CROSS-SECTIONAL AND LONGITUDINAL ANALYSES OF THE EFFECTS OF AGING ON MEMORY IN HEALTHY YOUNG, MIDDLE-AGED, AND OLDEST-OLD ADULTS

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To my mother, Jeanie Paton, now 90 years of age, an indomitable Scotswoman whose remarkable memory ignited my curiosity in just what does happen to memory during the aging process

Abstract

While a growing body of research indicates that older adults typically perform more poorly on many types of memory tasks than do younger adults, relatively little research has addressed the question of whether this trend continues unchanged into the late ninth and tenth decades of life. Such decrements in memory have been reported as linear declines from early adulthood up until about 80 years of age. Questions arise as to whether such memory declines slow or accelerate in very advanced aging, and to what extent differences are due to aging, per se, or variables that intervene between age and memory.

To address these two questions, six memory types – verbal recall, nonverbal recall, short-term memory, working memory, face recognition, and prospective memory – were examined using both cross-sectional and longitudinal methodologies. The six types of memory and the influence of verbal processing speed, nonverbal processing speed, and intelligence were examined in mixed-gender groups of 20 - 40 (n = 40, M = 30.7, SD = 5.52), 50 - 70 (n = 44, M = 59.2, SD = 4.94), and 85+ year olds (n = 42, M = 87.8, SD = 2.43), at two points, the second occurring two years after the first. Each participant completed tests of word recall, geometric shapes recall, short-term memory (digit span), working memory (letter-number sequencing), face recognition, and prospective memory. Additionally, there were two processing speed tasks (Identical Pictures and Finding As), and the National Adult Reading Test of verbal fluency was used to estimate intelligence. The Mini-Mental State Examination and the Beck Depression Inventory (BDI-II) were used to screen for dementia and depression, respectively.

At Time 1 testing the 85+ participants showed declines in all memory types (compared to the 20 - 40 year olds). Nonverbal recall (66.2% lower than the young group), working memory (46.2%), verbal recall (45%), and prospective memory (38.2%) produced the largest differences, short-term memory (12.3%) and face recognition (14.7%) the least. Two years later, the 85+ years old participants had shown further declines, relative to the 20 - 40 years group. Nonverbal recall (72.3% lower than the young group), prospective memory (63.2%), working memory (55.3%), and verbal recall (54.7%) continued to produce the largest decrements, with short-term memory (18.9%) and face recognition (19.8%) the least. The results for the young and middle participants

did not change appreciably between Time 1 and Time 2. The difference between unadjusted scores and scores adjusted for intelligence, verbal processing speed, and nonverbal processing speed, increased markedly between Time 1 and Time 2 testing for the oldest-old participants.

These findings support the view that while memory declines may be approximately linear from age 20 to 80 years, there is a sharp decline in most types of memory after the age of 85 years, recall and working memory suffering the most. Intelligence and processing speed have an effect on some types of memory, but age is by far the largest contributor to memory decline. Furthermore, as expected, all memory types declined over the two-year period, with prospective memory, verbal recall, nonverbal recall, and working memory showing the greatest declines. Short-term memory and face recognition declined at a noticeably slower rate.

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PREFACE

There may be no more pressing intellectual need in our culture
than for people to become sophisticated about the function of memory.

Hampl (1996, p. 211)

Memory is at the very core of human existence. Everything from daily activities to the smallest perception, thought, or reflection involves the memory. Our every action, speaking, writing, opening a door, driving a car – all mobilise and depend on memory.

One of the most remarkable and far-reaching demographic development in the last century has been the ‘greying’ of populations. By 2051, it is anticipated there will be 1.18 million people aged 65 years and over in New Zealand, representing an increase of 165% since the year 2000. Within this demographic group, the number of people aged 85+ years is expected to rise to 320,000 by 2051 (Statistics New Zealand, 2004). While there has been an explosion of research on memory over the past two decades, there has been little investigation of the changes in memory of healthy, community-dwelling individuals, particularly those over 85 years of age.

The automatic linking of age and forgetting may well play a significant role in shaping the stereotypes of aging. Writing in 1793 (Partington, 1996, p. 376), Samuel Johnson has said:

> There is a wicked inclination in most people to suppose an old man decayed in his intellects. If a young or middle-aged man, when leaving a company, does not recollect where he laid his hat, it is nothing; but if the same inattention is discovered in an old man, people will shrug up their shoulders, and say, ‘His memory is going’.

However, existing alongside the biased expectations, clearly memory deficits do occur with advanced aging. To clarify how memory is affected by aging, it is imperative intensive research effort is carried out. Nevertheless, despite the urgency of the need the bias against older people has existed even within experimental endeavour, including leaving them out altogether. Although a large body of research literature now exists on all aspects of memory, few studies have included individuals in their late ninth and tenth decades of life. Of the studies which have included the oldest-old, many of them are directed toward memory deficits which are a result of pathologies such as Alzheimer's disease, Parkinson's disease, and so on. Few studies have been carried out on healthy people who have reached these advanced ages.

The main purpose of the present research is to examine six specific types of memory across the adult life span, with a particular focus on adults who have reached 85 years of age and over. The choice of the memory types to be studied was a difficult one. There are a plethora of memory aspects which could have been chosen. The final decision – verbal recall, nonverbal recall, short-term memory, working memory, face recognition, and prospective memory – was made because these memory types are integral to the continued independence and to efficient cognitive functioning in advanced old age.

The choice to incorporate both cross-sectional and longitudinal methodology in the research design was made in order to access a balanced picture of memory ability during advanced aging. Hartley, Harker, and Walsh (1980) note that a reliance on cross-sectional methods has resulted in research findings that describe age differences rather then age changes, and Schaie (1980) suggests that the role of cohort effects are likely to influence results when reliance is placed only on cross-sectional data, although cross-sectional investigation remains the most common method of investigating memory to date. To the present time, little investigation which incorporates cross-sectional and longitudinal data on the oldest-old has been carried out.

The inclusion of a longitudinal design brings its own difficulties when investigating individuals who are in their late 80s and 90s. An inter-test interval of two years was chosen. While this may be viewed as a short time for a longitudinal study, when life expectancy is reduced to single digits a balance needs to be drawn between an expected attrition rate due to declining health or death, and capturing memory change over time.

The mixed design of the current study, while allowing for a comprehensive observation of both differences and changes in memory across the life span, presented difficulties in the choice of statistical analyses. Analysis of covariance (ANCOVA), widely used in memory research, was chosen so that the main effects and interactions of the independent variables could be assessed after dependent variable scores were adjusted for differences associated with the covariates (Tabachnik & Fidell, 2001). However, while this provided the necessary adjusted scores for the six types of memory, it did not answer the question of how much unique variance was associated with each of the chosen covariates. Thus, the decision was made to run a second analysis, multiple regression. These two analytical methods nicely complement one another, and together allowed for an in depth examination of certain memory changes across ages and across time.

Chapter One

A BRIEF HISTORICAL SURVEY OF MEMORY AND MEMORY RESEARCH

This chapter briefly reviews the early roots of memory research, and discusses the important contribution made by Ebbinghaus. The review traverses landmarks in recent memory research, considers the importance of the computer revolution, and presents a selection of influential models of memory which have formed the basis of memory research over the past few decades. Lastly, a glossary of terminology used in memory research is presented.

Learning and memory are primary mental activities essential for life. Learning makes possible the acquisition and integration of new knowledge and information which is then encoded, stored, and is later made available for retrieval (Loeb & Poggio, 2002).

The earliest recorded theorising on the nature of memory is that of the Greek and Roman philosophers and scholars. Traditionally, the first mnemonic method is ascribed to Cicero (106-43 BC). In *De Oratore* (Cicero, 55BC/1962), he describes a tragedy wherein the poet Simonides (556-468 BC) used the method of loci. Following a roof cave-in during a banquet, Simonides was able to identify the bodies by remembering who had been sitting at each place. Cicero suggested this experience showed how memory could be improved by forming mental images of things to be remembered associated with particular places. Cicero, along with other orators of the time, used this effective mnemonic method to aid in the recall of material for his own speeches (Higbee, 1988).

An early reference to memory is written by Plato (427-347 BC) in *Theaetetus,* where he has Socrates liken memory to wax-tablet imprints (the recording method of the times). Some inscriptions are bigger with more clarity, and others are soft, illegible impressions made into dirty wax (Plato, 360 BC/1990). In this template theory of memory, what is stored is believed to be an exact copy of the original and is used to match a new perception against the wax-like impression. This metaphor was, some 2,000 years later, explored by Freud as he speculated upon the Mystic Writing Pad model of memory processes (Draaisma, 2000).

The theoretical perspective, that memory provides an exact representation of information or events which can be compared with current input, provides a starting question for all following theoretical standpoints: “Does memory operate in this manner?” Clearly, memory is much more complex than these theories suggest, and template theories (e.g., Plato, 360 BC/1990) fail to account for the ability to comprehend variable stimuli with ease, such as familiar letters written by different people. Similarly, seeing an object or a person from a differing position would render the image unrecognisable within the template theory, as the image would be entirely different in form and content (Morris, 1992). Despite its obvious flaws, the template theory of memory held sway for hundreds of years. Whilst the preoccupation of early philosophers was to understand people’s knowledge and beliefs about the world, to do so requires remembering past experience. This inevitably resulted in speculation about the phenomenon of memory. Indeed, it was Plato’s metaphor of an aviary, where a bird is enclosed but may still remain uncaught (Plato, 360 BC/1990) that first recorded the distinction between stored memory which is available, but may not be retrievable from memory. This distinction between storage and retrieval was to be examined again by Tulving and Pearlstone (1966), researchers who distinguished between information encoded and stored in the memory which is accessible to the individual and that which has become irretrievable.

Aristotle (384-322 BC), a student of Plato, is credited with being the first person to suggest association of ideas as the basis of memory, propounding three laws of association: similarity, contiguity, and contrast (Leahey, 1987). Early British philosophers, such as Locke in the 17th century, further developed theories of knowledge relying heavily upon the basis of memory being association of ideas (Woolhouse, 1971). Such ideas developed through experiences and thus became accumulatively written on the mind of the individual, considered to be blank at birth. Aristotle further asserted that thinking inevitably produced a mental image, a view which is very evident in the work of the first experimental psychologists (Morris, 1992). However, mental image theories of memory are often criticised for a failure to take into account the representation of abstract concepts and meanings, although Barsalou (1999) argues for perceptual symbol systems wherein during perceptual experience, association areas in the brain capture patterns of activation in sensory-motor areas which will later be partially reactivated to implement perceptual symbols. The storage and reactivation of the perceptual symbols operate at the level of perceptual components rather than at the level of perceptual experiences.

The Influence of Ebbinghaus

The development of psychology during the latter half of the nineteenth century saw the beginnings of experimental memory research. Like his earlier counterparts, Ebbinghaus, whose work is traditionally regarded as the starting point of memory research, was influenced both by the historical theorising on mental images and the laws of association (Ebbinghaus, 1885/1964).

Hermann Ebbinghaus (1850-1909) is strongly associated with the laws of human learning and forgetting. His book *Memory: A contribution to experimental psychology,* first published in 1885, reported experiments commenced in 1879 (Ebbinghaus, 1885/1964). The results of these experiments provided an important foundation for the experimental psychology of his time. Prior to Ebbinghaus, who rejected the use of introspection as a methodology, techniques for the study of memory had simply not been developed (Eysenck, 1986). During the 1880s, Ebbinghaus continued experimentation on memory, arguing against the entrenched ideas of older generations toward the 'new' psychology, while struggling to obtain apparatus, funds, and space to continue his experiments (Sprung & Sprung, 1986). Always an innovator, Ebbinghaus was an initiator of the first German Congress of Experimental Psychology held in Giessen on the 18th of April, 1904.

Ebbinghaus's significance for the history of psychology lies in the uniqueness of his experiments in varied fields of psychology, many of which had long been considered inaccessible to an experimental approach (Sprung & Sprung, 1986). Indeed, the methods propounded by Ebbinghaus for the study of rote memory scarcely changed in the following century and, furthermore, he discovered most of the major phenomena of rote memory (Wertheimer, 1986). He was the first researcher to subject the higher mental processes to experimental scrutiny, resulting in an extraordinary plethora of discoveries. Amongst these are: the rate of forgetting curve and its surprising early steepness; the dramatic increase of memorisation time required when the load of units to be remembered increased; the finding that, although overlearning enhances memory, the efficiency decreases as the amount of overlearning increases; the increased efficiency of distributed practice over mass practice; primacy and recency effects; even small amounts of practice facilitates quicker re-memorising of material; and that memorising meaningful material takes only about one tenth of the effort required to memorise meaningless material. Furthermore, he produced mathematical formulas to describe many of the functions yielded by his carefully controlled experiments. Most of Ebbinghaus's work has subsequently been replicated by later researchers using more sophisticated techniques (Eysenck, 1986).

One of the most significant discoveries of Ebbinghaus is the theory of 'savings', permitting precise measurement of degrees of retention of material regardless of whether the material can be consciously recalled (Wertheimer, 1986). This method of assessing memory by savings during relearning permeats virtually all of his empirical research. The essence of the method involved the learning of the same stimulus material on two occasions, noting the improvement on the rate of relearning over the original learning, the savings, thus providing a measure of retention.

It is interesting to consider Ebbinghaus's notion of savings in relearning as an index of retention rather than measures such as recall or recognition. Ebbinghaus offered three reasons for his preference. He considered savings provided information about whatever is already stored in the long-term memory, whereas recall and recognition are limited to conscious memories, that savings is a more sensitive measure than either recall or recognition, and that it provides a more fine-grained measure than simply success or failure of recall and recognition. Eysenck (1986) suggests that although the last of these assertions can be overcome by the introduction of confidence ratings, for example, Ebbinghaus's decision to use the savings method as a major measure of retention still seems sensible a century later. Indeed, priming, which is considered to operate by activating a representation so that it is easier to re-activate at a later time when triggered by an appropriate stimulus, has become one of the most researched memory phenomena in recent times (Tulving, 2000).

Additionally, Ebbinghaus noted the immediate memory span is about seven items, a discovery which would be important in the computer-analogue models of short-term memory proposed by Miller (1956) many decades later. Whilst Ebbinghaus cautioned that his findings had been obtained from only one subject, himself, they subsequently turned out to be highly generalisable. Although he acknowledged Ebbinghaus was an important steppingstone in the development of the study of memory, Kintsch (1985) launched a particularly strong attack on the Ebbinghaus approach. He noted Ebbinghaus's lack of concern with the psychological processes which operate on the content of memory which Kintsch asserted was the main point of contemporary work on memory. Kintsch (1985) suggested that Ebbinghaus's austere associationism was to later interact with American functionalism and behaviourism in ways that "jointly helped to quell the beginnings of a more cognitively oriented psychology of memory" (p. 461), without which information-processing theories of memory might have been constructed decades earlier than they were. This may well have been a valid criticism but, as in many disciplines, new and progressive ideas eventually breach the walls of entrenched theoretical standpoints.

Eysenck (1986) points to differences in orientation between Ebbinghaus and contemporary cognitive psychologists. Simplifying somewhat, Eysenck suggested many of the differences can be clarified as a distinction between the stimulus-as-presented and the stimulus-as-encoded. Ebbinghaus attempted, in his experimentation, to make the stimulus-as-encoded as similar to the stimulus-as-presented as he could by the use of relatively meaningless material, the avoidance of mnemonic strategies, the use of serial learning, and the imposition of rapid response rate. Eysenck suggests this to be a limited goal in the light of the understanding that the learner is not a passive receiver of information. As will be discussed later, contemporary researchers such as Craik and Lockhart (1972) have attempted to identify some of the processing operations that determine relationships between the stimulus-as-presented and the stimulus-as-encoded.

Other Early Research

Free recall, today one of the most widely used procedures in memory research, also traces its roots back to the late nineteenth century. Kirkpatrick (1894) proposed the method of retained members whereby participants are requested to reproduce all the items possible, not necessarily in the order first memorised. Again, as in Ebbinghaus's experiments, Kirkpatrick found the superiority of meaningful, compared to unmeaningful, stimulus items, and that connected discourse is easier to memorise than lists of unrelated words.

The end of the nineteenth and early twentieth centuries brought refinements to the findings of the early memory researchers. The existence of plateaus in the learning curve, particularly in complex skills, was described prior to the end of the nineteenth century (Bryan & Harter, 1897). Witasek (1907, cited in Wertheimer, 1986)[1] showed that substantial recitation, rather than passive reading, enhances memorisation, and Poppelreuter (1912, cited in Wertheimer, 1986) empirically supported an assumption, made by Ebbinghaus, that intent to learn aids in the memorisation of nonsense syllables. Memory for real events came under the scrutiny of Binet (1905/1969) and Stern (1910), but did not become popular as a focus for experimentation until some decades later.

An influential theory of memory was proposed by Bartlett (1932) who noted that remembering does not involve activating fixed, lifeless and fragmented traces. Rather it "is an imaginative reconstruction, or construction, built out of the relation of our attitude towards a whole active mass of organised past reactions or experience, and to a little outstanding detail which commonly appears in image or in language form" (p. 213). Thus, memory is not reproductive, but rather reflects the development of 'schemata' that evolve from the individual's stored traces of past experiences, images, and abstract concepts: the individual is not a passive learner, as implicit in much of the Ebbinghaus research, but rather an active learner processing the incoming information, drawing inferences, elaborating on the presented stimuli, and making connections with past experiences. Bartlett showed how wide the gap can be between what is presented and what is subsequently remembered.

These early investigations into human memory provided a rich foundation for the intense experimental study heralded by the emergence of the computer, with all its promise of enhanced understanding of the complexities of human cognition, including memory.

Influential Landmarks In Recent Memory Research

The computer revolution

Gardner (1987) suggested that cognitive science "entails an empirical effort to answer long-standing epistemological questions" (p. 389) posed by classical philosophy, such as how we perceive the world, how we classify objects, words, images, and other

[1] As it has not been possible to locate English translations of the original writing, a secondary citation has been used.

constructs, and the assessment of human rationality. Perhaps the first stirrings of the computer revolution in cognitive enquiry began at a 1956 meeting of ten young scholars at the Dartmouth College in Hanover, New Hampshire, who gathered to confer about the possibility of producing computer programmes able to ‘think’ or ‘behave’ intelligently (Gardner, 1987). Since the early beginnings of the computer revolution in cognitive psychology, the field has separated into many streams of interest such as programming languages, creating models of psychological constructs, or testing theories of how a cognitive process may work. It is the latter stream that is of interest to the current thesis.

Arguably, the dominant approach to psychological investigation during the 1960s and early 1970s was that of information processing (IP). Palmer and Kimchi (1986) explain that “the intuitive basis of the information processing approach is a theoretical analogy between mental activity and a program running on a computer” (p. 38). The five underlying assumptions of this approach, as proposed in a metatheoretical view by Palmer and Kimchi, are: *Informational Description* – mental events comprising the input, the operation carried out on the input, and the output information; *Recursive Decomposition* – complex mental events can be specified more fully at a lower level by decomposing it into a number of temporally ordered components which will flow through the system; *Flow Continuity* – all input information required to perform an operation must be available; *Flow Dynamics* – no output operation can be produced until its input information is available and sufficient time has elapsed for its processing; and *Physical Embodiment* – the physical, dynamic system carries the information items (termed *representations*) and operations using this information are embodied in changes of state (termed *processes*). Palmer and Kimchi note that the term ‘mental events’ includes not only conscious experiences but all internal happenings influencing behaviour. The computer analogy, underpinned by IP assumptions, is that information from the environment (input) is available through sensory systems in a similar way that information is made available to a computer via a terminal. Some of this information is manipulated by way of mental operations in much the same manner as a computer manipulates information according to the rules the computer programme embodies. These mental operations include those that select, transform, store, and match information arising from present or past experience. Following such operations, the individual produces information (output) which may be expressed as overt behaviour in a similar way as the computer produces output through a printer (Palmer & Kimchi, 1986).

With the advent of the computer revolution, the terminology of memory became one of encoding, storage, and retrieval. Sperling (1960) found evidence of the fast-fading nature of briefly presented visual information, leading to extensive research on echoic and iconic memory, defined as very brief sensory memory of auditory stimuli (echoic) stored for slightly longer periods of time than are iconic (visual) stimuli. Sperling showed that a more or less complete, almost photographic, but very rapidly decaying image is maintained by the visual system for up to half a second after the disappearance of the stimulus. In other words, there was a new type of memory to be taken into account before short-term memory and processing of information was reached. This information-processing orientation was stimulated to further new interest with the finding by Sternberg (1966) that the scanning of items in memory is sequential rather than parallel.

Norman (1968) proposed a theory of attention and memory that followed on from those of visual information storage (Sperling, 1967) or iconic storage (Neisser, 1967). Norman posited the need for the storage of events to have at least two modes of operation: a mode for immediate, transient memories and a permanent mode for long-term memories. Immediate memories were considered to be clear and complete, prior to fading within a few seconds to a bare outline of the actual event. Historically, William James (1890, 1892) asserted that retrieval from each of these modes constituted very different tasks, with recovery from the transient mode being effortless and automatic, and the recovery from long-term memory requiring much mental effort. Norman suggested such an assertion erroneously assumes separation of the two storage capacities, whereas recognition of words or familiar sensory inputs requires the ability to access some representation of the input in the secondary storage. Clearly there must be sufficient connection between the transient and long-term modes to allow a selection process, implying primary storage is the temporary activation of part of the larger storage capacity precipitated by sensory input. Norman (1968) describes the retrieval process as a methodical, organised search of stored representations and interconnections which could be described as “associative networks, directed graphs, list structures, or matrices” (p. 531). In a similar way to the computer analogy, the query made when accessing information is all-important. When retrieval fails, it is imperative to alter the query in order to redirect the search of interconnections, so preventing a fruitless and repetitious search.

Reitman (1970) proposed a model using computer simulation to explore memory processes, where to-be-remembered items were seen as passing through a series of processors until long-term storage was achieved. As items typically arrived more quickly than they could be processed, queues formed prior to processing (Bower, 1967; Reitman, 1970). The behaviour of these queued items was postulated to conform to regularities. For example, items decay over time, and incoming items bump each other out of the ‘waiting room’ which is of fixed size. Reitman presented strong predictions such as the primacy effect varying with changes in presentation rate and the recency effect varying with different types of items. Feigenbaum and Simon (1962) also utilised a computer-simulated memory model in accounting for queued input effects by arguing that a computer programme could specify priorities for ‘preferred customer’ status of queued items. This priority scheme was embodied in a programme, EPAM (Elementary Perceiver And Memorizer), in which an individual selected an item, termed an anchor point, to be processed first and which accounted for fluctuations in the speed of processing and decay. Computer programming was thus considered an invaluable research tool because of the speed of computers, their accuracy, and memory size. Reitman postulated that the locus of individual differences in memory may be a function of maximum queue length and/or decay rate. Reitman did, however, recognise that this computer simulation model, though encouraging, was inadequate as it assumes that incoming items are equal and independent and that information is accessible for recall, assumptions which could not be supported.

Multi-System Models

During the 1960s, whether memory should be regarded as a single unitary system or should instead be divided into two or more subsystems became a major controversy within the discipline of cognitive psychology. In 1958, Brown published research showing that information is forgotten within seconds if rehearsal is prevented. Similarly,

Peterson and Peterson (1959) developed a short-term forgetting paradigm, and asserted that their research implied the operation of a limited-capacity short-term memory store fundamentally different from the system required for long-term learning and memory.

The study of brain-damaged patients also yielded persuasive evidence for a two-system model. Patients suffering from the classic amnesic syndrome appeared to have gross disruption of the capacity to form new memories, but showed preserved performance on a range of tasks assumed to utilise short-term memory. Conversely, patients were identified who appeared to exhibit normal long-term learning but were capable of retaining only one or two items in short-term memory (Shallice & Warrington, 1970). Termed a double dissociation, the observation that short-term memory and long-term memory are dissociable processes and served by separate neurological systems has been well supported by recent research (e.g., McCarthy & Warrington, 1987; Postle, Berger, & D'Esposito, 1999; Sullivan and Sagar, 1991). For example, in a study comparing a normal control group with three groups of neurologically-impaired adults on measures of nonverbal memory, Sullivan and Sagar found different patterns of sparing and loss for short-term memory and long-term memory: In Parkinson's disease only short-term memory was impaired, whereas in medial temporal lobe amnesia only long-term memory was impaired. Sullivan and Sagar (1991) concluded that there is, indeed, a double dissociation of short-term and long-term memory for nonverbal material. Short-term memory depends upon intact corticostriatal systems, whereas long-term memory depends on intact medial temporal lobe systems. Studies such as those reported by Shallice and Warrington provided evidence for one of the seminal theories of memory, that proposed by Atkinson and Shiffrin in 1968.

The Atkinson-Shiffrin Model

The multistore model of Atkinson and Shiffrin (1968) became popular within the emerging field of cognitive psychology (Nadel, 1992; Squire, Knowlton, & Musen, 1993). This influential model proposed that external stimuli from the environment first entered sensory memory, a large-capacity storage system able to reasonably accurately record information from each of the senses. Although information from touch, smell, and taste are represented, the overwhelming majority of research has studied iconic memory (visual sensory memory) and echoic memory (auditory sensory memory). Information in sensory memory decays quickly, and is lost unless processed into the short-term store (STS) (Shiffrin & Atkinson, 1969).

The STS contains only the small amount of information actively being used. Memories in the STS are fragile and are likely to be lost from memory within 30 seconds unless a rehearsal process is used. By means of this rehearsal, information is passed from the STS to the long-term store (LTS), a large-capacity store containing relatively permanent memories from those decades old to newly learned items (Shiffrin & Atkinson, 1969). Atkinson and Shiffrin (1968) proposed that information in the LTS is encoded semantically (i.e., in terms of its meaning) whereas verbal information entering the STS is encoded acoustically.

In addition to the structural features of the model, Atkinson and Shiffrin (1968) proposed control processes – the strategies individuals use flexibly and voluntarily to aid memory, depending on the nature of the to-be-remembered material and personal preference. For example, rehearsal encourages information to be recycled through the STS until transference to the LTS. Furthermore, control processes allow individuals to decide whether they want to utilise the available STS space to remember items or to leave work space to process something else and, at the same time, decide which memory strategy to use on a particular occasion – the emergence of the concept of a working memory (Shiffrin & Atkinson, 1969). More recently, Shiffrin (1993) proposed that failures of retrieval from the LTS are related to choice and use of cues. Thus, the LTS may fail at one moment and succeed later.

Other cognitive researchers of the day set about testing the Atkinson and Shiffrin (1968) model of memory. For example, Kintsch and Buschke (1969) tested the assertion that material in short-term memory is coded acoustically, whereas material in long-term memory is coded in terms of semantic characteristics. Using lists of words containing pairs which were either semantically or acoustically similar, Kintsche and Buschke did, indeed, find that items at the beginning of a 16-word list produced a greater number of semantic confusions suggesting that items at the beginning of the list, which should be in long-term memory, are coded in terms of their meaning. In contrast, in a second list containing pairs of homonyms, items at the end of a 16-word list, presumably still in the short-term memory, create more acoustic confusions, suggesting they were stored in terms of their sound.

Rundus (1971) set about testing the hypothesis that frequently rehearsed items would be most likely to be transferred to long-term memory. Having presented a list of 20 nouns to students with the instruction they should rehearse the words aloud, Rundus recorded both the number of times each word was rehearsed and the total number of words recalled for each participant. Plotting the results of this research showed clear serial position effects highlighting the primacy effect (better recall for items at the beginning of a list), and the recency effect (better recall for items at the end of the list). It was clear in the Rundus study that the most rehearsed items were best remembered. This supported Atkinson and Shiffrin's (1968) hypothesis that well rehearsed items would be processed to long-term memory and retrieved with ease. By the time participants had seen six or seven words, however, frequent rehearsal became impossible. The probability of recall decreases sharply as a function of serial position for the first portion of the list. Thus, the primacy effect appears to be explained by the frequency of rehearsal. However, rehearsal does not account for the clear recency effect shown.

Rundus (1971) proposed that the recency effect can be explained by the existence of a short-term store. More recent research has demonstrated a long-term recency effect. For example, if individuals were asked to list past Prime Ministers of New Zealand it is highly likely they would recall those of the last 10 years more readily than those of an earlier era, even though the names were not stored in short-term memory (Crowder, 1993). Tharpar and Greene (1993) suggest the standard recency effect and a long-term recency effect may both be explained by the same mechanism – one which does not involve the short-term memory. Tharpar and Greene suggest one reason for skepticism regarding the recency effect being used as evidence for a short-term store is that they demonstrated large recency effects even when the retention interval was one day long, stating that "presumably, the subjects in that experiment were not continuously maintaining items in a STS for a complete day" (p. 335). It seems likely that a separate long-term explanation will be needed to account for long-term recency effects.

Levels-Of-Processing

In a further development, Craik and Lockhart (1972) proposed that the level of processing (LOP) at encoding would determine the accuracy of retrieval. This approach suggests that deep, meaningful information processing leads to more permanent memory retention than shallow, sensory processing (Craik, 1979; Craik & Lockhart, 1972). The LOP theory was to become one of the most influential of its time, with Roediger (1980) pointing out that within eight years, at least 700 articles had cited the Craik and Lockhart (1972) paper. The premise upon which the theory was built is that individuals can process incoming stimuli at a number of different levels. Shallow levels involve processing on the basis of physical or sensory characteristics, whereas deep levels require processing in terms of meaning, which may be elaborated by other associations, images, and experiences relating to the stimulus.

Craik and Lockhart (1972) also placed emphasis on rehearsal, or a process of cycling information through the memory facilitating the transfer from short-term to long-term memory, as did Atkinson and Shiffrin (1968). However, Craik and Lockhart proposed two kinds of rehearsal – maintenance rehearsal or merely repeating the type of analysis which has already been carried out on the incoming stimuli, and elaborative rehearsal involving a more meaningful analysis of the stimuli. As Craik and Lockhart asserted that short-term and long-term memory were not separate structures, increasing the amount of time spent in simple, repetitious maintenance rehearsal did not result in increased recall, whereas using deep elaborative rehearsal would do so, as it was proposed that thinking about extra images, associations and memories relating to the original stimulus positively influenced later recall (Matlin, 1998). While this model specifically emphasised encoding without offering detailed analysis of how retrieval was carried out, in a later paper (Moscovitch & Craik, 1976) it was suggested to be of benefit if the retrieval conditions match the encoding conditions, even when processing is achieved only at a superficial level. Recall is further enhanced by distinctiveness, where a stimulus to be processed is different to all other memory traces (Craik, 1979). One of the questionable aspects of LOP is the difficulty of deciding the LOP used by learners, due to the lack of an independent measure of processing depth. Lockhart and Craik (1990) updated the LOP theory, accepting both the notion of transfer-appropriate processing (providing a similar context for encoding and retrieval) and that their previous theoretical assumption that shallow processing led to rapid forgetting was not always correct. However, LOP theory fails to account for there being little difference between intentional and incidental learning (Roediger, Gallo, & Geraci, 2002), and Challis and Brodbeck (1992) found only a small LOP effect in implicit learning. Craik (2000) argues that deep processing is necessary but not sufficient, and efficient long-term processing involves both deep processing and a process of consolidation.

To the present day, the distinction between short-term and long-term memory is still debated. Shiffrin (1993) states that “models of short-term retention have been a bone of contention in the literature for as long as the field has existed, and are constantly undergoing refinement” (p.194). Research results have been equivocal. Whilst many cognitive theories still make the distinction (e.g., Estes, 1991), other researchers conclude short-term memory does not appear to be a single, limited-capacity storehouse. Shiffrin (1993) concluded that, as it was generally understood, short-term memory contained the components of temporary activation, control processes, and capacity limitations. Thus, the original Atkinson-Shiffrin model (1968) was too simple to adequately account for subsequent memory research. This was becoming increasingly clear in the early 1970s, and was supported by neuropsychological evidence. In the 1968 model, Atkinson and Shiffrin proposed that the short-term store also acted as a working memory, involved in learning, retrieval, and the performance of many other cognitive tasks. Baddeley (1992) points out that if this were the case then it could be expected that patients with a grossly defective short-term memory would show many other cognitive problems when, in fact, this is not the case with many appearing to have surprisingly few cognitive handicaps.

The Baddeley and Hitch Model

Baddeley and Hitch (1974), finding that patients with a pure short-term deficit were rare, attempted to simulate this condition by using a dual-task technique. Their experiment was based on the premise that the number of digits retained in a digit span procedure was determined by the capacity of the store, and therefore that it should be possible to interfere systematically with working memory capacity by requiring individuals to remember digits while performing other cognitive tasks. Reasoning, comprehension, and learning tasks all showed a similar pattern of interference with the digit-span task, but the degree to which the distracting tasks interfered with the number of digits retained fell short of that expected.

To accommodate this, and other, experimental results, Baddeley and Hitch (1974) proposed a tripartite system comprised of an attentional controller known as the central executive, supplemented by two subsidiary slave systems: The articulatory or phonological loop was proposed to be responsible for maintaining speech-based information such as digits in the digit span tests, and the visuospatial sketch pad which was assumed to perform a similar function in initiating and manipulating visuospatial imagery. Baddeley (1986) suggested that while the early understanding that working memory comprised concurrent storage and processing of information is important, this view reflects only one aspect of working memory. Baddeley suggested that the coordination of resources is the prime function of working memory, exemplified in the major role of the central executive as the coordinator of information from the slave systems.

The phonological loop lies closest to the earlier concept of working memory and has been examined extensively with memory-span procedures. The phonological loop is made up of a phonological store which can hold speech-based information for 1 to 2 seconds, along with an articulatory process similar to inner speech. The latter has two purposes; it can maintain information by subvocal repetition, and it can transform visually presented information and register it within the phonological store by subvocalisation (Baddeley, 1992). Investigation of the phonological loop has produced a plethora of laboratory-based findings such as the *acoustic similarity effect* (Baddeley, 1992; Conrad, 1964) where hearing and repeating dissimilar words such as 'pit, day, cow, pen, rig,' is easier than phonologically similar lists such as 'man, cap, can, map, mad', presumably because the basic code of the store is phonological. The *irrelevant speech effect,* where there is a reduction in recall of lists of visually presented words when interference by irrelevant spoken material is introduced, is assumed to be a result of the disruptive spoken material gaining obligatory access to the phonological memory store (Colle & Welsh, 1976). The *word-length effect* (Naveh-Benjamin & Ayres, 1986) refers to the finding that individuals can generally remember about as many words as they can say in two seconds. Evidence is found in digit span tests conducted in different languages. When languages requiring longer sounds for digits are used, rehearsal takes longer and there is a corresponding shorter memory span (Naveh-Benjamin & Ayres, 1986). Further evidence arises from the tendency for digit span capacity to increase with age throughout childhood; as children grow older, they are capable of faster rehearsal (Baddeley, 1992). *Articulatory suppression*, disruption of subvocal rehearsal by having participants utter repeated irrelevant sounds, prevents rehearsal of material thus removing the effect of word length and preventing visually presented material registering in the phonological store. Recall is thus reduced, and the acoustic similarity effect is also abolished, presumably because those words that are remembered are not stored using a phonological code (Baddeley, Lewis, & Valler, 1984; Valler & Baddeley, 1984).

The second slave system proposed by Baddeley and Hitch (1974), the visuo-spatial sketchpad, stores visual and spatial information, as well as verbal information encoded as visual imagery (Gathercole & Baddeley, 1993; Logie, 1995). Whilst investigation of the visuo-spatial sketch pad lags behind that of the phonological loop, dual-task interference studies developed specifically for the study of the sketchpad are appearing (Baddeley, 1997). For example, Hatano and Osawa (1983) observed that people who use the abacus for calculation become so expert that they can dispense with the abacus itself, using only a mental representation. Japanese competitions are held in which experts can add and subtract up to 15 numbers, each containing five to nine digits. Hatano and Osawa devised a simple span procedure using digits, letters, and fruits to discover whether such individuals were using the visuo-spatial sketchpad, a chunking procedure such as that described by Hunter (1962), or storing the items in long-term memory. They found the abacus experts had a forward span of 16 digits and backward span of 14 digits, although if letters or fruits were substituted for the digits the experts exhibited similar scores to non-expert university students. Furthermore, the imagery hypothesis was further tested in a dual-task procedure where participants were required to remember sequences of digits or letters whilst performing secondary tasks producing imagery disruption or verbal disruption. Memory for consonants was disrupted most by the verbal processing task, whilst digit span was disrupted by the concurrent visual task, suggesting the visuo-spatial system was being used to remember the digits. Lastly, Hatano and Osawa tested the abacus experts by aurally presenting successively 10 sequences of 10 digits at the rate of one per second. When asked to recall these after a 30 second delay this was accomplished with ease. However, after delays over 30 seconds the abacus experts recalled few, if any, of the sequences. Long-term storage of the digits had not been achieved. Hatano and Osawa concluded the abacus experts were using a visuo-spatial representation held in the visuo-spatial sketchpad of working memory.

In comparison with the phonological loop and the visuo-spatial sketch pad, the central executive presents major difficulties in devising controlled research because of the complexity of its apparent tasks. The central executive is thought to integrate information from the phonological loop, the visuo-spatial sketch pad, and from long-term memory, as well as playing a major role in attention, planning, and coordinating behavior (Baddeley, 1988, 1992; Gathercole & Baddeley, 1993; Morris & Jones, 1990). Norman and Shallice (1986) proposed a model of attention control that assumes action can be controlled either by the operation of a series of existing schemata or by the supervisory attention system (SAS) which takes control when novel tasks are encountered or when existing habits have to be over-ridden, such as when danger threatens (Norman & Shallice, 1986). Baddeley (1986) chose this model as a working hypothesis for his proposed central executive model.

In 2000, Baddeley proposed a new component of the working memory model – the episodic buffer (Baddeley, 2000). The episodic buffer comprises a limited-capacity system providing temporary storage of information held in a multimodal code. The episodic buffer is thought to be capable of binding information from the subsidiary systems and from the long-term memory, into a unitary episodic representation. It is assumed retrieval is activated by conscious awareness. Baddeley (2000) explains that the “buffer is episodic in the sense that it holds episodes whereby information is integrated across space and potentially extended across time” (p.421). Thus, it resembles Tulving’s (1989) concept of episodic memory.

Schacter and Tulving

Later theories of memory suggest that memory is not a homogeneous entity, but rather is both highly versatile and multifaceted (Richardson-Klavehn & Bjork, 1988; Whittington, 1999). Heindel, Salmon, and Butters (1993) define memory as comprising several distinct, mutually interacting systems and subsystems, which differ according to the type of information stored and the processes acting upon the stored information. Similarly, Schacter and Tulving (1994) believed memory consists of large, elaborate, complex, and overlapping systems and processes. Overall, whilst it is generally agreed that anatomically, systems within memory are distinct, what constitutes a memory, or the neural networks mediating their processing, is still a matter for debate (Gabrieli, Fleischman, Keane, Reminger, & Morrell, 1995).

Over a period of years, Schacter and Tulving (1994) formulated a theoretical perspective of memory consisting of five major systems: procedural memory, a perceptual representation system, semantic memory, working memory, and episodic memory. According to Schacter and Tulving, procedural memory is implicated in learning behavioural and cognitive skills and algorithms, and involves the subsystems of motor skills, cognitive skills, simple conditioning, and simple associative conditioning. Procedural memory operates at an automatic rather than a conscious level, and is characterised by gradual, incremental learning. Schacter and Tulving propose that the output from procedural memory is noncognitive, although their description of procedural memory as "the vast terra incognita" (p. 27) reflects the need for clarification and elaboration of this, and many other questions, through research on the construct of procedural memory.

Working memory, Schacter and Tulving's (1994) second major system, is responsible for the temporary holding and processing of information, whilst the third system, the perceptual representation system (PRS), is a memory system which encodes and stores the features of an item, and operates at a pre-semantic or structural level. The PRS is involved in implicit expressions of memory such as priming.

The fourth major system, semantic memory, involves factual information and includes such facts as "sparrows are birds" and "cows have legs" (Shoben, 1992). It is semantic memory that enables both the acquisition and retention of information about the world. Schacter and Tulving (1994) note that the semantic memory system is vitally important, as all general or specific, concrete or abstract, knowledge and beliefs about the world that individuals gain, retain, or use, depends utterly upon it.

The fifth major system, episodic memory, transcends semantic memory and allows the recollection of personal experience through multifeature representations utilising spatial, temporal, or contextual information (Schacter & Tulving, 1994). Interestingly, Tulving (1998) has stated: "Episodic memory does exactly what the other forms of memory do not and cannot do – it enables the individual to mentally 'travel back into her personal past'." (p. 265). Schacter and Tulving point out that neither memory tasks, such as recognition memory and recall, nor memory processes such as encoding, rehearsal, and retrieval, should be thought of as memory systems. Rather, they concern the operation of memory, and possible utilisation of more than one system. Furthermore, task performance usually involves interaction between cognitive systems (Markowitsch, 1998).

Schacter and Tulving (1994) suggested that *explicit* and *implicit* memory are not necessarily, as commonly held, discrete memory systems, but refer to forms of memory distinguishable on both psychological and behavioural grounds. While the terms *implicit* and *explicit* are commonly used to distinguish between two classes of memory tests, it is not yet clear whether they are subserved by the same underlying memory system. Moscovitch (1994) defines explicit memory tests as those requiring conscious recollection of past events, and implicit tests as those in which memory for the past is inferred from changes in performance with experience or practice. Similar distinctions have been made with the terminology *declarative* (explicit) and *nondeclarative* (implicit) memory (e.g., Cohen & Squire, 1980; Squire, 1994; Whittington, 1999). Using this terminology, Schacter and Tulving describe the perceptual representation system and procedural memory as nondeclarative, whilst the other three systems are declarative.

The need for clarification of terminology

Even the most cursory glance through the large body of literature on memory reveals the plethora of definitions used. Comparisons between studies, and between theories, are made difficult by the use of over-lapping definitions – often with similar, but not interchangeable, meanings. Memory research is in great need of the standardisation of terms and definitions, both in the theoretical language utilised, and to bring clarity regarding what is meant by age-group descriptors. Crook et al. (1986) note that the lack of agreement regarding a precise terminology in memory research creates problems for researchers attempting to study the clinical phenomenon of memory as well as for those who wish to develop effective therapeutic interventions. Interestingly, Shiffrin (1993) notes, in a discussion of the fuzziness besetting memory research terminology, that “some would regard the present state of affairs as a cause for despair: I regard it as a natural evolution in a field that, in many respects, is still in its infancy” (p. 193). Such an assertion gives rise to the question of why lessons have not been learned from the development of other areas within psychological research. It could be expected that a developing field would have, as a priority, a firm foundation of standard terminology and constructs that would allow for between-study comparisons. Nevertheless, standardisation remains a matter of urgency. A glossary of commonly used terms relating to types of memory is presented in Table 1.1. It will be seen that many definitions represent similar and over-lapping concepts. The lack of a standardised terminology has contributed to the somewhat chaotic state of memory literature.

Table 1.1. *A glossary of terms commonly used to describe memory types.*

Conscious memory:	A conscious recollection of facts and events. Sub-divided into episodic and semantic.
Contextual memory:	Remembering in what context, where, and when an event took place.
Declarative memory:	Memory for facts. What is known consciously. Sub-divided into episodic and semantic memory.
Episodic memory:	Memory for past and personally experienced events. Information about when events happened and the relationships between events.
Explicit memory:	A conscious recollection of facts and events, usually by intentional retrieval. e.g., “What did I have for dinner?”
Implicit memory:	Memories that are manifested in subsequent behaviour without awareness of remembering.
Long-term memory:	A large capacity storage system containing and preserving memories that can be from minutes to decades old.
Long-term store:	The permanent memory store of procedural and declarative (or explicit, or conscious) memories.
Primary memory:	Information held in current awareness.
Procedural memory:	Retains memory of how to do things, e.g., riding a bicycle or playing the piano. The ‘doing’ demonstrates the memory.
Prospective memory:	Remembering to carry out planned actions at a later time.
Remote memory:	Personal memory from the past. These memories are highly selective, typically not mundane, frequently rehearsed and recounted, and liable to unconscious distortion and embellishment.
Secondary memory:	Long-term memory functioning.
Semantic memory:	The accumulated, organised knowledge of the world. Conceptual and factual knowledge such as vocabulary. A fairly constant knowledge structure, in contrast to changing events registered in the episodic memory.
Sensory memory:	Records information from each of the senses with reasonable accuracy: visual, auditory, touch, smell, and taste. Most commonly: iconic – visual – about half a second duration echoic – auditory, several seconds duration
Short-term memory:	A limited-capacity system providing capacity to hold in mind new information. The small amount of memory currently active. Fragile, capable of holding 7±2 unrehearsed items for about 20-30 seconds.

Table 1.1 continued over

Table 1. 1 continued

Short-term store:	Active in the performance of a range of tasks in which small amounts of material need to be remembered for short periods of time. Not entirely synonymous with short term memory which is based on the persistence in time of the information.
Source memory:	Remembering where and when an event took place.
Verbal memory:	The ability to encode, store, and recall meaningful language units.
Working memory:	(i) Processing information while maintaining other information as well as the coordination of task-relevant goals and strategies at the conscious level. (ii) a three-part system that temporarily holds and manipulates information as cognitive tasks are carried out. Working memory is not simply a passive storehouse.

Such over-lapping terminology renders it difficult to make comparisons between studies using different terms for very similar concepts. It is a matter of concern that, as yet, a clear and concise standardised description of memory types has not yet emerged.

As well as the ever-burgeoning terminology relating to memory types, a search of memory literature quickly reveals a somewhat confused and over-lapping vocabulary of terms utilised when describing the processes of memory. A glossary of examples of the plethora of memory terminology is presented in Table 1.2.

Table 1.2. *A glossary of terms commonly used in memory research.*

Acquisition:	The process by which new information is converted into a memory trace.
Attention:	The memory system encodes only what is currently attended to. The limited resources of working memory are allocated – the process of allocation is generally referred to as 'attention'.
Automatic processing:	Processing which requires little attentional capacity and occurs without intent.

Table 1.2 continued over

Table 1.2 continued

Conceptually driven processes:	The mental processing of conceptual relations, required when an item cannot be processed through its physical features.
Conditioning:	The pairing of unrelated items which occur at a similar time.
Controlled processing:	Processing which is effortful, consciously controlled, and requires intent.
Crystalised intelligence:	The ability to apply acquired skills and knowledge to a problem. Measured using tests of accumulated knowledge, such as vocabulary.
Cued recall:	When a person is given specific cues to aid recall.
Disinhibition:	The loss of the ability to inhibit information which is irrelevant to the task to be completed, thus impairing efficiency of processing.
Elaborative rehearsal:	Rehearsing by linking a stimulus to other information at the time of encoding.
Encoding:	Taking in information via the senses or through thinking about things. The way items are placed into memory.
Encoding specificity:	The degree of match between the encoding and the retrieval operations
Executive function:	Refers to cognitive activity that controls and integrates other cognitive actions.
Free recall:	The retrieval of information from memory without the aid of cues. Items may be recalled in any order.
Fluid intelligence:	Reasoning ability, memory capacity, and speed of info processing. Reflects current processing rather than prior knowledge.
Levels of processing:	Assumes a short-term or primary memory system that can process material in variety of ways, from taking note of visual characteristics of a printed word to elaborately coding in terms of meaning.
Limited time mechanism:	Hypothesised to operate because relevant cognitive operations are executed too slowly to be successfully completed.
Maintenance rehearsal:	Repeating the type of analysis which has already been carried out on the incoming stimuli.
Metamemory:	Self-knowledge about current memory use, contents and states, and beliefs about one's own memory abilities.
Perceptual Identification:	Identification based on the visual or auditory form of words and the structural form of objects.
Perceptually driven processes:	Processing the physical features of a word, for example, into memory.

Table 1.2 continued over

Table 1.2 continued

Priming:	After recent experience with words or objects, there is an improved ability to detect or remember them.
Processing resources:	Reservoirs of mental energy, particularly important as the demand for self-initiated (performed without verbal or nonverbal cues) processing increases.
Recognition:	Selecting previously learned items or information from an array of options.
Rehearsal:	The process of repetitively verbalising or thinking about information to be stored in the memory.
Retrieval:	The recovery of items from memory. Information is transferred from long term memory into the short term memory so it can be used there.
Serial recall:	The retrieval of items from memory in the order in which they were learned.
Simultaneity mechanism:	Hypothesised to operate because slow processing reduces the amount of simultaneously available information needed for higher level processing.

