpected. Previous research had demonstrated that improvement in memory performance due to strategy use came at a cost to performance in the secondary task only for older adults (Naveh-Benjamin et al., 2005). The finding that older adults could improve their memory through strategy use without incurring secondary task costs is difficult to reconcile with the

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[21] This thread will be revisited in the limitations section.

reduction in cognitive resources theory, as it would be expected that when you are reducing the amount of resources available (by adding a secondary task), this should affect older adults more if they have less resources to begin with, which was not shown in the current research.

8.1.3.2 *Frontal Lobe Hypothesis*

Similar to the reduced resources hypothesis, it is argued that tasks that rely on the frontal lobes, are more sensitive to the effects of aging (Moscovitch & Winocur, 1995, West, 1996). In studies 2 and 3, measures of executive functioning (focusing on cognitive flexibility and planning) were used to investigate this theory. In study 2, despite older adults not performing as well as younger adults in these measures, this difference was not significantly different. Study 3 revealed that older adults possessed less cognitive flexibility than younger adults as they made significantly more errors in the IED task. The SOC task, which is thought to reflect an individual's planning ability (and thus reliant on frontal lobe functioning) was not shown to be affected by aging. In fact in study 2, performance between older and younger adults was equivalent in the SOC task. Taken together, these findings do not provide much support for the frontal lobe hypothesis.

8.2 Limitations of Research

Specific limitations pertaining to the studies conducted in this research have been stated in the experimental chapters. The broader limitations of the research will now be briefly discussed, before going on to consider the implications of the research and outline ways in which our understanding in this field can be advanced by future research.

One such limitation is that this research did not directly examine the role of metacognitive beliefs. Although this was acknowledged in the research, it was not directly investigated.[22] There is a plethora of research suggesting that older adults and younger adults differ in their beliefs about memory. For example older adults typically hold more negative views about their memory and are more susceptible to a negative stereotype threat (Levy, 1996; Desrichard & Köpetz, 2005). Crucially, it has

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[22] In the memory strategy training- information about how memory works was given and how beliefs may affect this were briefly discussed.

been proposed that older adults are not as good as younger adults at monitoring their own memory performance (Brigham & Pressley, 1988).This has implications for the current research as strategy choice has been shown to be affected by knowledge and experience when performing memory tasks. For example, when individuals are shown through task experience that an imagery strategy is superior to repetition, younger adults updated their strategy knowledge to accommodate this, and utilised an imagery strategy more when given a choice, whereas older adults did not (Hertzog, Price & Dunlosky, 2012).

Although in the current research, both older and younger adults did increase their use of effective strategy use and benefit from its use, older adults did report more negative views about their memory. Anecdotal evidence from the testing sessions highlighted this, with older adults making more comments such as "I won't be any good in this task" "I won't remember anything." It would be remiss to think that this would not have an impact on memory performance. Future research should ensure that metacognitive beliefs are investigated when examining strategy choice and execution in older adults.

Another limitation of the current research concerns the nature of the dual tasks. In dual tasks, individuals have to allocate cognitive resources between the two tasks. Research has shown that these resources are under an individual's direct control and can be flexibly allocated (Bherer et al., 2005). As the mechanisms responsible for the allocation of resources (executive attention/central executive) have been implicated in aging, this may have a bearing on how older and younger adults executed the tasks. In the current research, although participants were asked to divide their attention equally between the two tasks, it may be that they were experiencing difficulty in allocating the resources equally, or were consciously prioritising one task over the other.

Evidence from dual-task studies examining gait and cognitive tasks, has revealed that older adults, who are at a risk of falls, typically prioritise cognitive performance rather than walking, due to inefficient resource allocation (Maclean, 2013). Although, this is not the same situation, the possibility that older adults may allocate their resources differently to younger adults cannot be ruled out. In fact, when asked about how they found the tasks, some older adults reported that they focused on the tones more than

the words in the dual tasks as they found it easier and thus felt that they could perform better in it. This could be the reason why secondary task costs were not found in this body of research, contrary to what was predicted. Future research could examine this by asking individuals to differ in their prioritisation of the tasks, and seeing how this affects performance, and whether there are any age-differences.

Although this research focused on encoding strategies used in free recall task, retrieval strategies undoubtedly play a role in remembering information. Recent work conducted by Hertzog, Fulton, Mandiwala and Dunlosky (2013) has revealed that age differences in memory performance may be more to do with poorer use of retrieval strategies rather than inadequate encoding strategies. In their study, older and younger adults were asked to either use a interactive imagery strategy or a sentence generation strategy to study 40 unrelated word-pairs. The concreteness of the word pairs was manipulated so that half of them were easy to imagine and half represented abstract words (not easy to imagine, e.g. justice). The mediators that were used by individuals to associate the two words together were also recorded at recall. In addition to the expected age effects, and concreteness effect, it was found that older adults failed to decode the mediators as successfully as younger adults. Interestingly, even when older adults recalled the mediator correctly, they were more likely to unsuccessfully retrieve the target word.

It has been proposed that older adults rely on gist-based memory more than younger adults, and this leads to more retrieval errors in uncovering the target word. This coupled with research identifying that older adults are less likely to utilise effective retrieval strategies such as distinctiveness, and other controlled retrieval strategies (Gallo, Bell, Brier & Schacter, 2006; Luo & Craik, 2009), provides a strong account that retrieval strategies are an important factor in recalling information.

Due to the intensive nature of the research and the topic being studied, recruitment was a difficult process, especially with older adults. Therefore, although the sample size is adequate for examining the main effects of age and strategies employed in the no-choice conditions, it is less so in the choice conditions. As strategy use cannot be controlled in this condition, it is difficult to establish a priori how many participants will use particular strategies. Therefore, some of the comparisons are run on a very small sample. Whilst the current research may be sufficient for detecting large

effects, a study with a larger study sample size may prove more sensitive to detecting relatively small effects.

Changes to the recruitment strategy over the course of the research may have influenced the results obtained. As previously stated, in studies 1 and 2 the older adults were mainly recruited from local organisations such as University of the Third Age, which represents members who are actively engaged with the local community and are typically well educated. For studies 3 and 4, older participants were primarily recruited from local sheltered accommodation organisations and although volunteered to take part in the research, did not necessarily seek out the opportunity. These subtle motivational differences coupled with the educational differences present (overall the older adults in studies 3 and 4 were less educated than those in study 1 and 2) could have influenced some of the findings. For example, no age differences in cognitive resources were found in study 2, whereas older adults were shown to perform more poorly than younger adults in measures of executive functioning, working memory and planning in study 3 .

A higher educational level and greater participation in intellectual, physical and social activities has also been associated with cognitive reserve (Stern 2002), which in turn is said to act as a buffer against cognitive decline (Hulstch, Hertzog, Small & Dixon, 1999). If the older adults recruited in studies 1 and 2 had greater cognitive reserve than those in studies 3 and 4, then it makes comparisons between the studies difficult. Nevertheless as aforementioned, these limitations are not unique to this body of research, but are prevalent in most cognitive aging research. Future research may benefit from the use of more heterogeneous samples.

Studies involving memory training are often criticised for their lack of ecological validity (Cavillini et al., 2003, Mohs, 1998), and this research is no exception. As the studies in the current research, investigate participants ability to utilise strategies on unrelated word lists, it can be argued that this situation is not very representative of everyday life. Although the tasks were carefully chosen so that they could be substituted with more real-life examples (e.g. listening to a train announcement whilst memorising a shopping list) they still can be considered 'artificial' laboratory studies. Therefore the degree to which the findings can be generalised to other contexts is open to debate.

However, studies conducted in the laboratory do have their merits, for example they can be run in a controlled setting, and often demonstrate mechanisms that are in operation outside of the laboratory as well (Kvavilashi & Ellis, 2004).

Despite these limitations, the studies presented in this thesis do contribute to existing research on aging and strategy training. The current research also provides interesting and novel insights in relation to dual tasking and strategy use. It also offers some practical advice for the application and development of future research in this area, which will now be discussed.