Many theories and models of memory have emerged over the past decades. However, as yet, no one clear theory has emerged that captures the transition from lack of comprehension when the material to be remembered remains disorganised and nonsensical, to understanding when the material is coherent and makes sense to the individual (Wertheimer, 1986). Furthermore, few theories of memory make provision for how memory may change with advancing age.

Chapter Two

MEMORY AND AGING IN HEALTHY ADULTS

This chapter reviews prior literature in the field of age-related declines in memory and cognition. Inter-individual and intra-individual changes in older adults, general versus task-specific decrements, and the inevitability of age-related declines in memory are discussed. Changes particular to sensory memory, short-term memory, and long-term memory are considered. The confusing lack of precision in age descriptors is noted, as is the dearth of memory research in advanced aging – the oldest-old individuals.

The widely held belief that the ability to remember declines in many healthy people during later life, is supported by a large, well-developed body of empirical data (e.g., Craik, 1977; Crook et al., 1986; Flicker, Ferris, Crook, Bartus, & Reisberg, 1985; Poon, 1985; Sherwin, 1994). The ability to remember information depends on many inter-related variables. One such variable found to have a marked effect on cognitive capacity, including memory, is that of age (Hasher & Zacks, 1979). Light (2000) notes that, although age-related changes in memory are well-documented, explanation of such changes lags behind their documentation. The possible ways in which the aging process may have a deleterious effect on memory has been the subject of debate over several decades. Medical advances have extended the average life span and people are living longer, healthier lives. As these trends continue, there is an ever-increasing need to understand what is cognitively ‘normal’ for healthy, very elderly people without dementia.

Schaie and Labouvie-Vief (1974) suggest age-related decline may, in part, be attributed to socio-cultural and generational cohort differences, as each succeeding generation is exposed to different sets of historical and personal events such as improved nutrition, health care, and changes in educational opportunities which occur over time. Furthermore, Labouvie-Vief (1985) notes that whilst many cross-sectional studies document significant declines in cognitive performance with advanced age, the findings of several longitudinal studies indicate the apparent decline with age may be due to a confounding of age and cohort. Age effects reflect differences due to underlying biological and psychological changes of the aging process, whereas cohort effects are due to experiences and circumstances pertaiing to the particular generation to which the individual belongs. Another major difficulty with cross-sectional studies is that the validity of age differences in cognitive ability scores assumes the comparability of the younger and older samples (Christensen, Henderson, Griffiths, & Levings, 1997; Hultsch, Hertzog, & Dixon, 1984, 1990).

While it is now well established that memory performance declines with advancing old age (Kausler, 1994; Ryan, 1992), it has also emerged that not all aspects of memory are equally impaired (Burke & Light, 1981; Craik, 1983; Shimamura, 1989). The difference in the magnitude of the decline varies as a function of both task and participant characteristics (Madden et al., 1999), particularly for tasks requiring substantial capacity (McEntee & Crook, 1990). McEntee and Crook suggest that the majority of people over the age of 50 will be affected by age-associated memory loss, at least to some degree, compared to healthy young adults. Jenkins (1979), who viewed memory as a context-sensitive phenomenon, proposed a tetrahedral model of memory experiments comprising four major sources of variation in memory performance: acquisition variables, test variables, materials, and subjects, which vigorously interact.

Inter-Individual and Intra-Individual Change

In a review of inter-individual and intra-individual variability in cognitive ability with age, Christensen (2001) sought to describe the cognitive changes which may be expected with normal aging. Data were drawn from the Canberra Longitudinal Study (CLS). Longitudinal studies provide information not obtainable from cross-sectional designs, such as rates of decline, risk factors for decline, and data on the correlations between changes in cognitive ability and changes in non-cognitive domains. The disadvantage of longitudinal studies is that they may underestimate change because of selective attrition and practice effects (Christensen, 2001). The sample consisted of 887 participants aged 70 to 93 years divided into five-year age groups with the exception of the oldest-old who were 85+ years. Participants were examined in 1991 and followed up in 1994 and 1998. Prior research had demonstrated that cognitive change is not unitary, with some abilities declining more rapidly than others (e.g., Hultsch, Hertzog, Dixon, & Small, 1998; Salthouse, 1991; Schaie, 1996). Christensen characterised cognitive ability as consisting of three major abilities: crystallised intelligence (the ability to apply acquired skills and knowledge to problem solving), memory, and cognitive speed (the speed of task performance), with memory being divided into short-term and long-term, with both types further fractionated into declarative and procedural memory.

Christensen (2001) asserts that crystallised abilities increase up to the sixth or seventh decade and may decline only in late old age, whilst memory and cognitive speed generally show a continuous linear decline from early adulthood. Such decline may accelerate in late old age. A meta-analysis of cross-sectional studies (Salthouse, 1982) suggests that cognitive speed drops by approximately 20% by the age of 40, and by 40 to 60% by 80 years of age. Salthouse (2004) argues for a linear decline in speed across the age span, with speed typically measured on tasks such as pattern comparison, number matching, or letter or picture scanning (Salthouse, 1996a). However, it is notable that scant attention was given to the oldest-old. Differing trajectories for different mental abilities have long been recognised (e.g., Baltes, Staudinger, & Lindenberger, 1999; Horn & Cattell, 1967). For example, in the CLS crystallised intelligence did not decline significantly for any age group, including those who were over 85 years at the commencement of the study. Memory declined significantly across all age groups, with the decline of the oldest-old more rapid than that of other groups. Cognitive speed deteriorated significantly in all age groups over the 7.5 years study. A similar significant deterioration in memory and cognitive speed over the lifespan was also found in other longitudinal data such as the Victorian Longitudinal Study (Hultsch et al., 1998), the Seattle Longitudinal Study (Schaie, 1996), and the Einstein Ageing Study (Sliwinski & Buschke, 1999).

According to Schaie and Willis (1993), age is associated with decreases in performance on most tests of learning, memory, reasoning, and psychomotor speed. Rabbitt (1993) found that as groups of people aged, the differences in the cognitive abilities of the most and least able became more extreme. Christensen et al. (1994) also found that aging is also associated with greater variability in performance, with the performance difference between the least and most able increasing with, a) the age of groups studied, b) increased variability for memory, c) increased reaction time, and d) fluid intelligence. Christensen et al. did not find the same association between age and crystallised intelligence. In contrast, Salthouse (2004) suggests that age-related declines are not accompanied by increases in variability amongst participants, but rather that increased age is associated with a smaller range of scores on performance of cognitive tasks. In a review of 127 gerontological studies covering cognitive, biological, personality, and social variables, Nelson and Dannefer (1992) reported 43% of the studies found increases in variability with age.

Clearly, the question of an association between aging and increased variability of performance on cognitive tasks is yet to be resolved, and a complete account of variability will take into account possible interactions between aging and non-cognitive variables, and possibly other cognitive variables not currently explored in the research. Plomin and McClearn (1990) suggest that much of the variation in biological, behavioural, and cognitive changes during aging is inherited, although the influence of genetics may lessen as, for example, more individuals within a society live longer as the society attains improvements in nutrition, medical treatment, and environmental factors. In a discussion of the course and causes of cognitive aging, Holland and Rabbitt (1991) suggested health differences contributed to increased variability between individuals, with healthy individuals both living longer and maintaining cognitive integrity later in life.

General Decline versus Task Specific Decrements

Opposing views have emerged as to whether memory decrements with age represent a general decline or are task-specific. Salthouse (1985) argues that a general decline across all abilities is associated with aging, representing a slowing in the speed of cognitive processing. This, according to Salthouse, is found in a variety of tasks, especially those placing more demands on central aspects of processing as, for example, encoding, constructing, transforming, retrieving, and memory search. Salthouse (e.g., 1993, 1996a, 1996b) has argued that cognitive slowing accounts for much of the age-related variance in a number of memory tasks. However, as will be discussed in Chapter Four, many studies have found nowhere near as much of the variance in cognitive tasks accounted for by processing speed as has been found by Salthouse. Zimprich (2002) suggests that although cross-sectional studies have provided support for the processing speed theory for age-related cognitive differences, longitudinal studies show processing speed accounting for much less of the variance.

An opposing view to that suggested by Salthouse (1985) argues that age-related deficits are task-specific. Wingfield, Stine, Lahar, and Aberdeen (1988), for example, compared young (*M* = 18.8 years *SD* = 1.1) and elderly (*M* = 70.0 years, *SD* = 6.3) participants on three tests of short-term storage: digit span, word span, and loaded word span. The latter task required participants to read sentences and make a decision as to whether each one made sense, and at various points to read aloud the last word of each sentence. Age differences were minimal on the two simple tasks, but the elderly adults performed much more poorly on the loaded span task. Wingfield et al. concluded that the observed results provided evidence that working memory loading represented a special problem for the elderly. It should be noted, however, that the elderly participants in the Wingfield et al. study ranged in age from 59 to 84 years, arguably drawing upon participants who might reasonably be regarded as middle-aged. Wingfield et al. took a median split within the elderly group at age 70, to verify the difficulty with the loaded word span task was present prior to this age. The use of smaller age bands is likely to have yielded useful information regarding the development of the decline observed, particularly its genesis. Research remains equivocal as to whether age-related declines are general across all memory abilities or task-specific, but it has been consistently shown that increasing the processing resources required for a task is accompanied by a reliable, deleterious effect on older adults' performance when compared with their younger counterparts (Salthouse, 1988)

Are Age-Associated Declines in Memory Inevitable?

Age-associated memory impairment (AAMI) is a clinical state which describes the loss of memory function in otherwise healthy persons (McEntee & Crook, 1990). McEntee and Crook suggest it is important, when researching the concept of a 'normal' decline of memory among the aged, that the memory abilities of elderly individuals be compared with those of younger adults. Furthermore, they propose that AAMI may affect most of the over-50 population to some degree.

It may be that intelligence and lifestyle factors are protective of verbal abilities, but not nonverbal abilities, in old age (Hultsch et al., 1984, 1990; Shimamura, Berry, Mangels, Rusting, & Jurica, 1995). Perlmutter and Nyquist (1990) have suggested that good health may ameliorate memory declines with aging. Christensen et al. (1997) conducted a 5-year longitudinal study comparing 69 eminent Australian science academics, 70 years of age and over, with 30 retired blue-collar workers, and with 30 PhD students. They found high ability is not associated with slower rates of decline and cognitive deterioration is universal on nonverbal intelligence. As expected, the academics scored significantly higher than their blue-collar counterparts on the National Adult Reading Test (NART), used to measure intelligence. Contrary to expectations, at Wave 2 testing the scores for the academics had declined (M = 47.09, SD = 2.14, to M = 44.64, SD = 2.74) words correct from a total of 50, whereas the scores of blue-collar workers had remained stable (M = 29.25, SD = 10.60, to M = 29.44, SD = 8.92). The amount of decline did not differ between the groups on tests of fluid abilities (Symbol Digit Modalities Test and the Raven's Progressive Matrices), in the word recall test of memory the academics declined (M = 4.14, SD = 1.64, to M = 3.38, SD = 1.46), whilst the blue-collar workers improved over the 5-year inter-test period (M = 3.38, SD = 1.46, to M = 4.56, SD = 2.16). The Christensen et al. study produced results which were consistent with other studies which show that nonverbal intelligence declines independently of pre-morbid intelligence, but failed to find evidence that initial intelligence may protect against a decline in verbal tests.

In contrast, in a large community longitudinal study, Colsher and Wallace (1991) reported an association between low education and decline in cognitive function in later life: less well educated people deteriorated to a greater extent than better educated people over various follow-up periods. Similar findings have emerged from other large epidemiological studies, although such studies typically utilise a single measure of mental state performance with, at best, one additional outcome measure, usually memory (Evans et al., 1993; Farmer, Kittner, Rae, Bartko, & Reiger, 1995; White et al., 1994). Such divergence of research findings highlight the important question 'Does aging inevitably lead to decreases in cognitive function?'

In an attempt to answer this question, many researchers have examined declarative memory. Within declarative memory, research generally indicates that older adults have a much larger disruption in episodic memory tasks than they have in semantic memory tasks (Balota, Dolan, & Duchek, 2000). One example of this disruption can be observed in the retrieval phase of recall tasks where Balota et al. note that age-related deficits in retrieval performance diminish when cued-recall, rather than free recall, is required. Within information-processing models such as that proposed by Atkinson and Shiffrin (1968), age-related change in declarative memory could occur at the stage of the sensory memory store, the short term memory, or the long term memory.

Sensory Memory

Baltes and Lindenberger (1997) note that the roles of sensory functions as antecedents, correlates, and consequents of cognition have not generally been a focus of aging research. This may be because the majority of cognitive research has been conducted with children and younger adults when sensory systems operate at relatively high levels, and the likelihood of finding strong relations with memory, for example, may be reduced.

From studies where sensory memory has been the focus of investigation (e.g., Granick, Kleban, & Weiss, 1976; Kline & Orme-Rogers, 1978; Nettelbeck & Rabbitt, 1992), there appears to be little difference between young and older adults in sensory memory, the fragile storage system that retains information for less than two seconds (Kausler, 1994). For example, Kline and Orme-Rogers presented their young (18 - 21 years) and old (59 - 78 years) participants with two word fragments which would only produce a meaningful visual word when fused together in the same spatial location. Kline and Orme-Rogers found older adults were better at identifying the fused word, achieved by the visual persistence of the first stimulus fragment after its offset, than were younger counterparts. This suggests that older adults may retain visual information in the sensory store slightly longer than younger adults, although control for attentiveness would have been useful in clarifying this matter. Similar results have been found in investigations of echoic (auditory) sensory memory (e.g., Craik, 1977; Kausler, 1994).

The overall conclusions, drawn primarily from cross-sectional data, are that very little decline occurs in sensory memory (Kline & Orme-Rogers, 1978), minimal impairments take place in short-term memory, but there are substantial declines in long-term memory when the performance of old and young adults is compared for both verbal and nonverbal information (Crook et al., 1986).

Short-Term Memory

Short-term memory, a limited-capacity store that can maintain unrehearsed information for about 20 to 30 seconds, seems largely unaffected by aging (Sherwin, 1994). Unfortunately, Sherwin does not report whether the lack of aging effects for short-term memory continues for the oldest-old. In such tasks as the Brown-Peterson task where participants are asked to remember three letters for a brief period of time during which a secondary distractor task is performed, Puckett and Stockburger (1988) found similar levels of memory performance for young (18 - 32 years) and old (64 - 78 years) participants. Similarly, Craik (1971) found that if a decision-making activity is required at the same time as information is to be retained in the short-term memory; there are decreases in both accuracy and speed when adults 55 - 84 years are compared with young adults between 19 - 28 years, and middle-aged adults 35 - 47 years of age. When there was no decision-making activity required, there was no decrement in short-term memory for the older people. Although the wide age band employed for older participants does not allow a fine-grained analysis of the pattern of decline, Craik concludes the difficulty encountered by older adults is primarily one of retrieval, as the observed decline did not hold in a simple digit recognition task designed to test acquisition. If an older adult must remember items that have left conscious awareness from seconds ago to years ago, performance will depend on the efficiency of both encoding and retrieval (Waugh & Barr, 1982). Poon (1985) suggests encoding and retrieval processes are not necessarily independent, and Perlmutter and Mitchell (1982) argue that inefficient use of both encoding and retrieval strategies may, at least in part, account for age-related declines in memory with advancing age.

Long-Term Memory

It is well understood that older adults, compared to younger adults, have increased difficulty with such episodic long-term memory tasks as, for example, answering the question “Where did you go yesterday morning?” It appears that even when the environment or instructions could be expected to encourage the formation of rich, elaborate memory traces, older adults are less likely to do so (Craik & Byrd, 1982; Rabinowtiz & Ackerman, 1982). In contrast, there appears to be relatively little difference in forgetting rates between younger and older adults for learned items, even across differing retention intervals (Giambra & Arenberg, 1993; Park, Royal, Dudley, & Morrell, 1988; Rybarczyk, Hart, & Harkins, 1987). For example, Rybarczyk et al. found no differences between groups of young (*M* = 22 years) and older (*M* = 70.5 years) participants in remembering line drawings of objects for periods of up to 48 hours. Giambra and Arenberg reported similar findings for verbal material comparing 18 - 21 year-olds to 55 - 64 year-olds up to 24 hours after acquisition. Balota et al. (2000)

consider the lack of age-related difference in forgetting rates is somewhat difficult to determine because possible differences in the efficiency of the initial encoding processes with aging may mean that information, which appears to have been forgotten, may not have been encoded in the first place. An incomplete picture of long-term memory is given in many of these studies, as participants are seldom more than 75 years old, as in the above examples.

It may be that whilst older adults have memory traces in the long-term store, they find it more difficult to gain access to the information. Investigation of retrieval from long-term memory provides clear evidence of age-related changes, with the greatest age difference being found in tests of free recall, a smaller age difference in cued recall, and few or no age differences in recognition memory (Craik, Byrd, & Swanson, 1987; Craik & McDowd, 1987; Rabinowitz, 1984).

Schonfield (1965) asserts that older people show an increasing rate of decline in recall when compared to recognition, seemingly due to a loss in ability to retrieve memories from storage rather than to a deficiency in the long-term memory store itself. Schonfield’s participants ranged from 20 to 60+ years of age, grouped into 10-year age bands. As all participants completed the recall and recognition tasks for two lists of 24 words, the consistent drop in recall scores with advancing age cannot be due to a difference at the encoding stage since this would affect both types of memory test. A study by Schonfield and Robertson (1966) found no apparent deterioration with age in recognition, whereas recall resulted in a loss of almost 50% between the scores of young adults and adults over the age of 60 years. Craik and McDowd (1987) devised a recognition task that equated, in difficulty, to a recall task in order to investigate whether the typical absence of a significant age effect in recognition was a result of recognition being an easier task. Young and elderly adults performed cued-recall and recognition tasks whilst carrying out a choice reaction-time test. Age-differences were not found on the recognition test, although elderly adults performed more poorly on the recall task than did young adults. As the distinction between recognition and recall appears to be that in recall an individual must produce a set of responses in the absence of cues, whereas a recognition task usually requires participants to accept or reject items which have been seen before (Burke & Light, 1981; Deese, 1963), findings such as Schonfield’s suggest that age-related impairment of long-term memory may be confined to situations involving the retrieval of acquired items from storage. Retrieval difficulties in the elderly can, however, be modified by the degree of match between the encoding and the retrieval operations, termed encoding specificity by Tulving and Thomson (1973) who found that memory performance is best when the cues present at retrieval match those present at encoding. Similarly, transfer-appropriate processing suggests memory performance is enhanced when the cognitive processes at retrieval (for example, semantic as opposed to phonetic in verbal tasks) match those at encoding (Dudai, 2002; Morris, Bransford, & Franks, 1977).

Differing Rates of Change

A striking feature of declines in memory is that age differences are quite large in some situations but small, or non-existent, in others (Craik, 1986). Craik explains that changes in memory can be described in terms of discrete mechanisms and structures such as those proposed by Atkinson and Shiffrin (1968). According to this approach, memory decline can be viewed as the shrinkage, disconnection, and disintegration of the structures as aging progresses. It is possible that some structures remain intact whilst others fail, giving rise to a paradoxical pattern of results, such as digit span (utilising primary memory) remaining largely intact, whilst free recall (involving a substantial secondary memory component) does show age-related losses (Craik, 1977). Similarly, Perlmutter (1978) found that memory for factual knowledge holds up well, whereas memory for recent events shows an age-related loss. Craik (1986) argues that, using Tulving's (1983) terminology, semantic memory holds up well during the aging process whilst episodic memory declines.

In an alternative paradigm, Craik (1983, 1994) suggests the pattern of age changes may be understood in terms of processes which are determined by mental operations and environmental constraints. According to Tulving and Thomson (1973) and Mandler (1980), the goal of memory is to reinstate some previous mental state, and remembering will be more effective when the original context is reinstated. When the same context is not present when the attempt to remember is made, the mnemonic system must be returned to its previous state by self-initiated activities of the person, which may be described as retrieval processes or reconstructive processes (Craik, 1986). This suggests that age-related deficits will be least when there is substantial external support such as cued recall or recognition.

Short-term memory tasks such as digit span and the recency effect in free recall, show only slight age decrements because the required information is still held within the short-term memory and requires little self-initiated activity. In contrast, age differences will be the greatest on tasks in which self-initiated operations play a major role, tasks such as remembering to remember or free recall. For example, the difference in performance between young and older participants' performance can be reduced by giving recognition tests rather than recall tests at retrieval (Craik & Byrd, 1982). To illustrate, a study was carried out by Craik and McDowd (1987) where the difficulty level of two tasks was equated by devising an easy free cued-recall task and a relatively difficult recognition task. For the cued-recall task, 12 lists of 12 phrase-target word items, for example, 'a body of water - pond', were created. The first two lists were used as practice items and of the remaining 10 target lists, 5 were tested by cued-recall and 5 by recognition. Both tests were pre-recorded and presented through headphones at the rate of 5 seconds per item. For the recall test the participant responded verbally to each randomly-ordered phrase by saying aloud "yes" or "no" to each of the 60 target words which had been randomly interspersed with 60 distractors. If the interaction between task and age was still evident, the result could be attributed to the nature of the tasks themselves. Indeed, age interacted with task despite the fact that in this particular study cued-recall was designed to be an easier task than recognition. Craik and McDowd concluded that the age deficit is associated with certain types of retrieval rather than with difficulty level as such. Craik (1986) suggests that recall tasks are more resource-demanding than are recognition tasks, and older people seem to have a smaller pool of processing resources on which to draw.

Craik (1986) reports a further experiment to investigate whether older people are particularly penalised by tasks such as free recall which rely heavily on self-initiated operations, when compared with recognition. Two levels of difficulty were devised for both recall and recognition. The easy recall task consisted of the free recall of an 8-word list after a 20-second distractor task to eliminate the primary memory component; the difficult version was free recall of a 14-word list, again with the distractor task between study and recall. Similar 8-word lists were used for the easy recognition test with the ratio of distractors to target words at 2:1. The difficult recognition test consisted of a distractor target ratio of 5:1. Probability of correct recall or recognition was the measure. Analysis of variance yielded a significant Age x Task interaction, but no Age x Task x Difficulty interaction, thus appearing that the greater age decrement in recall is found at both levels of task difficulty. In the comparison between the difficult recognition task and the easy recall task, the age decrement for recall (.27) was still greater than the corresponding age decrement for recognition (.09) (Craik, 1986).

Even the most casual scanning of the literature on memory and aging highlights two important omissions: failure to specify the chronological age of participants, and the failure to include people 85 years and over in aging studies. All too often, researchers fail to define their use of the words ‘old’ or ‘elderly’. It is vital that age ranges are clearly specified so that comparisons between studies can be made, in order that an accurate picture of memory during the aging process may emerge. It is a matter of great concern that whilst decrements are clearly to be observed in many aspects of memory as people reach old age, there is a dearth of knowledge about the declines that may be expected in the oldest-old – individuals over the age of 85 years. Thus far, the vast majority of aging studies have used participants in their 70s, or early 80s at best. It is a matter of urgency that sound investigation of memory in the oldest-old be undertaken. It is the fastest growing sector of the population in New Zealand (Statistics New Zealand, 2004), as in other Western countries (Howieson, Holm, Kaye, Oken, & Howieson, 1993), and it is vital to understand how those who are 85+ years of age will be able to function in society, an ability to which remembering is key.

Chapter Three

MEMORY AND THE OLDEST-OLD

This chapter reviews prior literature on memory and the oldest-old[2] *- individuals 85 years of age and over. Advanced age as a variable in memory research is discussed, with evidence from longitudinal and cross-sectional studies. Finally, consideration is given to the possible relationship between cognitive decline and mortality in the oldest-old.*

"It is of particular interest to know if empirical regularities derived from traditional cognitive aging research generalise to persons in late senescence" (Bäckman, Small, Wahlin, & Larsson, 2000, p. 500). The prime goal in memory research of the oldest-old is to identify factors that may determine whether decline in very old age is gradual or accelerated compared to the rate of decline prior to 85 years of age.

Relatively little memory research has been conducted involving people in the later portion of the adult life span. Although recent research suggests age-related deficits in memory may extend into very old age (Hill, Wahlin, Winblad, & Bäckman, 1995a; Wahlin et al., 1993; Wahlin, Bäckman, & Winblad, 1995), the memory deficits encountered in the late ninth and tenth decades of life have only rarely been the target of cognitive aging research. Indeed, Poon et al. (1992) pointed out that as the bulk of existing knowledge is centred on the average person up to around the age of sixty-five years of age, increasing longevity creates an urgency for research because current knowledge is not yet sufficient to formulate 'laws' of human development and aging. Because medical advances have extended the average life span so that people are living longer, healthier lives, there is an increasing need to understand what is cognitively 'normal' for the healthy elderly.

[2] Throughout this thesis the term 'oldest-old' refers to individuals who are 85 years of age and over.

Who are the Oldest-old?

A clear definition of the 'oldest-old' has yet to be established. Neugarten (1974) was among the first to divide the aging population, regarding 55 to 74 year-olds as 'young-old', and those above 75 years as 'old-old'. In their review of cognitive functioning in very old age, Bäckman et al. (2000) also utilise 75+ years as the criterion for inclusion in this segment of aging research, and little research on individuals in their late 80s or 90s is reported. Alternatively, Singer, Verhaeghen, Ghisletta, Lindenberger, and Baltes (2003) compare individuals in their 70s with those in their 80s and 90s, with the latter labeled as an old-old group. As life expectancy continues to increase as a result of advances in medical techniques and lifestyle behaviours (Rowe & Kahn, 1998; Taeuber & Rosenwaike, 1992), researchers increasingly refer to people 85 years of age and older as the 'oldest-old' (e.g., Dunkle, Roberts, & Haug, 2001; Lindenberger & Baltes, 1997; Suzman, Willis, & Manton, 1992). To cloud the issue further, some researchers have used the terms 'third age' and 'fourth age' (e.g., Baltes & Mayer, 1999; Laslett, 1991), with the onset of the fourth age defined as the age at which 50% of a birth cohort have died. Clearly, consistent, standardised age-group descriptors would do much to enhance the usefulness of data in research on the oldest-old.

The Scarcity of Memory Research Investigating the Oldest-old

Experimental memory data showing declines in memory, particularly secondary memory, are consistent with more general psychometric studies of changes in cognitive function with advancing age (Crook et al., 1986). Horn (1982) has demonstrated that a decline in memory is one of several strong influences in the changes observed in fluid intelligence during the aging process.

Although demographic changes reflect an increasingly aging population, the oldest-old have been largely neglected by cognitive aging researchers. Bäckman et al. (2000) report a literature search in *Psychology and Aging,* and the *Journal of Gerontology: Psychological Sciences* showed that less than 10% of the articles published between 1990 and 1997 targeted very old adults, even for comparative purposes, though these journals are leading publications in aging research. Korten et al. (1997) discuss compelling reasons to know more about decline in later life: While it is understood declines do exist, the pattern is far from established, and little is yet known about factors influencing outcomes. In addition, decline in memory is significant because of its high prevalence and, furthermore, it is important to elderly people to know if their decline in memory and thinking is likely to herald a dementia (Korten et al., 1997). In a study investigating the connection between sensory and cognitive functions, Baltes and Lindenberger (1997) observe that in cognitive aging research, samples rarely reach into advanced old age.

Much of the available data on memory changes in very old age is drawn from large-scale multidisciplinary studies in which memory performance is assessed alongside other measures of cognitive functioning. Bäckman et al. (2000) report that there is less systematic information available on memory functioning in very old age in comparison with the domain of psychometric intelligence. As in much of the aging research available, many of the available studies define old-old adults as those over 75 years, and stop short of examining individuals in their late 80s and 90s. For example, Colsher and Wallace (1991), examining episodic memory changes, found their oldest group (75+) experienced greater decline than young-old participants (65 - 74 years) in immediate recall, although the age-related decline was invariant across age in delayed recall and recognition. Clearly, classifying all individuals over the age of 75 years as one oldest-old group, does not allow for a careful investigation of whether the pattern of decline continues into the ninth and tenth decades of life, or whether such changes plateau or accelerate in very advanced old age. Johansson, Zarit, and Berg (1992) point out that when the primary focus of a study is on a broader group of elderly the number of adults of very advanced age may be small, and not representative of the larger population. Furthermore, the high mortality among the oldest-old individuals means that little longitudinal data are available on the stability or decline in cognitive performance, including memory.

Advanced Age as a Variable in Memory Research

Of particular importance is a study conducted by Hassing, Wahlin, and Bäckman (1998), designed to assess the influence of age, education, and gender on episodic memory functioning in a sample of healthy individuals between 90 and 100 years of age (*M* = 92.03). A total of 80 Swedish people (15 male and 65 female) completed a face recognition task, immediate and delayed word recall, object recall, and the Mini-Mental State Examination (MMSE). MMSE scores averaged 25.14 (Scores of 26 or more are generally considered reflective of normal cognitive function). Hassing et al. note that when investigating the oldest-old, it is important to distinguish between the effects of aging pathology (such as dementia), and the MMSE has become widely used for this purpose in aging research. Episodic memory has been shown to be sensitive to a variety of conditions such as amnesia and aging, which may leave other forms of memory (semantic memory, primary memory, implicit memory, for example) relatively unaffected (Tulving & Schacter, 1990). In the Hassing et al. investigation, the face recognition test consisted of 20 target faces at study, and then the 20 target faces randomly mixed with 20 distractor faces in a yes-no recognition task. In this task, *d´* was used to index performance as it reflects both hits and false alarms (Hochhaus, 1972), and resulted in a mean *d′* of 1.65 (*SD* = 0.82). The *C* measure (Snodgrass & Corwin, 1988) was used to determine response bias, where *C* = 0 indicates a completely neutral bias, a positive value indicates a conservative bias, and a negative value indicates a liberal bias. The mean *d′* score was 1.65 (*SD* = 0.82), and the mean *C* measure was 0.16 (*SD* = 0.51).

For the recall of words, 12 concrete nouns from different taxonomic categories were used. These were printed in a book, and simultaneously read aloud by the experimenter at the rate of 5 seconds per word. Following presentation, participants were given 3 minutes for immediate recall, and a delayed free recall test was given 20 minutes after the initial word presentation. Word recall furnished scores of *M* = 4.91 (*SD* = 1.76) for immediate recall, and *M* = 1.73 (*SD* = 1.88) for delayed recall (possible score = 10). Wide variability was found in the object recall task. The total recall score reflected a task where ten common objects were to be remembered across four trials (possible score = 40), whereas the long-term retrieval condition denoted the total number of objects correctly recalled on at least two consecutive trials without reminding. Immediate recall produced a total score of *M* = 23.14 (*SD* = 7.13), and a long-term retrieval score of *M* = 16.24 (*SD* = 9.54).

Overall, Hassing et al. (1998) found the influence of age, education, and gender on episodic memory functioning to be relatively low, with the results showing these three variables accounted for between 3% and 8% of the variation in the dependent measures. An exception was object recall where increasing age was associated with decreasing performance. The years of education participants had undertaken was a significant predictor of delayed word recall and MMSE score. There were no effects of gender.

Perhaps the most striking observation from the Hassing et al. (1998) study, when compared with similar studies of younger-old adults (e.g., Inouye, Albert, Mohs, Sun, & Berkman, 1993; Wiederholt et al., 1993), is that age, gender, and education seem to have greater predictive power with younger-old adults in their 70s and early 80s than for the oldest-old in their late 80s and 90s. Notably, Bäckman and Wahlin (1995) found age, gender, and education accounted for between 10% and 18% in episodic memory tasks when examining younger-old participants, compared to between 3% and 8% in the Hassing et al. study.

Interestingly, Hassing et al. (1998) point to possible reasons why a relatively small influence of age emerged in their study, given that increasing age has previously been found to be strongly related to lower performance in episodic memory tasks (e.g., Bäckman, 1991; Rabbitt, Donlan, Watson, McInnes, & Bent, 1995). It may be that the restricted age range of the study restricts the predictive power of age, or the typical age-related cognitive changes with age may become less apparent at very advanced ages when the group tends to reflect a genetically select group of individuals by the very fact of their survival. The chance of obtaining stronger associations may well have been greater with a larger sample size than the 80 participants used in the Hassing et al. study, but as this would have been accomplished at the cost of applying less stringent inclusion criteria, other problems would have emerged related to distinguishing the influence of age itself from that of disease-related factors. Overall, the authors conclude that demographic characteristics play a comparatively limited role for memory functioning in very late senescence. Inclusion criteria in the study of the oldest-old remains a conundrum: To apply stringent exclusion criteria is likely not only to restrict the number of participants available, but would no longer, perhaps, leave a sample typical of the oldest-old population. People in the ninth and tenth decades of life are more likely to be exhibiting health problems that require medications on the one hand, and to be a somewhat selective group on the other hand, simply because they have survived to an advanced age.

The finding of Hassing et al. (1998) that age exerts a relatively small influence in nonagenarians was borne out in a 4-year longitudinal analysis of the effects of the aging process of community-dwelling, healthy adults. A group of thirty-three 65 to 74 years old (M = 70.9, SD = 2.5), and a group of twenty people 84 and over (M = 86.3, SD = 2.2), recruited from the Oregon Brain Aging Study (OBAS), were investigated by

Hickman, Howieson, Dame, Sexton, & Kaye (2000). Results show that healthy older adults from 65 to 94 years can expect their cognitive abilities, including memory, to remain relatively stable over a 4-year period, and that the oldest-old do not decline at a faster rate than the young old. Hickman et al. report that 11.7% of the sample was lost to attrition, and note that this is a very low number for a longitudinal study, suggesting the exceptionally low mortality rate is due to the initial medical screening. The OBAS utilised a number of neuropsychological tests including digit span, block design, vocabulary, logical memory, visual reproduction, and word list memory. Vocabulary showed a significant longitudinal decline for the young-old group compared to a smaller, non-significant decline in the oldest-old group, indicating that a gradual decline in verbal vocabulary does occur with advanced aging (Hickman et al., 2000). This is surprising, considering vocabulary skills are generally thought to exhibit stability over the life span. However, in the normative data for the Wechsler Adults Intelligence Scale - III (Wechsler, 1997b), the best performance for vocabulary was in adults aged 45 - 54 years, with a 12% decline in vocabulary scores in adults from 65 - 74 years, and a 24 - 25% decline for adults from 80 - 89 years of age, suggesting a gradual decline in verbal vocabulary occurs with advancing age.

The Hickman et al. (2000) study found that many cognitive functions were relatively well preserved in the healthy oldest-old with longitudinal scores that were similar to those of a control group almost 20 years younger. The exceptions were performance on constructional and visual perceptual tasks. However, differences in cross-sectional baseline scores raise the question of when changes in cognitive function occur. Hickman et al. suggest that the follow-up interval of four years may not have been sufficient to fully capture age-related decline and that over time the cumulative effects of small changes may result in substantial changes, a point also made by Schaie (1994).

The Betula Prospective Cohort Study (Nilsson et al., 1997) demonstrated continuous age deterioration in a comprehensive cross-sectional study testing free recall of words, recall and recognition of sentences and actions, face and name recognition, activity memory, fact recall and source recall. For all these tasks a consistent pattern of a continuous decline in memory performance was shown, but with 100 participants in each of 10 age cohorts from 35 to 80 years taking part, the ceiling age of 80 years did not allow exploration of whether this pattern slows, continues, or is accelerated in oldest-old individuals.

In a study designed to investigate whether cognitive support could ameliorate the observed declines in old age, Bäckman and Larsson (1992) used 36 female participants in each of four groups: 18 - 35, 60 - 69, 70 - 79, and 80 - 92 years of age, with random assignment to each of two instructional conditions – standard instructions (SI) to remember as many items as possible, and instructions to organise (OI) items into categories. Sixty items belonging to 12 taxonomic categories were prepared both as words and objects. Two memory lists, each comprising 30 items, were constructed with one list being words printed on cards (one word per card), and the other list comprising objects which were presented in the same way. For example, the item 'glove' appeared as a word for half the participants, and as a picture of a glove for the remaining half. Items were counterbalanced, so that half the participants received the word recall before the object recall test, and vice versa for the other half of the participants. The counterbalancing procedures resulted in four unique presentation orders with 9 people in each age group randomly assigned to each order. An immediate free recall test followed presentation of the final item in the first list, and then the second list was presented and followed by a further free recall test. These tasks were followed by an unexpected delayed free recall test (20 minute delay). This was followed by a cued recall test where the 12 taxonomic category names were provided as retrieval cues. The overall pattern of results suggested an age-related increase in the level of cognitive support required to optimise episodic remembering.

The results of this study showed that only the oldest group (80 - 92 years) performed reliably better in the OI condition than participants in the SI condition, indicating that this learning support was redundant for younger groups (Bäckman & Larsson, 1992). Specifically, in immediate free recall, the 80 - 92 years group, on average, scored 12.33 (SI) and 15.00 (OI), and in delayed free recall, 9.11 (SI) and 11.94 (OI) out of a possible score of 20. Providing the oldest participants with supportive instructions did not result in scores equivalent to younger participants who did not receive helpful instructions, with the 18 - 35, 60 - 69, and 70 - 79 groups scoring 20.75, 16.53, and 17.08, respectively, in the OI condition. The researchers concluded that with increasing adult age, there appears to be an increase in the level of cognitive support required to optimise episodic memory functioning, an increase which accelerates over the age of 80. However, it seems likely that the design of this study led to problems with interference between the two presentations of items which may have influenced the findings.

Using a wider range of participants (70 - 102 years), Korten et al. (1997) found the amount of decline increased with advancing age in measures of verbal recall, nonverbal recall, and face recognition over a 3-year period, with a change in cognitive scores close to being normally distributed. Korten et al. examined groups of adults aged 70 - 74, 75 - 79, and 80 years and over, with an additional group of nursing home residents aged 92 and over. Results (analysed in age-bands of 70 - 74, 75 - 79, 80 - 84, 85 - 89, and 90 years and over) showed a distinct downward shift in the MMSE, with a decline between testing waves becoming greater with age. That is, the 70 - 74 group showed a -0.3 change of scores between Wave 1 and Wave 2 testing, whilst the scores for the 85 - 89 and the 90+ groups showed a -2.3 and -2.5 decline in scores, respectively (MMSE maximum score = 30). Those with a lower MMSE score in initial testing declined more quickly than those with a high initial score. Cognitive speed, measured by the Symbol Letters Modalities Test, showed a rapid decline for the younger groups, but appeared to level out for the oldest age groups, leading Korten et al. to suggest that decline on speeded tasks may precede decline in other areas and that individuals may reach a floor on this type of test. No sex differences were found.

In an attempt to capture the nature of changes over time, many researchers have turned to large-scale longitudinal studies. Studies such as the Seattle Longituindal Study (see Schaie, 1996), for example, have extended over many years.

Longitudinal Aging Studies

Providing a description and explanation of changes over time is a central goal of research focused on human development and aging (Hultsch, 2004). Research in cognitive functioning in adulthood is still dominated by age-comparative cross-sectional methods of research (Hofer & Sliwinski, 2001). However, there has been increasing emphasis on longitudinal studies in recent years, recognising that development is a lifelong process with interactions from multiple sources of influence producing increasingly differentiated trajectories of both individual change (Baltes et al., 1999), and between varying types of memory, for example.

Although longitudinal studies of aging and memory have produced some inconsistencies, these have rarely found magnitude and rate of decline to be as great as could be expected from the results of most extreme-groups cross-sectional comparisons.

The Seattle Longitudinal Study

The Seattle Longitudinal Study (SLS) (Schaie, 1996) has charted the course of selected cognitive abilities, including verbal memory, from young adulthood to old age. One of the stated aims of the SLS was to answer the question "At what age is there a reliably detectable decrement in ability, and what is its magnitude?" (Schaie, 1996, p. 13). The study shows, in contrast to many prior studies, that detailed analyses of individual differences can demonstrate that even at age 81 fewer than half the participants showed reliable decremental change over the preceding 7 years. In the abilities of particular interest to the present study, Schaie found that, on average, verbal memory peaks in the 60s, whereas perceptual speed peaks in the 20s, with a severe decline in very old age. Furthermore, Schaie found that while individual decline prior to 60 years of age is almost inevitably a symptom of pathological age changes, it is clear that by the mid-70s significant average decrement can be observed across abilities, and by the 80s average decrement is severe, with the exception of verbal ability. From the SLS data, Schaie (1996) concludes that many individuals begin to experience noticeable ability declines during the late 60s and 70s, and in the 80s are likely to fall below the middle range of performance for young adults. In the 1991 testing of verbal memory, for immediate memory recall of a list of 20 words young adults (aged 25) had a standardised score of 59.7 (*SD* = 6.0) whereas the old adults (81 years) scored 42.4 (*SD* = 8.0). After a delay period of 1 hour during which other cognitive tests were administered, the scores were 61.2 (*SD* = 6.4) and 42.6 (*SD* = 7.6) for young and old adults, respectively. By the age of 74, there is likely to be statistically significant decrement in memory, particularly in verbal memory.

The Duke Longitudinal Study

Early in the 1950s the first of two longitudinal aging studies was planned at Duke University, with 11 testing times between 1955 and 1976 (Siegler & Botwinick, 1979). The participants in the oldest group were between 75 and 94 years at the first testing. This oldest group survived only for the first 6 test waves, although the younger groups 60 to 64, and 65 to 74 years continued. From the latter two groups emerged a sizeable proportion of old people of superior intellectual ability, identified as such by their initial WAIS test and by their continued presence as participants in a longitudinal study, who declined very little, or not at all, except in extreme old age. It is unfortunate that Siegler and Botwinick do not identify either the actual proportion of this group who decline very little, or expand on their definitions of ‘old’ or ‘extreme old age’ in this context. In this study of intellectual ability using the verbal and performance parts of the WAIS, there was a general pattern of higher test scores as the number of participants diminished, with the individuals who scored higher at Wave 1 testing more likely to remain in the study. Siegler and Botwinick concluded that intellectually superior older adults seem to maintain their intellectual abilities over many years, whereas less able ones show more age change.

A similar finding, that the initially more able declined less on tests in a cognitive battery than did the initially less able, was reported by Blum and Jarvik (1974) in the testing of 54 octogenarian survivors of 268 twins selected in 1947-1949 for a long-term investigation of the hereditary aspects of aging and longevity (Kallmann & Sander, 1949). Because participants were born before the end of the 19th century, prior to intelligence testing, performance on a vocabulary test was used to divide participants into high and low ability groups. Participants were tested on the Similarities, Digits Forward, Digits Backward, Block Design and Digit Symbol Substitution sub-tests of the Wechsler-Bellevue battery (Wechsler, 1944), as well as vocabulary and a simple tapping test. In all seven tests, the mean scores for the high ability group exceeded those for the low ability group throughout the 20-year period, even though the classification for high and low ability was based only on a single test. The differences were statistically significant on all the tests except one each year (Block Design in 1947; Digit Symbol Substitution in 1967). On all tests except Tapping, the rate of change was greater for the low ability group. Blum and Jarvik (1974) concluded that indeed “age was kinder to the initially more able” (p. 372).

Manton, Seigler, and Woodbury (1986) suggest that data from the First Duke Longitudinal Study (FDLS) provides evidence that disease or declining health contributes more to lowered cognitive and intellectual function with increasing age, than does age, itself. They further suggest that the implications of patterns of change in cognitive ability and their health correlates are not yet well understood. However, excellent cognitive performance could be maintained in individuals who retained their physical and mental health. Similarly, Steuer, LaRue, Blum, and Jarvik (1981), examining data from the last survivors of the New York State Psychiatric Institute twin study, found that for the oldest-old (83 - 99 years of age), a diagnosis of dementing illness, rather than decline in cognitive performance, was related to death, suggesting there may be different patterns of cognitive change, survival, and mental illness in the oldest-old compared to the younger-old: it is possible that the relationship between ‘critical loss’, or rapid decline in cognitive tests, and mortality is characteristic of the young-old (54 - 74 years), but not the old-old (over 75 years). It is important to note the possible effect of inadvertently including some elderly people with early dementia in studies comparing young and old adults, thus magnifying observed mean differences (Sliwinski, Hofer, Hall, & Buschke, 2003). However, even in the numerous studies where medical and neurological evaluations have been used to exclude unhealthy participants, age-related deficits were evident (Crook et al., 1986).

Wilkie and Eisdorfer (1985) suggested the Duke sample may represent an elite group of elders as they were survivors of a 15-year study. The oldest group of participants in the FDLS, who were between 75 and 94 years of age at commencement, had dropped from 67 to 5 participants over the same 15-year period. Reporting on the FDLS, McCarty, Siegler, and Logue (1982) suggested that participants who remained in the study longer and were present at all testing waves tended to score higher than those who dropped out earlier. Furthermore, they suggest that selective attrition may mean that longitudinal curves provide an overestimate of memory scores and an underestimate of expected declines, as it is suggested that those who die earlier or drop out of the study through lack of motivation, are likely to be those demonstrating a lower ability level at baseline (Bosworth & Siegler, 2002; Cooney, Schaie, & Willis, 1988; Riegel & Riegel, 1972; Siegler, 1975; Singer et al., 2003; White & Cunningham, 1988).

The Canadian Victoria Longitudinal Study and the Swedish Kingsholmen Project

Dixon et al. (2004) drew data from 400 older adult volunteers from the Canadian Victoria Longitudinal Study (VLS) and 168 from the population-based Swedish Kingsholmen Project (KP), both being 3-year longitudinal studies begun in the 1980s with similar, complementary characteristics. Two testing waves were available for elderly people from 55 to 95 years of age, allowing for both cross-sectional and longitudinal data on organised free recall, story recall, random free recall, cued recall, recognition, primary memory and secondary memory. The aim of the study was to explore generalisability of 3-year change with advancing age.

Overall, Dixon et al. (2004) found memory decline to be modest and gradual, even across a 40-year span of older adulthood. Dixon et al. utilise the terminology of primary memory and secondary memory. Items in list recall were considered to be retrieved from primary memory if not more than seven terms intervened between presentation and recall. Other items were classified as retrieved from secondary memory. Overall, little change was found in primary memory which indexes a relatively passive holding of information in consciousness, supporting prior research (e.g., Wahlin et al., 1995). Secondary memory, the ability to transfer information from consciousness to some sort of permanent memory representation, appears to undergo gradual decline in later life (Craik, 1983). The authors point out that although a 3-year longitudinal study is relatively short when looking across the entire life-span; it is, indeed, a significant time when investigating the oldest-old when the expected years to live is measured in single digits. It is known that working memory deteriorates over relatively short periods at this age (Hultsch et al., 1998; Hultsch, Hertzog, Small, McDonald, Miszczak, & Dixon, 1992), and this study provides evidence for detectable rates of decline in some aspects of episodic memory (Dixon et al., 2004). Overall, Dixon et al. suggest the evidence from the study supports the view that the average memory decline is modest and gradual for normal older adults across a 40-year band of older adulthood, although differential change patterns may occur around the mid-70s with a leveling off of loss after this transitional phase. Because of the inclusion of oldest old adults, up to the age of 95 at Time 1 testing, it is possible that terminal decline processes had the effect of lowering individual performances (Bäckman, Jonsson, Wahlin, Small, & Fratiglioni, 2002). Terminal decline refers to the fact that there is a relationship between proximity to death and declining cognitive performance (Siegler, 1975; Small & Bäckman, 1999).

The Berlin Aging Study

Singer et al. (2003), examining 6-year longitudinal data from the Berlin Aging Study (BASE), reported the cognitive changes in 132 individuals whose age ranged from 70 to 100 years. In this comprehensive study, at Time 1 testing the original sample consisted of 516 individuals obtained from the city registry (*M* = 84.9, *SD* = 8.7) with 43 men and 43 women in each of six different age brackets (70 - 74, 75 - 79, 80 - 84, 85 - 89, 90 - 94, and 95+ years). At the first of four test waves, which were carried out at 2-year intervals, the mean age was 84.9 (*SD* = 8.7). The longitudinal cognitive test data consisted of four intellectual abilities: speed, episodic memory, fluency, and knowledge.