8.3   Implications of Research

This research highlighted a number of important factors when investigating the effects of memory training. Firstly, it shows the value of monitoring strategy use in studies looking at the effects of training. In most studies looking at strategy training, it is assumed that if participants increase their performance then it because they are using the strategies trained, even if explicit instruction to use a strategy is given.   The current research revealed that although participants do increase their use of effective strategies following training they still report using a variety of different strategies. Furthermore, older and younger adults may be relying on different strategies to enhance their performance, as was the case in study 2 and as demonstrated by Tournier and Postal (2011).

Secondly, there are merits in utilising a choice/no-choice method in these circumstances. Firstly as it allows for a greater investigation into which strategies people choose and how well they can use them, it can reveal subtle differences, which may not be apparent in traditional methods. For example through this method it was shown that when participants were able to choose their strategy in the dual tasks, an imagery/association was shown to be superior to a less effective one (rehearsal), yet when participants were asked to use imagery or rehearsal this effect disappeared (imagery and rehearsal showed similar recall levels). Of course the choice is the crucial element here, in the no-choice condition some participants are being asked to use a strategy that they would not voluntarily adopt, and therefore may not be very adept in its use.

These findings, taken together bring attention to an important point which may be overlooked in traditional strategy training research, namely the distinction between results when participants are given a choice or no choice. In the current research, if only no-choice data were collected it would read as though following strategy training both older and younger adults were able to utilise an imagery strategy to the same extent, which although true does not capture the full picture. Also, it would point toward an imagery strategy not being an effective strategy in a dual task, when in fact it is, but only when participants voluntarily choose to use it.

This has implications for not only the way in which memory strategy training is measured and monitored, but also for the training itself. As participants were shown to use a number of different strategies post strategy training in the choice condition, this adds to the emerging literature advocating the use of training multiple strategies (Craik et al., 2007; Lustig & Flegal, 2008; Derwinger et al., 2005).

The research also shows that a short duration of memory strategy training (45mins) can not only lead to increased performance, but also in the promotion of effective strategies, even in untrained tasks (such as the RSPAN). Increased performance due to strategy training was not consistent across the studies, showing that this training method may only be effective with particular samples or in specific contexts. Nonetheless it does provide partial support to a growing body of research showing that a short training procedure can have a positive impact on older adults performance and strategy use (Gross & Rebok, 2012; Bailey et al., 2014). Even if does not directly improve performance in older adults, strategy training has consistently been found to boost strategic behaviour in older adults and even to increase everyday functioning (Gross al, 2012).

8.4   Future Directions

It is clear that there are many different avenues that research has yet to explore concerning aging, strategy use and dual tasking. In order to further knowledge in this area, and address some of the limitations raised in this research, the following recommendations for future work are made.

Firstly, the role of metacognitive beliefs should be explored fully in order to ascertain how beliefs about memory impact performance. This is particularly salient for older adults, who typically hold more negative stereotypical beliefs about their memory (Desrichard and Köpetz, 2005). Measures such as the Metamemory in Adulthood Scale (MIA) (Dixon, Hultsch & Hertzog, 1998) or Multifactorial Memory Questionnaire (MMQ) (Troyer & Rich, 2002) can be administered alongside cognitive tasks to ascertain how individuals feel about their memory and assess strategic behaviour. Administration of these questionnaires in conjunction with studies examining strategy choice and execution in single and dual tasks could give a more refined insight into why certain strategies are adopted and in which tasks.

Secondly, assessing how individuals allocate their resources between the two tasks when performing dual tasks would be a useful line of enquiry. As previously stated, differences between older and younger adult's allocation of resources in the dual task may have been responsible for the lack of disproportionate dual task costs seen in the older adults, which are more typical in the literature (Naveh-Benjamin et al., 2005). Therefore it would be useful to investigate this in future research to determine if older and younger adults allocate their resources differently. This is important, as inefficient allocation of resources has been shown to be worse for older adults in dual tasks examining postural control and cognition, but have also been shown to be amenable to training (Bherer et al., 2005).

Another interesting avenue to pursue is to further examine the role of processing resources. Although the results from the current research revealed that there was a relationship between strategy use, aging and performance in the single and dual tasks, these were mainly correlational in nature. It would therefore be useful to examine the individual contribution of processing resources using regression techniques or structural equation modelling. These could be assessed in different contexts (e.g. in choice/no choice conditions or single/dual tasks) to establish whether these change. For example, it may be that these are more required for older adults (Bouazzaoui et al., 2003), or executive functioning explains more variance in the dual task conditions (Holtzer, Stern & Rakitin, 2005).

8.5   Summary and Conclusions

In summary, the main aim of this research was to determine whether strategy training could improve performance in younger and older adult's performance when undertaking a free recall task on its own, or concurrently with another task. The findings highlight that strategy training can improve performance in both single and dual tasks, however this was not a consistent finding among the studies conducted within this thesis. Effective strategy use was also shown to be enhanced following strategy training, for both older and younger adults, even in tasks that were not trained.

Overall the results have implications for theories of cognitive aging. Firstly, they do not point toward a production deficiency/strategy deficit in older adults, as older adults were shown to spontaneously use effective strategies prior to strategy training (study 2 and 3). The findings are also hard to reconcile with the environmental support hypothesis (Craik & Byrd, 1982) for the same reason. Older adults should experience deficits when the environment is not very supportive, yet in study 2 older adults were shown to be able to utilise an effective strategy to the same extent as younger adults prior to any training (support) being given in the dual tasks. The results partially support an utilisation deficiency theory, but only when the imagery level is high, as older adults do not utilise a sentence generation strategy to boost performance. Promisingly, improvements to older adult's dual task performance did not come at a cost to their secondary task performance. This is at odds with the reduced resources account of cognitive aging, as it would be expected that any task which taxes resources would be more demanding for older adults and would therefore equate in greater costs.

Cognitive resources, namely working memory and executive functioning were found to have an impact on performance and strategy use. However, in contrast to the literature, age-differences were not consistently found in these measures. It was found that higher cognitive resources were related to increased performance in the tasks, and also greater spontaneous effective strategy use. These findings are in line with Bailey et al. 2009 who found that although effective strategies account for individual

differences in memory performance, age differences in effective strategy use do not account for age-related differences in performance.

Finally, this research supports the use of teaching a number of different strategies to older adults to boost their memory performance. Even if memory performance is not increased per se, it may lead to more strategic behaviour, which in turn may lead to greater everyday memory functioning outside of a laboratory setting (Gross et al., 2012).

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APPENDICES

APPENDIX A

Participant Information Form

Department of Psychology and Counselling
University of Greenwich
Avery Hill Campus
London SE9 2UG
Tel: 020 8331 8217/9925
Email: V.G.Masters@gre.ac.uk

Dear,

My name is Vicki Masters and I am a PhD student studying memory at the University of Greenwich, supervised by Sandhi Patchay (PhD). Thank you for your interest in taking part in this study. Before you decide if you would like take part, please read the following information very carefully. Feel free to contact me and ask any questions if you are unclear about anything or would like more information.

There are many circumstances in everyday life that require us to do more than one thing at a time. This research is looking at how younger adults and older adults do this, and if there are any differences between them. In particular, this research is concerned with how well people can use their memory in these situations. This piece of research is not concerned with the memory capacity of individual participants, rather the performance of everybody as a whole.

This research has been approved by the University Research Ethics Committee. If you agree to take part then you will be invited to attend a number of sessions atthe University of Greenwich (Avery Hill Campus), in which you will be asked to perform a number of memory tasks on a computer/paper pen and answer some questions about yourself. Specific instructions will be given to you prior to the start of the tasks.