Speed was measured by a digit letter task and the Identical Pictures test, episodic memory by paired associates and memory for text, fluency by categories and word beginnings, and knowledge was measured by vocabulary and spot-a-word. The researchers sought to examine six themes in cognitive aging research: mortality-associated and experimental selectivity effects with age (see below), the degree of convergence between cross-sectional and longitudinal data, cognitive change as a function of chronological age, the acceleration of decline in from 70 to 104 years of age, the effect of gender and life-history variables, and the differential effects of demographic variables on fluid and crystallised intelligence.

Mortality-associated (differences between those who survived and those who died) and experimental selectivity (differences between those who completed the study and those who were alive but were unwilling or unable to complete the study) were decomposed, as it is suggested that mortality-associated attrition does not compromise the validity of longitudinal observations because dying reflects a population rather than a sample process. In contrast, experimental selectivity introduces a bias that may limit the generalisability of data because the observed sample is no longer a random subsample of the surviving population (Singer et al. 2003). In addition to the expected increase in mortality-associated selectivity as participants aged, a small degree of mean level bias in the old-old (in this instance, 80+ years) sample emerged, as the survivors who did not participate in both longitudinal follow-ups had a lower average level of functioning at Time 1 than did survivors who participated in both follow-ups.

It has long been understood that over the course of the adult life span, the age gradients of decline for fluid and crystallised aspects of cognition tend to diverge (Baltes, 1987; Horn, 1982; Schaie, 1996), with fluid abilities showing relatively large negative age differences, whilst crystallised abilities remain relatively stable. Singer et al. (2003) suggest that this pattern may no longer hold in very old age, as in their cross-sectional Time 1 testing data both fluid and crystallised abilities were negatively related to age. In contrast to the cross-sectional data, the longitudinal data demonstrated stability for knowledge, and significant decline in speed, memory, and fluency. “The observed yearly linear decline, expressed in *T*-score units, was 0.53 for perceptual speed, 0.38 for memory, 0.36 for fluency, -0.02 for knowledge, and 0.40 for intelligence” (Singer et al., 2003, p. 323). Detailed analyses suggested that knowledge may decline after 90, although overall it shows a high degree of late-life stability in positively selected samples of survivors. Unfortunately, in this study a change from clearly defined chronological age bands to terminology such as ‘old’, ‘old-old’, ‘very old age’, and ‘oldest-old’ without an explanation of how these fit into the chronological age bands or whether they are used interchangeably, makes it somewhat difficult at times to know which part of the sample the authors are referring to. When the age groups were collapsed into two groups for comparative purposes, Singer et al. (2003) contrasted individuals in their 70s with those in their 80s and 90s “because this split seemed roughly consistent with theoretical considerations and available evidence, with the additional benefit of obtaining two subsamples of equal size” (p. 319). Banding participants in their 80s and 90s together into one group may mask changes within this wide age group: an individual in their 90s may well be expected to perform somewhat differently to a person 80 years of age. Furthermore, the decision to collapse the four original age groups (80 - 84, 85 - 89, 90 - 94, and 95+ years) together for analysis makes it difficult to compare with studies which define 85+ years of age as the oldest old (e.g., Dunkle et al., 2001; Lindenberger & Baltes, 1997; Suzman et al., 1992). Comparisons within the study are made more difficult by the sample attrition data being reported as attrition for those under 78 and over 78 years, different age groups to other reported data.

In summary, longitudinal studies are able to test the pattern of change in terms of both the shape of the decline curve and the rate of change over time (Bosworth & Siegler, 2002). M. M. Baltes (1998), and P. B. Baltes (1997) have suggested the causes of the cognitive changes observed in the oldest-old may differ from those of earlier adulthood. It has been proposed that losses in the oldest-old are more pronounced, broader, less subject to intervention, and increasingly more controlled by biological, rather than cultural, factors (Lindenberger & Baltes, 1994, 1997; Singer et al. 2003). In the BASE study under review, Singer et al. concluded that participants in their 70s showed less marked decline than individuals in their 80s and 90s on all abilities tested. Both processing speed and knowledge continued to decline at an accelerated rate within the old-old age group, even though this group represented a positively selected group.

The Relationship Between Cognitive Decline and Mortality in the Oldest-Old

It has been suggested that cognitive function is negatively related to subsequent mortality, and that some of the age differences in cognitive performance in old age may be accounted for by the presence of terminal change (Cooney et al., 1988; Siegler, 1975; White & Cunningham, 1988). Riegel and Riegel (1972) first suggested a ‘terminal drop' hypothesis to describe the relationship between the decline in cognitive function and mortality. More recently Bosworth and Siegler (2002) refer to 'terminal change' to encompass the general association between mortality and changes in cognitive measures. Siegler (1975) suggests the maintenance of function should be associated with survival, and decreases in cognitive performance may be indicative of proximity to death rather than simply being a reflection of changes associated with chronological age.

To date, research findings regarding the association between changes in cognitive decline and mortality are somewhat contradictory, particularly on whether decrements are pervasive across all cognitive abilities (Bosworth & Schaie, 1999). Whilst some researchers have found an identifiable cognitive decline separating survivors from those approaching death (Berg, 1987; Deeg, Hofman, & Van Zonneveld, 1990), others have not found any association between cognitive decline and survival (Botwinick, West, & Storandt, 1978; Steuer et al., 1981). It seems reasonable to assume that those who live into their late 80s and 90s constitute a unique population, because of their selective survival. The majority of studies of older adults use participants with no evidence of neurological abnormality and no long-standing illnesses (Hickman et al., 2000). It is possible a more typical sample of older adults would show greater age-related changes in memory than those reported in much of the literature, but there is evidence that less rigorous screening would be likely to include people with early stages of dementia (Rubin, Morris, Grant, & Vendegna, 1989). Additionally, the highly educated individuals are likely to be over-represented in the healthy oldest-old (Stern, Alexander, Prohovnik, & Mayeux, 1992). Such sample characteristics do limit generalisibiity of research findings, but this must be balanced with the avoidance of unwanted selection effects.

One of the few studies conducted entirely within the oldest old age group is that of Hassing, Small, von Strauss, Fratiglioni, and Bäckman (2002). The investigation was designed to examine cross-sectional and longitudinal changes in episodic memory performance related to impending death among 98 Swedish people 90 - 101 years of age who were assessed three times across a 6-year interval. For the cross-sectional analyses, participants were divided into three groups: those alive at Time 3 (the survival group) (n = 40), those who died between Time 1 and Time 2 (n = 44), and those who died between Time 2 and Time 3 (n = 14). Longitudinal analyses utilised only those who participated in the memory testing at both Time 1 and Time 2, as very few participants participated in Time 3 testing. The episodic memory tasks consisted of face recognition, word recall, word recognition, and object recall.

The face recognition task consisted of studying 20 black and white photographs of unfamiliar faces, and then participants making a yes-no judgement when these 20 faces were re-presented along with 20 distractor faces in randomised order. In the word recall task, two lists of 12 concrete nouns, comparable on word length, concreteness, and imagery, were read aloud by the experimenter whilst the participants read them in bold typeface. Participants were then given 3 minutes for an oral immediate free recall test. The recall data were partitioned into primary memory (PM) and secondary memory (SM), with an item assumed to be retrieved from PM if not more than 7 items intervened between its presentation and recall, as devised by Tulving and Colotla (1970). Word recognition was ascertained in a task similar to the face recognition task, with 12 target and 12 distractor words used. Object recall was measured by participants naming 10 common objects produced from a bag, and subsequently recalling as many as possible on four recall trials, in accordance with the Fuld Object-Memory Evaluation procedure (Fuld, 1981).

Cross-sectional analyses in the Hassing et al. (2002) study showed a significant age group effect for object recall-total only, showing that the survivors outperformed the group that died between Time 1 and Time 2 testing. Longitudinal analyses, however, revealed significant overall decline in face recognition and object recall for both groups who completed Time 1 and Time 2 testing, with no significantly greater decline in those who died before Time 2 testing. Bringing all analyses together, Hassing et al. concluded that there is a reduction of the mortality-related memory deficit in very advanced age, and speculated that this reduction could reflect that many of those who survived into the later testing round may, themselves, have entered into a phase of the cognitive decline related to proximity to death.

It is interesting to note that in the Hassing et al. (2002) study, only object recall and face recognition, tasks involving considerable cognitive support at encoding, showed significant impairment. This supports the finding of Small and Bäckman (1997) who showed that the independent tasks that best predicted future mortality in a sample of people 75 - 95 years of age (178 individuals who were alive at retest and 44 individuals who had died) were word recognition and organised recall, both involving a high level of cognitive support. Siegler, McCarty, and Logue (1982) also found that episodic memory performance was related to subsequent mortality in their sample of older adults (63 to 87 years of age), when tested for logical memory, paired associate learning, and visual reproduction. These results are consistent with White and Cunningham's (1988) suggestion that such deficits show clearly in episodic tasks which are highly supported and relatively well-preserved in old age (Hassing et al., 2002). Overall, Hassing et al. concluded that mortality-related cognitive deficits are evident in very old age, but are relatively small and may be task-specific.

In a 2-year longitudinal study of the relationship between age, gender, and cognitive performance in the very old, Perls, Morris, Ooi, and Lipsitz (1993) found that within each age group (65 - 79, 80 - 89, 90 - 99 years of age) mortality rates for men and women with intact cognitive performance were not statistically different. In contrast, in the two older age groups, the mortality rates of participants with impaired cognitive performance were significantly greater for men than for women ($p < 0.01$ for both age groups). Cognitive performance in the community sample ($n = 2497$) was considered impaired if a participant responded incorrectly to one of the orientation questions: "What is your address?", "What month is it?", or "What year is it?"; or if the answer to the question "Do others make decisions regarding how to organise and schedule the day?" was 'yes' (p. 1194). Perls et al. suggest that if some very old individuals are spared the development of dementing illness, then genetic and epidemiologic studies may uncover the specific characteristics conferring this advantage.

An examination of the relationship between cognitive function and mortality was undertaken with a sample of 601 decedents and 609 survivors from the Seattle Longitudinal Study (Bosworth & Schaie, 1999; Bosworth, Schaie, & Willis, 1999). It was found that the relationship between mortality and cognitive function tended to be associated with specific cognitive declines (crystallised abilities, spatial orientation, verbal memory, and perceptual and psychomotor speed) rather than being a pervasive phenomenon (Bosworth & Siegler, 2002). Bosworth et al. (1999) found that individuals from 75 to 95 years who had significant declines in verbal meaning, spatial ability, and psychomotor speed had greater risks of mortality than those with limited declines.

Anstey, Luszcz, Giles, and Andrews (2001), examined change in memory, verbal ability, processing speed, health, sensory function, and grip strength in a 2-year longitudinal study of very old adults. The sample ($n = 1{,}947$ at Wave 1 testing), drawn from participants in the Australian Longitudinal Study, were stratified into three 5-year cohorts (70 - 74, 75 - 79, 80 - 84), and a fourth cohort of individuals over 85 years of age. Prior studies had been equivocal as to whether stronger relationships with mortality had been shown by a sudden decline of crystallised intelligence (e.g., Birren & Cunningham, 1985) or by rapid decline of fluid abilities (e.g., Korten et al. 1999). Korten et al. found that performance on the MMSE and the Symbol Digit Modalities Test predicted mortality, but that performance on the National Adult Reading Test (NART) and an episodic memory test did not. Similarly, Maier and Smith (1999) found fluid measures to be stronger predictors of mortality than crystallised measures. After controlling for age, socio-economic status, and health, perceptual speed, reasoning, memory, knowledge, and fluency were also predictive of mortality. In contrast, in the Seattle Longitudinal Study, crystallised abilities, perceptual speed, visualisation abilities, and verbal memory all predicted mortality (Bosworth et al., 1999).

The Anstey et al. (2001) study examined the role of memory, verbal ability, processing speed, and health as predictors of mortality in the following 4-year follow-up. The MMSE was administered. Verbal measures included similarities, NART, and picture naming. Memory measures included picture recall and symbol recall. Picture memory consisted of the total number of pictures correctly recalled from the picture naming measure (Luszcz, Bryan, & Kent, 1997) and the symbol memory was the total number of symbols recalled from the processing speed task. For this incidental learning task, participants were not informed at any time that they would be required to recall either the symbols or pictures. Processing speed was assessed using the Digit Symbol Substitution subscale of the WAIS-R (Wechsler, 1981). Consistent with previous studies (e.g., Bosworth & Schaie, 1999; Maier & Smith, 1999; Korten et al., 1999; Small and Bäckman, 1997), Anstey et al. found that after demographic variables were controlled for, poor performance on several cognitive measures was predictive of mortality. The exception was the NART. It was also found that after controlling for self-rated health and measures of disease, some cognitive variables were no longer significant predictors of mortality, perhaps reflecting the view that cognitive performance in very old adults is to some extent a reflection of disease processes. Poor performance on processing speed, similarities, symbol recall, and the MMSE remained significant predictors of mortality. Anstey et al. suggest that poor cognitive performance may be a predictor of biological aging processes as well as a reflection of disease. Although it remains unclear whether decline in any specific cognitive ability is the most salient predictor of mortality, a general association between cognitive decline and mortality appears robust. Because crystallised abilities are least affected by normal aging, Cooney et al. (1988) have suggested changes in these abilities may be a stronger predictor of the biological antecedents of mortality, as a decline in crystallised abilities may signal impending death.

In a study of the neurologic function in the optimally healthy oldest old, Howieson et al. (1993) compared 34 oldest-old participants ranging from 84 to 100 years of age, with 17 people between 65 and 74 years of age on several measures of memory, including digit span, visual reproduction, logical memory, and word list memory. There were no significant effects of gender. While results showed a significant difference between the groups for word list recall, visual reproduction, and logical memory, the researchers concluded the effect of aging was greatest on visual perceptual and constructional tasks rather than on memory tasks. As this study utilised participants of above-average education and vocabulary level, the extent to which conclusions can be generalised to people of average and below-average intellectual ability is unknown. The authors point out that data from Blum and Jarvik (1974) suggest that age effects interact negatively with intellectual ability, with greater rates of cognitive decline in persons of lower intellectual ability.

In the 1993 National Followback Mortality Study conducted for the National Centre for Health Statistics in the United States of America, the cognitive functioning of 17,135 decedents were analysed using proxy reports from informants listed on the death certificates (Yoder et al., 2001). Three questions were used to address the issue: “In the last year of life, did X have any trouble remembering what year it was?”, “Did X have any trouble understanding where he/she was?”, “Did X have any trouble recognising family members?” It was found that 17.8% of males and 28.7% of females had some cognitive problems during their last year of life, with most of the problems in remembering what year it was and where he/she was. It should be noted that the gender difference may have been the result of the information being provided by proxies, as reports on a person’s behaviour and memory abilities have been found to be more valid if the proxy is female than if male (Chaffin, Crawford, Herrmann, & Deffenbacher, 1985).

Findings across studies of aging and memory are equivocal. Some studies reported no relationship between memory and mortality (e.g., Anstey et al., 2001: Bosworth et al., 1999), whilst others described memory as a strong predictor (Deeg et al., 1990; Johansson & Berg, 1989). Johansson and Berg investigated the robustness of the terminal decline phenomenon by testing a group of 70 year olds on a digit span memory test. A second age cohort, also 70 years at baseline, was examined five years later. Both cohorts were reexamined at the age of 75 and 79. Johansson and Berg found a decline in performance emerging several years prior to death for non-survivors. The researchers suggest that the terminal decline phenomenon implies that the aging course is more complex than a gradual deterioration with advancing age, and suggest the course of decline is more strongly related to unique experiences and genetic makeup than to normative age-related influences. Small and Bäckman (1997), when comparing groups of elderly individuals who did and did not survive a 3-year interval, found significant group differences in recognising words and faces, spatial ability, and short-term memory.

In summary, in the investigation of the memory abilities of the oldest-old, ambiguities abound. The prime goal in memory research of the oldest-old - the identification of factors that may determine whether decline in very old age is gradual or accelerated compared to the rate of decline prior to 85 years of age - has yet to be reached. Results of both cross-sectional and longitudinal studies, including several multidisciplinary population studies, have been equivocal. For example, it has been considered that there is increasing divergence between fluid and crystallised abilities during advanced aging (Baltes, 1997; Horn, 1982), with fluid abilities continuing to decline whilst crystallied abilities remain relatively stable. Conversely, in a cross-sectional analysis Singer et al. (2003) found the divergence between fluid and crystallised abilities is discontinuous with the oldest-old showing declines in both fluid and crystallised abilities. Similarly, there is disagreement regarding the factors contributing to declines in the oldest-old. A number of studies have found that those with higher cognitive functioning decline less in oldest-old age than their lower functioning counterparts (e.g., Blum & Jarvik, 1974; Siegler & Botwinick, 1979; Singer et al., 2003). This is reflected in the selective attrition that occurs in the oldest-old, both because it has been established that less able people are more inclined to leave the study before its conclusion, and because the relationship between declines in cognition during oldest-old age and mortality appear robust (Cooney et al., 1988; White & Cunningham, 1988; Reigel & Reigel, 1972; Siegler, 1975). This suggests declines in the oldest-old may be more indicative of closeness to death than of chronological age. Manton et al. (1986) concur, suggesting that disease, declining health, and approaching death may be the prime factors in declining memory in the oldest-old. However, Hassing et al. (2002) found no significantly greater decline of memory for those who died prior to Time 2 of testing, than for those who survived to complete all testing.

Such examples of equivocal findings typical in memory research for people in their ninth and tenth decades of life point to the urgency of further research. It is imperative that anomalies are investigated so that a clearer picture of the memory decrements which may be expected in the healthy oldest-old may emerge.

Chapter Four

EXPLANATIONS FOR AGE DIFFERENCES IN MEMORY

This chapter reviews possible explanations for age differences in memory. Firstly, cognitive explanations are considered, including the possibility of reduced processing resources, speed of processing, and reduced efficiency of working memory being implicated in age-related decline in memory. Secondly, the changes in the neural substrates of memory are discussed. The effects of brain changes on working memory and episodic encoding and retrieval are addressed. The focus then turns to demyelination and neurochemical changes as possible explanations for age differences in memory.

Despite the paucity of memory research for the oldest-old, basic cognitive abilities such as verbal ability and working memory have been investigated. Several major theories attempting to account for the observed age-related changes in memory have been suggested: reduced processing resources, speed of processing, reduced efficiency of working memory, and changes in the neural substrates of memory, for example. It is clear from aging research studies that statistical control of processing speed and working memory variables can attenuate the extent of age-related variation in memory performance. For example, Lindenberger, Mayr, and Kliegl (1993) examined the relationship between speed and intelligence in 76 old (M = 77.2, SD = 4.6) and 73 oldest-old (M = 92.3, SD = 4.7) adults to investigate whether speed continues as a main determinant of age-related variability after the age of 70 years. Participants completed 14 tests to measure speed, reasoning, memory, knowledge, and fluency. Age trends in all abilities tested were well described by a negative linear function. The data were consistent with the hypothesis that age-related decrements are a result of age differences in speed, although the researchers caution against the conclusion “that speed is all there is to cognitive aging” (p. 218). Further investigation is necessary to establish the contribution of such variables as health status, education, and social involvement. Bäckman, Small, and Wahlin (2001) concur, suggesting future research combining biological aspects with health-related factors would increase our knowledge of memory functioning in old age.

Cognitive Explanations

Reduced processing resources

Craik and Byrd (1982), proposed that “reduced attentional resources lead to an attenuation or shrinkage in the richness, extensiveness, and depth of processing operations at both encoding and retrieval” (p. 208). Attentional resources are those required to focus on, and react to, the auditory, visual, and tactile stimuli (Spence, Kettenmann, Kobal, & McGlone, 2001). While the role of such resources in encoding has been well investigated (e.g., Craik & Byrd, 1982; Perlmutter & Mitchell, 1982) the role of processing resources in retrieval have received less attention (Fastenau, Denburg, & Abeles, 1996).

Fastenau et al. (1996) suggest that age differences in processing resources are particularly salient to age-related decline in the formation of new memories and in recent long-term memory. They investigated this assertion in a cross-sectional study utilising 47 younger (M = 43.5, SD = 7.4) and 43 older (M = 67.5, SD = 7.4) adults, who completed four memory tests and four measures of processing resources designed to assess memory span, attention span, speed, and accuracy. The hypotheses that retrieval would be less efficient in older adults was fully supported, whilst the prediction that these age effects would be reduced when controlling for differences in processing resources was largely evident. These results support those of Corgiat, Templer, and Newell (1989) who compared young (18 - 30 years) and older (60 - 88 years) adults to determine the relationship between memory and processing resources, finding the older adults recalled less than their younger counterparts under the most effortful condition. Thus, Fastenau et al. concluded both their own results and those of Corgiat et al., provide support for explanations of aging memory such as that proposed by Salthouse (1988). Both of these studies, however, fail to provide comprehensive evidence for Salthouse’s resource-reduction explanation. The oldest group included in the Fastenau et al. study had a mean age of only 67.5 years, while the Corgiat et al.

study utilised an older group with a 28 year age range. Clearly, it could be expected that individuals who are 85+ years are going to perform very differently to 60 year old people, and studies which exclude the oldest-old or even the young-old cannot provide a complete picture of memory performance during aging.

Arguably, the reduced processing resource theory which has received the most attention is that of a reduced processing speed in the elderly.

Speed of Processing

The speed with which information can be processed reflects the efficiency of the cognitive system. The processing speed hypothesis argues that the speed with which elementary cognitive operations are carried out places fundamental limits on all aspects of cognitive functioning, including remembering (Luszcz & Bryan, 1999). Hartley, Harker, and Walsh (1980) note that by the early 1980s the hypothesis had emerged that neurophysiologically-based change could account for much of age-related changes in memory. Waugh and Barr (1980) and Salthouse (1980) suggested older people employ the same types of processing strategies as younger people, but the limiting factor in memory performance is the rate at which these operations can be accomplished by the central nervous system (CNS). Salthouse (1991, 1996a) suggests the speed at which the CNS processes information influences both the quantity and quality of memory. Salthouse (1996a) further suggests that age-related differences may be a function of slower processing speed with advancing age, because memory traces for previous operations may decay before later information is received, weakening linkages between representations.

A decline in processing speed appears to provide a parsimonious account of some of the memory losses encountered in normal aging. The slowing has been hypothesised to be a reflection of greater interference or noise in the nervous system (Salthouse & Lichty, 1985), damaged neural connections (Cerella, 1990), weakened linkages between connections (MacKay & Burke, 1990), or an accumulation of loss at each step of processing – encoding, storage, and retrieval (Salthouse, 1985). Salthouse (1996b) suggests two mechanisms underpinning the relationship between speed and cognition. The *limited time mechanism* is assumed to result from cognitive operations being executed too slowly to be successfully completed in the available time, whilst the *simultaneity mechanism* is hypothesised to operate because slow processing reduces the amount of simultaneously available information needed for higher level processing. For most memory tasks there is a limited window of time in which a specific operation must be completed to avoid compromising the end result (Luszcz & Bryan, 1999).

The speed hypothesis has impressive support. In 1991, Salthouse and Babcock partitioned the components of working memory into storage, processing efficiency, and coordination components. Evidence was found that processing efficiency, measured by ability to answer simple numerical and verbal comprehension questions, mediated most age-related variance in measures of working memory. However, Salthouse and Babcock also reported that the age-related deficiencies in processing efficiency were mediated by speed. Salthouse (1991) recruited between 220 and 230 adults from 20 - 84 years in each of three studies in which tasks were designed to measure perceptual comparison speed and working memory. The results suggested that many of the differences in measures of cognitive functioning with increased age may be mediated by reductions in the speed of executing relatively simple processing operations. Salthouse reported that whilst working memory appeared responsible for some of the age-related declines, many of the working memory differences may also be mediated by reductions in the speed of carrying out elementary operations.

Salthouse (1993), in a later cross-sectional study using a large number of adults from students to adults in their 70s, measured processing speed (measured by pattern and letter comparison tasks and number and letter transformation tasks) and motor speed (marking and copying tasks), as well as long-term memory. He found that between 80% and 100% of the age-related influences on memory were eliminated after statistical procedures to equate participants on an index of speed. For example, 18.4% of the variance in the memory composite was associated with age prior to statistical control of the speed variable, whereas after statistical control of processing speed the age-associated variance was 3.2% for memory. Reviewing this, and numerous other similar studies, Salthouse (1994) concudes that “it is apparent that the results were similar in every study in that the age-related variance in the measure of working memory was greatly attenuated after control of the measure of speed” (p. 539). Many other studies, however, demonstrate nowhere near such a large amount of the variation accounted for by processing speed (e.g., Hultsch et al., 1990; Rabbitt, 1993; Schaie, Maitland, Willis, & Intrieri, 1998).

A plethora of studies, typically correlational studies using hierarchical multiple regression, have found that speed of processing is an important factor in age-related memory decline (e.g., Bryan & Luszcz, 1996; Hultsch et al., 1990; Park et al., 1996; Salthouse, 1996a). This robust effect persists across a wide range of age groups utilising differing memory tests and statistical analysis procedures, as well as in population-based samples of the very old (Lindenberger et al., 1993), and across studies of a wide range of predictors of memory variance both cross-sectionally and longitudinally (Luszcz et al., 1997). Schaie et al. (1998), discussing the invariance of adult psychometric ability over 7 years, caution that although processing speed is an important factor in cognitive abilities, when adults over 75 years are included, only longitudinal data gives an accurate picture, and cross-sectional studies including adults over 75 years would require specific demonstrations of invariance before the age-difference findings can be accepted.

Zimprich (2002) constructed a test of processing speed balancing the cross-sectional age range and the time period covered longitudinally to test the findings that cross-sectional studies have provided impressive support for the processing speed theory although longitudinal studies provide much weaker support. Data were collected from the Bonn Longitudinal Study on Aging. At first measure in 1965, the average age of the 221 participants was 67.7 years (*SD* = 4.9). The fifth and final measure was in 1976, at which time 38% of the original 221 participants completed the last of five assessments. Participants completed a German version of the WAIS (Wechsler, 1981). At Time 1 testing speed differences, on average across all subtests, explained 85% of the age-related intellectual ability. However, the covariance between the amount of change in processing speed and the amount of change in intellectual abilities over 9 years was only about 4%. Zimprich and Martin (2002) tested the hypothesis that if speed of information processing is at the core of cognitive aging, the correlation between changes in processing speed and fluid intelligence should be substantial. In a 4-year longitudinal study (two test waves), a sample of 417 individuals (*M* = 62.96 years, *SD* = 0.92) completed a range of speed and fluid intelligence measures. Compared to cross-sectional data, in which processing speed and fluid intelligence share up to 79% common variance (Verhaeghen & Salthouse, 1997), Zimprich and Martin report that age-related changes in processing speed and fluid intelligence shared only 28% common variance.

This is comparable to the findings of Sliwinski and Buschke (1999) who juxtaposed cross-sectional age-difference effects and longitudinal age-change effects in a sample of 302 people (*M* = 77.2 years, *SD* = 5.0) in a 4-year longitudinal study. Utilising hierarchical linear models, Sliwinski and Buschke reported that cross-sectionally speed of processing accounts for 70% (verbal fluency) up to 100% (verbal comprehension) of age differences. In contrast, longitudinal analysis showed that processing speed accounts for only 6% (verbal comprehension) to 29% (memory span) of age changes. Schaie (1989) also points out that a single-effects model of processing speed must be questioned as, in the 1977 cross-sectional data from the Seattle Longitudinal Study, it is clear that substantial age effects remain even when speed is accounted for. Taken together, the results of these studies suggest that the explanatory power of speed of processing theory appears to be reduced when age changes, rather than age differences, are taken into account.

Lindenberger et al. (1993), in a large sample of adults from 60 - 90 years, also found that even in very advanced age, speed mediated performance on all measures of cognitive abilities. However, it remained unclear whether working memory was a separate key mediating construct, in conjunction with speed, a matter addressed in studies by Mayr and Kliegl (1993) and Kliegl, Mayr, and Krampe (1994). These latter two studies suggest speed and working memory might independently contribute to age-related declines in memory. Hultsch et al. (1990) and Rabbitt (1993) also propose that discrepant research findings suggest that speed is not sufficient to explain age-related declines in memory, and suggest that there is at least one, if not more, other factors operating in age-related decrements.

Light (1991) warns that strong testimonials for general slowing hypotheses such as that of Cerella (1990) who asserts that it replaces “the myriad task-specific explanations of age effects that have proliferated in the literature” (p. 217), must be tempered as it is by no means clear that a single slowing parameter suffices to describe age-related differences. Salthouse (1994) concurs that the mechanism for the robust and large influence of speed on the relationship between age and working memory is not yet well understood, but points out in a review of studies designed to explore the relationship demonstrated that between 71% and 96% of the age-related variance in measures of working memory is shared with measures of processing speed. Salthouse further suggests there is support for the interpretation that advancing age is associated with a reduction in the speed of encoding or activating information, as the preservation of information over very short intervals is relatively unaffected by aging. However, it must be noted that many studies have found nowhere near this percentage of working memory shared with processing speed (e.g., Hultsch et al., 1990; Rabbitt, 1993).

Furthermore, Hartley et al. (1980) caution against viewing the speed of processing as the prime mediator between aging and memory on three counts:

(a) Walsh, Williams, and Hertzog (1979) found that older adults require some 30% more processing time than younger people when constructing a sensory memory representation of visual output, whilst Walsh and Prasse (1980) found that older adults need as much as 80% longer than their younger counterparts to extract information from sensory memory and recode it into primary memory. Hartley et al. (1980) contend that this does not provide evidence for large amounts of slowing being in memory-related mechanisms, as such research would suggest difference between young and older adults on primary memory tasks, and such differences are not supported by research. If there was validity to the speed of processing explanation, then brief tachistoscopic presentations should produce age differences in primary memory span for digits, even though the same individuals, using standard presentation rates may show no age differences in memory span.

(b) For processing speed to have validity, Hartley et al. (1980) assert it is necessary to supply detailed specifications on how affected memory systems might result in less information stored or retrieved from secondary memory. This can be clarified by the Hartley et al. computer metaphor: Two computers may differ by almost 100% in the speed at which they execute hardware instructions, though each will store and retrieve identical amounts of information when executing the same programme. Slower processing does not in itself mean that less information is stored or retrieved. A longer time to remember does not always mean slower processing – rather than proposing that older people remember less because they process more slowly, it may be that they divert their processing resources to concurrent processing demands, thus never completing the operations necessary for efficient encoding and retrieval from secondary memory.

(c) The pattern of age differences in memory is the reverse of the pattern predicted by processing speed explanations. There is strong evidence of age differences in processing speed at early stages of information output where memory performance does not differ greatly with advancing age. Conversely, there is little evidence of substantial slowing where greatest differences in memory are demonstrated. i.e., There is no change with advancing age in speed of retrieval from semantic memory (Eysenck, 1975), or naming latencies (Waugh & Barr, 1980). These are paradoxes as yet unexplained.

In sum, processing speed needs to be incorporated into any explanation of age-related decrements in memory, and further research is needed to define and refine both what it should stand for and the degree to which it impacts on memory. While impressive results have claimed between 80% and 100% of the age-related influences on memory was eliminated after statistical procedures to equate participants on an index of speed (Salthouse, 1993), in other studies speed of processing influences declines much less spectacularly. For example, Lindenberger and Baltes (1997) found just 38% of the variance was reliably associated with processing speed.

It is clear that processing speed impacts on age-related declines in memory, but much remains to be explained. Myerson, Hale, Wagstaff, Poon, and Smith (1990) assert that speed of processing is not yet well explained, suggesting that slowing may be a consequence of neurobiological changes that lead to an increase in the proportion of information lost at each processing step in a way not yet fully understood. A powerful connection between sensory functions and speed was found by Baltes and Lindenberger (1997) with a comparison of younger individuals (M = 48.2 years, SD = 14.7) and older adults (M = 84.9, SD = 8.66) showing a high degree of age-relatedness of the link between sensory and intellectual functioning, including speed of processing. Lindenberger et al. (1993) also suggest there is a need for further research on the reasons underlying age differences in measures of speed. Additionally, it is essential to ensure the measures of processing speed under investigation accurately represent the hypothesised construct.

A further avenue of investigation into reduced capacity has centred on the role of working memory resources in observed age changes in memory, particularly in the functioning of the central executive.

Working Memory and the Role of the Central Executive

A mounting body of research has investigated a decrease in the efficiency of central executive functioning with increasing age (Fisk & Warr, 1996; Salthouse, Atkinson, & Berish, 2003; Salthouse & Babcock, 1991).

Broadly defined, central executive functioning consists of “control processes responsible for planning, assembling, coordinating, sequencing, and monitoring other cognitive operations” (Salthouse et al., 2003, p. 566). The authors propose executive functioning encompasses tasks such as inhibition, updating, and attentional capacity, suggesting that whilst these functions have largely been viewed as independent, it is possible they represent different aspects of a single function. Furthermore, such executive functioning is associated with the frontal lobes and is relevant to theories that propose that age-related deficits are associated with a deterioration of the frontal lobes of the brain (Crawford, Bryan, Luszcz, Obonsawin, & Stewart, 2000; Moscovitch & Winocur, 1995; Raz, 2000; Shimamura, 1984; West, 1996). This view of central executive processes provides a neuropsychological model of aging and memory rather than a purely cognitive explanation (Luszcz & Bryan, 1999).

Troyer, Graves, and Cullum (1994) tested the extent to which measures of executive function contributed to age-related declines in episodic memory performance in a sample of 51 adults 60 - 91 years of age. They found that age predicted memory performance before, but not after, measures of executive function were partialled out, suggesting executive function does play a mediating role. Troyer et al. found that executive functioning accounted for 36% of the variance in recall performance. However, the Troyer et al. study did not include measures of general cognitive ability and it is not clear whether the demonstrated declines were mediated by decrements in central executive functioning over and above that contributed by general cognitive ability.

In a study comparing younger (20 - 33 years, M = 25, SD = 3.73) and older (60 - 80 years, M = 67, SD = 5.40) people, Fisk and Warr (1996) found controlling for age difference in central executive performance removed over 50% of the age-related variance in working memory, but these differences were largely eliminated after controlling for age deficits in speed. In contrast, Fisk and Warr found that controlling for the central executive left 60% of the age effect in speed intact. Thus, they concluded that rather than an age-associated breakdown in central executive functioning, advancing age is associated with the slowdown in the rate at which information is activated within the whole working memory system.

Salthouse and Miles (2002) assert that central executive processes may be a particularly important factor in age-related individual differences in cognition, if the control and coordination of cognitive processes are impaired with age. However, a study of 150 adults between 20 and 91 years of age (where participants performed a visual-tracking task at the same time as performing a spatial, reasoning, or memory task), provided only moderate support for the role of executive functioning in adult age differences in cognition. The relationship of age to other measures of cognitive functioning was weak relative to those associated with processing speed. Other studies have found little, or no, executive function mediation of age-related memory decline after controlling for speed and working memory. Luszcz and Bryan (1999) suggest such findings reflect the likelihood that age-related declines in executive function are of the same order of magnitude as declines in other measures of cognitive ability, a contention which questions the assertion that executive tasks are the earliest and most extensively affected by normal aging (Daigneault & Braun, 1993; Woodruff-Pak, 1997).

In a recent study of 261 adults from three age groups (18 - 39, 40 - 59, and 60 - 84 years), designed to investigate executive functioning as a potential mediator of age-related cognitive decline in normal adults, participants completed a test battery comprising vocabulary, fluid intelligence, episodic memory, processing speed and neuropsychological tests (Salthouse et al., 2003). Results suggested several methodological and theoretical implications. Because few cognitive or neuropsychological concepts have a ‘gold standard’ external criterion against which they may be validated, Salthouse et al. note validity may have to be established by relying on patterns of convergent and discriminant validity with other variables. It is vital to ensure the variables under investigation actually represent the hypothesised construct, in this case executive functioning. Because the concept of executive functioning overlaps with related concepts such as working memory and attentional capacity, much broader explanations of individual differences will have to be found. Although such constructs appear to involve the frontal lobes, no single construct can, at present, take into account how measures of performance on a wide variety of apparently different cognitive tasks, including memory, tend to be correlated with one another (Salthouse et al., 2003). Overall, these authors conclude that the results of the study suggest that it is important for researchers to recognise that central executive functioning is likely to be just one aspect of a larger phenomenon, and it is necessary to obtain relevant empirical evidence before assuming something novel and distinct has been isolated.

The Role of Attention

Nieuwenstein (2004), exploring the role of attention in forming, storing, and retrieving memories and the extent to which attentional selectivity determines the contents of memory, defines attention as “a selective agent that regulates the flow of information and restricts the operation of memory processes” (p. 225). A dichotomy appears to exist between automatic and controlled processes, with controlled operations considered resource demanding (e.g., Anderson, Craik, & Naveh-Benjamin, 1998; Hasher & Zacks, 1979; Shiffrin & Schneider, 1977). The majority of experimental investigations of memory utilise explicit tests, such as whether one has seen a particular face before, visual scanning, or recalling a list of words presented earlier. Attention, or attentional resource, is not a unitary concept, as multiple aspects of attention are necessary for the ability to pay attention to selecting, encoding, remembering, and retrieving information (Lyon, 1996), a notion referred to as *selective attention* (Halperin, 1996).

Selective attention is typically studied in the laboratory using visual search tasks. Participants are required to search for items such as words, letters, or pictures, in an array of distracting objects. For example, individuals may be required to scan a list of words searching for a target letter. Thus, they would have to selectively attend to the letter of interest whilst ignoring distractor letters. Plude and Doussard-Roosevelt (1989) found reliable age-related differences in selective attention when selection of information was based on two or more features. In a task requiring participants to find a red *X* in a field of green *X*s and red *O*s, young adults’ search rate was faster than that of their older counterparts. The age-related decrement may, however, be reduced if the older individual has experience with the target and distractor information or cues are provided (Rogers, 2000).

An important aspect of attention is the ability to inhibit extraneous, distracting information when focused on a task. Whether older adults have difficulty inhibiting distracting information remains an unresolved and controversial issue. While some studies have found evidence for disinhibition in older adults, others have not. Rogers (2000) suggests that future understanding of the role of inhibition may ultimately provide a unifying theory for age-related differences in attention. However, to date research on attention has produced equivocal results. Furthermore, Rogers suggests that while some types of attention show age-related change, others do not, and some attention types (e.g., selective and divided) appear in both categories as some types show declines only in certain contexts.

The Neurobiological Substrates of Memory

Loeb and Poggio (2002, p. 5) state that "Neurological and neuropsychological observations, as well as investigations with imaging techniques, have shown that each mental function depends on the activity of neural networks in cerebral structures that are spatially distributed and heavily interconnected". The search for the neural substrates of age-related memory decline is being actively pursued, including research into both cellular structures and neural circuitry.

Neuroimaging investigations of individuals with memory disorders have shown that memory is not a unitary function but many different types of memory are distributed across many brain regions and are dependent on a variety of neural systems (Loeb & Poggio, 2002). Recently, attention has been focused on the neocortex, hippocampus, amygdala, basal ganglia, thalamus, and diencephalic and brain stem systems such as the cholinergic basal forebrain, locus ceruleus, raphe nuclei, cerebellum (Crook et al., 1986), and on synaptic plasticity (Okano, Hirano, & Balaban, 2000). Additionally, attention has been directed to cellular metabolism, neurotransmitters, and related enzymes. Whilst severe cell loss and pathological features such as neuritic plaques, neurofibrillary tangles, lipofuscin, and Lewy bodies (all typical of degenerative diseases such as Alzheimer's disease) are not too difficult to detect, subtle changes occurring over long periods of time are more difficult to measure (Katzman & Terry, 1983). More recently, the development of neuroimaging techniques such as positiron emission tomography (PET) and the event-related functional magnetic resonance imaging (fMRI) have facilitated the identification of the neural correlates of memory and an understanding of how they are integrated in both normal and pathological aging. For example, it is known that brain tissue is lost at an ever-increasing rate in the aging brain, particularly after 80 years of age (Esiri, 1994). Immunolabelling measures of synaptic terminations show a 15 - 20% reduction in synapses in the frontal cortex between the ages of 1 and 98 years (Masliah, Mallory, Hansen, De Teresa, & Terry, 1993). Similarly, electron microscopic studies show a 14 - 20% reduction in the synaptic density of the frontal cortex during aging (Gibson, 1983; Huttenlocher, 1979).

The Aging Brain

The aging process is deeply rooted in the genetic makeup and metabolic workings within every cell (Strehler, 1986). Understanding the complex interactions between brain aging and memory depends on understanding the typical changes to the very old brain that are required to encode new information, store the memories, and retrieve the information as required.

Postmortem studies have demonstrated a modest but persistent decline in brain-weight and volume of 2 - 3% per decade after about 50 years of age (Esiri, 1994), with normal aging associated with expansion of the cerebral ventricles and enlargement of the cerebral sulci (Stafford, Albert, Naeser, Sandor, & Garvey, 1988). Although the notion of age-related neuronal loss has had widespread acceptance, this has become a subject of lively debate. Raz (2000) argues that evidence from recent studies suggests the magnitude of neuronal loss may be an artifact of older, inadequate measurement techniques, and that shrinkage of neurons, rather than attrition, may be a more helpful concept in describing aging effects on the memory structures of the brain. In a study designed to determine which brain regions lose volume over time in healthy elderly, Mueller et al. (1998), made comparisons of rates loss in groups of 11 young-old (65 - 74 years), 15 old (75 - 84 years), and 20 oldest-old (85 - 95 years) participants. Looking across a 40-year age spectrum, volumetric losses were recorded in frontal lobes, temporal lobes, basilar-subcortical region, and the hippocampus. Mueller et al. found no significant differences between groups regarding rates of change after the age of 65 years, and suggest that large changes observed in the oldest-old in cross-sectional studies may reflect the presence of preclinical dementia.

PET and fMRI Studies

The advent of brain imaging techniques, particularly fMRI, has created the opportunity to observe the brain at work. Dobbs (2005) notes that thousands of studies have explored a wide range of differences in brain activation, leading cognitive neuroscientists to cite the scans heavily in the recent expansion of literature expounding increased understanding of the brain. For example, Cabeza and Nyberg (2000) conducted an empirical review of 275 PET and fMRI studies of attention, perception, imagery, language, working memory, semantic memory retrieval, episodic memory encoding and retrieval, priming, and procedural memory. The aim was to identify consistent brain activation patterns associated with these cognitive operations, and analysis of regional activations suggested several brain regions, including the cerebellum, could be identified in relation to functional specialisation. The prefrontal cortex was found to be involved in almost all high-level cognitive tasks, particularly during working memory and memory retrieval. Parietal regions were activated consistently during tasks involving working memory, attention, episodic encoding and retrieval, and skills learning. Cabeza and Nyberg suggest that anatomical, evolutionary, neuropsychological, and fMRI evidence all indicate that the cerebellum plays an important role in cognition, but the nature of this role is still controversial and it is a challenge for future research to unify several different views.

Study of the localisation of function in the brain is still in its infancy. It is known, however, that damage in certain parts of the brain cause memory dysfunction (e.g., Loeb & Poggio, 2002; Scoville & Milner, 1957). For memory, two key parts of the brain are the frontal lobes and the hippocampus, areas in which marked deterioration occurs in the very old (Petersen, Jack, Smith, Waring, & Ivnik, 1998).

Nevertheless, Dobbs (2005) casts doubt over the reliability and accuracy of fMRI findings as it measures neuronal activity indirectly by detecting associated differences in blood flow. This overlooks both the networking necessary between brain areas because of the distributed nature of cognitive functions, including memory. Neuronal action in the brain is carried out in milliseconds, whereas the blood flow increase takes some two to six seconds. Dobbs suggests it may well be that the blood flow increase is attached to several neuronal activations and, therefore, interpretation of fMRI-produced graphics may not be as accurate as implied. Additionally, Bullmore (2003) notes that some parts of the brain are poorly visualised because of the different magnetisation properties, suggesting this is particularly noticeable in the inferior temporal cortex and the orbitofrontal cortex which lie adjacent to bone and air-filled sinus cavities. Bullmore suggests the typical univariate analysis employed in fMRI studies limits the usefulness of the ensuing data. An example of the way in which parts of the brain are poorly visualised is noted by Cabeza & Nyberg (2000), who report that a low signal-to-noise ratio in the polar temporal lobe region is particularly unfortunate as it is likely to play an important role in cognition, perhaps by linking the prefrontal-lobe and temporal-lobe regions. Perhaps the most critical comment is that of Uttal (2003) who likens the use of fMRI to a new phrenology, a modern version of interpreting the bumps of the skull as determining brain function.

For a non-invasive scan, fMRI has moderately good spatial resolution. The temporal response of the blood supply, which is the basis of fMRI, is poor relative to the electrical signals that define neuronal communication. Therefore, some research groups are working around this issue by combining fMRI with data collection techniques such as electroencephalography (EEG) or magnetoencephalography (MEG), which have much higher temporal resolution but rather poorer spatial resolution (Banich, 2004).

Working Memory

Working memory is almost always accompanied by increased activity in the prefrontal cortex, with verbal/numeric tasks tending to be lateralised to Broca’s area in the left hemisphere, suggesting phonological processing. It appears the increased activity in these two areas is related to general working memory operations rather than being task-specific (Cabeza & Nyberg, 2000). In addition, working memory studies typically show activations in parietal regions, again tending to be left-lateralised. Paulesu, Frith, and Frackowiak (1993) suggest left parietal activations reflect the phonological store, whilst rehearsal processes are associated with activations in the left prefrontal area. Verbal working memory tasks, especially those involving phonological processing, also resulted in cerebellar activations (Cabeza & Nyberg, 2000). In contrast, nonverbal spatial tasks, but not object tasks, are associated with bilateral activations in the parietal area. Ungerleider (1995) asserts that the distinction of activation patterns between spatial and object tasks points to a ventral pathway for object processing (the ‘what’ or ‘how’ system) and a dorsal pathway for spatial processing (the ‘where’ system) within working memory.

In summary, working memory appears to be linked to neurological integrity, especially of the frontal lobes of the brain (Baddeley, 1990; Woodruff-Pak, 1997). Firstly, the frontal lobes appear to be the earliest and most extensively affected by aging

(Woodruff-Pak, 1997). Secondly, older adults perform more poorly on neuropsychological tests of frontal lobe function than their younger counterparts (Parkin & Walter, 1992). Lastly, there is marked similarity between the memory deficits of healthy, old and oldest-old adults and individuals with frontal lobe lesions (Moscovitch & Winocur, 1992), including free recall (Luszcz & Bryan, 1999).

Episodic Memory Encoding

Episodic memory, memory for personally experienced events (Tulving, 1983), involves the three successive stages of encoding, storage, and retrieval. Unlike lesion studies where damage may reflect deficits of either encoding or retrieval, functional neuroimaging permits separate measures of activity during encoding and retrieval. Cabeza and Nyberg (2000) report that episodic encoding is associated with the prefrontal, cerebellar, and medial-temporal brain areas. Verbal encoding processes are left lateralised in the prefrontal region, whereas retrieval for verbal material involves right lateralised prefrontal activation. In contrast, nonverbal materials are associated with bilateral and right-lateralised activation during encoding (Brewer, Zhao, Glover, & Gabrieli, 1998). Kelley et al. (1998) suggest such right-lateralised encoding may reflect the use of non-nameable stimuli such as unfamiliar faces.

Recent fMRI studies have demonstrated the importance of the medial-temporal structures during encoding. Brewer et al. (1998) have suggested that the strength of medial-temporal activity during encoding predicts what, and how well, items will be remembered, with left-lateralisation for verbal items, and bilateral activation for nonverbal materials. Grady, McIntosh, Rajah, & Craik (1998) argue that the stronger medial-temporal activity typically observed during the encoding of pictures, may account for the finding that pictures are usually remembered more readily than are words.

However, in the light of criticisms leveled at the integrity of fMRI scans (Bullmore, 2003; Dobbs, 2005; Uttal, 2003), caution is required in the interpretation of findings of fMRI scanning techniques, particularly those involving temporal-lobe structures, unless, as suggested by Banich, 2004, a combination of techniques are utilised.

Episodic Memory Retrieval

Of particular relevance to memory and aging, retrieval effort for explicit memory tasks is associated with activation in specific prefrontal regions, and increased activity is observed with advancing age, a phenomenon interpreted as compensatory by Cabeza et al. (1997). As in episodic encoding, lateralisation of prefrontal activations is evident during retrieval, showing a clear tendency for right-lateralisation, although some bilateral activations do occur (Cabeza & Nyberg, 2000). However, in contrast to the tendency for encoding activation to occur in the left hemisphere of the medial-temporal structures, episodic retrieval activations tend to occur in both hemispheres regardless of the type of items to be remembered (Cabeza & Nyberg, 2000).

Within the medial-temporal lobe, Schacter, Alpert, Savage, Rauch, and Albert (1996) found the hippocampus to be associated with conscious recollection. Furthermore, the hippocampus has been implicated in both the recognition of false target items (Schacter, Reiman, et al., 1996) and in the spontaneous reminding of past events (Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1997). Additionally, memory retrieval is associated with posterior midline, parietal, anterior cingulate, occipital, and cerebellar regions (Cabeza & Nyberg, 2000). As it is known that brain volume is reduced during the normal aging process (Esiri, 1994), memory function, requiring activation in a large proportion of the brain, may be expected to be negatively affected.

Of great importance to the study of memory and aging, and to the preservation of memory, is the observation of age-related changes in the brain structures. Raz (2000) suggests global changes in the healthy aging brain are found at neuroanatomical, neurochemical, and metabolic levels with the heaviest toll on the prefrontal cortex, a vital structure for efficient encoding, retrieval, and working memory.

The Role of the Hippocampus

A growing body of knowledge on the age-related changes in the hippocampus, a component of the medial temporal lobe, has been garnered from patients with amnesia following the surgical removal of deep temporal lobe structures to relieve severe epileptic seizures (Squire, 1992). Scoville and Milner (1957) described the case of H.M. who underwent a bilateral ablation of the medial temporal lobe, including the hippocampus, resulting in H.M. losing the capacity to encode a new memory into a permanent long-term memory. This deficit is confined to explicit memory, with both implicit memory and recollection of information acquired prior to surgery remaining intact (Loeb & Poggio, 2002). Petersen et al. (1998) suggest a possible anterior-posterior gradient of age-related vulnerability in the hippocampus, with the posterior body and tail areas showing more atrophy in normal elderly individuals who are experiencing age-related memory decrements. Scoville and Milner suggested the posterior aspect of H.M.'s lesion was especially critical, raising the possibility that this portion of the hippocampus may be implicated in the difficulties many very old people experience with the encoding, and subsequent retrieval, of new information.

In a study focusing on newly learned information, fMRI imaging allowed visualisation of the hippocampal formation in detail, demonstrating abnormalities in four patients displaying impaired memory (Squire, Amaral, & Press, 1990). In these four patients, although the hippocampus suffered severe atrophy the remaining temporal lobe was normal. None of the patients were as severely memory-impaired as H.M., suggesting that H.M.'s inability to process new information involved damage to medial temporal lobe structures other than the hippocampus. Similarly, Vargha-Khadem, Gadian, and Watkins (1997) investigated anterograde amnesia in three patients aged 14 to 22 years. In spite of magnetic resonance techniques revealing bilateral hippocampal pathology and pronounced amnesia for the episodes of everyday life, all three patients attended mainstream schools and attained levels of speech, literacy, and factual knowledge within the low average to average range. Vargha-Khadem et al. suggest these results provide support for the view that the episodic and semantic components of memory are, in part, dissociable, and only the episodic component is fully dependent on the hippocampus.

Furthermore, the hippocampus is a focal point of pathological events associated with age-related diseases such Alzheimer's disease (AD). In a study by Jack et al. (1998) of cognitively normal elderly participants (70 to 79 years) mild hippocampal loss was observed over a one year period, whereas demographically matched AD showed more than twice the rate of change. In a 3-year longitudinal study of normal elderly people and AD patients, shrinkage of the hippocampus was about 1% per year for the normal elderly participants, whilst AD patients demonstrated an accelerated trend of between 3% and 5% per year (Laakso, Lehtovirta, Partanen, Riekkinen, & Soininen, 1999).

The role of the hippocampus in healthy individuals is still a matter of controversy, with some studies finding a correlation between delayed (15 - 20 minutes) recall and hippocampal atrophy (Ylikoski et al., 2000) while other studies have found no statistically significant association (Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998). In a study of 44 cognitively normal older adults (*M* = 68.4 years), Golomb et al. (1996) found that baseline MRI measurements of hippocampal formation size significantly predicted a decline in memory performance. Participants with mild impairment at a 3.8 year follow-up had significantly smaller hippocampi at baseline than those who remained stable. In contrast, in a 5-year follow-up study evaluating 35 neurologically non-diseased people between 55 and 70 years, Ylikoski et al. found no statistically significant association between hippocampal or temporal lobe atrophy and memory test performance. Ylikoski et al. concluded that other factors beside neurological considerations should be studied when defining the mechanisms affecting age-related memory decline. Nevertheless, whilst evidence suggests the hippocampus is important for memory, the role of adjacent and anatomically related cortical structures (particularly the entorhinal, perirhinal, and parahippocampal cortex) have received less empirical attention (Squire, 1992). Similarly, the role of structures further removed from the hippocampus, such as the mammillary bodies in the hypothalamus, have received scant attention. Indeed, Squire suggests that the role of the hippocampus is narrower than once believed.

In the 1970s, the first hypotheses that the hippocampus is involved in only one type of memory emerged (Hirsh, 1974; O'Keefe & Nadel, 1978). Demonstrations of intact abilities to learn and remember by patients who were otherwise severely amnesic supported the early findings (Cohen, 1984; Squire, 1982). It appears that the hippocampus is essential only for declarative memory, as the learning of skills and habits, simple conditioning, and priming are accomplished in the absence of the hippocampus (Squire, 1992). Furthermore, Zola-Morgan and Squire (1990), in a study of retrograde amnesia in the monkey, report that the role of the hippocampus in memory storage is temporary, with memory initially reliant on the hippocampus formation, but its role diminishes as a more permanent memory is gradually established.

Demyelination

The deterioration of the white matter of the brain through demyelination may underlie the age-related slowing that has been argued as a fundamental factor in cognitive aging. Double et al. (1996), as a result of post mortem studies on adults from 46 to 92 years of age at death, report declines in brain volume occur for white matter at the same rate, and to the same extent, as that of total brain loss, suggesting that loss of white matter accounts for all brain atrophy. Moreover, the loss is significant only in the frontal lobes. Therefore, it is likely that subcortical as well as cortical connections will be affected, as frontal lobes have significant additional input from brainstem and basal ganglia circuits. Similar magnitudes of white matter atrophy were found by Leuchter et al. (1994) who demonstrated that white matter atrophy correlates with cognitive decline and a decrease in processing speed. The question remains as to whether this is simply demyelination or the loss of the nerve pathways in general.

Neurochemical studies

Several neurochemical parameters have been assessed in tissue sections and shown to be affected by age in brain areas considered important for memory. Reductions of neurotransmitters have been described in cholinergic, noradrenergic, serotoninergic, and dopaminergic systems (Bartus, Dean, Beer, & Lippa, 1982). Generally, both neurotransmitters and receptors decrease in number with age. Understanding both the neurotransmitter-specific substrate of memory impairment, and changes occurring in glucose, protein, lipid, and nucleic acid metabolism are important to age-related memory research, as both these aspects of brain aging may be of significance in the development of treatment (Crook et al., 1986). For example, in working memory, the processing of auditory and visuospatial information activates the neural pathways in the dorsolateral prefrontal and posterior parietal cortices, with the neurotransmitter, dopamine, playing a major role in the prefrontal cortex during working memory processing (Goldman-Rakic, 1996).

Raz (2000), suggests that, overall, the brain exhibits a somewhat patchwork pattern of declines and preservation. However, age impacts on the prefrontal cortex, and to a lesser degree on the hippocampus, the cerebellum, and the temporal, parietal, and occipital cortices, and various brainstem nuclei that produce catacholamine neurotransmitters. Other parts of the brain remain unaffected by aging. Raz comments that the biological mechanisms giving rise to such patterns of differential brain aging are not yet understood. It is clear that a localising of function model that consists only of brain mapping neural correlates of memory will not be sufficient to answer the complex questions involved in understanding how the aging human brain responds to, and remembers, experience.

In conclusion, despite the empirical and phenomenological reality of age-related memory loss and the attempts to explain it, much work remains to understand its occurrence.

In summary, while an integrated theory of memory which incorporates the oldest-old has yet to emerge, the following are providing fruitful areas for continued research.

1. Processing speed (PS). The large body of literature which has accumulated shows PS to be implicated in memory declines with age. While it appears to offer a parsimonious account of some of the memory losses with advancing age, much remains to be explained: the nature of PS must be defined, how much of the change in PS is a function of the aging brain, and whether PS can be separated from memory, itself.
2. Working memory (WM) function deteriorates with advancing age. As central executive functioning is integral to WM, it may be a potential mediator of age-related declines in memory.
3. Some types of attention show age-related change while others do not. Results in the literature are equivocal. Attention, alongside emotion, the positivity effect, and motivation are among variables worthy of inclusion in future research.
4. It seems that changes in memory performance in the old mirror changes in the aging brain. The last decade has brought about an increased interest in neuropsychological, neurobiological, and neurochemical explanations for memory decrements. It seems that the deterioration associated with the aging brain must be incorporated into multidisciplinary research programmes endeavouring to clarify the underpinnings of age-related memory loss.

Therefore, the aim of the present study is to examine six basic types of memory across the adult lifespan (verbal and nonverbal recall, working memory, short-term memory, face recognition, and prospective memory), giving consideration to the role of the current theories of the underlying causes of memory loss. The study will have a particular focus on the oldest-old, and will explore the impact of seven covariates known to have interacted with memory in prior research: intelligence, verbal and nonverbal PS, depression, physical and mental health. While variables clearly related to memory such as the above (e.g. emotion), the ones chosen were considered the most important for this study.

Chapter Five

THE PRESENT STUDY

Chapter Five presents the aspects of memory which will be utilised in the present study: verbal free recall, nonverbal free recall, short-term memory, working memory, face recognition, and prospective memory. The methodological issue of cross-sectional versus longitudinal designs is then discussed. Finally, the predictions for the present study are stated.

Verbal Recall

Arguably, the most common verbal recall tasks are those requiring participants to study and then recall a list of words, which may be unrelated to one another or, alternatively, able to be categorised. A robust finding in memory research is that of a significant decline of self-initiated recall from episodic memory with aging (Kausler, 1994; Wingfield & Kahana, 2002). This deficit can be observed in significant age differences in word list recall, reflecting a common complaint among older adults of increasing difficulty with memory for learned names and recently experienced events (Gilweski & Zelinski, 1986). Unlike recognition memory and cued recall, free recall requires participants to initiate retrieval cues that may aid access to the desired information, making it a likely reason that recall is one of the most age-sensitive of cognitive tasks (Craik & Jennings, 1992). Thus, recall tests offer a useful paradigm for researching verbal memory processes (Brand & Jolles, 1985; Engle, Clarke, & Cathcart, 1980). Zacks, Hasher, and Li (2000) suggest that, in addition to creating retrieval cues, success in recall depends on the effective inhibition of related, but non-required memories. Failure to inhibit such irrelevant information may result in false memories, a problem which increases with advancing age (Norman & Schacter, 1997).

The number of words normal participants recall immediately after study remains relatively stable through the early and middle adult years (Lezak, 1995). When five age groups (20s, 30s, 40s, 50s, and 60s) of men were tested with familiar one-syllable words, participants did not differ on lists of up to seven words (Talland, 1965). However, the oldest groups did a little less well than younger groups on 9- to 11-word lists, and the three oldest groups did less well when lists were extended to 13 words. Delbecq-Derouesné and Beauvois (1989) found participants from 55 - 65 years retrieved significantly fewer words than three younger age groups when tested on recall from 12 lists of 15 words.

In an early study of word recall, Schonfield (1965) found a clear pattern of consistent decline in word recall on a list of 24 words which were presented singly on a screen at intervals of 4 seconds. For 20 - 29, 30 - 39, 40 - 49, 50 - 59, and 60+ year age ranges, participants recalled 13.8, 12.3, 10.0, 9.6, and 7.5 words, respectively (*SD*s were not reported). A similar word list used as a recognition test showed no decline across the age groups, which Schonfield interpreted as suggesting that age-related impairment of long-term memory may be confined to situations which involve the retrieval of acquired material from storage.

A similar decline in middle age was evident in a 16-year longitudinal study of changes in memory and cognition in older adults (Zelinski & Burnight, 1997). This study incorporated free recall of a list of 20 nouns with immediate recall. List recall was scored as the proportion of the 20 words remembered. Over the five age groups of 30 - 36, 55 - 59, 60 - 63, 64 - 69, and 70 - 81 years, Zelinski and Burnight found a change (reported as *z*-scores) over 16 years of -0.113, -0.434, -0.579, -1.224, and -0.476, respectively. Recall significantly declined over time, with the greatest decline observed between 64 and 69 years of age, similar to the 'watershed' between 65 and 74 years suggested by Giambra, Arenberg, Zonderman, Kawas, and Costa (1995). The oldest-old were not represented in this study.

A similar problem of the exclusion of the oldest-old arises in the investigation by Hultsch et al. (1992) who measured word and text recall in young-old and old groups over a 3-year period. The old cohort showed a slight deterioration which did not reach a statistically reliable level compared to the young-old cohort which showed stability over the tasks. However, as the groups of adults consisted of adults from 55 - 70 years and 71 - 86 years, the research could not show whether the deterioration in the old group reflected the beginning of an accelerating deterioration with advancing age – arguably the question of greatest interest when investigating memory in very elderly adults.

Salthouse (1996a) did include some oldest-old in a study which included a free recall task presenting 10-word lists at each of three stimulus presentation rates: 0.5, 1, or 2 seconds per word. Immediate word recall declined significantly across the age groups (18 - 39, 40 - 59, and 60 - 93), but as the oldest age group ranged over more than 30 years, the pattern of decrement for the very oldest participants is not evident.

In a recent review of cognitive aging (Salthouse, 2004), data from 997 adults aggregated across several recent studies (Salthouse, 2001a; 2001b; Salthouse et al., 2003; Salthouse & Ferrer-Caja, 2003; Salthouse, Hambrick, & McGuthry, 1998; Salthouse et al., 2000) were reported for a memory test involving three auditory presentations of the same list of unrelated words, with the participants required to recall as many words as possible after each presentation. The age-related effects on recall memory were relatively large, with the performance for adults in their early 20s being near the 75th percentile in the population, whereas the average for adults in their early 70s was near the 20th percentile (Salthouse, 2004).

Schaie and Willis (1993), presenting cross-sectional data from the fifth (1984) wave of the Seattle Longitudinal Study (SLS), reported significant differences with increasing age, with the greatest declines between 67 and 74, and between 81 and 88 years of age. When a delay between study and recall of 1 hour was imposed, the rate of decline increased from the age of 67 years. For example, reporting on delayed recall Schaie and Willis found 29-year-olds to demonstrate a total score of 57.68 (SD = 8.16), whereas for 67, 74, 81, and 88-year-olds the scores were 48.61 (9.11), 44.52 (7.61), 41.10 (8.41), and 38.59 (7.92), respectively. Seven years later, in the 1991 wave of testing in the SLS (Kennet, McGuire, Willis, & Schaie, 2000), participants studied a list of 20 concrete nouns for 3.5 minutes and then engaged in immediate and delayed (1 hour) recall tasks. The main effect of age group indicated that mean word recall proportions were significantly lower for each successive age group over middle age. Furthermore, a significant Age x Occasion interaction was obtained, indicating a decline in the oldest cohort (M = 74.42, SD = 2.89) over seven years. It is to be noted that the oldest participant in this report was 86 years of age – the oldest-old were not included.

Of particular interest for the current study, the Leiden 85-Plus Study, a population-based study investigated 599 (87% of the 1912 to 1914 cohort) inhabitants of Leiden in the Netherlands. Van Exel et al. (2001) utilised word lists to test immediate and delayed (25-minute) recall. This oldest-old sample demonstrated a large difference between immediate and delayed scores with females recalling 21 to 29 words (M = 26), and males recalling 20 to 27 words (M = 23) (possible number not reported). After a 25-minute delay interval, however, both males and females recalled an average of only 9 words (range 7 to 11). Education (higher education ≥ 6 years) did not make a difference in verbal recall scores, although the Stroop test and the letter-digit test showed a strong education effect in the same study.

A comprehensive review of post-1975 studies of memory and aging was carried out by Verhaeghen, Marcoen, and Goossens (1993). Regarding word-list recall, the authors reported several types of moderators to account for results in this ability. Firstly, increasing the categorisability of words leads to a decrease in age differences, suggesting the process or strategy of spontaneously organising information is age-sensitive. Klatzky (1980) suggested attempts to organise or categorise words into clusters are, in general, correlated positively with recall. Burke and Light (1981) argue that if older adults do not spontaneously engage in organisational strategies, their recall performance should be poorer than that of young people. Indeed, decreases in spontaneous organisation have been found in free recall of unrelated words, with poorer performance for older adults (e.g., Hultsch, 1974). However, overall, Burke and Light suggest that whilst older adults engage in less spontaneous organisation during recall, there is little evidence that this is because they do not organise at all. When they are able to use organisational cues supplied by the experimenter at recall, age differences in performance remain. Secondly, self-pacing during encoding does not yield smaller age differences. Similarly, slower pacing in experimenter-paced conditions does not reduce age differences. In the reviewed studies, pace ranged from 1- to 20-seconds per word, with a median split of 5 seconds per word. At encoding, no significant differences were found for either learning instructions (intentional versus incidental). Nor was there a reliable difference in effect sizes for semantic versus nonsemantic orienting tasks within incidental learning studies. For intentional learning, findings indicate that the elderly benefit as much as younger adults from manipulations aimed at directing attention to the material to be remembered.

Verhaeghen et al. (1993) suggest that the age difference in list recall performance is situated at the encoding or storage stage of processing rather than at the retrieval stage. Overall, the authors found that providing both young and older adults with retrieval cues does not reduce age differences. The finding that age differences in recall are attributable to differences in encoding activity has been well established (e.g.,

Craik, 1977; Craik & Rabinowitz, 1984; Hasher & Zacks, 1979; Light & Singh, 1987).The Verhaeghen et al. (1993) review found no age differences as a function of recall delay. In contrast, Hassing et al. (1998), in a study of nonagenarians (*M* = 92.03, *SD* = 2.24), found that in a free recall of a 12-word list, participants remembered 4.91 (*SD* = 1.76) on immediate recall, and 1.73 (*SD* = 1.88) after a 20-minute delay.
In summary, a robust finding in memory research is that self-initiated recall from episodic memory declines significantly with advancing adult age. Because free recall requires individuals to initiate retrieval cues, it is likely that free recall is one of the most age-sensitive of cognitive tasks. Free recall of verbal material seems to be relatively stable until the mid-50s or early 60s, followed by a relatively linear decline from then until approximately 80 years of age. It is not yet clear whether the linear decline continues in the same manner into the late ninth and tenth decades of life, or whether there is acceleration or slowing of the decline. Few studies have included oldest-old participants, or have included the oldest-old as part of an age band which may span as many as 30 years.

Nonverbal Recall

Many studies have demonstrated that pictorial material is more memorable to both younger and older adults than verbal material – the pictorial superiority effect (e.g., Park & Puglisi, 1985; Park, Puglisi, & Smith, 1986; Park, Puglisi, & Sovacool, 1983). The effectiveness of memory depends on how readily and completely information can be retrieved – the process of memory recall (Lezak, 1995). Pavio (1971) suggests that nonverbal material is typically remembered better than words because it is more likely to be stored in both verbal and imaginal codes. In contrast, Feenan and Snodgrass (1990) argue that as verbal items are more polysemous than pictorial items which have only one semantic representation, pictures are less likely to be confused than words which may have many semantic representations. Nonverbal memory is more difficult to assess than verbal memory. Finding stimuli that cannot easily be encoded verbally is problematical (Butters & Delis, 1995).

As visual patterns frequently involve highly distinctive stimuli, memory for them could be expected to be insulated from the influences of aging (Giambra et al., 1995). This does not, however, appear to be so. The visual reproduction (VR) sub-test of the

Wechsler Memory Scale - Revised (Wechsler, 1987) requires participants to reproduce geometric line drawings immediately after studying the stimuli (one at a time for 10 seconds) to assess short-term storage for geometric designs. In a delay condition, the task is attempted following 30 minutes of unrelated testing to assess longer-term storage. It has been reported that the VR sub-test has the steepest age gradient of all the Wechsler memory tests (Margolis & Scialfa, 1984; McCarty et al., 1982). Ivnik, Malec, and Smith (1992) found average performance in the 30 - 35 point range at ages 56 - 66 years dropping to a 20 - 28 point range for those aged 77 - 87 years. Futhermore, Lezak (1995) reports that 80 - 92 year old adults exhibit VR recall 2.6 *SD*s below that of 20 - 29 year olds. A sharp decline was also found by Haaland, Linn, Hunt, and Goodwin (1983) in a study where participants over 80 years of age demonstrated VR recall 1.3 standard deviations below the mean of 65 - 69 year olds. Other cross-sectional studies of WMS subtests (e.g., Bak & Greene, 1980; Fastenau et al., 1996; McCarty, Logue, Power, Ziesat, & Rosentiel, 1980) indicate that such decreases in VR memory performance may begin around, or even before, the age of 50 years.

The cross-sectional findings hold true for longitudinal studies. For example, McCarty et al. (1982), using two cohorts from the Duke Longitudinal Study (those aged 70 or less and those aged 71 or more at Wave 2 testing) found significant longitudinal declines on the VR test after 4, 10, and 16 years for individuals initially 60 - 80 years old. McCarty et al. (1982) comment that whilst the longitudinal curves “no doubt provided an overestimate of memory scores and an underestimate of expected declines” (p. 174), the findings support previous reports of the relative vulnerability of nonverbal compared with verbal memory test performance.

The Benton Visual Retention Test (BVRT) (Benton, 1974) also requires immediate reproduction of geometric designs after a 10-second study period. In an extensive investigation of BVRT performance Arenberg (1982), in the Baltimore Longitudinal Study of Aging (BLSA) (Shock et al., 1984), reported that the mean number of recall errors of adults 80 - 89 years of age was 3.7 *SD*s above the mean number of errors for 20 - 29 year olds. The performance measure was the total number of errors in reproducing the 18 original designs. In addition, longitudinal change was consistent

with the cross-sectional findings: for adults 20 - 39 years of age at baseline there was little or no change, whereas for adults initially in their 40s, 50s, 60s, and 70s there were increasingly larger changes (Giambra et al., 1995). In the BLSA study, Giambra et al.

reported that immediate visual memory began to show decrement by late middle age, and the decrement accelerated thereafter when measured cross-sectionally. Longitudinally, the intraindividual change was not significant until after 64 years. It was noted that the 65 - 70 year age period is particularly important because from this period the older a participant is at later testing, the greater the magnitude of the decrement, providing evidence of a positively accelerating age decline. This concurs with Schaie (1994) who asserted that, consistent with the results of 30 years of longitudinal study of primary mental abilities in the Seattle Longitudinal Study, "reliable average decrement is indeed found for all abilities by age 67" (p. 308).

The Memory-For-Designs Test (MFD) (Graham & Kendall, 1946, 1960) is, according to Dustman and Beck (1980), one of the most widely used of any single psychological test for the diagnosis of perceptual, motor, and memory deficits related to brain dysfunction. In a study of 80 adult males divided into 21 - 30, 41 - 50, 61 - 70, and 71 - 90 years groups, the 15 geometric designs which comprise the MFD were presented, one at a time, for 0.5 seconds, differing from other studies which utilise a 5-second exposure. Participants were required to draw as much as they remembered immediately after each exposure. Results showed that although there was no difference between the two youngest groups or between the two oldest groups, collapsing the two youngest and two oldest groups resulted in a significant difference between younger and older adults. Kendall (1962) added thirty 61 - 70 year-olds, and six 71 - 88 year-olds to the original sample reported in the MFD Manual (Graham & Kendall, 1960). While only a gradual decline in ability with age occurred in earlier years, after the age of 60 there was a marked and disproportionate decline in performance. Riege, Kelly, and Klane (1981) found age reliably predicted performance on the MFD for 120 normal, healthy adults from 20 to 84 years of age, divided equally into decade age bands. Riege et al. found that adults over 60 years of age demonstrated omission and distortion errors at three to four times the rate of those less than 40 years of age.

A possible source of an age-related decline in immediate visual memory is slower reproduction time. It has been found that the memory span for verbal items appears to be limited to material that can be spoken in 2 seconds (Schweickert, 1993). It may be that items in immediate verbal memory decay irretrievably in about two seconds in the absence of rehearsal. In other words, the longer it takes to produce items from immediate memory, the fewer items will be recalled. Giambra et al. (1995) note that the BVRT requires each geometric design be reproduced on paper. It has been established that older adults are slower figure tracers and hand-writers than younger people (Dixon, Kurzman, & Friesen, 1993; Welford, 1977), so it may well be that slower reproduction has an effect on the number and accuracy of geometric figures recalled.

Short-Term Memory

In the present study, short-term memory will be measured by the digit span subtest from the WAIS-III (Wechsler, 1997a). The digit span test depends both on auditory attention and short-term storage capacity (Shum, McFarland, & Bain, 1990). Many studies, such as that of Ryan, Lopez, and Paolo (1996), have utilised digit span as a measure of attention-concentration, working memory, and/or short-term memory. In an examination of digit span performance of persons 75 to 96 years of age, Ryan et al. report that individuals ≥75 years should repeat at least 4 or 5 digits forward. Years of education were found to affect scores, and indicated normal expectations for elderly participants are 4 digits forward span with ≤11 years of education, and 5 digits forward span with ≥12 years of education. Similarly, when Orsini et al. (1986) investigated the effects of age, education, and sex on the digit span task in adults from 20 to 99 years of age, the oldest-old (80 - 99 years) (*n* = 125) demonstrated increasing scores with increasing years of education. Those with 0 - 5, 6 - 12, or 12 years of education, attained scores of 4.34 (*SD* = .72), 5.12 (*SD* = 1.07), and 5.68 (*SD* = 1.0) digits remembered, respectively.

In a study of healthy, very old adults, Wahlin et al. (1993) administered the digit span test to 228 adults divided into four age groups: 75 - 79, 80 - 84, 85 - 89, and 90 - 96 years. Digits remembered for each of the four groups averaged 5.53 (*SD* = 1.14), 5.63 (*SD* = 1.12), 5.35 (*SD* = .88), and 5.88 (*SD* = .91), respectively. Similarly, in the Ryan et al. (1996) study, young-old participants (75 - 79 years) demonstrated an average score of 5.80 digits remembered (*SD* = 5.80), and the old-old (≥ 80 years) achieved 5.79 (*SD* = 1.27) digits remembered. In a study of 17 young-old (65 - 74 years) and 34 oldest-old (84 - 100 years), Howieson et al. (1993), the young-old participants obtained an average score of 6.1 digits remembered (range = 4 - 9), whilst the oldest-old participants remembered 5.7 (range = 4 - 8).

Whilst Ryan et al. (1996) found that age and gender did not impact on digit span performance, both education and past occupation was meaningfully associated with the task. It is suggested that information on these variables is important with reporting test results of elderly people, as many senior citizens have achieved occupational success without the benefit of long years of education.

Beside the studies cited, a large body of research has found a lack of significant change in digit span scores with advancing age (e.g., Aronson & Vroonland, 1993; Craik, 1986; Dobbs & Rule, 1989; Hickman et al., 2000; Perlmutter & Nyquist, 1990; Salthouse & Babcock, 1991; Small, Fratiglioni, von Strauss, & Bäckman, 2003).

Working Memory

A decline of working memory is clearly implicated in age-related declines in memory as a whole. In recent years, considerable attention has been focused on determining the extent to which changes in working memory are implicated in age-related cognitive changes. Park et al. (1996) suggest working memory, a processing resource mechanism distinct from slowing, may contribute to age-related memory decline. Working memory, typically defined as the ability to store and manipulate information simultaneously, influences long-term memory primarily by allowing the integration of information at encoding (Cohen, 1988). With advanced age there is a reduction in working memory ability to execute tasks and retain required products of these operations for a subsequent memory task. For example, Salthouse and Babcock (1991) found that older adults had shorter reading and computation spans than young adults, with the young adults being more accurate on longer sets than were their older counterparts . Salthouse and Babcock suggest that the observed age differences are best explained by the younger adults' superior processing efficiency rather than because of age-related differences in the ability to store information.

Working memory constitutes a complex mediator of the aging memory, comprising components of storage of basic information, processing, and the coordination of storage and processing (Luszcz & Bryan, 1999). Experimental research has shown that either storage (Craik, Morris, & Gick, 1990), or processing (Salthouse & Babcock, 1991), or a combination of both (Salthouse, Babcock, & Shaw, 1991) may decline with advancing age. Luszcz and Bryan note that the coordination function of working memory bears a striking resemblance to the monitoring aspect of executive function (Baddeley, 1990), demonstrated by the similarity of memory deficits experienced by both healthy older adults and patients with frontal lobe lesions. These include impairments in free recall, the sequencing of responses, and memory for spatio-temporal context (Luszcz & Bryan, 1999).

In the present study, working memory will be measured by the letter-number sequencing task (LN), a new subtest from the WAIS-III (Wechsler, 1997a). Limitations in working memory are often suggested as either a full or contributing explanation for age-related changes in memory (Craik & Rabinowitz, 1984). Working memory is typically understood as a limited capacity system comprised of respresentational codes for temporary storage of recent input, plus a ‘central executive’ to control operations on the items held in storage (Baddeley, 1981; Daneman & Carpenter, 1980; Wingfield et al., 1988). This differs from older conceptions of short-term memory, such as that proposed by Atkinson and Shiffrin (1968), primarily in the emphasis on the manipulation of information rather than on simple storage and maintenance capacity. The concept of working memory as a system with limited capacity implies that the more processing required for one operation, the fewer processing resources will be available for the performance of others simultaneously, whereas tasks demanding minimal processing would leave the working memory relatively free for other activities (Hasher & Zacks, 1979; Posner & Boies, 1971)

To test this notion, Wingfield et al. (1988) administered memory span tests to represent varying degrees of primary (or short-term) memory and working memory involvement. As a measure requiring very little processing except storage, a digit span test was chosen. Next was a simple word span test, where participants heard progressively longer word lists for immediate recall, on the supposition that this would require more extensive identification operations than the simple digit span. Thirdly, participants completed a loaded word span test based on the working memory span test of Daneman and Carpenter (1980). In this, participants were required to make true/false judgements after statements and then recall the last word of each statement in the set at the end. Wingfield et al. argued that these tasks reflected progressively more working memory involvement in addition to primary memory functions. Thirty-four

community-dwelling elderly participants ranged in age from 59 - 84 years (*M* = 70.0, *SD* = 6.3), and the young group were 34 university undergraduates with ages ranging from 17 to 21 years (*M* = 18.8, *SD* = 1.1). As was expected, for the digit span test, there was no difference between young and elderly participant groups with an identical mean score of 7.2 for both groups. The 2-word span test (simple word span vs. loaded word span) showed a significant effect of age, with the age difference being greater for the loaded word span than for the simple word span condition, thus providing evidence for a decrease in the efficiency of working memory with increasing age.

Providing further evidence for a differing rate of decline between simple digit span and working memory tasks, Myerson, Emery, White, and Hale (2003) utilised the data from the standardisation tables for the Wechsler Memory Scale – Third Edition (Wechsler, 1997c). In a study of 1,050 people between the ages of 20 and 89, Myerson et al. examined data from the subtests of digit span, LN, and a Spatial Span (SS) task. It was presumed that the LN and SS would place a higher load on the ability to manipulate information than the digit span, thus providing a more sensitive test of the effects of age on the processing or executive aspects of working memory. Indeed, the LN regression line was significantly steeper than that of the digit span, and slightly less steep than that of the SS. Some researchers have argued that digit span tasks, both forward and backward, require relatively little executive processing (Dobbs & Rule, 1989; Engle, Laughlin, Tuholski, & Conway, 1999; Ryan, Sattler, & Lopez, 2000). Conversely, Myerson et al. suggest categorising items such as digits and letters requires substantial executive processes, and argue that the pronounced age-related decline found in the LN task may well be attributable to decline in executive aspects of working memory.

Face Recognition

Human society relies greatly on the ability of people to recognise the faces of those with whom they interact, thus requiring the capacity to identify individual members of relatively homogeneous stimuli (Young, 1998). Young further suggests that because all individuals are experts at face recognition, the face provides a rich, ecologically valid stimulus for research. Ellis (1981), on the other hand, argued that faces constitute a complex, meaningful, and natural class of stimuli, in contrast to the simple and artificial stimuli often employed in psychological research. The standard procedure for facial recognition tasks is to present a series of pictures or photographs of target faces and then test memory with a combination of previously studied and distractor faces.

A plethora of such recognition studies appeared in the 1970s, heralding a burgeoning interest (Ellis, 1981). A voluminous body of literature accumulated during the following decades. In a meta-analysis of such studies, Shapiro and Penrod (1986) examined in excess of 100 studies utilising almost 1,000 experimental conditions in the attempt to isolate and examine the effects of many participant and stimulus characteristics. Of prime interest has been how faces are perceived, encoded, stored, and retrieved (Carey, 1981) - phenomena which have been investigated by a variety of experimental methods. Additionally, there has been prolific research on the effects of variables on the individual's ability to recognise faces, such as age (Lamont, Stewart-Williams, & Podd, 2005), familiarity (Bartlett, Hurry, & Thorley, 1984), distinctiveness (Shepherd, Gibling, & Ellis, 1991; Wickham, Morris, & Fritz, 2000), load (Lamont et al., 2005; Podd, 1990), differential experience (Chance, Goldstein, & McBride, 1975), race (Bruck, Cavanagh, & Ceci, 1991; Davies, 1978; Ellis, Deregowski, & Shepherd, 1975; O'Toole, Peterson, & Deffenbacher, 1996), the use of explicit and implicit knowledge (Bruce, Burton, & Craw, 1992), prior knowledge (Bäckman, 1991), typicality (Light, Kayra-Stuart, & Hollander, 1979) and the mental and neurobiological processes underlying face recognition (Carey, 1992; Madden et al., 1999).

People appear to be good at recognising photographs of unfamiliar faces in laboratory tasks, and Goldstein (1977) notes that participants exposed to a set of 20 faces are immediately able to select them from distractors with up to 90% accuracy. In a study of the effects of age, memory load, and face stimulus type on facial recognition, Lamont et al. (2005) found accuracy rates of up to 100% with old adults (80 stimulus faces), particularly with old stimulus faces (*M* = 78, *SD* = 7.8 years). Carey, Diamond, and Woods (1980) found that very brief exposure to previously unfamiliar faces allows people, ranging in age from 20 to 72 years, to distinguish those faces from new ones at a high level of performance across stimuli sets of faces. This is a robust finding, capable of surviving changes of expression and pose between the study and recognition phases (Patterson & Baddeley, 1977).

Typical face recognition studies

The majority of face recognition studies use faces, or pictures of faces, within a laboratory setting. A typical study involves presenting participants with a number of photographs or pictures, presented sequentially. Although participants would typically be informed that they will be asked to recognise the target faces later, Courtois and

Mueller (1981) found that it made little difference to the results whether or not participants knew a recognition test would follow (intentional versus incidental learning).

In the recognition or test phase, which may take place immediately after the study phase or after a specified delay, participants are shown the target faces again, either randomly interspersed with distractor faces or, as in the present study, the participants view a target face and a distractor face placed side by side on a computer screen and attempt to identify the face previously presented in the study phase.

Typically, the faces used are of males only, or of males and females. Shepherd (1981) notes that females show greater facility than males at recognising female faces, thus the use of male photographs only avoids the likelihood of a sex of participant by sex of stimulus face interaction.

The length of delay between the study and recognition phases varies greatly, with many studies utilising more than one retention interval for comparison (e.g., Podd, 1990). Deffenbacher (1986) reported (in an overview of literature on laboratory facial recognition studies), a “vast range” of retention intervals from “one minute to 350 days” (p. 63).

Age differences in face recognition research

A considerable body of research has accumulated on the question of whether there is an age-related decline for facial recognition. In a study of 650 adults between the ages of 18 and 80 years, Crook and Larrabee (1992) found that the facial recognition performance does not decline in linear fashion, but accelerates after the age of 70. Crook and Larrabee’s interest, in addition to affirming the relationship between aging and facial recognition, was to investigate whether the relationship would be similar across two differing methodologies: signal detection theory (SDT), and delayed nonmatching-to-sample (DNM). SDT allows one to measure sensitivity – how well a participant is able to make correct decisions and avoid incorrect decisions – independent of bias, the extent to which evidence is ignored in favour of a tendency toward a particular hypothesis (McNicol, 1972). In the DNM condition, a face was presented on a computer screen, and every 8 seconds another was added in a manner that ensured the same face never occupied the same space twice, until 25 faces were on the screen. The task was to point out the new face at each trial (Crook & Larrabee, 1992). Results of the two methodologies converged, thus providing evidence of the relationship between aging and facial recognition memory. Although significant age-related decrements were found as early as 50, the largest decrements were over the age of 70, suggesting an accelerated rate of decline after the seventh decade of life. For example, the SDT sensitivity index, *d´,* declined from 3.16 to 2.21 between the 18 - 39 years and the 70 + age groups. Additionally, the Crook and Larrabee study demonstrated that false alarm rates are more strongly associated with increasing age than are hit rates. No response bias was present. Unfortunately, the oldest-old were excluded from this study, as oldest participants included in the 70+ were 80 years of age. A similar decline in *d´*was reported by Lamont et al. (2005) in a face recognition task where *d´* declined from 2.14 to 1.90 for participants 18 - 39 years and 60 - 75 years, respectively, with a further decline to 1.90 for participants over the age of 75 years.

Similarly, comparing young participants of 18 to 25 years of age with older adults between 50 and 80 years, Smith and Winograd (1978) found that the hit rate remained stable across the age groups, and the groups differed only by an increased false alarm rate for the older adults. This suggests that these changes were due to differences in recognisability and not a response bias which would have been reflected by an increase in both hit and false alarm rates. Bäckman (1991) found a similar increase in false alarm rate in a series of experiments in the recognition of contemporary and dated famous faces, and of familiar and unfamiliar faces. Backman, too, found an increase in false alarms over four age groups (19 - 27 years, 63 - 70 years, 76 year-olds, and 85 year-olds). However, in contrast to many other researchers, he found a recognition test of unfamiliar old and young target faces to be accompanied by a significant decrease in hit rate, with the deficit in face recognition memory most pronounced in the 85 year-old group. Again, the oldest-old were not included in this study. A higher false alarm rate for elderly participants, compared with young adults, was also found by Ferris, Crook, Clark, McCarthy, and Rae (1980). As participants demonstrated no significant response bias between young and elderly adults, the higher false alarm was considered to be due primarily to the older adults' poorer ability to discriminate between target and distractor faces.

Wahlin et al. (1993), in a study of the influence of prior knowledge on face recognition, similarly found an increasing rate of decline with advancing age revealed by the *d´*

data. Utilising four age groups (75 - 79 years, 80 - 84 years, 85 - 89 years, and 90 - 96 years) Wahlin et al. found a clear age-related deficit in hit rate and a tendency to an age-related increase in false alarm rate. Whilst this pattern of increased false-alarm rate is similar to previous findings, the accompanying decrease in hit rate differed from the findings of earlier researchers who had found minimal age differences in hits (Bartlett & Fulton, 1991; Bartlett, Leslie, Tubbs, & Fulton, 1989; Lamont et al., 2005). A further finding of interest in the Wahlin et al. investigation is that the ability to access and utilise prior knowledge in a face recognition task is preserved among healthy older adults up to the tenth decade, whereas Bäckman and Herlitz (1990) found this ability exhibited a pronounced deficit in mildly demented patients in their 60s. Lastly, multiple regression analysis in the Wahlin et al. investigation showed that among a variety of psychometric, demographic, and biological variables, age was the best predictor in facial recognition performance. Shapiro and Penrod (1986) cited subject age as a variable that reliably impacts on face recognition accuracy.

The age of stimulus faces

Fulton and Bartlett (1991) investigated whether an Age x Age of stimulus face interaction may account, in part, for age-related decline in face recognition. Half the young (*M* = 27.6 years) and half the elderly participants (*M* = 71.4 years) examined young and middle-aged faces, and the remainder studied and recognised middle-aged and elderly faces. The prime purpose of the study was to examine whether the age-related increase in false alarms was smaller with older faces than with younger faces. Using the same middle-aged faces in both conditions was intended to reveal the presence of any effect of stimulus set age as opposed to individual item age: the nature of any Condition x Participant Age interaction would be clarified by the effects of Condition when only middle-aged faces were taken into account. It was found that participant age differences in recognition accuracy depend on face age and that the effect is asymmetric: young adults showed higher discrimination with young adult faces than with elderly faces, but elderly participants recognised young or old stimulus faces equally.

In contrast, the study by Lamont et al. (2005) investigated age-related decline in face recognition memory, and whether this decline is moderated by the age of the target faces and by the number of faces that the participant must learn (memory load). Thirty-two participants in each of three age groups 18 to 39 years (*M* = 25.93, *SD* = 5.85), 60 to 75 years (*M* = 66.84, *SD* = 4.69), and 76 to 96 years (*M* = 81.22, *SD* = 5.52) completed a face recognition task. Signal detection analyses confirmed that face recognition accuracy declined with age. However, this finding was qualified by an interaction between participant age and target age, which revealed that the decline in face recognition accuracy with age occurred for young faces but not old faces. Increased memory load produced comparable performance decrements across all age groups. Recent research findings are accumulating evidence for an own-age bias in face recognition, particularly for older adults (e.g., Anastasi & Rohodes, 2006; Perfect & Harris, 2003; Wright & Stroud, 2003), although these studies have excluded the oldest-old participants.

In sum, much of the large body of facial recognition literature concurs with the robust finding that older and younger adults demonstrate similar hit rates for face recognition. However, the false alarm rate is greater for older adults (Bartlett & Leslie, 1986; Ferris et al., 1980; Lamont et al., 2005; Smith & Winograd, 1978). Older adults are just as likely as their younger counterparts to recognise a previously seen item, but they are likely to respond to new items as “old” at a higher rate. This does not appear to be due to a change in response bias. Rather, aging appears to be accompanied by a change in recognisability, mainly as a result of an increased false alarm rate. As yet, evidence of the effects of stimulus age is equivocal, and the contrasting results found in the Fulton and Bartlett (1991) and Lamont et al. studies may be the result of methodological differences. Few studies, as yet, have investigated face recognition in the ninth and tenth decades of life.

Prospective Memory

A common, everyday memory task is to remember to perform an intended action at some point in the future. Intended actions often cannot be performed immediately, and must be maintained in the memory until there is an appropriate opportunity to perform them, or the right time for execution arrives. Therefore, prospective memory requires individuals to not only set a goal, but also the intention must be maintained and then cancelled once the goal is complete and the intended action activated (Styles, 2005). This ability is vital to maintaining function in everyday life, so it is of great interest whether this type of memory declines significantly in later adulthood. This particular type of memory has been termed *prospective memory* (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Maylor, Smith, Sala, & Logie, 2002). In prospective memory studies a distinction is made between event-based and time-based tasks. An event-based task is one in which an action is to be performed when a cue occurs, such as a bell ring or target word appearing. A time-based task is one in which an action is to be performed after a specified amount of time passes, such as pressing a key in 10 minutes time without a reminder (Cherry & LeCompte, 1999).

An oft-stated comment in the memory literature is that, as yet, little is known about prospective memory (e.g., Ceci & Bronfenbrenner, 1985; d'Ydewalle, Luwel, & Brunfaut, 1999; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). Dobbs and Rule (1987) note that this gap in the literature is a serious one as many memory situations require prospective memory. Prospective memory functioning is necessary for tasks such as remembering to take medicine, remembering appointments, or to turn off the heater – tasks essential to the continuing independence of older adults.

One consistent finding in the memory and aging literature is that a great many types of memory task show large age-related declines, whereas others are better preserved during the aging process (Craik & McDowd, 1987). Craik (1986) suggests that prospective memory should be particularly problematic for the elderly, as external cues, such as contextual cues, often prompt the reconstruction of an event. In prospective memory such cues are not always available. Therefore, Craik suggests the self-initiated nature of many prospective memory tasks, in the absence of retrieval cues, will result in an age-related deficit. Craik further suggests that this is theoretically similar to the greater deficits shown by elderly people in free recall or cued recall tasks, compared to recognition tasks.

In a study designed to determine whether age has a differential impact on prospective memory when naturalistic stimuli are utilised, McDermott and Knight (2004) required participants to recall each of 27 event-based tasks when cues appeared on a videotape showing the view a person would have walking along a city street. The older participants (65 - 79 years) averaged 9.03 tasks correctly recalled out of a possible 27, compared to 13.80 for middle-aged (40 - 55 years), and 16.80 for young (18 - 25 years) participants, respectively. Although the McDermott and Knight study did not include the oldest-old, it demonstrates the way in which prospective memory shows noticeable decrements by middle-age, with continuing decline as people age further.

In an examination of whether or not prospective memory seriously deteriorates in older people, Einstein and McDaniel (1990) devised two laboratory prospective memory tests which were administered along with other tests of memory. The basis of the experimental paradigm was to have participants busily working on a short-term memory task, a recall task presented on a computer screen. Participants were told a secondary interest in the study was investigating the ability to remember to do something in the future. When a reminding cue (the word *rake*) appeared on the screen, an action was to be carried out – in this case, pressing a key on the keyboard. Half the participants (external-aid condition) were given 30 seconds to devise a memory aid of their own choosing, while the no-aid condition required participants to remember the target word without an external cue. The two participant groups were young adults 17 to 24 years of age, and older adults 65 to 75 years of age. The major finding was a lack of age-related deficits in prospective memory, regardless of whether external cues were, or were not, available. Einstein and McDaniel argue that there is the possibility that prospective memory is an exception to the age-related deficits found in other types of memory. It should be noted that the presence of a reminding cue (the word *rake*) in both conditions suggests that this is not a standard prospective memory task.

Support for the notion that retrieval processes are an important component of age-related declines in prospective memory tasks was provided by Einstein et al. (1995). The tasks employed differed in the amount of self-initiated retrieval required: a time-based task (where participants were to perform a task at a later time without a reminder) was presumed to be high in self-initiated retrieval whereas an event-based task was presumed low in self-initiated retrieval as a cue was provided. In all experiments the young participants were between 18 and 27 years of age and the older participants were between 60 and 76 years. Age differences were found with the time-based task, but not in the event-based task, suggesting that the more self-initiated retrieval was required the greater the age-related difference. A similar finding, of an age-related decline in time-based compared with event-based prospective memory, emerged in a comparison of young (18 - 22 years) and older (55 - 81 years) adults carried out by d’Ydewalle et al. (1999).

Examining event-based prospective memory in young adults (19 - 22 years) and older adults (60 - 80 years), Einstein, Holland, McDaniel, and Guynn (1992) manipulated task difficulty by varying both the delay between instruction and the occurrence of the memory cue, and the number of different target events. Results showed no significant difference between the groups when there was just one target event cue for the prospective memory task. However, increasing the number of planned actions for which participants had to remember cues, reduced prospective memory in the older participants.