The experimental sessions:

- Participants will be divided in to equal groups by the researcher
- Depending on which group you are in, you may participate in different tasks.
- Sessions will take place over 2 separate days over 2 weeks and on each day you will participate individually in a number of tasks. The most time you will have to spare in a single day will be approximately 1.5 hours
- Total participation in all of the tasks will be 2-3 hours, and the minimum amount of time will be 30mins.
- In these sessions you will be required to undertake some memory-based/attentional tasks (e.g. remembering a list of words/numbers) some of which will be on a computer (no prior computer experience is required).
- We request that you do not discuss the nature of the experiments/questionnaires with any other participants over the duration of the study.

Only sign the consent form if you are able to offer that much time

<u>Please note:</u>   Due to the nature of the tasks in this research, there will be some reasons that participants will have to be excluded. Unfortunately, you will not be able to participate if any of the below apply to you.

➢ If you have an uncorrected hearing impairment.
➢ If you do not have good command of the English language
➢ If you take any medication that is known to affect your thinking ability/concentration etc.
➢ If you are not aged 18-30 or65+

Your participation in this study is completely voluntary; you are free to withdraw at any time, and can ask that any information about yourself, including your results on the tasks can be withdrawn.

Once agreeing to take part in the research, prior to participating in the research you will have an opportunity to ask any questions and handed a consent form to sign. A debrief sheet will be given to you after you have finished the final session. You will also be given this information sheet with my contact details on, so that you are able to contact me in between sessions if you wish too.

At the end of the study, it is expected that the information obtained will be published. Your anonymity and confidentiality will be respected at all times, by asking you to create a personal code for yourself which will be used instead of your name. If you want to withdraw your data from the study you can be easily identified by your personal code. This is the only way the data will be attached to you and no names will be mentioned at any point. The data that you provide will be kept in a locked cabinet and will be destroyed after seven years. Your information will not be used for any other purpose, other than described here, without your prior consent.

If you have any questions, or would like to arrange a time to take part in the research then please do not hesitate to contact me on 020 8331 8217, 020 8331 9925 or alternatively email V.G.Masters@gre.ac.uk. You can also contact my supervisor, Sandhi Patchay (PhD) on 020 8331 9587 or email S.Patchay@gre.ac.uk

Yours Sincerely,

Vicki Masters

Participant Consent Form

Title of Research: Memory performance in younger and older adults during single and dual-task conditions
Investigator's name: Victoria Masters

To be completed by the participant
 	
 1. Have you read the information sheet about this study? — YES/NO
 2. Have you had an opportunity to ask questions and discuss this study? — YES/NO
 3. Have you received satisfactory answers to all your questions? — YES/NO
 4. Have you received enough information about this study? — YES/NO
 5. Which researcher/investigator have you spoken to about this study? — ……………
 6. Do you understand that you are free to withdraw from this study:
   • at any time? — YES/NO
   • without giving a reason for withdrawing? — YES/NO
 7. Do you feel well enough to take part in the study? — YES/NO
 8. Do you agree to take part in this study? — YES/NO

Signed   Date
Name in block letters
Signature of investigator   Date

The consent form **must** be signed by the actual investigator concerned with the project after having spoken to the participant to explain the project and after having answered his or her questions about the project.

This Project is Supervised by: Dr Sandhi Patchay
 Contact Details   Department of Psychology and Counselling
              University of Greenwich
              Avery Hill Campus
              London SE9 2UG
          Tel:020 8331 9587
          Email: S.Patchay@gre.ac.uk

Personal Information Form

For this study, it is useful to collect some information from participants. To respect your anonymity, please do not write your name on this form, instead invent a personal code that is memorable and unique to you, (e.g. the first two letters of your mother's maiden name and the number of the house in which you grew up). This way, if you do wish to withdraw your data at a later stage it can be removed on production of your personal code.

Personal Code: _____

Ethnicity: *Please tick*

White British	☐
White Other	☐
Black British	☐
Black Caribbean	☐
Black African	☐
Asian	☐
Chinese	☐
Mixed	☐

Gender   Male ☐ Female ☐

Other   *(please   state)* _____

Age: _____

Occupation:
_____

Level of Education:
_____

(e.g. school/college/university level)

Do you currently use any memory strategies to help you remember information?
Handy 'tricks' that help you remember things more easily.

Yes ☐   No ☐

If yes, please list which strategies you currently use and for what purpose:

(e.g. making a list to take shopping, using imagery to help revise for exams, using association to remember people's names)

_____ _____

_____ _____

_____ _____

Please list any medication that you are currently taking and for what condition: (if known)	_____ _____ _____ _____ _____ _____

Please feel free to omit any questions that you do not wish to answer

Overview of Memory Strategy Training
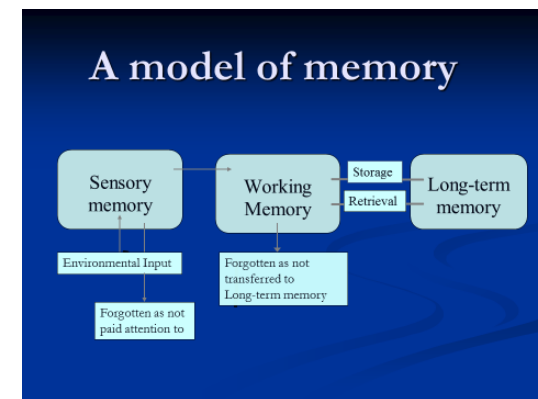
Memory Strategies

Vicki Masters

What is memory?

"Memory is the scribe of the soul"
Aristotle BC 384-322, Greek Philosopher

- Memory is the process of storing information to be remembered at a later date. It is a fundamental process and is necessary in order to function properly.

- There are different components involved in memory processes:

  - ➢ **Sensory Memory**: this is where all sensory information will be stored (e.g. all sights, sounds etc).
  - ➢ **Short-term Memory/Working Memory**: This is the information in conscious thought at one time.
  - ➢ **Long-term Memory:** Contains all your memories that are not in your conscious awareness but are stored, ready to be remembered.

A model of memory

Sensory memory → Working Memory → [Storage / Retrieval] → Long-term memory

Environmental Input

Forgotten as not transferred to Long-term memory

Forgotten as not paid attention to

Encoding & Retrieval

- **Encoding:** The process of getting information into memory.

- **Retrieval:** Getting information from long-term memory into conscious thought-'working memory'. There are 2 ways in which this can occur:

  Recognition or **Recall**.

  (Recognition is easier than recall)

Strategies

- There are some strategies that can be used in a variety of situations, which are referred to as **Global Strategies**.

- There are also some strategies that are better suited to specific tasks, which are known as **Task-specific Strategies**.

Global Strategies –
Visualisation/Imagery

- Visualisation & Imagery-

Visualising a picture/image in your 'mind's eye' of what you want to remember.

How many windows are in your house?

Visualisation

- The Visualisation strategy is good for remembering many things:
  - A shopping list
  - The name of the cereal brand you want to try
  - A route to a place you want to visit.

Forming images is a core component for many other memory strategies, therefore it is useful to master this skill before using other strategies.

Association

- Associating new information (you would like to remember) with existing knowledge or linking it to another object that needs to be remembered.

  - **Visualisation** is a useful technique to use for this. For example if I wanted to remember the words "shoe" and "bench" I may want to imagine a shoe on a park bench.

An Example

- How would I remember the following two words?

  Sheep
  Pirate

You could imagine a pirate holding a sheep, or maybe instead of a parrot on his shoulder a miniature sheep. Or You could imagine something like this………

The Pirate Sheep!

Now you try………

- Try and think of a way to remember the following things:

  Tree
  Cat
  Violin
  Lake

Global Strategies- Recap

Both Visualisation & Association are useful strategies that lead to deeper encoding and aid recall at a later stage.

Strategies are difficult to use at first, and do require effort and practice.

Task- Specific Strategies
Name-Face Association

- **Name- Face Association**: Pick a prominent feature of a person and link it with their name.
  (Hair, eyes, nose, smile etc)

  You can also this technique to associate the person's name (you want to remember) with somebody you already know with the same name.