Event-based prospective memory requires responding to cues in the environment that are associated with a previously established intention (Marsh, Hicks, & Watson, 2002). The notion that intentions reside in memory at an above baseline level of activation - termed the intention superiority effect - was investigated in three experiments using a sample of university students. Marsh et al. note that, prior to the study under review, the majority of laboratory studies of prospective memory were based on the Einstein-McDaniel paradigm in which cues are embedded in an ongoing activity during which a target event, such as the appearance of a particular word, appears (e.g., Ellis, Kvavilashvili, & Milne, 1999). Marsh et al. proposed that an intention superiority effect (faster reaction times to event-based cues) would be masked by the process of noticing the target as relevant to the intention, retrieving the intention itself, and coordinating ongoing activity with the activity needed to fulfill the intention. In other words, heightened activation of the intention should cause cues to be identified quickly, but the processes following the identification may slow responses instead. In the Marsh et al. study, intention superiority was demonstrated by faster latencies to the ongoing activity on failed prospective trials, compared to latencies on successful trials. The three experiments embedded within the Marsh et al. study all provided evidence that successfully performing an event-based intended action requires the cognitive processes of noticing the cue, retrieving the intention, and coordinating its execution with ongoing activity, which tended to mask the intention superiority effect. Similar response latency data, whereby older adults demonstrated increased response latency for missed prospective cues and slower responses to correct cues when compared to younger adults, was reported by West and Craik (1999). This may be particularly noticeable when the cue blends into the ongoing activity context (McDaniel & Einstein, 1993), and Marsh et al. suggest that a highly salient or distinctive cue should attenuate the slowing.

A similar high cost to performance on the concurrent task was found in a prospective memory study by Park, Hertzog, Kidder, Morrell, and Mayhorn (1997). In an experiment examining event-based prospective memory, young (*M* = 19.21 years, *SD* = 0.94) and older (*M* = 69.77 years, *SD* = 5.61) participants were compared when the concurrent working memory task was highly demanding of cognitive resources. Words were presented one at a time on a computer screen at 3-second intervals with a changing background pattern which was unrelated to the word. Participants were instructed to monitor the words and at all times to keep the last three words in memory. Older control participants who were required only to perform the working memory task exhibited errorless performance. Participants in the 6- and 12-event prospective conditions were told that, in addition to performing the working memory task, they should respond to the target background pattern (out of six backgrounds used) by pressing a computer key. In contrast to the control group, older adults in the prospective memory condition performed poorly on the prospective memory task compared with their younger counterparts. Park et al. report that age differences did occur in the event-based task, with the deficit appearing to be due to trying to remember to perform the prospective task while at the same time performing another working memory task. The event-based task was performed perfectly when it was not placed in the context of ongoing cognitive activity.

Despite the hope of Einstein and McDaniel (1990) that prospective memory may be an exception to the typical age-related declines in memory, the majority of prospective memory studies report decrements in older age groups. Difficulties arise in comparisons across the reviewed studies, in part because of the variety of age spans represented as ‘old' groups. For example, groups between 60 - 76 years (Einstein et al., 1995), 65 - 79 years (McDermott & Knight, 2004), 60 - 80 years (Einstein et al., 1992), 65 - 75 years (Einstein & McDaniel, 1990), 55 - 81 years (d'Ydewalle et al., 1999), and 57 - 84 years (Park et al., 1997), are all considered ‘old' groups. Particularly in the latter two studies listed, the age span of the group is much too wide to give a clear picture of prospective memory performance during aging. It could certainly be expected that an 84-year-old would perform very differently to a 57-year-old. It is unfortunate that the oldest-old have not been routinely included in prospective memory studies, as continuing independence depends, to a large degree, on this ability.

Methodological issue

Cross-sectional Versus Longitudinal Research

Considerable attention has been focused on the discrepancy in results between cross-sectional studies (which show a pattern of marked cognitive losses with advancing age), and longitudinal studies (which tend to show a much smaller degree of cognitive change) (Wilkie & Eisdorfer, 1985). Hartley et al. (1980) note that a reliance on cross-sectional methods has resulted in research findings that describe age differences rather than age changes, while Schaie (1980) cautions that the role of cohort effects must be considered when reliance is placed entirely on cross-sectional studies. Changes over generations in cultural and educational variables may place older individuals at a disadvantage during cognitive tasks. However, comparisons of cross-sectional and longitudinal data show that significant reductions in memory and other cognitive abilities remain when cohort differences have been controlled. Moreover, to the present time relatively little investigation of age changes in cognition has been directed specifically to those above 85 years of age.

Interestingly, empirical evidence has demonstrated that age gradients emerging from cross-sectional and longitudinal samples diverge. Sliwinski and Buschke (1999) and Zelinski and Burnight (1997) found, in some measures, steeper longitudinal than cross-sectional changes, whereas others (e.g., Schaie, 1996) have found evidence for the reverse. Singer et al. (2003) assert that cross-sectional age gradients of the total BASE sample were more contaminated with the effects of terminal decline and cognition-related disease processes than the age gradients of the longitudinal sample, and that this observation may hold true for comparisons between cross-sectional and longitudinal data on aging populations in general.

Lindenberger and Baltes (1997) caution that cross-sectional data in aging studies must be viewed with the understanding of the great extent and selective nature of mortality in very old age (Siegler & Botwinick, 1979), and the possible existence of cohort effects (Baltes, Reese, & Nesselroade, 1988). Aging studies necessarily engage with three fundamental effects: Age effects which are typically represented by chronological age, cohort effects reflecting differences due to the unique experiences and circumstances of being born in a particular generation, and time-of-measurement effects which reflect differences from events at the time data are collected (Cavanaugh, 1997). In cross-sectional designs, because all participants are measured at the same time, time of measurement effects do not apply. Unfortunately, however, cross-sectional designs do not allow for distinguishing whether observed differences arise from age differences or because of experiences peculiar to different cohorts: The confounding of age and cohort is a major problem with cross-sectional study design. For example, when an age-comparison study is conducted early in the 21st century, the oldest-old participants were born in the first 20 years of the 20th century, and can be expected to have made their way through very different experiences than young participants who may have been born some 60 years later. When people of different ages are tested at the same point, they may well differ in other characteristics, which may not directly reflect chronological aging effects (Salthouse, 2004). Additionally, cross-sectional studies are unable to address individual differences over time. The selective nature of the mortality process (as discussed previously) may result in an underestimate, rather than overestimate, of the average extent of intraindividual longitudinal decline in old and oldest-old age (Lindenberger & Baltes, 1997). In spite of these shortcomings, the majority of aging studies utilise cross-sectional design. They are able to be conducted relatively quickly and inexpensively, and highlight particular issues which may be followed up with more age-sensitive designs.

It has been suggested that as longitudinal studies assess performance in the same individuals over time, they should capture age-related declines more effectively than cross-sectional studies (Hultsch et al., 1992). Longitudinal studies provide information about age change, as the same people are studied at two or more testing waves over time. However, longitudinal studies are subject to particular difficulties. Firstly, performance may improve over time because of the practice effects created by being tested over and over again with the same measure (Baltes et al. 1988; Salthouse, 2004). Secondly, participant attrition may result in different participant characteristics as the longitudinal study progresses as attrition occurs because of death, disease, or lack of interest (Schaie & Hertzog, 1985). For example, by the 3-year testing in the Victoria Longitudinal Study (VLS), 22% of the original sample had left the study because of health or memory problems and, furthermore, those who left the study had worse baseline performance than those who completed the study (Hultsch et al., 1992). Sliwinski et al. (2003) note that observed decline may be minimised in such longitudinal memory studies as the VLS because only those with superior memory abilities may be retested. Thirdly, longitudinal studies are subject to effects associated with changes in society or culture (Salthouse, 2004). Schaie (1989) suggest that when wide age ranges are to be compared, or when the question being investigated requires knowledge of the magnitude of change, longitudinal data is essential.

Proponents of both cross-sectional and longitudinal methodologies propose different answers to the vexed question of distinguishing between age and nonage influences on cognitive declines. Salthouse (2004) suggests that researchers favouring cross-sectional methods deem it plausible to assume people of different ages at a specific point in time were similar in most important respects. Conversely, those favouring longitudinal methods assume that maturational effects are very much greater than influences such as practice effects or sociocultural change, and these non-maturational influences can be dealt with by statistical means.

Rupert, Eisdorfer, and Loewenstein (1996) note that researchers have used cross-sectional (which confound age and cohort) and longitudinal (which may confound age and time-of-measurement) methods, whilst paying scant attention to cultural and demographic factors. Thus, they suggest a combination of both cross-sectional and longitudinal data with a study may present a more balanced picture of cognitive abilities during aging.

The Present Study

In an experimental investigation incorporating both cross-sectional and longitudinal 2-year samples, word recall, geometric shapes nonverbal recall, face recognition, short-term memory, working memory, and prospective memory across the lifespan were examined, with a particular focus on the oldest-old. Salthouse (2004) shows that some aspects of cognitive decline, such as word recall, are a linear function of chronological age over a 20 years to 80 years age span. There is, as already discussed, a dearth of research literature pertaining to memory in the oldest-old, those 85 years of age and over.

The aspects of memory to be examined have been carefully chosen. Word recall is a standard task within memory research, and allows for comparison between studies. Between study comparisons highlight difficulties of interpretation within the memory research literature, as both the lack of standardised tasks and the haphazard use of age-band definitions have resulted in a somewhat confused picture of memory declines in old and oldest-old age. The nonverbal recall task was made structurally similar to the verbal recall, allowing comparison between the two types of memory. A new test of nonverbal recall, a geometric shapes test, was designed to achieve this goal. Both verbal and nonverbal tasks include delayed recall at 10 minutes, and 7 days after the study phase, as well as immediate recall.

A recognition task, face recognition, was included to allow a comparison of recall and recognition abilities through the lifespan. Additionally, although the ability to perceive and recognise faces demonstrates the extraordinary sensitivity and power of human memory, little is known about how face recognition declines in the *later* years of life. Can older adults recognise a relatively large ensemble of faces as well as younger adults?

Standardised tests of short-term memory and working memory were utilised. Short-term memory and working memory are abilities at the very foundation of human memory and are a common thread through aging memory studies. Thus, the use of the digit span and letter-number sequencing sub-tests from the WAIS-III (Wechsler, 1997a) allowed for comparison with findings from the prior literature

Prospective memory is of practical importance to the oldest-old who are living in the community, perhaps on their own. Remembering to carry out an action in the future, or remembering appointments, for example, are important to independence. Both prospective memory for questions (cued by a bell 20 minutes after the action is planned), and prospective memory for an object (at 75 minutes) will be tested.

The Expectations of the Present Study

It was expected that:

a) There would be a sharp, nonlinear decline in all types of memory for the oldest-old.

b) The rate of decline in memory would be moderated to varying degrees by covariates such as intelligence, physical health, mental health, depression, processing speed, and years of education.

c) There would be marked change over the period of two years for the oldest-old, but not for the young and middle-aged people. It was expected that for the oldest-old, at an age where life expectancy is measurable in single digits, the 2-year inter-testing interval would show declines in most, if not all, aspects of memory.

Chapter Six

METHOD

This chapter provides a description of the three participant groups, and of the experimental design and analyses used in the present study. The ethical considerations when investigating the oldest-old are discussed. The methodology employed is presented, including the measures and procedures used. The demographic and health questionnaires, and the memory and processing speed measures are described, followed by information regarding the administration of the measures.

Participants

One hundred and forty community-dwelling volunteers were recruited for the present study. Participants were aged 20 - 40 years (young group, *M* = 30.17, *SD* = 5.51), 50 - 70 years (middle group, *M* = 59.03, *SD* = 5.02), or were 85 years and over (oldest-old group, *M* = 87.73, *SD* = 2.44) at Time 1 testing. Each participant was screened at the beginning of the study using a structured interview which included health questions to ensure they met the following criteria: (a) no medical conditions with known CNS complications; (b) never suffered from a neurological impairment (e.g., Alzheimer's disease, stroke, brain tumour); (c) did not suffer from major depression. The Mini-Mental State Examination (MMSE) was used to screen for cognitive impairment. In all, seven volunteers were excluded from the study: one from the middle group and two from the oldest-old group because of a prior stroke, and another four oldest-old volunteers were excluded because they did not reach the MMSE score of 23 out of a possible 30, generally recognised as the cut-off score indicative of cognitive dysfunction (Bleecker, Bolla-Wilson, Kawas, & Agnew, 1988). No exclusions resulted from screening for major depression utilising the Beck Depression Inventory-II. Participant screening scores are shown in Table 6.1.

Table 6.1: *Means (SD) for the demographic characteristics of participants at Time 1 testing.*

	Young		Middle		Oldest-Old	
	Female *n*=24	**Male** *n=16*	**Female** *n*=30	**Male** *n*=16	**Female** *n*=33	**Male** *n*=14
Age	29.99 *(6.29)*	30.44 *(4.29)*	58.84 *(5.03)*	59.37 *(5.14)*	88.22 *(2.59)*	86.57 *(1.57)*
WAIS-FS	111.04*(10.91)*	110.06*(8.37)*	115.90*(9.50)*	115.75*(9.96)*	111.24*(7.97)*	112.79*(9.82)*
BDI-II	4.08 *(3.30)*	3.00 *(3.12)*	3.00 *(3.73)*	2.50 *(3.25)*	4.03 *(2.60)*	4.43 *(4.74)*
MMSE	29.50 *(.83)*	29.75 *(.58)*	29.40 *(.81)*	29.50 *(.89)*	27.79 *(1.45)*	27.86 *(1.82)*
SF-36 PF	28.92 (1.35)	28.56 (2.73)	26.37 (4.08)	27.13 (1.67)	19.52 (4.39)	23.00 (4.13)
SF-36 MH	24.21 (3.26)	24.38 (2.73)	25.03 (2.53)	25.13 (2.96)	26.15 (3.64)	26.14 (4.83)
Years Ed	15.29 (1.73)	15.06 (4.00)	16.30 (4.04)	16.38 (2.78)	11.79 (2.68)	13.98 (4.88)

Note: WAIS-FS = as calculated from National Adult Reading Test; BDI-II = Beck Depression Index – II; MMSE = Mini-Mental State Examination. SF-36 PF=Physical function. SF-36 MH = Mental Health

Within each age group, participants were randomly assigned to one of two task-ordering conditions (see Table 6.2, p. 112) with the proviso that there were equal numbers of males and females in each group. At Time 1 testing, age groups were divided by both gender and two recall conditions: In the first condition word recall was tested prior to shapes recall, and in the second condition the order of testing was reversed. Preliminary analysis showed that neither gender nor order of testing effects were significant, and all further analyses were carried out with the groups collapsed into age groups only.

For reasons unknown, the middle group averaged a statistically significant higher IQ measure compared to the young group. However, the young and oldest-old groups did not differ. The differences were considered acceptable and the study proceeded.
A small number of oldest-old were lost to the study in the 2-year inter-test interval, and it was decided to use only those who were available for both Time 1 and time 2 testing in the cross-sectional and longitudinal analyses.

Experimental Design and Analysis

The present study was designed to include both cross-sectional (at Time 1 and Time 2 testing), and longitudinal (2 years) components. The aim of the study was to compare three age groups (20 - 40, 50 - 70, and 85+ years) on six types of memory (recall of verbal and nonverbal items, short-term memory, working memory, face recognition, and prospective memory). While this is not an exhaustive selection of memory types, careful consideration was given to the advanced age of the oldest-old participants – several were in their 90s, and it was necessary to devise a battery of tests which would be neither too tiring nor too daunting for these people. Such ethical considerations informed the decision that the testing should be no more than 90 minutes duration, which in itself limited the number of memory types to be addressed. As discussed in Chapter 5, the tasks were selected to cover aspects of memory very relevant to the independent living of the oldest-old, and to give a comparison, where possible, with prior research. Some variation in the duration of the test battery was expected: Timed sections of the battery would necessarily be identical for all groups, but questionnaires were expected to be completed more quickly by younger participants.

Originally, the design consisted of 12 groups of participants. Each of the three age groups were divided, firstly by gender, and secondly, by task order, wherein half of the participants in each age group completed verbal recall tasks in the first part of the battery and the nonverbal recall tasks in the second part. For the other half of the participants the order was reversed in order to investigate if task order influenced results. As there were no significant gender or task order differences, groups were collapsed across gender and task order, and further analyses were completed only on the basis of the three age groups (Table 6.1).

Comparisons across tests presented some difficulties because of the differences in the scoring required for various tests. All scores were converted to standardised *z*-scores to allow for comparison among tests. ANOVA were carried out to ascertain whether there were significant age differences on memory scores between the three age groups. Planned analysis of covariance (ANCOVA) were utilised to enable assessment of the impact of potential confounds, such as processing speed, depression, physical functioning, mental health, years of education, and intelligence. Multiple regression analyses were then carried out to ascertain the unique variance which could be attributed to the covariates used. All raw data for the current study may be seen in Appendix R.

ANCOVA Analyses

It was decided to utilise ANCOVA analyses for the present study. ANCOVA, an extension of ANOVA, is widely used in memory research (e.g., Boswoth & Schaie, 1999; Dixon et al., 2004) wherein the main effects and interactions of the independent variables are assessed after dependent variable scores are adjusted for any differences associated with the covariates (Tabachnick & Fidell, 2001). Tabachnick and Fidell assert that in experimental settings, ANCOVA increases the sensitivity and power of an *F* test by removing predictable variance associated with the covariates from the error term. Additionally, when participants cannot be randomly assigned to groups, as in the present study, ANCOVA may be used as a statistical matching procedure, whereby it adjusts group means to what they would be should all participants score equally on the chosen covariates (Tabachnick & Fidell, 2001). Hanneman (2006) describes ANCOVA as a combination of ANOVA and multiple regression, the latter type of analysis also being common in memory research.

Multiple regression analyses

Multiple regression is an extension of correlation, intended for prediction (Aron & Aron, 2003). Tabachnick and Fidell (2001, p.139) state “If standard multiple regression is used, two fundamental questions are asked: (1) What is the size of the overall relationship between the [dependent variable] and the set of independent variables, and (2) How much of the relationship is contributed uniquely by each independent variable”. As these were two of the precise questions of interest, standard multiple regression was used.

In standard multiple regression, all of the independent variables enter into the regression equation at the same time, and each is assessed as if it had entered the regression after all the other independent variables had been entered. Thus, each independent variable is valued on what it adds to the prediction of the dependent variable (in this case, the memory type under study) that is unique and different from the effect of all the other independent variables (Tabachnick & Fidell, 2007). Standard multiple regression was used in the present study to ascertain the unique amount of variance associated with each of the chosen covariates.

Procedure

Several of the memory tasks were computer-administered, thus providing consistency and uniformity of stimulus presentation (Youngjohn, Larrabee, & Crook, 1992). Pilot work for the present study demonstrated that, whilst many of the middle-aged and oldest-old participants were unfamiliar with computers, they were interested and enthusiastic about taking part in the study. The verbal and nonverbal memory tests were specifically designed for computer use. A Toshiba Satellite M30 laptop computer was used, with participants viewing tasks on a separate 15” LCD screen to ensure maximum visual clarity. Tests were scored manually. At no time were participants required to operate the computer themselves – participants were required only to observe the screen.

General Procedure

The assessment procedures were conducted in each participant’s own home. Prior to testing, participants were requested to provide a quiet, distraction-free room where the testing would not be interrupted. The equipment was set up on a dining-room table and the position of the equipment was adjusted to suit the participant.

The administration of tasks was arranged to minimise fatigue and to avoid interference from tasks of a similar nature. Participants read an information sheet (see Appendix A) giving an overview of the study and listing the rights of participants. All procedures were approved by the Massey University Human Ethics Committee. Participants then completed a consent form (see Appendix B) and were verbally informed of their rights to withdraw from the study at any time. A visual acuity test was given to ensure the participants were able to clearly see the words and faces to be presented on the computer screen. Each participant was asked to read 18pt font sentences from *Reading Test Types* as approved by the Faculty of Ophthalmologists, London (1987). The vision sheet test was held at the same distance and angle as the computer screen. Hearing was tested by the researcher rubbing fingers together close behind each participant’s right ear. If this was audible to the participant it was considered hearing was sufficient to allow for the orally presented tests. The researcher sat to the right of the participant.

Each participant was then taken through a series of tasks using standardised verbal instructions. If a participant required clarification of the task instructions, or appeared to initially misunderstand them, standardised verbal prompts were provided. Participants completed each task (used to assess a specific function) as shown in Table 6.2. For half the participants, word list recall, digit span, identical pictures, and delayed word recall were interchanged with the geometric shapes task, letter-number sequencing, Finding A's, and the delayed geometric shapes task to ascertain whether completing verbal recall or nonverbal recall first influenced scores.

Table 6.2: *Experimental tasks (in order of presentation) and associated functions.*

Task	Function
Structured Interview	Demographic and disease data
Prospective Memory Object Task	Memory for a hidden article
Mini-Mental State Examination	Cognitive status
Beck Depression Inventory-II	Depression
Prospective Memory Question Task	Memory for two questions
[1]Word List Recall	Verbal immediate free recall
[1]Digit Span Forwards	Short-term memory
[1]Identical Pictures	Nonverbal processing speed
[1]Word List Recall	Verbal delayed (10 mins) free recall Then 7 days later
SF-36 Health Survey	Self-reported physical and mental health
Bell for Prospective Memory questions	
[2]Geometric Shapes Task	Nonverbal immediate free recall
[2]Letter-Number Sequencing Task	Working memory
[2]Finding A's Task	Verbal processing speed
[2]Geometric Shapes Recall	Nonverbal delayed (10 mins) free recall Then 7 days later
National Adult Reading Test	Premorbid IQ (WAIS-R)
Facial Recognition Task	Recognition memory
Prospective Memory for object tested.	

[1]and [2]: For half of the participants, the group of tests marked [1] and the group of tests marked [2] were interchanged to create two test orderings.

The interval between Time 1 and Time 2 was 24 months. Every effort was made to test each participant at the same time of day in each of the two test waves.

The tasks were categorised into three groups:

(a) Health assessment and demographic data,
(b) Memory tasks, and
(c) Processing Speed tasks.

Measures

Health Assessment and Demographic Data

The Structured Screening Interview

Rationale: The structured questionnaire was used to record the following data from all participants: date of birth, gender, marital status, years of education, problems with hearing and eye-sight, occupation, health status, and medication (see Appendix C).

Procedure: The questions were presented orally and the responses were recorded on the questionnaire by the interviewer.

Mini-Mental State Examination

Rationale: The Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) was used to provide a brief, objective measure of cognitive functioning. MMSE scores are known to vary by age and education within the general population. The MMSE is arguably the most widely used brief screen for cognitive status and dementia (Albert, 1994; Brayne, Gill, Paykel, Huppert, & O'Connor, 1995; Lezak, 1995). The MMSE provides a quick, simple test for a broad range of cognitive function, taking approximately 7 minutes to administer (see Appendix D).

Administration and scoring: Of particular importance to the current study, the MMSE includes an assessment of memory (delayed recall of three items and response to questions related to temporal orientation). The MMSE also includes items pertaining to language (naming common objects), repeating a linguistically difficult phrase, following a three-step command, and writing a sentence, spatial ability (copying a two-dimensional figure), and set-shifting (performing serial sevens – counting backwards from 100 by sevens – or, alternatively, spelling the word 'world' backwards) (Albert, 1994). Each correct response receives 1 point. Thus, scores on the MMSE range from 0 - 30. Scores above 26 are generally considered reflective of normal cognitive function, scores of 20 - 26 typically indicate mild impairment, moderate impairment is reflected by scores of 11 - 20, and severe impairment by a score of 10 or below. A score of 23 is generally accepted as the cut-off score indicative of cognitive dysfunction for research purposes, even for the oldest-old. Additional guidelines have been provided by the publication of population-based norms for differing age and educational levels (Crum, Anthony, Bassett, & Folstein, 1993). The MMSE was administered according to the User's Manual with standardised instructions throughout.

Prior use in aging research: Hereen, Lagaay, Beek, Rooymans, and Hijmans (1990) examined 1,258 very elderly people over the age of 85 years a part of an epidemiological study conducted in the Netherlands. They report the MMSE scores of 532 participants who showed no evidence of neurological or psychiatric disorders and who had more than four years of education. The median score for this oldest-old cohort was 28, with cut-off scores for the lowest quartile of 26 and 25 for participants in their eighties and nineties, respectively. A similar MMSE score of 28.3 (*SD* = 1.4) was found in the oldest-old (84+) in a study of neuropsychological test performance (Hickman et al., 2000), a drop from 29.2 (*SD* = 0.8) for the young-old group (65 to 74 years). MMSE scores of 27 or 28 have been found in a large number of studies of people between 65 and 87 years of age (see Benedict & Zgaljardic, 1998; Christensen et al., 1997; Howieson et al., 1993; Johansson et al., 1992), although an average MMSE score of 29.00 (SD = 1.71) was found in a study of healthy individuals 65 - 87 years of age (*M* = 76.53) (Stebbins et al. 2002).

Brayne et al. (1995) examined a sample of 1,111 survivors from a population aged 75 years and over, with two testing waves approximately two and a half years apart. The authors emphasise that because most demented individuals were excluded, the sample were biased towards higher MMSE scores. Overall, over the two and a half year between-testing period participant groups of 75 - 79 years, 80 - 84, 85 - 89, and ≥90 demonstrated a mean change of -0.8 (*SD* = 0.12), -1.5 (*SD* = 0.15), -2.3 (*SD* = 0.27), and -3.0 (*SD* = 0.53), respectively. Brayne et al. found the distribution of change in MMSE scores over time to be normal in shape, with a median drop of one point over a period of 2.4 years. There were very few individuals at the oldest ages who maintained high levels of scoring. A somewhat steeper slope of decline was found by

Izaks, Gussekloo, Dermout, Heeren, and Ligthart (1995) in a study of the cognitive functioning of 134 people aged 85 and over. After an interval of 3 years the median change in MMSE score was -4 points, prompting the suggestion of Izaks et al. that all participants in cognitive studies should be periodically assessed by the MMSE. Indeed, cognitive decline has been defined as a drop of at least 3 points on the MMSE at a four year follow-up (Paterniti, Verdier-Taillefer, Dufouil, & Alpérovitch, 2002). Brayne et al. comment that although the MMSE has drawbacks as an instrument to measure cognitive decline as it has to be assumed that it behaves as a linear scale, and has only moderate ceiling effects. It is a better measure of decline in the general population than other short mental tests, particularly for older people. Whilst the ceiling effect of the MMSE is obvious in younger age groups, it is not evident with elderly people.

Frisoni et al. (2000) conducted an investigation of mild cognitive impairment and physical health, collecting data on 1,435 individuals aged 75 to 95. It was found that the relationship of MMSE score to age followed a linear decline until approximately age 90 when the slope became steeper up to age 95 years. This pattern held for both high and low (< 8 years) education. For highly educated (high school, or high school and university) participants the MMSE mean scores were 27.8, 26.3, to 25.5 (out of possible 30) at 75, 90, and 95 years of age, respectively. The values for people with a lower education were 0.8 points lower than their more highly educated counterparts. Hassing et al. (1998), in a study of 80 healthy Swedish nonagenarians (M = 92.03, SD = 2.24), found lower levels of education was predictive of the MMSE score, supporting this well-documented finding (see Frisoni, Rozzini, Bianchetti, & Trabucchi, 1993; Jorm, Scott, Hendersson, & Kay, 1988; Korten et al., 1997; Ylikoski et al., 1992).

Psychometric properties: According to U.S. population-based norms, healthy individuals over 85 years of age with 5 - 8, 9 -12, and >12 years of education can expect to score 24, 26, and 28, respectively (Crum et al., 1993). Tombaugh and McIntyre (1992) reported test-retest reliability results for the MMSE ranging from about .80 to .95. Using the cutoff score of 23, they found the MMSE to have a sensitivity of at least 87%. Moderate to high levels of specificity have been found in most studies (Folstein, Folstein, McHugh, & Fanjiang, 2001).

Beck Depression Inventory-Second Edition (BDI-II).

Rationale: The BDI-II (Beck, Steer, & Brown, 1996b) is a 21-item self-report instrument for measuring the presence and severity of depression in adults and adolescents over the age of 13 (see Appendix E). The original BDI was first developed in 1961, with a later revision to the BDI-IA in 1979. In 1996, the BDI-IA underwent a major revision to allow for the assessment of symptoms corresponding to the American Psychiatric Association's *Diagnostic and statistical Manual of Mental Disorders – Fourth Edition* (DSM-IV) (American Psychiatric Association, 1994). The changes from the BDI-IA to the BDI-II included re-labelling or re-wording all but three items, and replacing or clarifying others (Beck, Steer, Ball, & Ranieri, 1996a). Other changes included providing a header to each item, thus providing focus on the purpose of the statement for the examinee. Also, the time frame for the BDI-II ratings was extended to 2 weeks, to give temporal compatibility with the DSM-IV criteria (Dozois, Dobson, & Ahnberg, 1998).

To screen for current depression amongst the participants of the present study, the BDI-II was chosen for two main reasons. Firstly, the BDI-II takes only 5 - 10 minutes to complete. Secondly, the BDI-II has widespread use and its psychometric properties are well documented (Dozois et al., 1998).

Administration and scoring: The instrument consists of 21 items: sadness, pessimism, past failure, loss of pleasure, guilt and punishment feelings, self dislike and criticalness, suicidal thoughts, crying, agitation, loss of interest, indecisiveness, worthlessness, loss of energy, sleeping patterns, irritability, changes in appetite, concentration difficulty, fatigue and loss of interest in sex. Participants were asked to endorse the most characteristic statements covering the timeframe of the past two weeks, including the day of completion. There were four statements for each item, representing an increase in symptom severity. Each item was scored on a 4-point scale ranging from 0 to 3, giving a maximum total score of 63.

Psychometric properties: Cutoff scores have been derived for the BDI-II (Beck et al., 1996b). Scores from 0 - 13 denote the minimal depression range, 14 - 19 mild depression, 20 - 28 moderate depression, and scores above 29 are considered indicative of severe depression.

The psychometric properties of the BDI-II were investigated by Beck et al. (1996a) using samples from four different psychiatric outpatient clinics and a college-student group, a total sample of 500 ranging in age from 13 to 86 years. The coefficient alpha for outpatients was .92, and for the 120 college students, .93. The test-retest correlation was *r* = .93 in a sub-sample of 26 outpatients with a one-week inter-test interval.

The BDI-II has good content validity because the items are designed to assess the DSM-IV criteria for depression. The generation of item-option curves showed how well the four statements in each item differentiate from one another, and how well each set of options measure the underlying dimension of self-reported depression. All 21 items demonstrated increasing monotonic relationships with overall self-reported depression, and 17 of the 21 items reflected appropriate ordinal rankings for discriminating those with more depression from those with less (Beck et al., 1996b).

Farmer (1999) reports that the validity of the BDI-II has been evaluated with a range of outpatient subsamples. When the BDI-IA and the BDI-II have been administered on the same occasion, the average correlation has been high (*r* = .93). Convergent validity has been assessed by correlating scores on the BDI-II with scores on the Beck Hopelessness Scale and the Revised Hamilton Psychiatric Rating Scale for Depression, showing reasonably high correlations between these measures (*r* = .68, *r* = .71, respectively). Correlation tests between scores on the BDI-II and the Revised Hamilton Anxiety Rating Scale have been carried out, and a moderate correlation has been cited as evidence of reasonable discriminant validity (*r* = .47). The BDI-II has been shown to discriminate patients with mood disorders from those with anxiety, adjustment, or other disorders.

SF-36 Health Survey

Rationale: The Medical Outcomes Study Short Form 36 Health Survey (SF-36) (Ware & Sherbourne, 1992) is a generic, structured self-report health inventory assessing general health concepts relevant to functional status and well-being (see Appendix F). The survey has been constructed for self-administration by individuals 14 years and over and is in common use for clinical practice, research, health policy evaluations and general population surveys (Jenkinson, Coulter, & Wright, 1993). The SF-36 was used as a resource- and time-efficient method of obtaining an assessment on a wide spectrum of information on physical and mental health. As it is widely used in New Zealand, it provides a basis for comparison with other studies.

Administration and Scoring: The instrument consisted of 36 items, grouped into 8 scales, each measuring a different aspect of health: physical functioning, role physical (the impact of physical health on performance of everyday role), bodily pain, general health, vitality, social functioning, role emotional (the impact of emotional health on role performance, and mental health. Participants were required to circle the appropriate response throughout the printed survey. Responses to each of the SF-36 items were scored and summed according to a standardised scoring protocol (Ware, Kosinski, & Gandek, 2000). This was expressed as a score on a 0 - 100 scale for each of the eight health scales, with higher scores representing better self-perceived health (The New Zealand Ministry of Health, 1999). Two overall scores were calculated, a physical function score (PF) and a mental health score (MH). This allowed for comparisons both within and between age groups.

Psychometric properties: By the year 2000, the SF-36 had been documented in some 4,000 publications (Turner-Bowker, Bartley, & Ware, 2002). The reported reliability coefficients in the subtests for USA population studies conducted since the late 1980s are generally above 0.70 for most sample groups (Garratt, Ruta, Abdalla, Buckingham, & Russell, 1993; Jenkinson et al., 1993).

The New Zealand Ministry of Health (1999) ‘Taking the Pulse’ survey includes a comprehensive psychometric analysis of the reliability and construct validity of the SF-36 in the New Zealand population. Internal consistency reliability (Cronbach’s alpha) were as follows: physical function 0.93, role physical 0.91, bodily pain 0.91, general health 0.82, vitality 0.82, social functioning 0.78, role emotional 0.83, and mental health 0.80 (New Zealand Ministry of Health, 1999). The internal consistency reliability responses suggest that participants in New Zealand are able to understand the questions and give consistent responses to the related items (Scott, Tobias, Sarfati, & Haslett, 1999).

In an examination of findings from the Taking the Pulse survey, Scott et al. (1999) found confirmation for the existence of two components, or factors, ‘physical health’ and ‘mental health’. The two-factor orthogonal solution explained 67% of the variance.

Examination of the factor loadings, the correlations between scales and components, provided evidence of similarity to those found in United States of America and Western European samples. In this investigation, the construct validity of the SF-36 (the extent to which it measures what it claims to measure) was also assessed in terms of item discriminant validity, described by Scott et al. as the scaling success rate which was found to be 100% for all scales, confirming the appropriateness of the item groupings for the hypothesized health concepts measured.

In the New Zealand sample (n = 7,445), age group profiles showed decreasing self-reported health with advancing age (Scott et al., 1996). The most pronounced declines were for the physical health-related scales. For the mental health scale, males demonstrated higher scores with increasing age, whilst female scores increased across the first three age groups (15 - 24, 25 - 44, 45 - 64 years), although the mean scores for the older age groups (65 - 74, 75+ years) did not differ significantly from each other.[3]

National Adult Reading Test – Second Edition (NART)

Rationale: The NART (Nelson, 1991) was used to provide a brief measure which could be converted to a WAIS-R intelligence score (Nelson & Willison, 1991). The NART is a measure of the ability to pronounce 50 irregular words (see Appendix G) each of which can be read correctly only if the participant both knows the word and recognises its written form (Nelson & O'Connell, 1978).

As IQ is correlated with almost all cognitive measures, meaningful comparison of memory changes in the groups in the present study required partialing out the effects of IQ. The validity of using NART rests upon the assumption that ability in reading irregular words is relatively independent of brain deficits and that it is a strong predictor of intelligence in the normal population (Bright, Jaldow, & Kopelman, 2002). Evidence from prior studies suggests that word-reading ability is preserved in people who have mild cognitive impairment (Christensen, Hadzi-Pavovic, & Jacomb, 1991; Ryan & Paolo, 1992). Thus the NART serves both as a useful predictor of premorbid intelligence and a useful measure of current intelligence.

[3] It was decided to use just the physical health (PF) and mental health (MH) scales of the SF-36, following a personal communication (2004) with one of the authors of the New Zealand Taking the Pulse Survey. M. Tobias suggested the PF and MH scales performed well as 'summary' measures.

Administration and scoring: The 50 irregular words utilised in the NART were presented, one at a time, as 2 cm high words on the computer screen. When the participant had attempted each word, the researcher presented the next word. The number of errors made was then compared to the table in the test manual in order to convert the NART errors to a WAIS-IQ score.

Psychometric properties: Nelson & O'Connell (1978) standardised the NART utilising 120 participants aged from 20 - 70 years, using the obtained data to form regression equations that can be used to predict WAIS Performance, Verbal, and Full-Scale IQ from NART errors. Ryan and Paolo (1992) built new regression equations to allow for the prediction of WAIS-R IQ scores.

Of particular interest for the current study, for an elderly (75 years and older) population, correlations between NART errors and the WAIS-R Verbal Scale and Full Scale IQ scores were -.78 and -.74, respectively, on the developmental sample, and -.83 and -.74, respectively, on a cross-validation sample. Thus Ryan and Paolo (1992) concluded that the "NART error score can provide a reliable estimate of a literate person's intellectual level as measured by the WAIS-R" (p. 58). Furthermore, in a study comparing NART and demographic variables and predictors of WAIS IQ scores, Bright et al., (2002) found that the NART produces a mean FSIQ (Full scale IQ) that is within a single point of actual mean WAIS and WAIS-R FSIQ in healthy controls.
Nelson's (1982) evidence of a high split-half reliability (0.93) was confirmed and high levels of inter-rater (0.96 - 0.98) and test-retest (0.98) reliabilities have been reported (O'Carroll, 1987; Schlosser and Ivison, 1989), even with naïve raters, indicating the NART can be used by inexperienced as well as experienced clinicians.

Memory Tasks

Verbal Recall

Rationale: The majority of studies of memory and aging have utilised word list recall as an assessment of free recall. The present study used the assessment to measure whether the rate of decline observed in prior studies with advancing age holds true for the oldest-old.

The recall of a list of 25 words (see Appendix H) was tested immediately after study, after a 10-minute delay, and again following a 1-week delay. The verbal stimuli used were a mix of 25 nouns of 3 - 6 letters (M = 4.48, SD = .77) derived from a pool of words generated by Lesch and Pollatsek (1993) and Kucera and Francis (1982). All stimuli ranged, in frequency of use in the English language, from 1 time per million words to 201 times per million words.

Administration and scoring: The words were presented, one at a time, in 2 cm high letters in the centre of a computer screen. Presentation rate was set at 3 seconds exposure of each word with no inter-stimulus interval. Immediately after the presentation of the stimuli at study, participants wrote as many as they could remember, in any order. No time limit was set for this task. The paper used for this task was then removed from sight. After 10 minutes, during which participants completed two nonverbal tasks, participants were again asked to write down as many words as they could remember. Participants were not informed the delayed task would occur. One week later, unexpected by the participants, the researcher visited participants and again requested the participant write as many words as possible. The raw score was the number of correctly remembered words at each assessment.

Nonverbal Recall

Rationale: The majority of aging studies have assessed free recall only by verbal tasks. The present study used the nonverbal assessment to measure whether the rate of decline observed in verbal free recall tasks with advancing age holds true for nonverbal free recall, particularly amongst the oldest-old.

In the current study, two criteria were considered of particular importance in the instrument to be utilised in the measure of nonverbal memory in the oldest-old. Firstly, there would be a measure of both immediate and delayed nonverbal recall. Secondly, the verbal and nonverbal measures would be as structurally parallel as possible to allow comparison across the verbal and nonverbal tasks. No existing test was found which fulfilled the requirements of this study, so a test was devised in which participants would study, and then attempt to reproduce, geometric shapes of varying complexity. A pool of geometric designs was devised and pilot tested with a group of university students and a group of older adults between 77 and 84 years of age. Fifteen designs were chosen to comprise the geometric shapes (shapes) test, ensuring there were no floor or ceiling effects within the age groups piloted (see Appendix I for the shapes used in the test, the test development, and the method of scoring). Whilst there were 25 verbal items and 15 nonverbal items, the time items needed to be remembered for immediate study remained the same as verbal stimuli appeared on the computer screen for 3 seconds and shapes for 5 seconds. Thus, the study period for both the verbal and nonverbal tasks was 75 seconds.

In order to match the verbal task as closely as possible, participants did not recall the stimuli immediately after the presentation of each design, one after the other, as in the Visual Reproduction subtest of the Wechsler Memory Scale (Wechsler, 1987) task of the WAIS, The Benton Visual Retention Test (Benton, 1974), or the Memory-for-Designs test (Graham & Kendall, 1946). Rather, all 15 shapes were presented and the participant then tried to draw as many of these shapes as possible.

Geometric designs were chosen to minimise verbal coding. Nonverbal recall tests designed for the elderly, such as the Kendrick Object Learning Task (Kendrick, 1985), use pictures of common objects as stimuli. However, common objects and easily verbally-coded material may mask age decrements in visual nonverbal memory (Riege & Inman, 1981).

Administration and scoring: The shapes were presented, one at a time, in the centre of a computer screen. The shapes, 10 cm in height, were presented as black shapes on a white background. Presentation rate was set at 5 seconds exposure of each shape. Immediately after the presentation of the stimuli at study, participants drew as many as they could remember, in any order. No time limit was set for this task. The paper used for this task was then removed from sight. After 10 minutes, during which participants completed two verbal tasks, participants were again asked to draw as many shapes as they could remember. One week later, again unexpected by the participants, the researcher visited participants and requested the participant again draw as many as possible. Each shape was scored from 0 - 4 according to a scoring schedule, with 0 reflecting a shape not remembered or totally unrecognisable, and 4 reflecting all elements present (see Appendix I for scoring criteria).

Psychometric properties: In an inter-rater scoring comparison across three age groups, inter-rater reliability was 0.95 over 135 shapes (see Appendix I). Nettelbeck and Rabbitt (1992) note that reliability of laboratory tasks have typically been assessed only in terms of internal consistency, rather than stability as indicated by test-retest correlations. To rectify this, the shapes test was subject to test-retest analysis with an inter-test interval of two weeks. For a group of 23 university students (*M* = 23.1, *SD* =

6.39), the test-retest correlation was .91. For a group of 25 older people (*M* = 79.5, *SD* = 2.48), the test-retest correlation was .89. Thus, overall, the test-retest correlation stood at an acceptable .90.

Delay in verbal and nonverbal recall

Two delay periods were used in both the verbal and nonverbal free recall tasks. The delayed recall of the nonverbal stimuli was matched with that of the verbal task. For both tasks participants were required to recall as many of the items as possible immediately after the study period, then again after 10 minutes of unrelated tasks, and again after seven days.

For verbal recall, delay periods have been used in prior studies. For example, Colsher and Wallace (1991), examining episodic memory changes, found their oldest group (75+) experienced greater decline than young-old participants (65 - 74 years) in immediate recall, although the age-related decline was invariant across age in delayed recall and recognition. Hassing et al. (2002) found a significant decline in delayed verbal recall in a group of adults in their 90s. Following the presentation of 12 concrete nouns participants were tested on immediate recall, and then again after a 20 minute delay. Word recall furnished scores of *M* = 4.91 (*SD* = 1.76) for immediate recall, and *M* = 1.73 (*SD* = 1.88) for delayed recall (possible score = 10).

In a prior investigation using familiar line drawings, Nielsen-Bohlman and Knight (1995) found recall immediately after initial study was at ceiling for both young and adults, but performance was poorer for older adults following a delay period. Additionally, Daniel and Ellis (1972) demonstrated that the inclusion of a delay period tends to reduce the tendency toward the verbal labeling of nonverbal items.

The inclusion of both short (10 minutes) and long (7 days) delays in verbal and nonverbal free recall was designed to obtain a picture of the extent of any decrements across delay periods, and whether this varies as a function of age, and to try to separate memory problems due to encoding or retrieval. If groups did not differ much at immediate recall, then reasonable encoding by the oldest-old could be assumed. If, after a delay, the gap widened, then this must be due to retrieval problems.

Forward Digit Span

Rationale: The Forward Digit Span (Wechsler, 1997a) task is a classic measure of short-term storage capacity which is used in a high percentage of cognition and aging studies (e.g., Blum & Jarvick, 1974; Bosworth & Siegler, 2002; Christensen et al., 1991; Giambra et al., 1995; Orsini et al., 1986; Salthouse & Babcock, 1991). It was used for this reason in the present study, enabling direct comparisons with the previous literature (see Appendix J).

Administration and scoring: In accordance with the standardised instructions provided by WAIS-III Manual (Wechsler, 1997a) the administrator read the digits at the rate of one per second, dropping the voice slightly on the last digit of each sequence. Two trials of each sequence length were given, from Item 1 consisting of a 2-digit sequence, to Item 8 consisting of a 9-digit sequence. The measure was discontinued when a score of 0 on *both* trials occurred on any item. Each item was scored 2 points if the participant passed both trials, 1 point if the participant passed only one trial, and 0 points if both trials were failed. The maximum score possible was 16.

Psychometric properties: The digit span was standardised using the Wechsler Adult Intelligence Scale-III (Wechsler, 1997b). The sample consists of 2,450 people, with 13 appropriate age-bands with 200 persons per group except for the 80 - 84 years group which comprised 150 participants, and the 85 - 89 years group with 100 participants. Reliability coefficients, derived from a single administration split-half testing, for the digit span task range from .90 to .93 for adults from 20 to 79 years of age. The reliability coefficient for adults from 85 to 89 years of age is reported at .84 (Wechsler, 1997b). Test-retest reliability, based on 2- to 12-week spans (M = 34.6 days) is .70 for 16 - 29 year olds, .80 for 55 - 74 year olds, and .75 for adults 75 - 89 years of age. Inter-rater agreement is high at .95.

Letter-Number Sequencing Task

Rationale: The Letter-Number Sequencing Task, a new subtest from the WAIS-III (Wechsler, 1997a), is designed to assess working memory and attention. The development of the subtest was based on the research of Gold, Carpenter, Randolph, Goldberg, and Weinberger (1997), who developed a like task to assess working memory in individuals with schizophrenia. Participants hear a random combination of letters and digits and then reorganise the numbers first in ascending order followed by the letters in alphabetical order (see Appendix K).

Letter-number sequencing is a quickly and easily administered measure of working memory capacity. Administering the digit span which provides a measure of short-term storage and letter-number sequencing within the same test battery allows for a measure of how much of the age-related decline in short-term memory is attributable to working memory as opposed to storage capacity.

Administration and scoring: In accordance with the standardised instructions provided by WAIS-III Manual (Wechsler, 1997a) the administrator read the digits and letters at the rate of one per second, dropping the voice slightly on the last digit or letter of each sequence. Using the standardised item instructions, the five practice items supplied in the WAIS-III Manual were given. Where the participant made an error on any practice item, they were corrected and the instructions were repeated.

There were three trials in each of 7 items. The assessment was terminated when a participant had failed on all three trials of a given item. Each trial was scored as 1 point for a correct response, giving an item score of 3, 2, 1, or 0 depending on the number of correct trial responses. The maximum score possible was 21 points.

Psychometric properties: The letter-number sequencing was standardised using the Wechsler Memory Scale-III (Wechsler, 1997b) which also uses the letter-number sequencing subscale. The sample consists of 1,250 people, with appropriate age-bands with 100 persons per group except for the 80 - 84 years and 85 - 89 years groups which contained 75 people per group.

Reliability coefficients, derived from single administration split-half testing, range from .77 to .86 for adults from 20 - 69 years of age, and .87 for adults 85 - 89 years of age (Wechsler, 1997b). Test-retest reliability, based on 2- to 12-week time spans (M = 35.6 days) is .70 for 16 - 29 year olds, .80 for 55 - 74 year olds, and .75 for adults 75 - 89 years of age. Inter-rater agreement is high at .95.

Face Recognition

Rationale: The perception and recognition of faces demonstrates the extraordinary sensitivity and power of the human visual memory system. The face mediates a wider variety of cognitive and social activities than any other visual object. Face recognition paradigms have been utilised in research through the life span, and a considerable body of literature has accumulated. However, less is known about how face recognition declines (if at all) in the later years of life, a focus of the present study.

Stimulus and Administration: The task was a 2-alternative forced-choice recognition memory task using photographs of young or older men. Photographs of target faces were presented sequentially one at a time during the study phase. Each stimulus face was centred on the computer screen as a colour image measuring 12 x 15 centimetres. Each stimulus was presented for 5 seconds with an inter-stimulus interval of 3 seconds during which the screen was blank. For the recognition phase each target face was paired randomly with a distractor and presented with the target and the distractor side by side on the computer screen. Target faces appeared at random, but equally often, to the right or left of the screen. In all, participants had eight seconds in which to make a response from the time each target/distractor pair appeared on the screen. The participant then indicated whether the previously seen target was on the right or left of the screen. Because of the advanced age of many participants, the right and left sides of the computer screen were clearly labeled.