The Link/Story Method

- Linking items in a list together- this can be either through visual images, or a story.

  Useful for memorising short shopping lists:

  Eggs, Bread, Bottle of Coke, Bananas

Chunking

- Chunking is a useful method for remembering numbers.

  The Principle is to break a digit of numbers own into manageable 'chunks'.

  1, 6, 8, 4, 9, 5, 4, 5.
  First organise them into 'chunks' of 2
  (16, 84, 95, 45).

Thank you for your participation in it is very much appreciated.

I hope that this session has been both enjoyable and informative.
I welcome any suggestions or feedback you may have.

Debriefing Form

Once again, thank you for taking the time to participate in this research, your participation is much appreciated.

As you are aware, this study was involved in looking at memory in both younger and older adults, and involved participating in a variety of different cognitive tasks. Previous research has shown that it is difficult for people to complete two tasks at the same time and this study focused on looking at how well memory can be used in these situations, and whether certain memory strategies are effective.. We are particularly interested in determining if these strategies will be beneficial to the older population (aged 65+). It is hoped that the findings of this research will offer insight into how we perform more than one task at a time and can help develop training programs to enhance performance in these circumstances.

At this stage, we do not know the results of this study, but if you are interested in knowing the outcome of this study then you can request a summary Please email V.G.Masters@gre.ac.uk or call me on 020 8331 8217It is likely that many of you found the tasks difficult, this is perfectly normal as the tasks were designed to be challenging. If you would like more information about the tasks or the nature of this study then please contact me on the email address above or the following phone number 020 8331 8217. You can also contact my supervisor Sandhi Patchay (PhD) S.Patchay@gre.ac.uk or 020 8331 9587 If you are concerned or anxious about your memory performance in any way then please consult your GP or contact any of the support services below that can offer you guidance.

NHS Direct   www.nhsdirect.nhs.uk   0845 4647

Age Concern   www.ageconcern.org.uk

Help the Aged   www.helptheaged.org/uk

It is anticipated that future research will be conducted in this area, if you would like to be contacted about participating in future studies or know of anyone who would be interested in taking part in similar studies then please let me know.

Many Thanks,

Vicki Masters   Personal Code _____

APPENDIX E

Dual Task costs

Study 2

In addition to the main analyses; it was felt prudent to examine the dual task costs as well, to ascertain how performance was affected by the introduction of another task. Examination of the dual task costs could also reveal whether certain strategies were more resource demanding then others, (evidenced by higher costs). Finally, the question of whether older adults are more penalised by the introduction of another task in comparison to single task performance can be answered, reflected by higher costs in the primary (word recall) or secondary (auditory discrimination) tasks. As in study 1, relative dual task costs were calculated to avoid differences at baseline (single task) artificially inflating the scores.

Choice Conditions

Primary task

A mixed ANOVA was performed on the data to determine whether dual task costs changed from pre to post strategy training. If the cost of dividing attention was higher post strategy training then it could be argued that utilisation of an effective strategy is more resource demanding (as more participants used an effective strategy post training). To that end a 2 (Age- younger, older) x 2 (Time, pre and post strategy training) was run on the dual task costs. All the results were shown to be non-significant (all F's <1).

Secondary task

When the analysis was repeated on the tone data, a different pattern of results was revealed. The main effect of time was still not significant ($F<1$), but the main effect of age was. The results showed that it was in fact younger adults who showed higher dual task costs in the secondary task ($F[1, 30]= 4.62$, $p=.04$, $\eta^2_p =.13$). The interaction between time and age was marginally significant, revealing that pre strategy training (T1), older and younger adults exhibited similar dual task costs, but following strategy training these were a lot smaller in older adults ($F[1, 30]=3.79$, $p=.06$, $\eta^2_p =.11$).

No-choice condition

To determine how different strategies effected dual task costs, and whether this was effected by age, analyses were conducted on the no-choice conditions. As the strategy employed could change from single to dual task, dual task costs of the different strategies could not be calculated for choice conditions. Data were only analysed from participants who self-reported as being compliant to the strategy instructions. Two 2 x 2 ANOVAs with strategy type (imagery, rehearsal) as a within subjects factor and age (younger, older adults) as a between subjects factor was conducted on the primary and secondary task dual task costs separately.