Eighty stimulus photographs were used. These were of male university students (n = 40) and older males (n = 40) between 63 and 97 years of age (M = 78, SD = 7.48). The photographs of the young men were part of a set held by Massey University School of Psychology for research purposes. They were of male, second-year psychology students aged approximately 20 years. The older men, who volunteered to have their photographs taken for the purposes of research, were recruited from the Papanui Returned Servicemen's Association and the Christchurch branch of the Italy Star Association. (A sample stimulus can be seen in Appendix L)

Photographs of male faces were used to eliminate confounding by a sex of participant by sex of face interaction.) Shepherd (1981) reports that the same-sex bias in recognition is often found with female, but not male, participants. Vokey and Read (1988) concur, stating that females show greater facility in recognising women's faces, than do males.

Any potential memory cues, apart from the faces themselves, were controlled by the photographs being taken with the model standing in front of a white screen and ensuring no model had facial hair, spectacles, jewellery, or unusual features. Clothing was obscured by a dark cape draped around the neck and shoulders. All photographs were taken full-face, with the model assuming a neutral expression and looking straight into the camera.

The number of correct responses for young and old stimuli were combined to give an overall possible score of 40.

Prospective Memory Tasks

Rationale: Anecdotal complaints of forgetting planned future events, from appointments to switching off the oven, are common amongst elderly people. Prospective memory tasks were included in the current study to assess how this aspect of memory may decline, particularly in the oldest-old. In the light of prior studies, it was considered the simple tests included in the current battery provided an effective measure of prospective memory for questions and objects. Prospective memory tasks require examinees to carry out a planned action at some point in the future. Tasks can be event-based or time-based (Einstein & McDaniel, 1990). Two event-based prospective memory tasks were used in the present study. The tasks were adapted from Huppert and Beardsall (1993) by Whittington (1999).

Administration and scoring: The measures of prospective memory were prospective memory for a question (PMQ) and prospective memory for an object (PMO). Both were event-based tasks. PMQ involved a short time period (20 minutes), whilst the second involved a longer time period (approximately 75 minutes).

The PMQ involved remembering to ask two questions when a bell sounded. At Time 1 testing, participants were told a bell would sound in 20 minutes, when participants were required to ask the experimenter two questions concerning their next testing session. The two questions were, “When will the next session be?” and “What will the procedure involve?” At Time 2 testing, the same procedure was used except the two questions were: “When will a summary of the results be sent to me?” and “What will the summary include?” If the participant failed to spontaneously ask the questions within 15 seconds, they were prompted with the question, “What were you supposed to do when the bell rang?” Participants were scored one point for each question recalled and an additional point for each response that was made without a prompt. Thus, the maximum score for PMQ was 4.

The PMO required examinees to ask for an object when the testing session concluded. Early in the test session, participants were asked for a small personal belonging. It was explained that the task was to remember to ask for it back when the session ended, and to remember where the object was put during the session. During the remainder of the session the object was stored behind the computer. Participants were assured that their belonging would be returned even if they did not remember to ask for it back. At the end of the testing session, it was made clear the session was finished and the equipment was being packed away. If the participant did not spontaneously ask for the object during this process, they were prompted with, "Was there something you were going to ask for now that we have finished?" Participants were scored one point for remembering to ask for the object, and another point if they recalled the location of the object. Additional points were given for each response made without a prompt. Thus, the maximum score for PMO was 4.

The PMQ and PMO scores were summed to give a possible prospective memory score of 8.

Processing Speed Measures

Two tests from the Perceptual Speed factor from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, & Dermen, 1976) were utilised in the current study to assess processing speed: The Identical Pictures task (IDP), and the Finding A's task (FA). Ekstrom et al. developed a set of 72 marker tests for 23 cognitive factors. In an effort to represent the research of many factor analysts, the kit was developed following a conference of researchers of people interested in multiple factor analysis. The tests are cited as suitable for adolescents and adults.

Processing speed is known to demonstrate a substantial average linear age decrement from 25 - 81 years (Schaie, 1989), although less is known of the rate decline in the very oldest ages. Schaie, Willis, Hertzog, and Schulenberg (1987) report that the two markers (IDP and FA) may reflect slightly different aspects of the speed construct, but factor-analytic investigation has suggested the two tests are highly salient markers of the primary factor of speed, and remain so across the entire range of 20 - 81 years. They do not load onto any other ability factors, whilst showing substantial communality with each other.

Identical Pictures Test

Rationale: The Identical Pictures test from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, et al., 1976) was administered as a measure of nonverbal processing speed. The IDP task has been used in prior aging research, thus providing a comparison for scores obtained in the current study. The task is straightforward and provides an accurate comparison of nonverbal processing speed attained across the age groups under study.

Administration and scoring: In the IDP task, the participant is required to mark which one of five geometrical figures or pictures in a row is identical to the given figure at the left end of the row. Each of two parts consists of 48 rows, with a time limit of 1.5 minutes to complete as many rows as possible. The task is presented as a booklet with instructions and practice items on the front page. The participant read the instructions, clarification was given orally when questions pertaining to completion of the task arose, and the practice items were completed. The participant was then given 1.5 minutes to complete as many of Part I of the test as accurately and quickly as possible. A 1-minute break was given and then Part II was completed in the same manner. Scoring consists of the number of items correctly completed over 3 minutes.

Prior use in aging research: Schaie (1989), reporting on data from the Seattle Longitudinal Study (SLS) for the age range 22 - 91 years, found the age progression to be virtually linear for the IDP task, with the oldest-old group (85 - 91 years) approximately 2 *SD*s below the youngest group (22 - 28 years). Cross-sectionally, in the 1977 wave of testing the first significant decline was observed by the age of 46, whereas for the 1984 sample there was a significant decline in performance between the ages of 25 and 32, but further significant negative differences occurred only after age 53. In the 1984 wave of testing the youngest group scored an average of 56.22 (SD = 4.38), whereas the oldest group averaged 37.84 (SD = 6.39) in a 3-minute period. Overall, the correlation between Time 1 and Time 2 testing, showing magnitude of change over 7 years was quite small (r = .11), Schaie points out that at least half the sample did not show such decline on IDP, and only the oldest group showed relatively large declines. Schaie suggests that individuals do not decline in a linear fashion, but are more likely to do so in a stepwise manner, quite possibly in response to changes in the underlying physiological resources.

Psychometric properties: A test-retest correlation of .81 for IDP over a 2-week interval has been reported by Schaie, Willis, Jay, and Chipuer (1989)

Finding A's Test

Rationale: The Finding A's Test (FA) from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, et al., 1976) was administered as a measure of verbal processing speed. The FA task provides an easily and quickly administered test of verbal processing speed which has been used in prior research with elderly people.

Administration and scoring: In the FA task, the participant is required to cross out the five words containing the letter 'a' in each column of 41 words. Each of two parts consists of 820 words, with a time limit of 2 minutes per part to cross off as many words as possible

The task is presented as a booklet with instructions and practice items on the front page. The participant read the instructions, clarification was given orally when questions pertaining to completion of the task arose, and the practice items were completed. The participant was then given 2 minutes to complete as many of Part I of the test as accurately and quickly as possible. A 1-minute break was given and then Part II was completed in the same manner. Scoring consists of the number of words correctly marked over 4 minutes.

Prior use in aging research: In the SLS sample, Schaie (1989) found similar magnitudes of age differences as for the IDP. For FA, however, peak performance was shown at 32 years of age, with significant age differences occurring by the age of 46 years. In the 1984 sample, at the age of 32 participants crossed out an average of 53.74 (*SD* = 11.80) words containing the letter 'a'. By the age of 81, however, participants crossed out an average of 41.69 (*SD* = 6.13) words (Schaie, 1989). Whereas variability remained almost level across age for IDP, it decreased with age for the FA, with a correlation between Time 1 and Time 2 scores showing a change over 7 years of r = .07).

Psychometric properties: A test-retest correlation of .87 over a 2-week interval has been reported by Schaie et al. (1989) for the FA.

When all tasks had been completed, participants were thanked and debriefed. They were asked if they would like to know their results. These were interpreted in a positive light by the researcher.

Chapter Seven

RESULTS

This chapter reports the results of the present study. Firstly, the cross-sectional results from Time 1 and Time 2 testing are reported, addressing the expectation that there will marked differences in all memory types for the oldest-old. Then the role of the covariates of years of education, intelligence, processing speed (verbal and nonverbal), depression, physical functioning, and mental health are examined. Longitudinal results are then presented, comparing participants across the two years between Time 1 and Time 2 testing. Lastly, delay incorporated into the verbal and nonverbal recall memory tasks is addressed and presented as subsidiary analyses.

It was decided to include only those participants who completed both Time 1 and Time 2 testing in both the cross-sectional and longitudinal data to allow for comparison across the two sets of data. Thus, the analyses include data from 126 participants, consisting of 40 young, 44 middle, and 42 oldest-old participants.

Cross-sectional Analyses

Memory Types

It was expected that there would be a sharp, nonlinear decline in all memory types for the oldest-old compared to the pattern of decline for younger groups.

Time 1 Testing

To address the question “How do various types of memory deteriorate in the oldest-old compared to younger groups?” participants were tested on six types of memory at Time 1: verbal recall (words), nonverbal recall (shapes), short-term memory (digit span), working memory (letter-number sequencing), face recognition (faces), and prospective memory. The raw scores and standard deviations (*SD*s) from these tests may be seen in Table 7.1.

Table 7.1. *Mean raw scores (SDs) and maximum possible scores for all memory tasks at Time 1 testing as a function of age.*

	Young *n*=40		Middle *n*=44		Oldest-Old *n*=42		Maximum Possible Score
Word Recall	10.38	*(3.26)*	9.50	*(3.24)*	5.71	*(2.45)*	25
Shapes Recall	30.48	*(6.90)*	26.00	*(8.22)*	10.29	*(6.47)*	60
Digit Span	11.18	*(2.07)*	11.39	*(2.14)*	9.81	*(1.94)*	16
Letter-Number Sequencing	12.33	*(1.94)*	11.45	*(2.40)*	6.64	*(2.17)*	21
Faces	36.15	*(2.91)*	35.80	*(2.68)*	30.83	*(4.05)*	40
Prospective Memory	7.17	*(1.11)*	6.82	*(1.17)*	4.43	*(1.82)*	8

Test scores were transformed into *z*-scores so that different memory types could be compared (Figure 7.1). For readability, however, mean raw scores will be used when reporting or discussing individual tests.

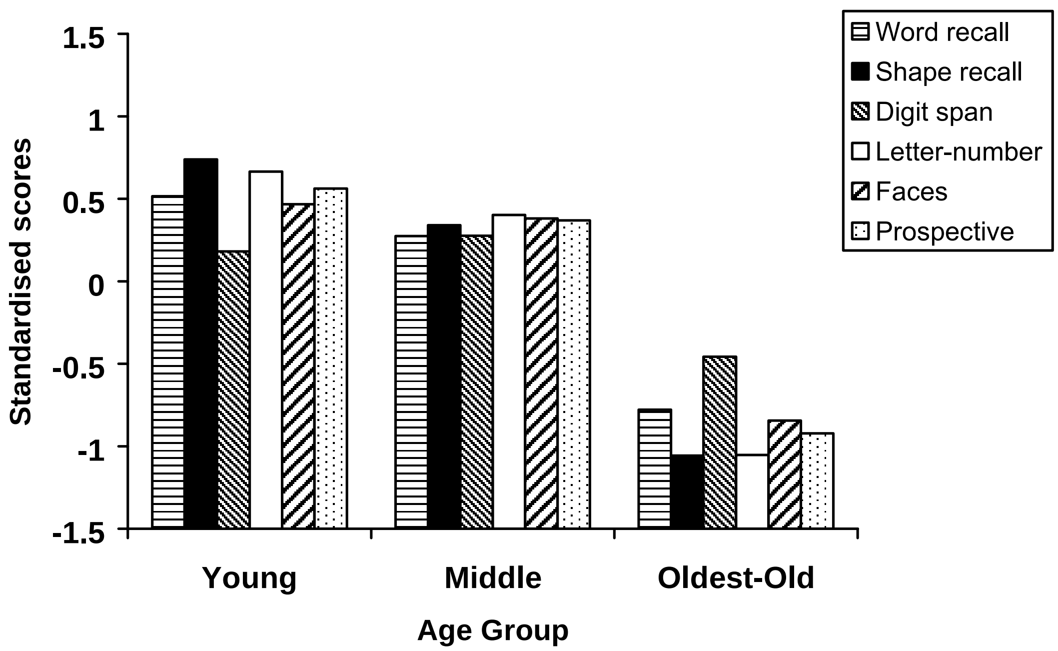

Figure 7.1. *Standardised (z) scores for all types of memory tasks for all groups at Time 1.*

A cross-test comparison indicated a sharp decline in all memory types for the oldest-old. While scores dropped only a little, if at all, comparing the middle group to the young group, the drop was very noticeable across the memory types for the oldest-old participants. The short-term memory system (measured by the digit span task) was less affected by aging than other aspects of memory. However, when the oldest-old were required to add a working memory component (measured by the letter-number sequencing task) there is a large drop-off when compared to participants in the young and middle groups. For those 85+ years, words are better recalled than are shapes, although performance for both abilities is considerably poorer than that of young and middle participants. The differences, relative to the young group, for those 50 - 70 and 85+ years (Table 7.2) indicate that face recognition is an ability retained relatively well throughout the lifespan, although the standard deviation increase as a function of age shows an increased variability after the age of 85 years. Although the mean age difference between young and middle groups is about 30 years, much the same as between middle and oldest-old groups, the decrease in performance across age in all types of memory is by no means linear. The percentage change between the groups for all memory types is presented in Table 7.2.

Table 7.2. *The percentage change in the middle and oldest-old groups relative to the young group in all memory tasks at Time 1.*

Memory task	Middle relative to young group	Oldest-old relative to young group
Word Recall	- 8.5	- 45.0
Shapes Recall	- 14.7	- 66.2
Digit Span	+ 1.9	- 12.3
Letter-Number Sequencing	- 7.1	- 46.2
Faces	- 1.0	- 14.7
Prospective Memory	- 4.9	- 38.2

Shape recall was most affected by aging, with means of 30.48 (*SD* = 6.90), 26.00 (*SD* = 8.22), and 10.29 (*SD* = 6.47) for the young, middle, and oldest-old groups, respectively. A similar pattern emerged in the letter-number sequencing (working memory) task with means of 12.33 (*SD* = 1.94), 11.45 (*SD* = 2.40), and 6.64 (*SD* = 2.17). Word recall and prospective memory produced a similar pattern with slightly smaller differences for the oldest-old. Only for digit span (short-term memory) and face recognition did the scores indicate memory types which were less affected by aging. Overall, in Time 1 testing there were clear differences between the middle and oldest-old groups, although the young and middle groups attained relatively similar results to each other.

One-way between-groups analyses of variance (ANOVA) were conducted to explore the impact of age on each of the six memory types (see Appendix M). The assumptions required for ANOVA were met, with the exception of the homogeneity of variance (utilising the Levene test of homogeneity of variance) assumption in the face recognition (Levene p = .001) and prospective memory (Levene p = .003) - types of memory ability where variance is greater for those 85+ years (Table 7.1). Stevens (2002) states that ANOVA is robust to violations of this assumption providing the groups are of reasonably similar size, as is the case in the present study. Dunnett's C test was used to compare means, as this allows for unequal variance across groups (Tabachnick & Fidell, 2001). At Time 1 testing, all F tests showed a statistically significant effect of age (all F tests, p < .001). Follow-up Dunnett's C tests revealed that there were significant differences between groups 1 and 3 (young and oldest-old) and groups 2 and 3 (middle and oldest-old), but none between groups 1 and 2, with the exception of the shapes task. These results are summarised in Table 7.3.

Table 7.3. *The mean difference for all memory tasks for young (= 1), middle (= 2), and oldest-old (= 3) participants at Time 1 testing.*

Task	Groups	Mean Difference	
Words	1 - 2	.88	
	2 - 3	3.79	*
	1 - 3	4.66	*
Shapes	1 - 2	4.48	*
	2 - 3	15.71	*
	1 - 3	20.19	*
Digit Span	1 - 2	-.21	
	2 - 3	1.58	*
	1 - 3	1.37	*
Letter-Number	1 - 2	.87	
Sequencing	2 - 3	4.81	*
	1 - 3	5.68	*
Faces	1 - 2	.36	
	2 - 3	4.96	*
	1 - 3	5.31	*
Prospective	1 - 2	.36	
	2 - 3	2.39	*
	1 - 3	2.75	*

* Significant difference at the 0.05 level or better

There were no significant differences between the young and middle groups, with the exception of the shapes recall test where the young group outperformed the middle group ($p < .05$). The differences between the young and oldest-old and the middle and oldest-old groups for shapes recall were both significant ($p < .001$).

Time 2 Testing

Two years elapsed between Time 1 and Time 2 testing. At Time 2 testing, participants completed the same memory tasks as at Time 1. Comparisons between Time 1 and Time 2 testing appear in the longitudinal analysis. For the mean raw scores on all memory types at Time 2, see Table 7.4.

Table 7.4. *Mean raw scores (SDs) and maximum possible scores for all memory tasks at Time 2 testing as a function of age.*

	Young *n*=40		**Middle** *n*=44		**Oldest-old** *n*=42		**Maximum Possible Score**
Word Recall	10.15	*(4.39)*	10.14	*(3.47)*	4.60	*(2.41)*	25
Shapes Recall	33.33	*(8.28)*	29.57	*(11.02)*	9.24	*(7.35)*	60
Digit Span	11.12	*(2.29)*	11.73	*(2.19)*	9.02	*(2.19)*	16
Letter-Number Sequencing	12.27	*(2.00)*	11.43	*(1.78)*	5.48	*(2.58)*	21
Faces	36.70	*(2.86)*	36.75	*(2.55)*	29.43	*(4.58)*	40
Prospective Memory	7.25	*(.84)*	6.66	*(1.60)*	2.67	*(1.90)*	8

The *z*-scores for all memory tests across the three age groups showed a pattern of relatively similar performance for the young and middle groups, with a steep drop-off in memory performance for the oldest-old irrespective of memory type (Figure 7.2).

As for Time 1, nonverbal recall (shapes) was most affected by aging, with means (and *SD*s in parentheses) of 33.33 (4.39), 29.57 (11.02), and 9.24 (7.35) for young, middle, and oldest-old groups, respectively. The mean scores for prospective memory were markedly lower for the oldest-old participants, being 2.67 (1.90) compared with the young, 7.25 (.84), and middle, 6.66 (1.60), participants.

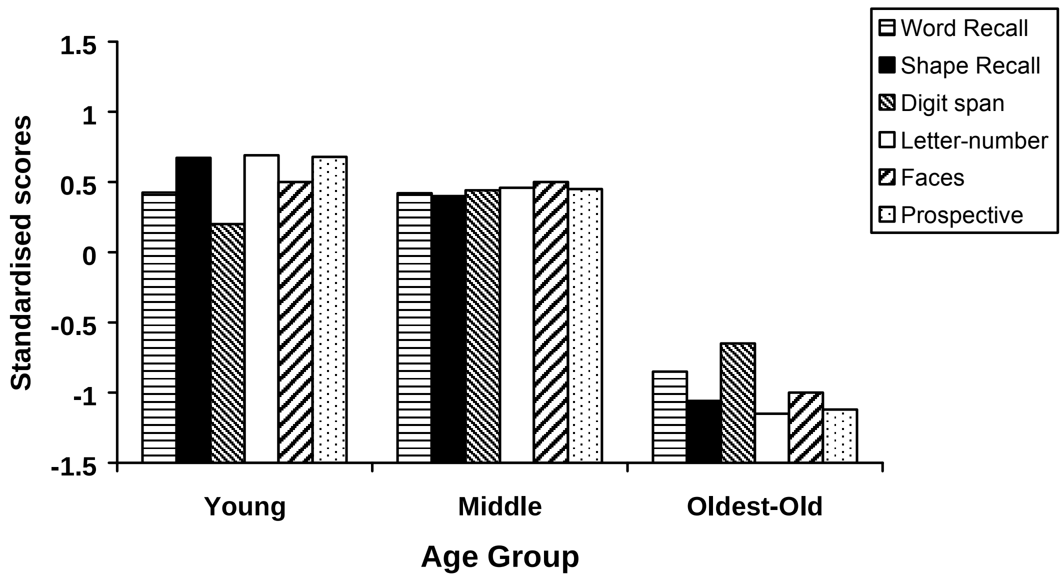

Figure 7.2. *Standardised (z) scores for the six memory tasks for all groups at Time 2.*

For the percentage difference for the middle and oldest-old groups, compared to the young group, see Table 7.5. It is notable that all percentage declines for the oldest-old are greater at Time 2 compared to Time 1 testing (see Table 7.2).

Table 7.5. *The percentage change in the middle and oldest-old groups relative to the young group in all memory tasks at Time 2.*

Memory type	Middle relative to young group	Oldest-old relative to young group
Word Recall	- 0.1	- 54.7
Shapes Recall	- 11.3	- 72.3
Digit Span	+ 5.5	- 18.9
Letter-Number sequencing	- 6.9	- 55.3
Faces	+ 0.1	- 19.8
Prospective Memory	- 8.1	- 63.2

ANOVAs were performed for each memory task to ascertain if there were statistically significant differences between the three age groups (see Appendix N). All *F* tests for the six memory types showed a statistically significant effect of age (all *F*s, $p < .001$). Dunnett's C tests showed that there were significant differences between groups 1 and

3 (young and oldest-old), and between groups 2 and 3 (middle and oldest-old), but none between groups 1 and 2 (see Table 7.6).

Table 7.6. *The mean difference for all memory tasks for young (= 1), middle (= 2), and oldest-old (= 3) participants at Time 2 testing.*

Task	Groups	Mean Difference	
Words	1 - 2	.01	
	2 - 3	5.54	*
	1 - 3	5.56	*
Shapes	1 - 2	3.76	
	2 - 3	20.33	*
	1 - 3	24.09	*
Digit Span	1 - 2	-.60	
	2 - 3	2.70	*
	1 - 3	2.10	*
Letter-Number Sequencing	1 - 2	.84	
	2 - 3	5.96	*
	1 - 3	6.80	*
Faces	1 - 2	-.05	
	2 - 3	7.32	*
	1 - 3	7.27	*
Prospective	1 - 2	.59	
	2 - 3	3.99	*
	1 - 3	4.58	*

* Significant difference at the 0.05 level or better

Overall, at Time 2 testing there were clear differences in all memory types among the middle and oldest-old age groups, with the difference being particularly marked for nonverbal recall, prospective memory, working memory, and verbal recall. Relatively little difference was observed between the young and middle groups. These results are similar to Time 1 except that the oldest-old group showed some further change in memory between Time 1 and Time 2, whereas no such change occurred in the other two groups.

In summary, all types of memory are affected by the aging process, some more than others. It can be seen in the graphs and analyses that the oldest-old were markedly more affected, compared to the young and middle groups. The decline across age is clearly not linear, but drops off sharply for the oldest participants.

Covariates at Time 1 and Time 2

It was expected that the rate of decline in memory would be moderated by covariates such as intelligence, physical health, mental health, depression, processing speed, and years of education.

Time 1 Testing

An examination of potential covariate intercorrelations was carried out to ensure the covariates were measuring different things. An examination of the intercorrelations (see Table 7.7) shows that the highest was *r* = .59. Therefore, at this stage, all were retained as none reached *r* = .8. Tabachnick and Fidell (2001) suggest an *r* of .8 or more means that the covariates involved do not both need to be included, as the two covariates overlap sufficiently to render one superfluous.

Table 7.7. *Pearson correlations between the potential covariates collapsed across age, at Time 1 testing (n = 126).*

Covariate	Years Ed	NART	IDP	FA	BDI-II	Phys Funct	Mental Health
Years Ed	1	.51	.39	.34	-.17	.38	-.21
NART		1	.09	.22	-.14	.10	-.01
IDP			1	.49	-.03	.59	-.24
FA				1	-.02	.39	-.05
BDI-II					1	-.21	-.33
Phys.Funct						1	-.13
Mental Hlth							1

Note: Table 7.7: Years Ed = years of education; NART = National Adult Reading Test (measure of intelligence; IDP = Identical Pictures (measure of nonverbal processing speed); FA = Finding A's (measure of verbal processing speed); BDI-II = Beck Depression Inventory – Second Edition; Phys Funct = Physical Function scale of the SF-36 Health qQuestionnaire; Mental Health = Mental Health scale of the SF-36 Health Questionnaire.

Subsequently, an examination of the correlations between each potential covariate andeach type of memory was carried out, collapsed over age (Table 7.8).

Table 7.8. *Pearson correlations between all potential covariates and all memory tasks collapsed across age at Time 1 testing (n = 126).*

Covariate	Words	Shapes	Digit Span	Letter-Number	Faces	Prospective
Years Ed	.30	.37	.28	.28	.28	.22
NART	.28	.19	.32	.22	.20	.11
IDP	.48	.75	.30	.66	.57	.62
FA	.45	.45	.35	.50	.47	.37
BDI-II	.10	-.13	-.08	.01	.01	.07
Phys.Funct	.40	.52	.26	.58	.37	.44
Mental Hlth	-.19	-.17	.00	-.15	-.18	-.14

The BDI-II (measure of depression) and the mental health measure had average correlations with memory scores across the age groups of $r = 0.06$ and $r = -.13$, respectively, and were thus dropped from contention as covariates, as they contributed little. Across all groups, the remaining potential covariates, Identical Pictures (IDP) (nonverbal processing speed), Finding A's (FA) (verbal processing speed), physical functioning, years of education, and intelligence (measured by the NART) showed r values of 0.56, 0.43, 0.43, 0.29, and 0.24, respectively, when collapsed over all memory types.

Analysis of covariance (ANCOVA), an extension of ANOVA, was used to explore the differences between groups while statistically controlling for the variables expected to exert an influence on the various types of memory scores. By removing the influence of such variables, ANCOVA can increase the power or sensitivity of the F test by reducing the size of the error term (Tabachnick & Fidell, 2001). All the assumptions for ANCOVA were met for Time 1 testing: i.e., absence of outliers, covariates were not highly correlated with each other, normal distribution of sampling means, linearity, homogeneity of regression, and reliability of the covariates (Tabachnick & Fidell, 2001).

After running preliminary ANCOVAs, it was decided to drop physical function as a covariate. Although quite highly correlated with memory types (see Table 7.8), this was misleading as it did not reach statistical significance in any ANCOVA. Years of education was also dropped as it reached statistical significance only for the measure of working memory and the letter-number sequencing task. Therefore, intelligence (NART), nonverbal processing speed (IDP), and verbal processing speed (FA) were the analysed covariates. A summary of the ANCOVA analyses for all memory types, and age, at Time 1 is presented in Table 7.9. Appendix P contains the full ANCOVA tables.

Table 7.9. *F test, significance, partial eta squared (η^2_p), and power statistics for the covariates of intelligence, nonverbal processing speed (IDP), verbal processing speed (FA), and age for all memory types at Time 1.*

Covariate		Words	Shapes	Digit Span	Letter-Number	Faces	Prospective
NART	*F*	10.07	5.24	9.08	6.57	2.05	.45
	Sig	.002	.02	.003	.01	.16	.50
	η^2_p	.08	.04	.07	.05	.02	.01
	Power	.88	.62	.85	.72	.30	.10
IDP	*F*	.59	9.58	.18	.34	2.80	4.94
	Sig	.44	.002	.67	.56	.10	.03
	η^2_p	.01	.07	.002	.003	.02	.04
	Power	.12	.87	.07	.09	.38	.60
FA	*F*	4.78	.07	2.29	2.61	3.04	.01
	Sig	.03	.79	.13	.11	.08	.94
	η^2_p	.04	.01	.02	.02	.03	.00
	Power	.58	.06	.32	.36	.41	.05
Age Group	*F*	8.82	12.72	.75	19.54	4.38	7.97
	Sig	<.001	<.001	.47	<.001	.02	.001
	η^2_p	.13	.18	.01	.25	.07	.12
	Power	.97	≈1.00	.18	≈1.00	.75	.95

The greatest influence exerted by the covariates is that of intelligence (NART) on word recall (η^2_p = .08), and on short-term memory (digit span) (η^2_p = .07). The nonverbal processing speed covariate (IDP) also reached η^2_p = .07. Although the analysed covariates had an overall small effect, age is still the major factor in changing scores across the age groups, as Table 7.9 shows.

The mean scores, adjusted for intelligence, verbal processing speed, and nonverbal processing speed tasks at Time 1 are presented in Table 7.10 and can be compared with unadjusted mean scores in Table 7.4.

Table 7.10. *Adjusted mean scores (SE)[a] for all memory tasks across young, middle, and oldest-old participants at Time 1.*

Memory Task	**Young** *n*=40		**Middle** *n*=44		**Oldest-old** *n*=42		**Maximum Possible Score**
Word Recall	10.80	*(.66)*	8.92	*(.46)*	5.92	*(.68)*	25
Shapes Recall	27.16	*(1.58)*	24.88	*(1.10)*	14.63	*(1.64)*	60
Digit Span	11.09	*(.46)*	11.01	*(.32)*	10.29	*(.47)*	16
Letter-Number Sequencing	12.15	*(.49)*	11.06	*(.34)*	7.22	*(.50)*	21
Faces	35.23	*(.73)*	35.20	*(.50)*	32.34	*(.76)*	40
Prospective Memory	6.67	*(.32)*	6.72	*(.22)*	5.02	*(.33)*	8

[a] *SE* = Standard Error

The differences between adjusted and unadjusted scores are presented in Table 7.11. An increase in scores when the effects of the three covariates are removed is indicated by a plus sign (+), whereas a drop in scores with the exclusion of the covariates is shown by a minus sign (-).

Table 7.11. *The percentage change between unadjusted and adjusted scores at Time 1 for all memory tasks as a function of age.*

Memory Task	Young	Middle	Oldest-old
Word Recall	+4.0	-6.1	+3.7
Shapes Recall	-10.9	-4.3	+42.2
Digit Span	- 0.8	-3.3	+4.9
Letter-Number	-1.5	-3.4	+8.7
Faces	-2.5	-1.7	+4.9
Prospective	-7.0	-1.5	+13.3

It is clear that when the covariates of intelligence, verbal processing speed, and nonverbal processing speed are taken into account, this improves the scores for the oldest-old participants in all memory tasks. This is particularly marked for both shapes recall (42.2% improvement) and prospective memory (13.3% improvement). For the young group, only word recall scores were increased by taking the covariates into account, and this effect was slight (4.0%). All other memory task scores for the young and middle groups were slightly lower when the three covariates were accounted for.

Figure 7.3 plots the corrected (adjusted) standardised scores for each memory task as a function of the uncorrected scores, showing the effect of removing the three covariates has on the memory scores. If the covariates exerted no effect, then all the memory task scores would lie on the diagonal line. Points falling above the diagonal indicate improved scores after correction, those below lower scores after correction. All memory tests yielded improved scores for the 85+ group but generally poorer scores after correction for the other two groups. That is, it appears as if processing speed and/or intelligence are an impediment to memory in the oldest-old, with the reverse being the case (albeit to a lesser degree) for the middle-aged and young groups.

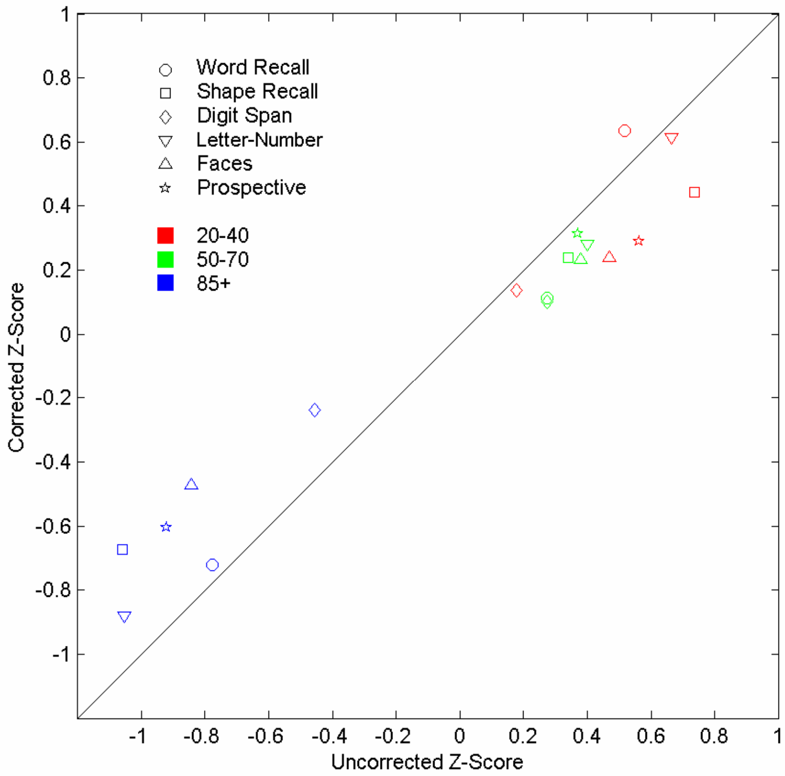

Figure 7.3. *The mean test scores at Time 1 after correcting for the covariates against uncorrected scores for all memory tasks and all age groups.*

Multiple Regression Analysis at Time 1

A multiple regression analysis was carried out to ascertain the unique variance contributed by each covariate to the memory type under study. Additionally, multiple regression analysis was used as a check of the overall pattern of results, desirable because the ANCOVA assumption of homogeneity of regression was not fully met in the face recognition (Levene p = .001) and prospective memory (Levene p = .003) types of memory - abilities where variance is greater for those 85+ years (Table 7.1). All assumptions required for standard multiple regression analysis were met.

In standard multiple regression, the adjusted R^2 reflects the variance contributed to the model by the combined covariates included. Because of the relatively small sample, the adjusted R^2 was chosen as it better reflects the true population value (Tabachnick &

Fidell, 2001). The squared semipartial correlation (sr^2_i) shows the unique variance a particular covariate contributes to the memory type under study. However, taken together, the covariates contribute overlapping variance to the model. For example, it is well understood that processing speed and age have a strong negative correlation (e.g., Hertzog, Dixon, Hultsch, & MacDonald, 2003; Salthouse 1993, 1996a, 2004). Thus, the difference between the combined sr^2_i and the adjusted R^2 for a particular memory type constitutes the variance containing the overlapping effects of the covariates. A summary of the adjusted R^2, statistical significance, and the sr^2_i of the covariates to each memory type is presented in Table 7.12.

Table 7.12. *The adjusted R^2, percentage of variance accounted for by the model, significance, and unique variance accounted for by the covariates, at Time 1.*

Memory Task	**Adjusted R^2**	**Sig.**	**Unique % variance accounted for (baed on squared semipartial correlation)**			
			NART	**IDPics**	**FA**	**Age**
Word Recall	.384	<.001	5.4%	n.s	3.5%	8.2%
Shape Recall	.613	<.001	2.0%	3.0%	n.s	5.1%
Digit span	.183	<.001	6.4%	n.s	n.s	n.s
Letter-Number	.570	<.001	2.8%	n.s	2.6%	9.2%
Faces	.381	<.001	n.s	n.s	3.4%	n.s
Prospective	.402	<.001	n.s	2.4%	n.s	3.0%

It can be seen by comparing the partial eta squared (η^2_p), an estimate of the degree of association for the sample, for Time 1 (see Table 7.9) that the overall pattern of the contribution of the covariates is similar for both the ANCOVA and multiple regression analyses, as might be expected. For all six memory types, the ordering of the covariates according to size of contribution toward the memory type score under study remains the same in both analyses, giving a very similar picture overall.

In sum, the potential covariates of depression, mental health, physical function, and years of education did not greatly influence the memory test scores across the age groups at Time 1 testing. In contrast, processing speed (both verbal and nonverbal) and intelligence show a clear effect on the memory performance of the oldest-old. With the exclusion of these covariates, performance on all memory tasks improved for the oldest-old participants whereas, with the exception of word recall for young participants, removing the effects of the covariates decreased young and middle group scores.

Time 2 Testing

Precisely two years later, exactly the same set of tests was run in the same order, looking for any changes over the 2-year period. It was expected that changes, if any, would only be observed in the oldest-old group.

An examination was made of the correlations between the seven potential covariates to ensure that Time 2 data did not warrant the inclusion of any covariate dropped after the analysis of Time 1 data. On the basis of the correlations, the covariates utilised at Time 1 were retained at Time 2. The Time 2 correlations between potential covariates are presented in Table 7.13.

An examination was also made of the correlations between the seven potential covariates and six memory types at Time 2 to ensure changes had not occurred, which would necessitate a review of possible covariate inclusion (see Table 7.14).

Table 7.13. *Pearson correlations between the potential covariates collapsed across age, at Time 2 testing (n = 126).*

Covariate	Years Ed	NART	IDP	FA	BDI-II	Phys Funct	Mental Health
Years Ed	1	.61	.44	.38	-.22	.31	-.21
NART		1	.29	.41	-.16	.23	-.13
IDP			1	.64	-.19	.68	-.18
FA				1	.02	.54	-.65
BDI-II					1	-.54	-.22
Phys.Funct						1	.09
Mental Hlth							1

Table 7.14. *Pearson correlations between all potential covariates and all memory types collapsed across age at Time 2 testing (n = 126).*

Covariate	Words	Shapes	Digit Span	Letter-Number	Faces	Prospective
Years Ed	.38	.40	.43	.38	.42	.42
NART	.52	.40	.54	.40	.42	.41
IDP	.58	.76	.43	.77	.68	.75
FA	.58	.64	.51	.67	.65	.57
BDI-II	-.62	-.15	-.41	.12	-.13	-.18
Phys.Funct	.45	.63	.39	.68	.54	.68
Mental Hlth	-.11	-.04	.002	-.10	-.05	-.10

It is notable that the pattern of correlations at Time 2 is *very* similar to that at Time 1 (see Table 7.8).[4]

A further check was made to ascertain if the choice of covariates made at Time 1 should be reviewed once Time 2 data became available. Running preliminary ANCOVAs showed that depression (measured by BDI-II), mental health, and physical function failed to reach statistical significance for any memory type. Again, years of education reached significance only in the working memory task and the decision was made to run all Time 2 analyses with the covariates of intelligence, verbal processing speed, and nonverbal processing speed, the same as for Time 1.

A comparison of the three covariates shows that the overall pattern of scores is consistent across Time 1 and Time 2. For the oldest-old participants scores on all three covariates declined, although the pattern remained the same at Time 2 as at Time 1 (Figure 7.4). Nonverbal processing speed was most affected by aging, closely followed by verbal processing speed. Only nonverbal processing speed (measured by the IDP task) shows a marked decline by the middle group and then a big drop-off in the oldest-old group. Likewise, Tables 7.1 and 7.4 show nonverbal recall also deteriorated rapidly with age at Time 1 as it did at Time 2. Pearson correlations show that the tasks measuring nonverbal processing speed and nonverbal recall (IDP and shapes) covary. There were moderately large correlations between them of r = .75 and r = .76 at Time 1 and Time 2, respectively.

[4] A full Time 1 and Time 2 comparison is presented after the Time 2 results.

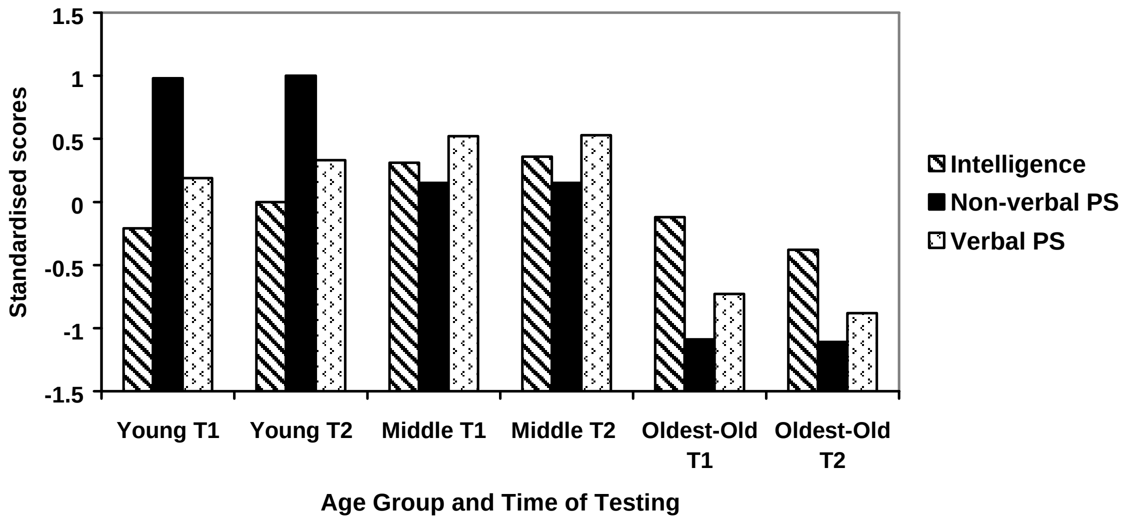

Figure 7.4. *Standardised (z) scores for intelligence, nonverbal processing speed (PS), and verbal processing speed at Time 1 and Time 2.*

All the assumptions for ANCOVA were met with the exception of homogeneity of regression slopes in some instances at Time 2 testing. Nevertheless, analyses continued because the alternatives suggested by Tabachnick and Fidell (2001) were not appropriate for the present data. Although this was only apparent in hindsight, and even though the homogeneity of regression slopes assumption was violated, the results obtained seem entirely consistent with the other covariate results, and with the regression analyses. A summary of the ANCOVA analyses for all memory types, and age, at Time 2 is shown in Table 7.15. (Full ANOVA tables can be seen in Appendix Q).

At Time 2, the covariates exerted much the same influence over the six memory types as at Time 1, although for word recall, digit span, and prospective memory the η^2_p statistic increased by .7, .10, and .8, respectively, for intelligence. All other variations were very slight.

Table 7.15. *F test, significance, partial eta squared (η^2_p), and power statistics for the covariates of intelligence, nonverbal processing speed (ID Pic), verbal processing speed (FA), and age for all memory types at Time 2.*

Covariate		Words	Shapes	Digit Span	Letter-Number	Faces	Prospective
NART (IQ)	*F*	21.62	7.00	24.65	7.77	6.52	12.45
	Sig	<.001	<.01	<.001	<.01	.01	.001
	η^2_p	.15	.06	.17	.06	.05	.09
	Power	1.00	.75	.99	.79	.72	.94
IDP	*F*	.45	6.51	.09	3.60	3.98	4.44
	Sig	.51	.01	.76	.06	.05	.04
	η^2_p	.00	.05	.00	.03	.03	.04
	Power	.10	.72	.06	.47	.51	.55
FA	*F*	4.04	3.73	3.57	6.14	6.55	.03
	Sig	.05	.06	.06	<.02	.01	.87
	η^2_p	.03	.03	.03	.05	.05	.00
	Power	.51	.48	.46	.69	.72	.05
Age Group	*F*	4.30	8.93	1.89	19.97	7.80	21.74
	Sig	.02	<.001	.16	<.001	<.01	<.001
	η^2_p	.07	.13	.12	.25	.12	.27
	Power	.74	.97	.97	≈1.00	.95	≈1.00

Partial eta squared *(η^2_p)* must be viewed with caution, as it incorporates adjustment for the other covariates. The variability in η^2_p for the young and middle groups, where little or no change would be expected, suggests the variability in η^2_p is more likely to be due to simple experimental error than reflective of an effect due to age.

As for Time 1, although the covariates have some effect, age remained the major factor in changing scores across the age groups (Table 7.15). The mean scores, adjusted for intelligence, nonverbal processing speed, and verbal processing speed at Time 2 are presented in Table 7.16.

Table 7.16. *Adjusted mean scores and standard error (SE) for all memory tasks across young, middle, and oldest-old participants at Time 2.*

	Young *n*=40		**Middle** *n*=44		**Oldest-old** *n*=42		**Maximum Possible Score**
Word Recall	9.48	*(.74)*	9.12	*(.50)*	6.30	*(.76)*	25
Shapes Recall	28.59	*(1.96)*	27.07	*(1.32))*	16.39	*(2.00)*	60
Digit Span	10.87	*(.47)*	11.10	*(.32)*	9.95	*(.48)*	16
Letter-Number Sequence	11.36	*(.46)*	10.80	*(.31)*	7.02	*(.47)*	21
Faces	35.15	*(.74)*	35.73	*(.50)*	31.98	*(.76)*	40
Prospective Memory	6.68	*(.34)*	6.41	*(.23)*	3.48	*(.35)*	8

The percentage change between unadjusted scores and scores adjusted for intelligence and processing speed (verbal and nonverbal) is presented in Table 7.17. In A drop in scores when the effect of the covariates is removed is indicated by a minus (-), and an increase in scores when the covariates are excluded is indicated by a plus (+).

Table 7.17. *The percentage change between unadjusted and adjusted scores at Time 2 for all memory tasks as a function of age.*

Memory Task	**Young**	**Middle**	**Oldest-old**
Word Recall	-6.6	-10.1	+37.0
Shapes Recall	- 14.2	-8.5	+77.4
Digit Span	- 2.4	-5.4	+10.3
Letter-Number	-7.4	-5.5	+28.1
Faces	-4.2	-2.8	+8.7
Prospective	-7.9	-3.8	+30.3

Compared with Time 1 (Table 7.11), the difference between unadjusted and adjusted scores increased markedly for the oldest-old group. That is, for the corrected scores to improve *more* at Time 2, it must have been the case that the covariates (verbal and nonverbal processing speed and intelligence) were having *greater* effects two years later. This is almost certainly indicative both of a slowing in processing speed, and a decline in intelligence for the oldest-old people. In the specific tests for processing speed, for verbal processing (FA) the mean scores for the oldest-old were 39.98 (12.77) and 35.43 (11.33) for Time 1 and Time 2, respectively. Similarly, for nonverbal processing speed (IDP) the mean scores for the oldest-old were 33.60 (10.25) and 30.48 (11.59) at Time 1 and Time 2, respectively. Intelligence showed a decline for the oldest-old over the 2-year period, with mean raw scores for the NART being 111.50 (12.77) at Time 1, and 107.69 (9.69) at Time 2. For comparison, the difference in the change between unadjusted and adjusted scores at Time 1 and Time 2 for the oldest-old group is shown in Table 7.18. The plus (+) sign in the table indicates an increase in scores for the oldest-old group resulting from the removal of the effect of the three covariates.

Table 7.18. *The difference between Time 1 and Time 2 for the percentage change between unadjusted and adjusted scores on all memory tasks for the oldest-old group.*

	Words	Shapes	Digit Span	Letter-Number	Faces	Prospective
Time 1	+3.7	+42.2	+4.9	+8.7	+4.9	+13.3
Time 2	+37.0	+77.4	+10.3	+28.1	+8.7	+30.3
Difference	33.3	35.2	5.4	19.4	3.8	17.0

As evidenced in Table 7.19, the oldest-old group memory scores benefited more from the adjustments for intelligence and processing speed at Time 2 than they did at Time 1. For this group, the improvement between Time 1 and Time 2 in the percentage of change between unadjusted and adjusted scores, ranged from 35.2% for nonverbal recall and 33.3% for verbal recall, to 19.4% and 17.0% for working memory and prospective memory, respectively. Short-term memory and face recognition showed considerably smaller changes of 5.4% and 3.8%, respectively.

Removing the the effects of the covariates at Time 2 produced the same outcome as at Time 1, with the effects being more pronounced at Time 2. Figure 5 plots the corrected *z*-scores against the uncorrected *z*-scores at Time 2 testing.

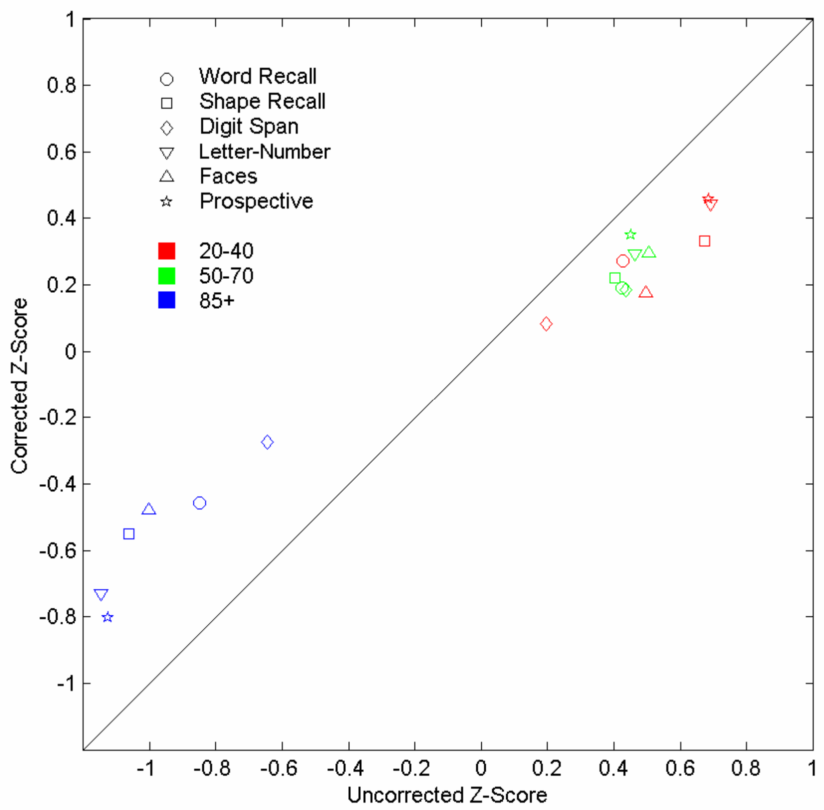

Figure 7.5. *The mean test scores at Time 2 after correcting for the covariates against uncorrected scores for all memory tasks and all age groups.*

Multiple Regression Analysis at Time 2

Again at Time 2, multiple regression analysis was carried out. The results are summarised in Table 7.19. For ease of comparison, the percentage of significant unique variance contributed by each covariate at Time 1 and Time 2, shown by multiple regression analyses, is shown in Table 7.20.

Table 7.19. *The adjusted R^2, percentage of variance accounted for by the model, significance, and unique variance accounted for by the covariates, at Time 2.*

Memory Task	Adjusted R^2	Sig.	Unique % variance accounted for (based on squared semipartial correlation)			
			NART	IDP	FA	Age
Words	.496	<.001	9.5%	n.s	3.4%	1.9%
Shapes	.645	<.001	2.4%	1.6%	2.7%	2.9%
Digit span	.387	<.001	13.1%	n.s	3.6%	n.s
Letter-Number	.702	<.001	2.3%	n.s	3.9%	5.1%
Faces	.569	<.001	2.8%	n.s	5.3%	1.4%
Prospective	.644	<.001	4.2%	n.s	n.s.	5.8%

Table 7.20. *Comparison of the percentage of unique variance contributed to the six memory types by the covariates at Time 1 and Time 2. Age is included for comparison.*

Covariate	Time	Memory Task					
		Words	Shapes	Digit span	Letter-Number	Faces	Prospective
NART	Time 1	5.4	2.0	6.4	2.8	n.s	n.s
	Time 2	9.5	2.4	13.1	2.3	2.8	4.2
IDP	Time 1	n.s	3.0	n.s	n.s	n.s	2.4
	Time 2	n.s	1.6	n.s	n.s	n.s	n.s
FA	Time 1	3.5	n.s	n.s	2.6	3.4	n.s
	Time 2	3.4	2.7	3.6	3.9	5.3	n.s
Age	Time 1	8.2	5.1	n.s	9.2	n.s	3.0
	Time 2	1.9	2.9	n.s	5.1	1.4	5.8

As shown in the ANCOVA comparison between Time 1 and Time 2, when the squared semipartial correlations (Table 7.20) are compared with Time 1, age contributes less unique variance for verbal and nonverbal recall, working memory, and face recognition. For short-term memory, age was nonsignificant at both Time 1 and Time 2. The exception for the contribution of age to the unique variance was for prospective memory, where the unique variance contributed by age rose from 3.0% at Time 1 to 5.8% at Time 2. While this is likely to be mostly due to the oldest-old group, multiple regression analysis does not clarify this. The ANOVA, however, did show an increase in the percentage change between unadjusted and adjusted scores on all memory tasks for the oldest-old participants (see Table 7.18). In contrast, intelligence contributed more of the variance, overall. It is notable that for the digit span task, intelligence contributes an increased unique variance at Time 2. This is coupled with a significant contribution from the verbal processing speed covariate, a contribution which was non-significant at Time 1. Caution is required in the interpretation of the squared semipartial correlations, as it is likely experimental error and random fluctuations might account for much of the observed change.

As shown in ANOVA, the assumption of homogeneity of variance was not met in face recognition and prospective memory at Time 1, and word and shape recall, face recognition, and prospective memory at Time 2. The contribution to the variance is not equal across the three age groups. Thus, age and unique variance interacted. For both verbal (IDP) and nonverbal (FA) processing speed, the change in the unique variance contributed to the six memory types are too small to interpret. The unique variance contributed by intelligence does increase between Time 1 and Time 2 across all memory tasks, although the change in shape recall and the letter-number sequencing task are very small.

In summary, the covariates of processing speed (both verbal and nonverbal) and intelligence had a clear effect on the memory performance of the oldest-old. With the removal of these covariates the oldest-old participants' scores improved on all memory types. However, this did not hold true for young participants for whom the removal of the covariates reduced scores. For the middle-aged participants the effects of the covariates varied according to the memory type. The overall pattern of *z*-scores shows a pattern similar to that at Time 1 testing. However, the oldest-old performance declined noticeably over time (between Time 1 and Time 2), particularly in verbal and nonverbal recall, working memory, and prospective memory tasks.

Longitudinal Analyses

It was expected that there would be a marked change over the period of two years for the oldest-old participants, but not in the young and middle-aged people. Further, it was expected that for the oldest-old, at an age where life expectancy is measurable in single digits, the 2-year interval would show declines in most, if not all, aspects of memory.

Two years passed between the collection of Time 1 and Time 2 data. The raw mean scores on the six types of memory (verbal and nonverbal recall, short-term memory, working memory, face recognition, and prospective memory) are presented for comparison in Table 7.21.

As noted above, Time 1 and Time 2 testing yielded a similar pattern of results. Exceptions were, notably, the improvement in shape recall for both the young and middle groups (although the oldest-old group had poorer performance in this task) and in the drop-off in the prospective memory scores for the oldest-old. Nonverbal recall appears to be a memory type which particularly suffers as time passes in very old age.

Table 7.21. *Raw mean scores for all memory tasks (SDs) and maximum possible scores at Time 1 and Time 2 as a function of age.*

Group	Words	Shapes	Digit Span	Letter-Number	Faces	Prospective
Young T1	10.38 *(3.26)*	30.48 *(6.90)*	11.18 *(2.07)*	12.33 *(1.94)*	36.15 *(2.91)*	7.17 *(1.11)*
Young T2	10.15 *(4.39)*	33.33 *(8.28)*	11.12 *(2.29)*	12.27 *(2.00)*	36.70 *(2.86)*	7.25 *(0.84)*
Middle T1	9.50 *(3.24)*	26.00 *(8.22)*	11.39 *(2.14)*	11.45 *(2.40)*	35.80 *(2.68)*	6.82 *(1.17)*
Middle T2	10.14 *(3.47)*	29.57 *(11.02)*	11.73 *(2.19)*	11.43 *(1.78)*	36.75 *(2.55)*	6.66 *(1.60)*
Oldest-old T1	5.71 *(2.45)*	10.29 *(6.47)*	9.81 *(1.94)*	6.64 *(2.17)*	30.83 *(4.05)*	4.43 *(1.82)*
Oldest-old T2	4.60 *(2.41)*	9.24 *(7.35)*	9.02 *(2.19)*	5.48 *(2.58)*	29.43 *(4.58)*	2.67 *(1.90)*
Maximum Possible Score	25	60	16	21	40	8

Table 7.22 shows the percentage change between Time 1 and Time 2 in the mean raw scores for the six memory tasks. A plus (+) sign denotes an increase of scores over the 2-year period, while a minus (-) sign indicates a drop in the mean score between Time 1 and Time 2 testing.

Table 7.22. *The percentage change between the mean raw scores at Time 1 and Time 2 testing for all memory types as a function of age.*

Memory Type	Young	Middle	Oldest-old
Words	- 2.2	+ 6.7	- 19.4
Shapes	+ 9.4	+13.7	- 10.2
Digit Span	+ 0.5	+ 3.0	- 8.1
Letter-Number Sequencing	+ 0.5	- 0.2	- 17.5
Faces	+ 1.5	+ 2.7	- 4.5
Prospective	+ 1.1	- 2.3	- 39.7

For the oldest-old participants the greatest decline over the 2-year inter-test period was in prospective memory (39.7%), followed by the verbal recall task (19.4%) and the working memory task (17.5%). While the decline for nonverbal recall exceeded 10%, both short-term memory and face recognition appeared less affected by time.

In contrast, the changes for the young and middle groups were generally small, with the exception of nonverbal recall where performance improved considerably for both groups (an improvement of 9.4% and 13.7%, respectively). The middle group also performed better in the verbal recall (words) task at Time 2, with an improvement of 6.7% over the Time 1 score. These improvements in performance are likely to be due to practice effects, even though there was a 2-year inter-test interval. The same practice effect was not evident for the oldest-old group.

Raw scores were transformed to *z*-scores to allow a cross-test comparison of the longitudinal changes over time. The *z*-scores for Time 1 and Time 2 for all memory tasks are shown in Figure 7.6. It is notable that there is a dramatic drop-off for the oldest-old overall. The declines in the six memory types are by no means linear over the adult years. Rather, they show a steep, nonlinear decline for the oldest-old for all memory types investigated in the present study, while there was little change between the young and middle groups. Overall, the pattern of memory scores remains much the same over the two years.

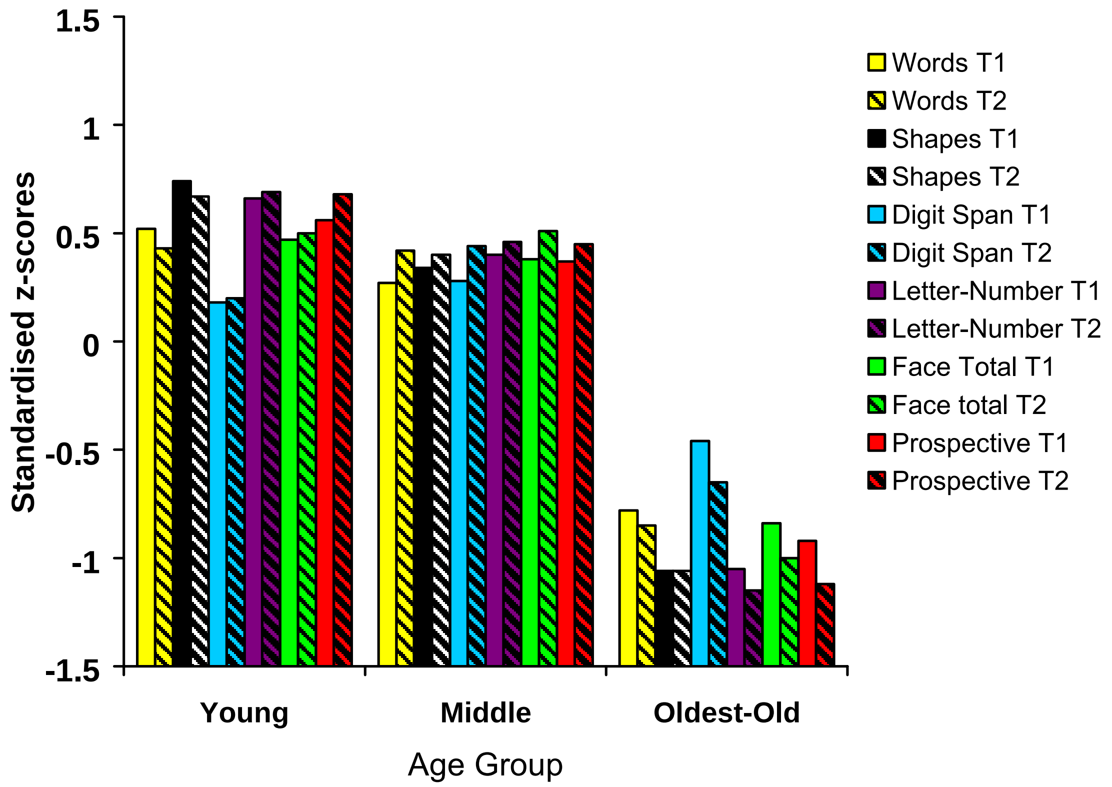

Figure 7.6. *Time 1 and Time 2 z-scores for all memory tasks as a function of age*.

Inferential statistical analyses were conducted on the Time 1 and Time 2 data. While the memory scores do not exclude the effects of the covariates, it can be noted that the Time 1 and Time 2 correlations for the covariates of intelligence, verbal processing speed, and nonverbal processing speed were r = .92, r = .94, and r = .89, respectively. Thus, it can be reasonably assumed that effects of the covariates were much the same at Time 1 and Time 2. Therefore, it was decided to analyse the two key factors of Age and Time *without* removing the effects of the covariates.

A mixed design ANOVA (Age as the between-groups factor and Time as the within-groups factor) was conducted for each memory type (see Appendix O). For the verbal recall task (words) there was no main effect of Time, but there was a main effect for Age, F (2, 123) = 39.17, p = .001, η^2_p = .39. However, this was qualified by a significant Time x Age Group interaction, F (2,123) = 3.96, p = .02, η^2_p = .06. The η^2_p of .06 represents a moderate effect (Tabachnick & Fidell, 2001). A dependent groups t-test showed a significant difference occurred only for the oldest-old between Time 1 (M = 5.71) and Time 2 (M = 4.60), $t(41) = 3.74$, $p = .001$.

For nonverbal recall (shapes task) there were main effects of Time, $F(1, 123) = 8.51$, $p < .01$, $\eta^2_p = .07$, and Age $F(2, 123) = 103.80$, $p <.001$, $\eta^2_p = .63$, but the main effects were qualified by a Time x Age Group interaction, $F(2, 123) = 5.51$, $p < .01$, $\eta^2_p = .08$. A dependent groups *t*-test showed that the young group scores improved from Time 1 (M = 30.48) to Time 2 (M = 33.33), $t(39) = -2.33$, $p = .03$. The middle group scores also improved for the Shapes task from Time 1 (M = 26.00) to Time 2 (M = 29.57), $t(43) = -2.96$, $p <.01$. For the oldest-old group there was no significant change from Time 1 (M = 10.29) to Time 2 (M = 9.24), $t(41) = 1.59$, $p < .12$.

There was no main effect of Time for short-term memory (digit span task) (F = 1.41). The main effect of Age, $F(2, 123) = 13.79$, $p <.01$, $\eta^2_p = .18$, was qualified by a Time x Age Group interaction with a moderate to large effect, $F(2,123) = 5.76$, $p < .01$, $\eta^2_p = .09$. The change occurred only for the oldest-old with a score of M = 9.81 at Time 1 and M = 9.02 at Time 2, $t(41) = 3.87$, $p <.001$.

Similarly for the working memory task (letter-number sequencing). The main effects of Time, $F(1, 123) = 6.49$, $p =.01$, $\eta^2_p = .05$, and Age, $F(2, 123) = 123.70$, $p <.01$, $\eta^2_p = .67$, were qualified by a Time x Age Group interaction, $F(2, 123) = 5.42$, $p =.01$, $\eta^2_p = .08$. The Time x Age Group interaction was due to the oldest-old participants with a decline from Time 1 (M = 6.64) to Time 2 (M = 5.48), $t(41) = 4.46$, $p <.001$.

There was no main effect for Time in the face recognition task. There was a main effect for Age $F(2, 123) = 54.13$, $p <.01$, $\eta^2_p = .47$. However, the qualifying Time x Age Group interaction, $F(2, 123) = 13.25$, $p <.01$, $\eta^2_p = .18$, produced a large effect size. There was significant change for face recognition in all three groups. The young group improved between Time 1 (M = 36.15) and Time 2 (M = 36.70), $t(39) = -2.68$, $p < .02$. The middle group also showed improved scores between Time 1 (M = 35.80) and Time 2 (M = 36.75), $t(43) = -2.58$, $p < .02$. The largest change was located in the oldest-old group who showed a decline in face recognition between Time 1 (M = 30.83) and Time 2 (M = 29.43), $t(41) = 3.37$, $p = .002$.

For prospective memory, the main effects for Time, $F(1, 125) = 16.00$, $p = <.01$, $\eta^2_p = .12$, and Age $F(2, 123) = 118.49$, $p <.01$), $\eta^2_p = .66$, were qualified by a Time x Age Group interaction again exerting a large effect, $F(2, 123) = 14.01$, $p <.01$, $\eta^2_p = .19$.

This was caused by the oldest-old group with a decline in scores from Time 1 (M = 4.43) to Time 2 (M = 2.67), $t(41) = 6.28$, $p < .001$.

In summary, while there were main effects for Time for nonverbal recall, working memory, and prospective memory, these were consistently qualified by a significant Time x Age interaction, which was present in all types of memory analysed. The oldest-old group declined significantly over time for all memory types with the exception of nonverbal recall, whereas the young and middle groups showed improvement over time for nonverbal recall and face recognition, and no significant decline in any memory type. It appears practice effects are sustained for nonverbal recall and face recognition over a 2-year interval, by both young and middle groups. This does not appear to hold for the oldest-old, although it is possible that a practice effect may have prevented an even greater decline for the oldest-old: perhaps the oldest-old's shapes and face recognition scores would have been worse if parallel forms of these tests had been used.

Overall, the various memory types did not decline with age at the same rate, with prospective memory, verbal recall, and working memory deteriorating more quickly than did nonverbal recall, short-term memory, and face recognition for the oldest-old participants. All types of memory show a non-linear pattern of decline across age. Although there is approximately 30 years between the mean ages of each group, the young and middle groups perform in a remarkably similar manner, while there is a sharp fall away of performance in the oldest-old group over the 2-year period.
All raw data for the current study can be found in Appendix R.

Subsidiary Analyses – Delay

The present study was designed to investigate the effect of delay on recall as a function of age for both verbal and nonverbal stimuli in two ways. Firstly, to attempt to ascertain whether any decline found over the delay period was due to encoding or retrieval difficulties – if a particular stimulus was remembered at 0-delay it can be considered to have been encoded, and subsequent forgetting of the stimulus can be indicative of a difficulty with retrieval. Secondly, a delay factor was included to observe whether the decay of memory occurred at the same rate across the lifespan for the recall tasks.

However, the data collected could not be used to investigate the effects because of unexpected floor effects (see below). Nevertheless, some of the data are interesting and are presented below as subsidiary analyses.

Free recall for both the 25-word list and 15 geometric shapes was measured immediately after study, and at 10-minute and 7-day delays.

Verbal Recall

The means and standard deviations for verbal free recall are shown in Table 7.23.

Table 7.23. *The raw score means (SD) for the verbal recall task for all groups immediately after study, and at 10-minutes and 7-days delay.*

Variable	Young		Middle		Oldest-old	
Words	**T1**	**T2**	**T1**	**T2**	**T1**	**T2**
0-delay	10.38*(3.26)*	10.15*(4.39)*	9.50*(3.24)*	*10.14*(3.47)	5.71*(2.45)*	4.60*(2.41)*
10 mins	8.50*(2.94)*	9.00*(4.11)*	7.43*(3.22)*	8.35*(4.02)*	3.26*(2.01)*	2.24*(2.01)*
7 days	5.35*(3.07)*	6.23*(3.63)*	3.70*(2.99)*	4.43*(4.03)*	1.48*(1.70)*	1.26*(1.82)*

Verbal recall declined sharply for the oldest-old group, relative to the young and middle groups. The rate of decline increased as the temporal delay between study and retrieval increased, with this decline particularly marked for the oldest-old group at both delay periods and the middle group when tested after a 7-day delay.

However, a floor effect was very evident for the oldest-old participants (see Table 7.24). The increasing number of zero scores across both Delay and Time means the standard deviations observed for the oldest-old group were spuriously low. The large number of zero scores would have truncated the standard deviations. Therefore, it was decided not to conduct any inferential analyses.

Table 7.24. *The number of participants in the oldest-old group (n = 42) scoring 0 in the verbal recall task at Time 1 and Time 2.*

Words	0-delay	10 min. delay	7 day delay
Time 1	0	5	17
Time 2	0	12	22

Nonverbal Recall

Nonverbal recall was measured by the shapes test score immediately after study of 15 geometric shapes, and after 10-minute and 7-day delay periods. The means for each group are shown in Table 7.25.

Table 7.25. *Raw score means (SD) for the nonverbal recall task for all groups immediately after study, and at 10-minutes and 7-days delay.*

Variable	Young		Middle		Oldest-old	
Shapes	**T1**	**T2**	**T1**	**T2**	**T1**	**T2**
0-delay	30.48*(6.90)*	*33.33*(8.28)	26.00*(8.22)*	29.57*(11.02)*	10.29*(6.47)*	9.24*(7.35)*
10 mins	27.88*(7.27)*	30.58*(9.26)*	24.05*(7.89)*	26.89*(12.01)*	6.88*(5.90)*	6.76*(7.63)*
7 days	*20.70*(7.29)	21.08*(8.26)*	15.27*(8.46)*	19.80*(12.16)*	5.81*(5.97)*	4.33*(5.61)*

Nonverbal recall declined sharply for the oldest-old compared to the young and middle groups. For the oldest-old group, most of the forgetting occurred between 0-delay and 10-minute delay testing, whereas for the young and middle groups the greatest decline occurred in the 7-day delay.

Again, a floor effect within the oldest-old group meant that the standard deviations do not accurately reflect the variance within this group. The number of oldest-old participants scoring zero for the nonverbal task is shown in Table 7.26.

Table 7.26. *The number of participants in the oldest-old group (n = 42) scoring 0 in the nonverbal recall task at Time 1 and Time 2.*

Shapes	0-delay	10 min. delay	7 day delay
Time 1	1	10	16
Time 2	3	10	19

However, overall, the scores for the shapes test indicate a high percentage of loss in nonverbal recall ability in the oldest-old group at all delays. The low scores for the oldest-old group for 0-delay recall show a Time 1 decline of 66.5% and Time 2 decline of 72.3%, relative to the young group. Although this may have over-estimated the ability of the oldest-old participants because of the floor effect, it is indicative of the great difficulty the oldest-old participants encountered with encoding this aspect of memory.

As for the verbal recall task, the high number of oldest-old participants scoring 0 is indicative of the difficulty these people found with the task. This, in turn, highlights the difficulty of devising a task which those in their late ninth and tenth decades of life can complete, but which would not result in ceiling scores for their younger counterparts.

All raw data for the present study is presented in Appendix R.

Chapter Eight

DISCUSSION

Chapter Eight discusses the results and implications of the present study, beginning with a re-statement of the key questions and expectations underlying the study. Firstly, the cross-sectional findings at both Time 1 and Time 2, presented separately for the six memory types, are discussed, followed by the longitudinal findings across the 2-year inter-test period. Secondly, a review of the rationale underlying the discarding of four possible covariates and the retention of processing speed (verbal and nonverbal) and intelligence as the analysed covariates, introduces the discussion of all data with the influence of the covariates excluded. Again, the six memory types are discussed separately, both cross-sectionally and longitudinally. This is followed by a brief discussion of the intention in the present study to introduce delay tasks for both verbal and nonverbal recall. Suggestions toward a theory of memory and aging are presented and, lastly, the limitations of the present study and suggestions for future research are discussed.

The present study aimed to investigate the nature and extent of the decline in memory associated with advanced aging. Even a cursory review of the literature documenting research on the effects of aging on memory, reveals a paucity of memory research for the oldest-old – those more than 85 years of age. The present study, therefore, sought to investigate six types of memory in the oldest-old, comparing their memory performance with young and middle-aged people. More specifically, the present study asked three key questions about memory and the oldest-old.

1. Is there a sharp, nonlinear decline in memory when the oldest-old are included? On the basis of previous findings, it was expected that memory performance would decline with age for those who are 85 years of age and over. Many studies suggest, at least up until around 80 years of age, such declines are linear (e.g., Lindenberger et al., 1993; Nilsson et al., 1997; Salthouse, 2004; Singer et al., 2003). However, in prior research few studies had addressed the

question in very advanced old age. As expected, there was a sharp, nonlinear decline in overall memory for the oldest-old, with the six types of memory investigated being affected differentially but all falling in a nonlinear fashion.

2. Is the rate of decline in memory in advanced age affected by covariates such as years of education, intelligence, depression, physical functioning, mental health, and speed of processing (verbal and nonverbal) as well as age? Prior research has implicated such covariates in the declines in memory during the aging process. The present study was interested in finding out if the covariates under study moderated memory scores in the same way across the life span, and how much of the decline in six types of memory could be accounted for by them rather than by age alone. Although intelligence and both verbal and nonverbal processing speed exerted considerable influence on the memory scores for the oldest-old, the covariates of years of education, depression, physical functioning, and mental health did not influence scores to any great degree.

3. Are there noticeable changes in memory scores over the period of two years for the oldest-old? Taking into account the typical changes to the very old brain, it was expected that for the oldest-old the 2-year inter-test interval would show declines in most, if not all, aspects of memory. Previous research has shown that brain deterioration correlates with memory loss. All memory types declined over the 2-year period, with prospective memory, verbal recall, nonverbal recall, and working memory showing the greatest declines. Short-term memory and face recognition declined more slowly.

Cross-sectional analyses at Time 1 and Time 2 testing

Memory Types

Until relatively recently, it has been believed that declines in memory with age have been roughly linear, with measurable age-related declines in memory beginning prior to 40 years of age for verbal recall (Salthouse, 2004). For example, Salthouse, in a memory test involving auditory presentation of a list of unrelated words to be recalled, found a correlation of $r = -.43$ between age and the memory variable. Salthouse further noted that the relation between age and memory is primarily linear, at least until about 80 years of age. He concluded that the lack of discontinuities in memory decline suggests that such events as retirement or menopause are unlikely to be responsible for any of the decline of memory during the aging process. However, Salthouse's oldest participants generally averaged approximately 80 years of age, so did not include the oldest-old.

The present study found otherwise, with little decline (and, in the case of short-term memory, slight improvement) from young to middle-age, followed by a sharp decline in all memory types for the oldest-old participants. As the types of memory under study resulted in different rates of decline, each memory type will be discussed separately, firstly considering the raw scores with the effects of the covariates still embedded.

In *verbal recall*, measured by scores on a 25-word list to be remembered, the middle group participants' scores were 8.5% lower than those of their younger counterparts at Time 1, and 0.1% at Time 2. Although there was approximately 30 years between the mean ages of each of the three groups, the oldest-old scored 44.0% lower than the young participants at Time 1 and 54.7% at Time 2, reflecting a sharp decline in this ability.

Hickman et al. (2000), drawing data from the Oregon Brain Aging Study, found that adults from 65 years to 94 years showed few declines in cognitive abilities, including word list memory. In contrast, the Betula Prospective Cohort Study (Nilsson et al., 1997) with 100 participants in each of 10 age cohorts from 35 to 80 years, found a consistent pattern of decline in the free recall of words, although the age ceiling of 80 years failed to account for advanced aging. Similarly, the Seattle Longitudinal Study (Schaie, 1996) found a 29% decline in verbal recall ability between 25 and 81 years of age, although the oldest-old were not included. From prior research, recall of verbal stimuli seems to be relatively stable until the mid-50s or early 60s, followed by decline until the early 80s. In the available research of verbal recall, particularly for the oldest-old where there is a dearth of research, ambiguities abound. It is not yet clear whether the linear decline continues into the ninth and tenth decades of life, or whether there is a deceleration or acceleration of the decline. The present study found, at both Time 1 and Time 2, a sharp decline in verbal memory for the oldest-old participants over-and-above that typically found in aging studies where the age range stretches only into the early 80s. It appears there is a marked drop in verbal recall ability during the late ninth and tenth decades of life, although it needs to be borne in mind that this age group could be considered a select group by the very fact of their survival into very old age, and because participants were screened to exclude those with any but the most mild cognitive dysfunction. While this affects generalisability to the whole population of those 85 years of age and over, the pupose of the present study is to examine memory in healthy, community-dwelling participants.

Because it was considered that very elderly participants may take longer to recall and write their list of remembered words, a time limit was not imposed at recall. However, it was clear during data collection that the oldest-old were able to recall the words they did remember almost as quickly as the young participants. Typically, the remembered words were written followed by a short pause, and then certainty that no more would be forthcoming. No participant used more than two and a half minutes for the recall of words. Because no time limit was imposed for the reproduction of the words, it seems that the speed of encoding the words during the timed (3 seconds per word) study period was particularly difficult for the oldest-old.

Nonverbal recall, measured by the recall of geometric shapes, was affected more by aging than was verbal recall at both Time 1 and Time 2. For nonverbal recall, middle and oldest-old group participants scored 14.7% and 66.2% more poorly than young participants at Time 1, and 11.3% and 72.3% more poorly at Time 2. These data reflect the difficulty that older people have with this type of memory.

The majority of research for nonverbal recall has been carried out using tasks such as the Visual Reproduction subtest from the Wechsler Memory Scale – Revised (Wechsler, 1987) or the Memory-For-Designs Test (Graham & Kendall, 1946, 1960), which require participants to reproduce the stimuli immediately after exposure to each one. The present study sought to devise a nonverbal recall task that was similar in structure to the verbal recall task by having all stimuli presented sequentially before recall was required. This does not, however, allow for close comparison with prior research, which has utilised a somewhat different form. Nevertheless, overall, it appears there is a significant drop in this ability during the advanced aging process compared to verbal recall. Giambra et al. (1995) suggest visual patterns might be expected to be well insulated from the detrimental influence of aging because they frequently involve highly distinctive stimuli and are, therefore, often quickly and easily apprehended. This does not appear to be so. On the Visual Reproduction subtest of the Wechsler Memory Scale (Wechsler, 1945), Lezak (1995) reported that 80- to 92-year-olds had recall at a level 2.6 standard deviations below that of 20- to 29-year-olds. As for verbal recall, research on nonverbal recall remains equivocal, particularly for those of very advanced years, as to whether this is a linear or nonlinear decline and, indeed, at what age the decline may be expected to begin. Although Reige et al. (1981) found that adults over the age of 60 showed significant declines in nonverbal recall ability, and Giambra et al. suggest no significant decline until after 64 years of age, other researchers have suggested decrements in this ability are significant at around 50 years of age (e.g., Bak & Greene, 1980; Fastenau et al., 1996; McCarty et al., 1980). Giambra et al. concluded that the watershed decade for decremental changes in nonverbal memory, tested by immediate memory for geometric designs after a 10-second viewing, was between 65 and 74 years of age.

The present study found, at both Time 1 and Time 2 testing, that while there was a small, significant decline in nonverbal recall for the middle group, there was a steep decline in this ability for the oldest-old. Nonverbal memory was the memory type that was the most affected by aging at both Time 1 and Time 2 testing, and the decline was noticeable at an earlier age than for any other type of memory in the present study.

When verbal and nonverbal recall scores were standardised, nonverbal memory performance for the oldest-old group was poorer than verbal memory performance at both Time 1 (z = -1.06 for nonverbal, and z = -.78 for verbal recall) and Time 2 (z = -1.06 for nonverbal, and z = -.85 for verbal recall). This did not hold true for the young and middle groups. For young participants, verbal recall scores were poorer at both Time 1 and Time 2 (z = .52 and .43, respectively) than were nonverbal scores (z = .73 and .67, respectively). For the middle group, nonverbal recall performance (z = .34) was slightly better than verbal recall (z = .27) at Time 1. At Time 2, the middle group score for nonverbal recall (z = .40) was slightly less than for verbal recall (z = .42). A very similar pattern of decline in nonverbal memory was observed at Time 1 and Time 2, with a relatively small decline from the young group to the middle group, and a marked drop to the oldest-old when examining unadjusted data.

Short-term memory was the memory type least affected by aging at both Time 1 and Time 2, with the middle group scores reflecting an improvement of 1.9% over the scores of the young group, and a decline of 12.3% for the oldest-old, relative to the young participants in the digit span task for Time 1. At Time 2, the middle group showed an improvement of 5.5% over the young group score, and the oldest-old an 18.9% decline relative to the young participants. Craik (1971) suggested that the memory difficulties encountered by older adults is primarily one of long-term memory retrieval, as the observed declines in memory for older adults did not hold in simple digit tasks which test acquisition and retrieval only from short-term memory, rather than the retrieval associated with explicit long-term memory. Again, it should be noted that the maximum age of participants in the Craik study was 84 years.

In a study which did extend the participant age to include a group of people 84 years and over, Hickman et al. (2000) found that the oldest-old compared favourably in the digit span task with participants aged from 65 to 74 years. Hickman et al. suggest that many cognitive functions, including short-term memory, produced scores over a 4-year period similar to a control group almost 20 years younger. Dividing participants into smaller age bands, Wahlin et al. (1993) administered the forward digit span task to adults in four age groups: 75 - 79, 80 - 84, 85 - 89, and 90 - 96 years. All groups averaged between 5.53 and 5.88 remembered digits. In 1996, Ryan et al. found 34 oldest-old participants (84 - 100 years) remembered 5.79 digits, a very similar result to Howieson et al. (1993) where the oldest-old remembered 5.7 digits. In the present study, the oldest-old remembered an average of 6.36 digits, compared with the young and middle groups who were able to recall 7.17 and 7.20 digits, respectively. The pattern was very similar at Time 2, when the oldest-old remembered an average of 6.15, compared with the young and middle groups who recalled 7.06 and 7.61, respectively. Similarly, Robertson-Tchabo and Arenberg (1989) reported only small decreases in digit span between the third and ninth decades, with the digit span for the oldest participants 90% relative to the youngest individuals.

There is general agreement among researchers that short-term memory remains less affected by aging than do other types of memory (e.g., Aronson & Vroonland, 1993; Dobbs & Rule, 1989; Hickman et al., 2000; Salthouse & Babcock, 1991; Small et al., 2003), a finding supported by the present study at both Time 1 and Time 2 where the pattern of scores was similar at both test times. It seems that short-term memory is preserved during aging, relative to other memory types, as it requires the individual to remember only a small amount of information for a relatively short time.

Working memory, measured by the WAIS-III (Weschler, 1997a) letter-number sequencing task, showed a substantial decline for the oldest-old participants at both

Time 1 and Time 2. The scores for this group declined 46.2% compared to the young group at Time 1 and 55.3% at Time 2. This reflects a very marked decline for this ability, as the middle group scores fell only 7.1% and 6.8% below that of the young group at Time 1 and Time 2, respectively. Both Time 1 and Time 2 scores support prior research which has consistently found that a working memory component included in a memory task disadvantages older participants. For example, Wingfield et al. (1988) designed a study comparing simple span tasks (digit and word span) with a task including a working memory component (loaded word span) which required participants to both read sentences and make a decision as to whether the sentence made sense, and to sometimes be required to read the last word of the sentence aloud. Wingfield et al. report that while the age difference on the simple span tasks was minimal, the elderly (59 - 84 years) performed much more poorly on the working memory task. Research evidence demonstrating the decline of working memory with aging is robust. Providing further evidence, a recent study by Myerson et al. (2003) examined the data from the standardisation tables for the Wechsler Memory Scale – Third Edition (Wechsler, 1997c), including digit span and letter-number sequencing utilised in the present study. Myerson et al. found that the regression line was significantly steeper for letter-number sequencing than for the digit span task, and argued that the pronounced age-related decline found for letter-number sequencing may well be attributable to decline in executive aspects of working memory. At Time 1 in the present study, young, middle, and oldest-old participants were able to remember, reorder, and recall 5.70, 5.35, and 3.66, respectively, demonstrating a clear, nonlinear decline of working memory ability. Similarly, at Time 2, participants attained scores of 5.63, 5.32, and 3.30 digits and letters sequenced correctly.

Face recognition is remarkably little affected by aging. For the middle group, relative to the young group, scores on the face recognition task fell by only 1% at Time 1 and by 0.1% at Time 2. For the oldest-old participants, the mean score 14.7% less than that of the young people at Time 1, showing only a slightly greater decline than for short-term memory, an ability known to be little affected by aging. The pattern of scores at Time 2 was similar to Time 1. At Time 2 the oldest-old had declined by 19.8%, again only a slightly greater decline than for short-term memory. It is clear from prior research that older people do well when externally cued, such as in a recognition task, whereas older people do not do as well when cues must be self-generated, as in a recall task (e.g., Craik, Byrd, & Swanson, 1987; Craik & McDowd, 1987; Parkin, 1993)

This finding is in contrast to that of Hassing et al. (2002). In a study of 98 people aged 90 - 101 years assessed three times across a 6-year period, Hassing et al. found only nonverbal recall and face recognition (tasks requiring a relatively large amount of cognitive support at encoding) showed significant impairment. The large variety of methodologies employed for face recognition studies make comparisons somewhat difficult and, furthermore, few studies have investigated face recognition in the ninth and tenth decades of life.

Variability in face recognition performance increased for the oldest-old, when compared with the two younger groups, with *SD* = 2.91, 2.68, and 4.05 for the young, middle, and oldest-old groups, respectively, at Time 1. Time 2 data showed a similar pattern of increased variability with age, with *SD* = 2.86, 2.55, and 4.58, for the young, middle, and oldest-old groups. The increase in variability for the oldest participants was greater than for any other memory type. In a study by Lamont et al. (2005), the decline in face recognition with aging was qualified by an interaction between participant age and target age, with the oldest participants (76 to 96 years of age) showing a decline in face recognition accuracy occurring for young target faces, but not for old target faces. There was no such interaction for younger participants. The inclusions of both young and old target faces in the present study increased the difficulty of the task for some of the oldest-old, and may well account for the increased variability.

Prospective memory, however, was affected by age, particularly for the oldest-old, whose scores were 38.2% lower than the young group at Time 1 testing, compared with a 4.9% decline for the middle group. At Time 2, prospective memory performance showed a very similar pattern of decline, relative to the young group, as at Time 1. At Time 2, the middle group score was 8.1% and the oldest-old score 63.2%, lower than the young group.

Craik (1986) suggested that prospective memory is likely to be very problematic for the elderly because prospective memory tasks require remembering in the absence of retrieval cues – self-initiated remembering. This type of memory requires the individual to remember to perform an intended action at some point in the future. This necessitates the setting of a goal, the retention of the appropriate time for the intended action to be activated, and the cancelling of the information when it is no longer required. Prospective memory functioning is essential for the continued independence of older adults as tasks such as remembering to turn off the heater, to attend to daily self-care, and the keeping of appointments depend on this ability. Thus, decrements in self-initiated remembering presents a difficulty for the oldest-old, and this seems to be a memory type which is particularly vulnerable to advanced aging. While little prospective memory research has studied the oldest-old, studies utilising participants up to the age of 75 or 76 years (Einstein & McDaniel, 1990; Einstein et al., 1995) and to the early 80s (d'Ydewalle et al., 1999; Einstein et al., 1992; Park et al., 1997) all provide clear evidence of a significant decrement in prospective memory ability in old age. Nevertheless, a dearth of research on the oldest-old inhibits understanding of whether the decline continues at the same rate, slows, or accelerates after the early 80s. At Time 1 and Time 2, the oldest-old showed significantly lower prospective memory performance, compared with the young and middle participants, even though the prospective memory tasks in the present study provided cues to aid memory. The data from the present study strongly suggest an accelerated decline in prospective memory in the ninth decade of life, as the Time 2 data replicated that of Time 1.

Across all memory types, shape recall (nonverbal recall) was affected most by aging, with means (possible score = 60) of 30.48, 26.00, and 10.29 at Time 1, and 33.33, 29.57, and 9.24 at Time 2, for the young, middle, and oldest-old groups, respectively. Nonverbal recall was also the memory type which demonstrated the largest decline of any memory type by middle-age. The middle group unadjusted scores were 14.7% and 11.3% lower at Time 1 and Time 2, respectively, than their younger counterparts. At Time 1, ANOVAs showed the only significant difference between young and middle group participants was in nonverbal recall where the difference was significant at $p < .05$. In the present study, it appears that nonverbal memory is affected at an earlier age than are the other types of memory studied. Verbal recall, also, showed a decline of 8.5% for the middle group compared to their young counterparts. However, the decline in this ability is clearly nonlinear, as the oldest-old demonstrated a decline of 45%, an additional decline of 36.5% between the middle group and attaining 85+ years of age. This sharp decline was replicated at Time 2, with a slightly larger effect for the oldest-old. The middle group demonstrated a very small decline of 0.1% relative to the young group, with a marked drop to a 54.7% decline for the oldest-old, relative to the young people.

While short-term memory was the memory type least affected by aging, when a working memory component was added, the percentage of decline for the oldest-old increased from 12.3% (digit span) to 46.2% (letter-number sequencing) at Time 1, and

18.9% (digit span) to 55.3% (latter-number sequencing task) at Time 2, when compared with the young participants. 1Age had statistically significant effects for all memory types at both Time 1 and Time 2.

Longitudinal Analyses Memory Types

For *verbal recall,* compared to Time 1 testing, the oldest-old declined a further 10.7% over a 2-year period, although the middle group demonstrated an 8.5% improvement, when compared with the young participants. The oldest-old appear not to have benefitted from having completed the same task two years prior, although the improvement in the middle group scores may well have been because of a practice effect. This possibility raises a serious question regarding test-retest reliability. If practice effects emerge after a 2-year inter-test interval, then doubt is cast on the usefulness of test-retest reliability studies which are often conducted over a period of a few weeks.

Interestingly, the young group did not show an improvement of scores at Time 2 for verbal recall. Change over time occurred only for the middle and oldest-old groups, with the middle group showing improvement and the oldest-old a decline. This differs from earlier research such as that of Salthouse (2004) who suggests verbal recall ability shows a linear decline starting before the age of 40, an age which is included in the young group of the present study. The middle group scores had not declined, but had rather improved, over the 2-year interval in the present study. It may be that the slightly higher mean intelligence score for the middle group (115.83 compared to 110.55 for the young group) may have advantaged the middle group as higher intelligence appears to be important for memory and may enhance the practice effect. Discussion on the importance of intelligence for memory will be found in a later section. If so, the benefit of higher intelligence was not found to the same extent in nonverbal recall.

For *nonverbal* recall, over the 2-year inter-test interval, both the young and middle groups showed a slight improvement in scores by 2.85 and 3.57 out of a possible 60, respectively. This may be because nonverbal stimuli are more memorable than verbal stimuli, and a residual memory of the stimuli presented at Time 1 may have remained available for retrieval. If so, this does not seem to have been so for the oldest-old who declined a further 6.1% in nonverbal memory over the two years, although there is a possibility that the oldest-old also retained a residual memory of stimuli presented at Time 1, and this masked an even greater deterioration in nonverbal recall to that observed. This compares with an improvement of 2.4% for the middle group, when compared to the young participants. The geometric shapes used for the nonverbal recall test were quite distinctive. If the images had been of a more ‘everyday’ nature, this distinctiveness difference may have lessened, or vanished altogether. This would be of interest in future research.

The present research gives some support to prior research which suggests significant declines in nonverbal recall ability by the mid 60s (e.g., Giambra et al., 1995) or even as young as 50 years of age (e.g., Fastenau et al., 1996). It also demonstrates a marked, nonlinear decline for this type of memory for the oldest-old for whom nonverbal memory shows a decline which increases over a 2-year period.

It has been claimed that *short-term memory* is the memory type which is least affected by aging, and the present study supports this. Over the 2-year inter-test period the oldest old showed a 6.6% decline in short-term memory over and above the decline found at Time 1. For those in the last years of life, short-term memory deteriorates little. This finding supports a large body of prior research which has consistently found a lack of significant change in short-term memory (measured by digit span scores) with advancing age (e.g., Aronson & Vroonland, 1993; Hickman et al., 2000; Small et al., 2003).

Like the short-term memory task, the *working memory* task (letter-number sequencing) was also a memory span task, but required manipulation of the letters and numbers to be remembered – the working memory component. This was much more difficult for the oldest-old participants, although made little difference to the performance of the middle group. Over the 2-year inter-test interval, the performance of the oldest-old deteriorated a further 9.1% relative to the young group, than at Time 1. Working memory clearly deteriorates at an increasingly fast rate during very advanced aging.

A decline in working memory is clearly implicated in age-related declines in advanced old age, and age-associated working memory impairment has been suggested as constituting a full or contributing explanation for changes in memory in very old adults (Craik & Rabinowitz, 1984). Letter-number sequencing requires substantial executive processing (Myerson et al., 2003), and the pronounced age-related decrements found in this task may be attributable, at least in part, to a decline in the executive aspects of working memory.

Face recognition, at both Time 1 and Time 2, showed less deterioration than other types of memory, with the exception of the short-term memory performance. However, while the middle group scored similarly to the young group on this type of memory, over the 2-year period, face recognition deteriorated a further 5.1% over and above the Time 1 decrement when the oldest-old were compared to the young group. Thus, face recognition was the most preserved memory type in the present study. The results of the present study support the findings of prior research which suggest only small decrements in face recognition occur before the age of 70 years, with an accelerated rate of decline thereafter (e.g., Bäckman, 1991; Crook & Larrabee, 1992; Lamont et al., 2005; Smith & Winograd, 1978). While faces present relatively homogeneous stimuli (Young, 1998), modern lifestyles rely greatly on the ability of people to recognise the faces of those with whom they interact. Thus, face recognition is a skill that is constantly in use throughout the life span, and appears to be maintained relatively well throughout life. Few studies have included the oldest-old, and it is of interest in the present study that face recognition is well preserved in the late ninth and tenth decades.

Prospective memory was clearly a problem for the oldest-old participants. Although there was no statistical difference between the young and middle groups' mean scores, the oldest-old group demonstrated a large drop-off in performance This oldest-old showed a 38.2% decline in performance, relative to the young group, at Time 1, and a 63.2% decline at Time 2. Furthermore, this represents a decline of 25% when compared with the young group, over two years. This is a type of memory strongly affected by advanced aging, even although the tasks in the present study were designed to give a cue to the action required by participants. This has ramifications for the independence of very old people – many of the everyday actions required for independence depend on prospective memory: remembering to take medication, to turn off the oven, to make necessary appointments, daily self-care, remembering to eat and so on. Such a rapid decline in prospective memory is deserving of further investigation.

ANOVAs showed that, at Time 2, there were no statistically significant differences among the young and middle groups. However, for all six memory types the oldest-old have significant declines in performance compared with the two younger groups. As at Time 1, all *F* tests for the six memory types showed a statistically significant effect of age (all *F*s, $p < .001$).

Furthermore, the mixed-design ANOVAs showed a Time x Age interaction for all six memory types. Independent groups *t*-tests found a drop-off in performance *only* for the oldest-old. Overall, the analyses of the raw means scores, both cross-sectionally and longitudinally, showed only small differences in the performances of the young and middle-aged participants. The oldest-old performed markedly more poorly in all memory tasks than either of the younger groups.

Covariates at Time 1 and Time 2 cross-sectional analyses

On the grounds of prior research, the majority of which has utilised participants up to about 80 years of age, it was expected that the covariates to be examined, years of education, intelligence, processing speed (both verbal and nonverbal), depression, mental health, and physical functioning, would affect the rates of decline of the various memory systems. It was of particular interest to see if the covariates under study moderated memory scores in the same way across the life span. It has been well documented that years of education, intelligence, processing speed, and depression have a deleterious effect on cognition, including memory, at least up until the early 80s. For example, it was expected that years of education would influence memory types, as there was a considerable difference between the years of education of the young group (M = 15.50), the middle group (M = 16.48), and the oldest-old group (M = 12.43). Ryan et al. (1996) showed that years of education affected scores in the digit span task, with participants over 74 years of age accurately repeating 4 digits with ≤11 years of education, and 5 digits with ≥ 12 years of education. In a similar manner, Orsini et al. (1986) demonstrated increasing digit span scores with education in adults 80 to 99 years of age. Conversely, Hassing et al. (1998) found that years of education showed only a small correlation with memory scores for participants in nonagenarians, although education accounted for more of the variance across memory types for young-old adults in their 70s and early 80s. It was decided to exclude years of education as a covariate in analysing the results of the present study as it contributed significantly to only one memory type – working memory.