Primary task:The results showed that there was a significant effect of strategy, higher dual task costs were found in the imagery (M= .26) as opposed to rehearsal conditions (M= -.07), (F[1, 20]=9.81, p=.005, η^2_p =.33. However, the main effect of age, and interaction between age and strategy was not significant (all p's ≥.16).

Secondary task: The main effect for age and strategy type were not significant (all F's <1). The age x strategy interaction was approaching significance, with older displaying lower dual task costs in the imagery condition than younger adults, with the opposite pattern in the rehearsal condition (F[1, 17]=3.12, p= .09, η^2_p =.16).

Overall the results from the dual task costs give an indication that using an effective strategy is resource demanding as when single task performance is taken into consideration, participants remember fewer words in the dual task condition when using an imagery strategy than when utilising a rehearsal task. The secondary task costs reveal that younger adults are more penalised than older adults when using an imagery strategy, and older adults are more penalised in the rehearsal condition than the imagery condition. However, this was only approaching significance. When choice conditions are examined, it appears as though younger adults exhibit greater secondary task costs than older adults, which could be attributed to greater effective strategy use.

Choice Condition
Primary task

A 2 (Age- younger, older) x 2 (Time, pre and post strategy training) x 2 (Group, control, experimental) mixed ANOVA was conducted on the relative dual task costs. The main effect of time was not significant ($p=$ .17), neither was the main effect of age ($F<1$). There was a marginal effect of group ($F[1, 34]= 2.92$, $p=$ .097, $\eta^2_p =..08$), with those in the experimental group exhibiting greater costs than those in the control group ($M=.33$, $M=$ .07, respectively). There was a significant Age x Time interaction, with younger adults exhibiting greater costs at time 2 than at time 1 and older adults showing the opposite pattern. All other interactions' were not significant (all F's <1).

Secondary task

A different pattern of results was obtained, when the analysis was repeated using the tone data. The main effect of time was still not significant ($F<1$), but the main effect of age was. Younger adults ($M = -0.35$) were shown to exhibit higher dual task costs in the secondary task than older adults ($M= 0.10$), $F(1, 33)= 6.59$, $p=.02$, $\eta^2_p =.16$. The interaction between group and age was significant, revealing that younger adults in the experimental group had greater dual task costs than those in the control group, and older adults showing the opposite pattern ($F[1, 33]=4.94$, $p=.03$, $\eta^2_p =.13$).

Error rates were also analysed, in order to determine whether they could reveal any costs which were not detected by looking at tone data. As the error rate was very low, before calculating dual task costs, 1 was added to the scores (see Yapotzis, Georgiou-Kaptins & Stout, 2013). The analysis revealed that there were no main effects or interactions (all p's $\geq$ .19).

No-choice Condition

Two 2 x 2 ANOVAs with strategy type (imagery, rehearsal) as a within subjects factor and age (younger, older adults) as a between subjects factor was conducted on

the primary and secondary task dual task costs separately. These analysis were only conducted with participants who were compliant.

<u>Primary task:</u> A main effect of strategy was found, with higher dual task costs in the imagery as opposed to rehearsal conditions $F(1, 13)= 6.31$, $p=.026$, $\eta^2_p =.33$. However, the main effect of age, and interaction between age and strategy was not significant (all p's $\geq.14$).

<u>Secondary task:</u> The main effect for age was significant, with younger adults displaying higher dual task costs than older adults ($F[1, 10]=8.77$, $p= .01$, $\eta^2_p =.47$). The main effect and interaction were not significant (all F's <1).
When the analysis was repeated using the error rates, the main effect of strategy was shown to be significant ($F[1, 10]=8.58$, $p= .02$, $\eta^2_p=.46$), with more errors being made when a rehearsal strategy was used in comparison to the imagery strategy.