The SF-36 Health Survey (Ware et al., 2000) provides norms for the physical functioning and mental health scale (standardised so scores on all scales are from 1 – 100) from 18 years of age up to a 75 years of age and over group. The SF-36 norms for physical functioning show a clear decline across the adult lifespan with mean scores declining from 92.13 for adults 18 - 24 years of age, to 53.20 for those over 75 years of age. It is notable that while the median score for the 18 - 24 year old group was 100, the median for the 75 years and over group was only 55.00. Furthermore, the 25th percentile average for the older group further declined to a mean score of 26.40, whereas the 18 - 24 year old group attained a score of 95.00 at the 25th percentile cut-off. In contrast, the mental health scale showed little change throughout the adult lifespan (Ware et al., 2000). In the present study, it was of interest to see if physical functioning and mental health, one of which showed marked differences and one of which did not, had a differential influence on memory scores through the aging process. Collapsed across age and the six memory types, the correlation for mental health (SF-36) was r = .14 at Time 1, and r = .04 at Time 2, and so mental health was dropped from contention as a covariate in the present study as it clearly contributed little. Finally, physical function (SF-36) was eliminated as a covariate in the present study. Although it was quite highly correlated with memory types (see Tables 7.8 and 7.14), it did not reach statistical significance in any of the preliminary ANCOVAs.

Depression, too, has been found to have a negative effect on memory and, on the basis of past research, was expected to do so in the present study. Even transient negative moods can reduce performance on cognitive tasks (Ellis, Thomas, & Rodriguez, 1984; Hertel & Hardin, 1990). Perlmutter and Nyquist (1990) found in a group ranging from 60 to 90 years, depressive symptoms were associated with significantly lower scores on cognitive abilities for older, but not for younger people. Rabbitt et al. (1995) claim that increased age may increase the vulnerability to the impact of depression on cognitive abilities. In an experiment using volunteers aged 50 - 93 years, Rabbitt et al. showed that both greater age and higher BDI scores were associated with lower levels for all cognitive tasks. Notwithstanding such prior research, the present study measure of depression (BDI-II), collapsed across age groups and the memory types, had an average correlation of only r = .06 at Time 1.

Thus, the covariates of intelligence (as measured by the NART), verbal processing speed (Finding A's task) and nonverbal processing speed (Identical Pictures) were retained in the present study. Both ANCOVA and multiple regression analyses were carried out to examine the relationship between the six memory types, the three remaining covariates, and age.

The Effects of the Retained Covariates on Memory

Caution must be exercised when speculating about the role of covariates in memory. This is particularly important to bear in mind in view of the fact that the results of studies on old age and cognition are very mixed. Not only are the results inconsistent, but processing speed (verbal and nonverbal) and intelligence may overlap with memory. For instance, processing speed may be an integral part of what is meant by ‘memory’. Therefore, the interpretations made hereunder are speculative, and are made cautiously. What is known is that in the present study, when the covariates of verbal processing speed, nonverbal processing speed, and intelligence were taken into account, memory scores changed.

Verbal Recall

At Time 1, intelligence (as measured by the NART) exerted the greatest influence of the three covariates on verbal recall, measured by studying and then recalling a list of 25 unrelated words. For verbal recall, intelligence was statistically significant ($\eta^2_p = .08$). While, in ANCOVA, nonverbal processing speed did not reach significance for verbal recall, verbal processing speed did have a significant influence ($\eta^2_p = .04$). At Time 1, the percentage of change between adjusted and unadjusted scores for verbal recall showed an improvement in the scores of the young (+ 4.0%) and oldest-old (+ 3.7%), whereas the middle group score declined by 6.1% when the covariates of intelligence, and verbal and nonverbal processing speed were taken into account. At Time 2, when the effects of the covariates were excluded the scores for the oldest-old improved by 37.0%, compared with a decline in the young and middle groups of 14.2% and 8.5%, respectively.

Multiple regression analysis showed that at Time 1 the model including intelligence, processing speed (verbal and nonverbal), and age, accounted for 38.4% of the variance for verbal recall. Of this, intelligence, verbal processing speed, and age contributed 5.4%, 3.5%, and 8.2%, respectively, of unique variance, with the remaining 21.3% of the variance accounted for being contained in the overlap between the chosen covariates and age itself. This is unsurprising, as it is well known from prior research that, for example, processing speed and age are inextricably intertwined, and statistical control of processing speed can ameliorate age-related differences in memory to some degree (e.g., Baudouin, Vanneste, and Isingrini, 2004; Earles & Kersten, 1999; Salthouse, 2004). It can be expected that much of the R^2 will be made up of overlapping variance. Multiple regression has importance in the present study in demonstrating the variance unique to the individual covariates and age. For verbal processing, multiple regression paints a similar picture of the contributions of the covariates to that shown by ANCOVA analysis (Table 7.9), where intelligence and verbal processing speed contributed significantly to verbal recall, but age was the major factor in this ability. ANCOVA and multiple regression were in agreement in showing that intelligence remained an important covariate at Time 2.

Overall, for verbal recall, the adjusted R^2 at Time 2 showed that, together, intelligence, verbal and nonverbal processing speed, and age accounted for 49.5% ($p < .001$) of the variance, showing the model to be explaining 11.1% more of the variance for verbal processing at Time 2 than at Time 1. The 2-year interval between Time 1 and Time 2 reduced the effect of age (from 8.2% to 1.9%). It may be that in the 2-year period, the oldest-old rely more on raw intelligence to accomplish verbal memory tasks, perhaps by the increased use of compensatory strategies. This would lend weight to prior research which suggests older adults of higher intelligence preserve cognitive abilities to a greater degree than do those with lower intelligence (e.g., Crook et al., 1986; Giambra et al., 1995). Indeed, Giambra et al. conclude that while crystallised intelligence is preserved well until the mid-70s, it affects verbal ability to a greater degree by the late 70s and early 80s. Christensen et al. (1994) suggest that inter-individual variability increases for fluid intelligence, rather than overall intelligence, and memory for the oldest-old. Hill et al. (1995b) showed in a group of old participants (mean age = 81.58) that high intelligence predicted higher scores on verbal and nonverbal recall, and face recognition. Similarly, Rabbitt (1993) argues that intelligence predicts many laboratory indices of both memory and processing speed.

It seems that processing speed influences scores for the oldest-old. The unique contribution to the variance in verbal recall remained constant (3.5% and 3.4%) at Time 1 and Time 2 testing. It is likely that the time taken to encode and retrieve the words has a deleterious effect for the oldest-old participants. Encoding 25 words, one after the other, at such a speed is a problem for the oldest-old. Furthermore, slow retrieval requires the words to be remembered for longer, and this presents an added difficulty for the oldest-old. In the present research, the study phase of the verbal task was timed (3 seconds per word), whereas retrieval was not.

Considering the overall model accounts for 34.4% of the variance for verbal recall at Time 1, and 49.5% at Time 2, the unique variance attributable to all three covariates is quite small, particularly for verbal and nonverbal processing speed. This seems to provide evidence for an inextricable intertwining of memory and processing speed, and it is arguable whether memory and processing speed can, indeed, be separated. Bryan and Luszcz (1996) state that while speed of processing has been found to mediate the relationship between age and many cognitive tasks, research results have not been consistent for recall performance. Bryan and Luszcz suggest this is because previous research has not considered a possible confound between speed of processing and other influences of recall performance, such as the differential use of encoding strategies by younger and older adults. However, the speed at which the central nervous system processes information is likely to influence memory performance regardless of encoding strategies, locating age-related slowing, at least in part, in the neurobiological decrements known to occur in advanced aging. Cabeza and Nyberg (2000) report that encoding and retrieval of words are amenable to functional neuroimaging research because they happen at specific points in time, unlike the storage and consolidation of information. Cabeza and Nyberg found the encoding of verbal information is associated primarily with the prefrontal, cerebellar, and medial-temporal brain areas, and are always left-lateralised when encoding verbal stimuli. Cabeza and Nyberg state that five specific brain regions are involved in retrieval in verbal tasks – the prefrontal cortex, particularly on the right; the anterior cingulated cortex; the midline area which includes the posterior cingulate, retrospenial, precuneus, and cuneus regions; the parietal cortex; and the cerebellum, particularly on the left. Hippocampal/parahippocampal region activations have been found in some studies of verbal retrieval, although Haxby et al. (1996) suggest they are not as common as could be expected on the basis of lesion data.

Nonverbal Recall

For nonverbal recall, measured by studying and then reproducing 15 geometric shapes, multiple regression showed that the model accounted for 61.3% of the variance in this type of memory at Time 1, and 64.5% at Time 2. ANCOVA demonstrated that the covariate exerting the largest effect was nonverbal processing speed (η^2_p = .07) at Time 1 and (η^2_p = .05) at Time 2, while intelligence reached statistical significance at both test times. Again, age was the most important factor in this ability at both Time 1 (η^2_p = .18) and Time 2 (η^2_p = .13). Multiple regression similarly showed age to be the most important factor in nonverbal recall at both Time 1 and Time 2.

It is notable that 54.9% of the total variance for nonverbal recall remains after the unique contributions of the covariates and age are accounted for. This is indicative of the way in which the covariates overlap for this memory type.

The data at Time 2 were much the same as Time 1, save for very small increases in the role of intelligence and verbal processing speed. It is possible that, as it becomes more difficult for the oldest-old to remember the shapes, there is an attempt to aid memory by attempting to create a verbal representation of the shapes, although they had been designed to make this somewhat difficult. Cabeza and Nyberg (2000) report that neuroimaging research showed that the encoding of nonverbal information, whilst usually lateralised in the right hemisphere of the prefrontal brain area, nonverbal encoding sometimes also shows left lateralisation. This is likely to be associated with an attempt to create a verbal representation of nonverbal stimuli to aid memory. Mysak and Hanley (1958) suggest a two-thirds reduction in speech rates between young and old people, and Salthouse (1980) argues for subvocalisation rates being reduced by 75% in old, relative to young, people. It is possible that, for the oldest-old, an attempt to create a verbal representation in the 5-second presentation of a shape, and then another, and another, creates more of a problem than simply trying to remember the shape itself. While it may that the age decrement in memory for shapes could be ameliorated if a correction were made for slower reproduction, the present study did not impose a reproduction time limit. It seems, rather, that the age-related decline is likely to be related to slower processing resulting in memory trace decay before the shape can be reproduced, or a slowing of the encoding process resulting in the shape disappearing from the computer screen before the memory trace can be established.

Cabeza and Nyberg (2000) suggest the prefrontal, cerebellar, and medial-temporal areas of the brain in are implicated in nonverbal encoding. Grady et al. (1998) found that during nonverbal encoding the medial-temporal activations were bilateral rather than the left-lateralised pattern found in verbal encoding. Furthermore, it appears the strength of medial-temporal activations determines not only what stimuli will be remembered, but how well they will be remembered (Brewer et al., 1998). As well as the five brain regions reported by Cabeza and Nyberg as essential to retrieval (prefrontal cortex, anterior cingulate cortex, posterior midline and associated structures, parietal cortex, and cerebellum), occipital activations occur, parietal activations are right-lateralised, and the posterior cingulate all are important to nonverbal retrieval. As the frontal and medial-temporal brain areas are amongst the first, and most markedly, affected by aging, it is likely this contributes to the difficulty the oldest-old have with nonverbal recall, and why it seems to be the memory type which shows the earliest decline.

In the present study, nonverbal recall was the memory type in which decline was most noticeable in the middle group (50 - 70 years of age). At Time 1, the middle group scores were an average of 14.7% below that of the young group, and the oldest-old performed much more poorly, with scores 66.2%, on average, below the young group. This is in contrast to the expectation of Giambra et al. (1995) who suggested, because geometric patterns involve highly distinctive stimuli, memory for patterns or shapes could be expected to be insulated from the effects of aging. Every effort was made in the present study to produce simple geometric shapes which were distinct from one another (Appendix I). It appears that the task proved particularly difficult as *all* the shapes were presented at study before the participants were required to reproduce them, unlike tasks such as the Visual Reproduction sub-test of the Wechsler Memory Scale – Revised (Weschsler, 1987) where participants reproduced each stimulus immediately after viewing it. The design utilised in the present study was chosen to make the structure of the recall task for words and shapes similar.

By Time 2, a marked decline had occurred for the oldest-old, compared to their performance at Time 1. Both the young and middle groups, in contrast, showed an improvement at Time 2. While the young and middle-aged people derived a small benefit from the test-retest effect even though there was a 2-year inter-test interval, the oldest-old did not, although it is possible that the practice effect (if any) was masked by the overall deterioration for the oldest-old. The delay conditions of the present study were unable to be analysed with any degree of confidence because of the floor effects found with the oldest-old, and this would lend support to the supposition that the oldest-old do not retain enough information about the stimuli over sufficiently long periods of time to benefit from test-retest designs. This will be discussed in more detail in a later section.

Short-term memory

In the short-term memory task (digit span), the only covariate to make a statistically significant impact was intelligence (η^2_p = .07 at Time 1, and η^2_p = .17 at Time 2). In ANCOVA, Age was not significant, supporting the robust findings of prior research that short-term memory is largely unaffected by age, at least into the early 80s (e.g., Craik, 1986; Hickman et al., 2000; Salthouse & Babcock, 1991; Small et al., 2003). The ANCOVA and multiple regression analyses converged, showing age failing to reach significance at either Time 1 or Time 2.

The adjusted R^2 showed that the amount of variance in sort-term memory accounted for by the model increased from 18.3% to 38.7% over the 2-year period. The present study supports the finding from prior research that there is little change in short-term memory ability with age. However, although it is a relatively small change compared to other types of memory, short-term memory also shows some decrement in very advanced old age.

Working memory

The measure for working memory (letter-number sequencing) was not a timed task, and neither verbal nor nonverbal processing speed reached significance. However, intelligence was an important covariate (η^2_p = .05). Age was by far the most important factor for working memory (η^2_p = .25). There were only small differences between Time 1 and Time 2.

Working memory is a memory type affected by age more than any other memory type, except nonverbal recall, at both Time 1 and Time 2. This is supportive of prior research which suggests limitations in working memory constitute an explanation, at least in part, for age-related changes in memory (Craik & Rabinowitz, 1984). Myerson et al. (2003) suggest reorganising items such as digits and letters requires substantial executive processing, and so argue that the pronounced age-related decline found in the letter-number sequencing task may well be attributable to decline in executive aspects of working memory.

While the participant response to each item in the letter-number sequencing task was not subject to any time restriction, the letters and numbers to be resequenced were read to the participant at the rate of one per second. Baddeley (2004) suggests if the rate of flow of information is not under an individual's control, older adults are more likely to make errors than younger people. While this may have been a difficulty for the oldest-old, it does not account for their poorer performance in working memory, compared to short-term memory, as the presentation of digits in the digit span task was also at 1-second intervals. The working memory task, however, requires participants to simultaneously hold and manipulate information before a response is made. Letters and numbers must be separated from one another, and then the numbers reordered into ascending order, and the letters into alphabetical order. This task was was clearly difficult for the oldest-old. It is likely that processing speed contributed to this difficulty. If the slowing typical of aging deleteriously affected the speed with which the oldest-old were able to sort out and reorder the letters and digits, then it is likely the memory trace of the items were lost to decay before the task was complete. If this type of processing speed is integral to working memory, it again raises a question about treating processing speed (in the case of working memory, at least) as an independent covariate.

Overall, at Time 2 of the present study, the adjusted R^2 shows that 70.2% of the variance for working memory is accounted for by adjusting for intelligence, verbal and nonverbal processing speed, and age. Such an extensive overlap of factors involved in working memory could be expected if, indeed, the age-related decline found in working memory is largely attributable to losses in executive aspects of the memory type (e.g., Norman, Kemper, & Kynette, 1992). Salthouse (1996a) argues that processing speed predicts working memory capacity and mediates between age and memory. This raises the question as to what causes the age-related differences in the general speed factor. Luszcz and Bryan (1999) suggest a neuropsychological model motivated by three lines of evidence. Firstly, the frontal lobes appear to be the brain area affected early and extensively by aging. Secondly, older adults usually perform more poorly than their younger counterparts in neuropsychological tests and, thirdly, there appears to be a remarkable similarity between memory deficits experienced by healthy older adults and people with frontal lobe lesions, such as impairments of free recall and sequencing of responses such as in the letter-number sequencing task.

Evidence for the impact of the aging brain on working memory tasks is mounting. For example, Petrides, Alivisatos, Evans, and Meyer (1993) have found, in a PET study, that the mid-dorsolateral frontal cortex is related to monitoring information within working memory. Cabeza and Nyberg (2000) also emphasise the importance of the frontal lobes in working memory tasks – an area known to be deleteriously affected by aging. In addition to prefrontal activations, Cabeza and Nyberg report that letter/numeric tasks also activate the parietal lobe, with the tendency to left lateralisation suggesting these tasks are phonologically stored and manipulated. Woodruff-Pak (1997) reports that the first part of the brain to be negatively affected by aging is the frontal lobe area, and this will be reflected in the difficulty the oldest-old demonstrate in working memory tasks. Additionally, Woodruff-Pak and and Papka (1999) state that it is the medial temporal lobe circuitry for declarative memory that is most affected by processes of both normal and pathological aging. Ylikoski et al. (2000) report that hippocampal atrophy has been found in one-third of healthy elderly people, although “whether different temporal lobe structures contribute to memory performance in healthy subjects is still a matter of controversy” (p. 273). The oldest participants in the Ylikoski et al. study were 70 years old at baseline testing (of a 5-year study), so the oldest-old were not included. The interwoven influence of the aging brain and processing speed on working memory is an area which is in need of further research attention.

Although the working memory task was similar in construction to the short-term memory task, with an added processing component (requiring the participant to reorder the letters and numbers), it clearly stretched the resources of the oldest-old. Verbal processing speed is again important, as the slower the speed of manipulating the information mentally, the longer the items must be remembered, and this is of the greatest difficulty for those over 85 years of age. As the memory fails, the slowness of the processing seems to mean decay of the memory trace occurs before the task is complete, and there is more chance that forgetting, or getting confused, will occur, especially in the oldest-old.

Face recognition

In ANCOVA none of the three covariates analysed in the present study reached statistical significance for face recognition at Time 1, although by Time 2 the contribution of the three covariates had increased slightly (see below). It appears that in the decline for the oldest-old group (14.7% at Time 1 and 19.8% at Time 2, relative to the young group), age is the critical factor. The relatively low η^2_p for age ($\eta^2_p = .07$ at Time 1, and $\eta^2_p = .12$ at Time 2) reflects the finding that face recognition is a memory, along with short-term memory, which is least affected by advanced aging.

Multiple regression at Time 1 also showed that intelligence and nonverbal processing were not significant contributors to face recognition. Verbal processing, however, did reach significance, contributing 3.4% of unique variance to the overall adjusted R^2, which indicated the model accounted for 38.1% of the total variance for face recognition. As in the ANCOVA, multiple regression showed the influence of age increased slightly at Time 2, as did verbal processing speed, and intelligence accounted for 3.0% of unique variance.

ANCOVA showed a similar picture, with intelligence (η^2_p = .05), nonverbal processing speed (η^2_p = .03), and verbal processing speed (η^2_p = .05) contributing to face recognition at Time 2, whereas at Time 1 they had not. It seems that the processes supporting the ability to recognise faces changes over time, although such small changes must be viewed with caution as they could be nothing more than random fluctuation. Perhaps, as people age, general slowing makes the timed encoding difficult – participants had 5 seconds to study each face, followed by an inter-stimulus interval of 3 seconds. Prior research has found that 8 seconds per stimulus face (presentation time plus decision time) is ample for young people (e.g., Anastasi & Rhodes, 2006; Lamont et al., 2005), but, to date, little research has been carried out during the late ninth and tenth decades of life. It would be a simple matter, in further research, to vary presentation time to clarify this with the oldest-old. It is likely that the pressure to gather the information relatively quickly overloads the resources of the oldest-old and the memory of individual faces is lost before they are transferred into the long-term memory. Additionally, faces are rather homogeneous stimuli (In the present study, all were male, clean-shaven faces devoid of distinguishing expression or clothing) making it all the more difficult for the oldest-old to keep the images separate in the memory when one face is followed by another, and another, and so on. It is hard to say whether the problem with face recognition at an advanced age is with the encoding or retrieval stage. The encoded image may lack detail, resulting in the increased false alarms that have been reported in prior research (e.g., Lamont et al., 2005).

Research has been equivocal as to whether the age of stimulus faces has a bearing on how well they are remembered. Are young and old stimulus faces remembered equally well? While only a handful of studies have considered how the age of the target face may interact with the age of the participant, such an interaction might be expected. Lamont et al. (2005) found that although there was a decline in face recognition ability with age, this occurred only for young stimulus faces, providing an important qualification to the claim that face recognition declines with age. Lamont et al. found that whilst young people were equally adept at recognising young and old faces, elderly people were not. The elderly people's decline was primarily in the recognition of young stimulus faces, whereas old stimulus faces were remembered quite well. Of interest, Lamont et al. found that this decrement in remembering young faces was already evident in middle-aged people, demonstrating that the decline in remembering young, but not old, faces commences relatively early. Thus it was in the present study. Although only the oldest-old group showed a significant decline at either Time 1 or Time 2, there is an effect of target age evident in both the middle and oldest-old groups in a pattern similar to that found in the Lamont et al. (2005) study.

Although face recognition is a skill which deteriorates at a slower rate than other types of memory, with the exception of short-term memory, the mechanisms used to maintain this type of memory appear to change over time. Intelligence and processing speed become more important to the maintenance of the skill, and age itself seems to become a less reliable predictor of face recognition ability in very old age. This is in contrast to the recall tasks of the present study (both verbal and nonverbal). While a recall task requires participants to generate the target items in the absence of cues, a recognition test usually requires participants to accept or reject items which have been seen before (targets) from those which have not been seen before. It could be expected a superior score would be attained on a recognition test compared with a recall task, as the act of recognition requires the matching of a stimulus to a stored trace rather than retrieval without any cues. This is a prediction well supported by research. While many researchers have found recognition tests reduce or negate the age-related decrements demonstrated in recall tests, others have found that recognition memory is affected negatively by increasing age (e.g., Ferris et al., 1980; Parkin & Walter, 1992; Tulving, 1985). It seems likely that both general slowing, reflected in the increased influence of processing speed, and the changes taking place in the aging brain during very old age, underlie the decrement in face recognition for the oldest-old. Haxby et al. (1996) found, using PET (particularly regional cerebral blood flow) scans, that attempting to commit unfamiliar faces to memory and subsequently attempting to recognise the faces from distractors, utilise largely dissociable brain areas. Whereas left prefrontal and left inferior temporal areas are associated with face encoding, the right prefrontal and bilateral parietal and ventral occipital areas are associated with face recognition. Haxby et al. found that the prefrontal involvement with encoding applies to verbal information as well, suggesting that the prefrontal area has a general role in memory independent of information type. It may well be that the dissociation of areas implicated in the encoding and recognition of faces contributes to face recognition being less affected by aging that most other memory types.

Prospective memory

The inclusion of prospective memory tasks in the present study denotes the importance of this type of memory, especially in advanced old age. Researchers such as d'Ydewalle et al. (1999) and Einstein et al. (1995) point to the gap in memory literature created by a dearth of prospective memory research. Craik (1986) argues that the elderly are likely to suffer age-related declines in prospective memory tasks because such tasks must be remembered and performed without the presence of retrieval cues (self-initiated tasks). The present study included two tasks designed to test prospective memory ability across the three age groups. Firstly, participants were required to ask two particular questions when a bell was rung some 20 minutes later and, secondly, to remember to ask for, and remember the location of, a personal object they had given to the researcher. The cue for this task was the researcher announcing the end of testing and proceeding to pack up the computer.

Of the three covariates utilised in the present study, only nonverbal processing speed reached statistical significance ($\eta^2_p = .04$) for prospective memory. Age, itself, produced a large effect ($\eta^2_p = .12$). Multiple regression supported the ANCOVA, with the only significant covariate being nonverbal processing speed which contributed 2.0% of unique variance to the total variance accounted for. The unique contribution of Age was 3%. This leaves a large proportion of the total variance contributed (40.2%) by the overlap between the various covariates and Age for this memory type.

By Time 2 testing, intelligence appeared to play a greater role in prospective memory ($\eta^2_p = .09$), a substantial increase from Time 1. Nonverbal processing speed remained constant across the two test times. At Time 2 testing, the variance due to Age increased from $\eta^2_p = .12$ at Time 1, to $\eta^2_p = .27$ at Time 2. Multiple regression, too, highlighted the increased importance of intelligence at Time 2. After the 2-year interval between testing, the model accounted for an increased amount of the total variance for prospective memory – 65%. Intelligence contributed 4.2% of unique variance to this, from having no effect at Time 1. Multiple regression also showed an increased role for age at Time 2.

In contrast to Craik's (1986) expectation that an age-related decline could be expected in prospective memory, Einstein and McDaniel (1990) found no such decline in a study of young (17 - 24 years of age) and old (65 - 75 years of age) participants. The participants were required to press a key when a target word appeared amidst a short-term memory task, with or without the presence of an external cue. However, the majority of prospective memory studies do report decrements in older age groups (d'Ydewalle et al., 1999; Einstein et al., 1995; Einstein et al., 1992; Park et al., 1997), The lack of inclusion of the oldest-old has left an unclear picture of prospective memory in the late ninth and tenth decades of life, making the prospective memory tasks in the present study particularly interesting.

As for other types of memory where there are steep declines in performance for the oldest-old, Burgess, Quayle, and Frith (2001) have found, in a study of the brain regions involved in prospective memory, that at least some of the processes which are critical to realising delayed intentions are supported by brain structures located in the frontal lobes and related structures. The Burgess et al. study used only younger (20 to 46 years) adults, and the researchers point out that the relationship of differing brain structures for prospective memory tasks is complex and has not, as yet, received sufficient research focus to fully describe the neurobiological substrates of this type of memory. Nevertheless, it is clear that the implication of the frontal area of the brain, an area associated with the earliest age-related declines in cognition, contributes to the difficulty the oldest-old encounter with prospective memory.

Overall Effects of the Covariates

An interesting finding in the present study is that not only did the exclusion of the covariates increase the scores of the oldest-old in all memory types, but such exclusion was found to slightly but consistently worsen the scores for the young and middle group participants. The only exception to this was for word recall for young people at Time 1, where the score did not deteriorate with the exclusion of the covariates. However, at Time 2, word recall did decrease when the effects of the covariates were removed.

While it is apparent that processing speed and intelligence affect the oldest-old increasingly over time, the reason(s) why the performance of the young and middle group participants was disadvantaged by their exclusion remains, as yet, unclear. If the slight decrease in scores is real when the covariates are controlled for, then it could be that processing speed is an aid to memory for the young and middle groups but an impediment for the oldest-old.

The Longitudinal Effects of the Covariates

While the pattern of the covariate effects was similar at Time 1 and Time 2, the difference between uncorrected and corrected scores increased substantially over two years for the oldest-old group (Table 7.18). As all corrected scores for the six memory types improved from Time 1 to Time 2 for the oldest-old, it appears that the covariates (verbal and nonverbal processing speed and intelligence) were having greater effect two years later.

Intelligence accounted for an increased amount of the variance across all memory types, with the exception of working memory, at Time 2. It seems that as people move into very old age and memory declines, intelligence becomes increasingly important for maintaining cognitive abilities during very old age. Hertzog (1989) suggests that it is likely there is an age change in intelligence independent of age changes in processing speed. The present research provides some support for this. It is particularly interesting that the role of intelligence increased across all memory types with the exception of working memory, as overall scores on the covariate of intelligence (measured by the NART) dropped over time for the oldest-old from 111.5 at Time 1 to 107.7 at Time 2. It may be that intelligence was a stronger covariate because of this – that the drop in memory scores was, at least in part, because of the drop in IQ. The results of the present study do not allow for a clear interpretation of the role of the increased influence of intelligence. Intelligence had a greater effect on the memory score at Time 2, but this does not necessarily translate into intelligence having a great impact on a person’s memory. It may simply mean that both memory and intelligence share some other common factor that causes them to overlap.

Additionally, the NART is a measure of crystallised intelligence (Parkin & Java, 1999), used in aging research because crystallised abilities are known to be relatively stable across the lifespan, compared to fluid abilities which typically show age-related decline.

As the tasks in the present study utilised fluid abilities, explanations for the increased role of intelligence across the memory types must be viewed with caution.

It has been suggested that intelligence may be protective of verbal abilities, but not nonverbal abilities in old age (Hultsch et al., 1984, 1990; Shimamura et al., 1995). This is supported, in part, by the present study where the unique variance contributed by intelligence rose from 5.4% at Time 1 to 9.5% at Time 2 for verbal recall, whereas for nonverbal recall it changed only from 2.0% at Time 1 to 2.4% at Time 2. Intelligence appears to have supported verbal recall at Time 2 more than it did nonverbal recall. It is possible that the rate of deterioration in the aging brain is greater in the areas associated with memory (primarily the pre-frontal cortex and associated structures), than in areas associated with general intelligence. Duncan et al. (2000) suggest intelligence reflects the function of a specific neural system, including a particular region of the lateral frontal cortex. Sternberg (2000) questions this, noting that fewer frontal lobe activations have been reported during tests of intelligence in people who have high intelligence scores. However, the exact functions of the lateral frontal cortex which Duncan et al. suggest are important to intelligence are still unknown: future research testing the abilities of people with damage to the lateral frontal cortex, may shed light on the brain pathways involved with intelligence.

The contribution of both verbal and nonverbal processing speed for all memory types was much the same at Time 1 and Time 2. However, the mean scores for nonverbal processing speed for the oldest-old group declined from 33.60 to 30.48 between Time 1 and Time 2. Similarly, the mean scores for verbal processing speed, 39.98 at Time 1 and 35.43 at Time 2, show that the oldest-old had slowed in both the verbal and nonverbal tasks over a 2-year period.

The Effect of Age

Although age remains the most important factor in memory decline for the oldest-old, its influence was greater at Time 1 than at Time 2 testing. Multiple regression showed the unique contribution to the variance in memory types to be 8.2%, 5.1%, 9.2%, and 3.0% for verbal recall, nonverbal recall, working memory, and prospective memory, respectively. Two years later, the unique contribution of age was generally less, being 1.9%, 2.9%, and 5.1% for verbal recall, nonverbal recall, and working memory, respectively. However, age had become statistically significant for face recognition

(1.4%), and for prospective memory the influence of age had increased to 5.8%. The changes over time are small, but were observable over the 2-year inter-test interval. This contrasts with the finding of Hickman et al. (2000) who found that healthy adults between 65 and 94 years of age did not decline faster over a 4-year period than young-old adults (65 - 74 years) on a series of neuropsychological tests. As participants were tested on five occasions over the four years, Hickman et al. suggest it remains unclear whether practice effects compensated for age-related decline, giving the illusion of stability on many tests, particularly for the oldest-old. In the present study, participants were tested only twice, with a 2-year interval between Time 1 and Time 2 testing, in an attempt to minimise practice effects.

In a population-based study of nonagenarians, Hassing et al. (1998) found that in their very old sample, age had a surprisingly small effect on cognitive tasks. Age, gender, and education together accounted for only 3% - 8% of the variance on the independent measures of verbal and object recall. This contrasts with Bäckman and Wahlin (1995), for example, who found the same variables of age, gender, and education accounted for between 10% and 18% in a study of young-old adults. It may be that as people move into very advanced old age the typical age-related changes in memory become less apparent as it is likely they reflect an increasingly genetically select group (Hickman et al., 2000). This is a phenomenon that is likely to be amplified in a sample that is screened for mental and physical health, as in the present study. The 2-year gap between testing in the present study may be short in terms of typical longitudinal studies, but becomes a significant length of time for the oldest-old whose expected remaining lifespan can most likely be measured in single digits.

Across the six memory types, it is notable that the difference between unadjusted and adjusted scores increased markedly for the oldest-old group over the inter-test period of two years. It seems possible that intelligence plays an increasing role in maintaining most memory types as people reach the late ninth and tenth decades of life. Bearing in mind the equivocal findings regarding the specific neural systems implicated in intelligence, it seems likely that as advanced aging takes a toll on the brain structures associated with memory, increased reliance is placed on the brain pathways involved with intelligence. For short-term memory it is intelligence rather than age that exerts the most influence in test scores. Intelligence played an increased role at Time 2 for all memory types for the oldest-old. At the same time, the role of age decreased slightly except for prospective memory where there was an even sharper increase in the effect of age than for other memory types. While there were problems with the homogeneity of variance in Time 2 ANCOVA, the multiple regression analyses, where there were no violations of assumptions, seem to support this interpretation. An ANCOVA using intelligence as the only covariate supported this conclusion. The changes are small, but consistent, and this would be an interesting matter for further research.

Overall, although the analysed covariates had some effect, age was still the major factor in changing scores across the age groups. Only for digit span (measuring short-term memory) did age not reach statistical significance.

Delay

The present study was designed with delay as a factor for both verbal and nonverbal recall. It was considered desirable to ascertain whether the middle and oldest-old participants were disadvantaged, compared to the young group, when information needed to be retained over 10-minute and 7-day periods. It was decided to introduce delay in an attempt to observe whether encoding had taken place - if participants could recall a word or shape after a 10-minute period it had, indeed, been encoded. If, after a 7-day delay recall failed, then this is likely to be due to information fading while stored or due to a problem with the retrieval mechanisms.

It was found that some of the oldest-old participants had great difficulty with delayed recall. The difficulty the oldest-old had with the delay between study and recall is evident from the number of zero scores found in the delayed recall tasks. In immediate verbal recall at Time 1, all of the oldest-old scored above zero, although the task was difficult for some, as 5 of the 42 oldest-old scored either one or two correct. After the 10-minutes delay, five of the oldest-old scored zero, and after the 7-days delay the number scoring zero had risen to 17. Two years later, at Time 2 testing, scores had declined even further. Eight participants scored either one or two for immediate recall, at 10-minutes delay 12 participants scored zero, and at the 7-day delay test, 22 out of the 42 oldest-old participants scored zero.

Nonverbal recall scores reflected a similar difficulty with delayed recall for the oldest-old. At Time 1, immediate recall of shapes resulted in a zero score for one participant, after 10 minutes this had risen to 10 participants with a zero score, and after 7 days 16 of the 42 participants had a score of zero. At Time 2, three individuals scored zero at immediate recall testing, 10 scored zero after 10 minutes, and after 7 days 19 participants scored zero.

These results were unexpected. The shapes test, devised for this study, had been pilot tested (see Appendix I) with volunteers aged 77 to 84 years, none of whom scored below 12 when asked to recall the shapes immediately after study. It seems as though there is a watershed time somewhere in the late 80s where the retention of nonverbal information over even a short delay period becomes increasingly difficult. In hindsight, the pilot testing should have been carried out on a sample 85+ years of age. Because of the difficulty in finding available oldest-old participants who met the screening criteria, all such volunteers were recruited into the study. This topic will be taken up again in the limitations section.

In the present study, only those participants who completed both Time 1 and Time 2 testing were included in any analyses. In the oldest-old group, five participants who took part only at Time 1 were eliminated from analyses. Interestingly, *all* of these participants had zero scores for both the 10-minute and 7-day delays in both verbal and nonverbal recall. It is only a small number, but perhaps can be taken as some support for the position of a noticeable decline in cognitive abilities prior to death (e.g., Bosworth & Siegler, 2002; Cooney et al., 1988; Riegel and Riegel, 1972; Siegler, 1975; White & Cunningham, 1988). Had these participants been included, the unexpected floor effect would have been even greater.

It would have been inappropriate to include the delay task in the main analyses of the present study because of the truncated *SD*s caused by the large number of zero scores. Nonetheless, the descriptive data underscore the importance of memory research with the oldest-old. The oldest-old clearly had great difficulty with the delay conditions in the present study, but delay tasks have been included in very few studies of the oldest-old to date. At the present time, this is a very under-researched group, within the vast body of literature on memory.

Towards a Theory of Aging and Memory in Normal, Healthy Adults

As yet, although many theories of aging have been proposed, none have emerged which encompass the memory changes in very old age. As research has made forays into the study of the memory of those over the age of 85 years, results have emerged in a piecemeal fashion covering varied types of memory and factors which are likely to interact with memory. A robust finding has emerged in the few studies of memory that have included the oldest-old: Increased age leads to decrements in many aspects of cognition, quite apart from dementia or other mental or physical illness. Unlike studies that have examined memory in individuals up until their late seventies or early eighties and have found memory decrements which tend to be linear, it is emerging that the oldest-old present somewhat different patterns of memory loss.

The mechanisms and processes underlying differing trajectories of decrement are still far from understood. For example, it is firmly established that aging itself results in a general slowing in processing speed, but the same cannot be said for understanding the processes which underlie such slowing. The impact of processing speed on some types of aging memory raises the question of whether processing speed effects can legitimately be removed, at least for some memory types. Some memory tasks are speed-dependent for success. For example, if either encoding or retrieval is deleteriously affected by slow processing speed, then the memory per se will appear poor. Working memory provides a good example: it is clearly speed dependent, or at least laboratory tests of working memory are speed dependent. It could well be found in future research that processing speed is an integral part of memory itself, at both encoding and retrieval stages, at least for some types of memory. If this is the case, then future attention must be focused on the theoretical implications of statistical control of processing speed.

So, what changes might be expected during the normal aging process as individuals reach the late ninth and tenth decades of life? And what are the processes most likely to underlie the expected changes? First and foremost, the present study supports the notion that age itself is the most important predictor of memory change for the oldest-old for most, if not all, types of memory. A possible exception is short-term memory which seems to be better preserved than other types of memory. All memory tasks require the encoding, storage, and retrieval of information, but the short-term memory task in the present study (digit span) required participants to retain information for a limited amount of time only. The oldest-old are particularly disadvantaged on tasks such as verbal and nonverbal recall, working memory, and prospective memory, which require participants to retain information over longer periods of time.

A likely underlying cause of the increasing difficulty the oldest-old experience with memory tasks is the neurobiological changes which occur with advancing age, whether at a cellular, structural, or neural circuitry level. Memory is not a unitary function, and researchers such as Loeb and Poggio (2002) have shown that different types of memory are distributed across differing brain areas and are dependent on a variety of neural systems such as those focused on the cerebellum, neocortex, hippocampus, amygdala, basal ganglia, and thalamus. Over and above this complex picture, it is now understood that after about 80 years of age brain tissue is being lost at a rapid rate (Loeb & Poggio, 2002). Encompassed within the loss of brain tissue is the reduction of some 15-20% of synapses in the frontal cortex alone between the ages of 1 and 98 years (Gibson, 1983; Masliah et al., 1993), and the expansion of the cerebral ventricles and enlargement of the cerebral sulci (Stafford et al., 1988). It has been established that marked deterioration (primarily volumetric loss and atrophy) occurs in the frontal lobes, medial-temporal region, basilar-subcortical region, and the hippocampus (Petersen et al., 1998), key areas for memory which were found by Meuller et al. (1998) to have the greatest volumetric loss in the 30 year span between 65 and 95 years of age.

The frontal lobes are important for many types of memory, particularly for the completion of tasks with a working memory component (Woodruff-Pak, 1997). Furthermore, Woodruff-Pak argues that this is the brain area first affected by aging. Additionally, a marked similarity between the memory deficits of healthy, oldest-old adults and individuals with frontal lobe lesions has been found for many tasks, including working memory, encoding, retrieval, and recall – all of which are central to the preservation of memory performance (Luszcz & Bryan, 1999; Moscovitch & Winocur, 1992; Raz, 2000).

Much work remains to be done to fully understand the complex relationships between the aging brain and memory. It has been established that much of the age-associated memory impairment of the very old is attributed to neurobiological and neurochemical changes. This is likely to be reflected in increasing deficits particularly in verbal and nonverbal recall (both at the encoding and retrieval levels), working memory, and prospective memory, the memory types which showed the greatest decrements in the present study. Other types of memory will also be affected, but those memory types which are less reliant on frontal lobe and hippocampus activity may be somewhat protected (Ylikoski et al., 2000). For example, there is evidence that faces are primarily processed in the fusiform gyrus of the temporal lobes (Haxby et al., 1996), and this is a type of memory quite well preserved in old age. Nevertheless, the oldest-old may be expected to be most affected by the aging of the brain, as neural deterioration is greatest for these people.

Theoretical evidence has mounted for a reduced-resources account of memory loss during advanced aging. Luszcz and Bryan (1999) define processing resources as the reservoirs of mental energy, and Craik and Byrd (1982) proposed that reduced resources lead to a shrinkage in the richness, extensiveness, and depth of processing operations at both encoding and retrieval. Arguably, the reduced processing resource theory which has received the most attention (in the elderly) is that of a reduced processing speed. This hypothesis argues that the speed with which basic cognitive operations are carried out places fundamental limits on all aspects of cognitive functioning, including memory (Luszcz & Bryan, 1999). It has been suggested that age-related differences in memory may be a function of slower processing speed, primarily because memory traces for previous operations may be lost to decay before later information is processed, weakening the linkages between representations (Salthouse, 1996a). The speed hypothesis has impressive support (e.g., Lindenberger et al., 1993; Park et al., 1996; Salthouse, 1993, 1994) with many researchers finding that memory decrements are greatly ameliorated when processing speed is controlled for. However, in many other studies processing speed accounts for considerably less of the variation (e.g., Hultsch et al., 1990; Rabbitt, 1993; Schaie, Maitland, Willis, & Intrieri, 1998). Interestingly, Zimprich (2002) found, in a research design combining cross-sectional and longitudinal data, that while cross-sectional analyses provided impressive support for processing speed theory, longitudinal studies provide much weaker support. This supported the finding of Sliwinski and Buschke (1999) when they juxtaposed cross-sectional and longitudinal age-difference effects. Cross-sectionally, speed of processing accounted for 70% to 100% of age differences in verbal tasks, whereas longitudinal analyses (over 4 years) reduced this to 6% to 29% of variance accounted for by processing speed in the Sliwinski and Buschke study. Schaie (1989) also cautioned about regarding processing speed as a single-effects model, as analysis of data from the Seattle Longitudinal Study made it clear that substantial age effects remained, even when processing speed was partialled out.

In the present study, at Time 1 verbal processing speed reached significance only for word recall, although at Time 2 statistical significance was reached for word recall, working memory, and face recognition. Nonverbal processing speed reached statistical significance only for shape recall and prospective memory at Time 1. Nonverbal processing speed exerted a similar influence two years later, although at Time 2 face recognition also reached statistical significance. For word recall, short-term memory, and memory, intelligence exerted more influence on participants' scores than did verbal and nonverbal processing speed combined. A similar picture emerged at Time 2, with prospective memory also influenced more by intelligence than by the combination of verbal and nonverbal processing speed. The present study supports the assertion of Schaie (1989) who cautioned against the suggestion that controlling for processing speed could ameliorate most, if not all, age-related decrements in memory.

There is little agreement in prior research on the causes of the differential decrements for various types of memory once control for processing speed has been applied. The study of the discrepancies between the trajectories of decline for differing types of memory may well be a valuable means of identifying genuine age-related memory impairment, as opposed to the effects of an age-related depletion of resources. Whilst it is clear that normal, healthy oldest-old individuals will be affected by a general slowing of processing this, in itself, does not account for the steep declines found in most types of memory at such advanced ages (Schaie, 1989; Sliwinski & Buschke, 1999; Zimprich, 2002).

Embodied in any theory of memory and aging must be the role of the central executive, and its effect within working memory, as a mounting body of literature has implicated a decrease in central executive efficiency in age-related working memory loss (e.g., Fisk & Warr, 1996; Salthouse et al., 2003; Salthouse & Babcock, 1991). Central executive functioning may be broadly defined as "control processes responsible for planning, assembling, coordinating, sequencing, and monitoring operations" (Salthouse et al., 2003, p. 566).

The focus on the central executive suggests a neuropsychological theory of aging and memory rather than a purely cognitive one, as its functioning is associated with the frontal lobes of the brain. This approach would suggest a neurobiological underpinning of the deterioration of the central executive, as the frontal lobes show early and extensive losses during the aging process. Researchers, such as Troyer et al. (1994), argue that age predicts memory performance before, but not after, measures of executive function were partialled out, and that executive functioning accounted for

36% of the variance in recall. However, Fisk and Warr (1996) found in a study of older people up to the age of 80 years, that controlling for central executive functioning left 60% of the age effect of processing speed intact. They concluded that advancing age is associated with the slow down in the rate of information activation within the working memory system, rather than it being confined to the central executive.

Although central executive functioning must be included in any theory of memory and aging, it must also be recognised that it is one further aspect to be investigated in forming any such theory, rather than providing a comprehensive explanation of age-related memory loss. Working memory appears to be a complex mechanism, and Luszcz and Bryan (1999) argue that identifying it as a mediator of age-related declines in memory depends on the way it is operationalised and manipulated, as well as the nature of the utilised memory tasks. Of particular concern to Luszcz and Bryan is the validity of tests of executive function, particularly the difficulty of establishing the specificity of these tasks, and differentiating between executive and nonexecutive tasks. Despite these concerns, Luszcz and Bryan found that central executive functioning made an independent contribution to age-related memory decrements in very old people. They caution, however, that further research is required to delineate the possible interconnections between executive function and memory performance. Normal, healthy adults over the age of 85 years will have decrements of working memory, which are likely to be attributable, at least in part, to a deterioration of central executive functioning. Baddeley (1994) notes that central executive functioning is the least understood part of working memory.

A comprehensive theory of aging and memory will also be inclusive of the ability to maintain attention, described as “a selective agent that regulates the flow of information and restricts the operation of memory processes” by Nieuwenstein (2004, p. 225). Typically, in a selective attention task participants may be required to scan a list of words searching for a target letter, thereby selectively attending to the target letter while discarding other letters. Age-related differences in attention have been found. Plude and Doussard-Roosevelt (1989) found that if a task required participants to base their selection on two or more features, such as finding a red *X* in a field of both green *X*s and red *O*s, for example, older adults had a slower search rate than their younger counterparts. This leaves the question of whether such findings are entirely due to attention, or whether processing speed effects are also implicated. Findings on the ability to inhibit extraneous, distracting information (attention) have remained equivocal.

Rogers (2000) contends that understanding the role of inhibition may provide a unifying theory for age-related difference, but at the present time this remains a controversial issue. It appears that while some normal, healthy oldest-old individuals may experience decrements in attention while undertaking selective and divided attention tasks, others will not. Berardi, Parasuraman, and Haxby (2001) found no age differences between young (20 - 39 years), middle-aged (40 - 59 years), and older adults (60 - 63 years) on a digit discrimination task designed to investigate sustained attention. Results showed overall levels of vigilance and ability to sustain attention over time was equivalent in all groups under conditions of both automatic and effortful stimulus processing. Conversely, Giambra (1991) reported very small changes with age have been observed in investigations of sustained attention, associated with an increased rate of false alarms for older adults, although Giambra points out that because of the marginal age effect more research must be carried out in the area of sustained attention before statements can be made.

A complete theory of aging and memory will also need to address the relationship between sensory functioning and memory, termed the common cause hypothesis (Baltes & Lindenberger, 1997). The common cause theory claims that sensory and cognitive aging are closely related, and sensory functioning should, therefore, mediate the relationship between age and cognition, including memory. This is held to be particularly likely in later life when the decrements in sensory function, vision and hearing, reflect changes in the central nervous system (Fozard, 1990). While this hypothesis has been supported in studies such as those by Lindenberger and Baltes (1994) and Anstey et al. (2001), more research is required to test the common cause hypothesis. Few studies have, as yet, utilised objective measures of sensory and memory function (Luszcz & Bryan, 1999). It is likely that normal, healthy oldest-old will experience deterioration of hearing and vision, and it seems this is also implicated in age-related memory loss. Therefore, it must be incorporated into any comprehensive theory of memory and aging.

It can be assumed that all types of memory involve multiple processes and, therefore, will be difficult to disentangle and interpret precisely. Additionally, the contributing factors in age-related deficits are not independent of one another. For example, Baltes and Lindenberger (1987) found a powerful inter-relatedness between sensory and intellectual functioning, including speed of processing. As another example, research is tending toward the conclusion that central executive functioning is implicated in the emergence of age-related differences in working memory which may, in turn, be mediated by deterioration in the frontal lobes of the brain. The disentangling of purely cognitive, neuropsychological, neurochemical, and neurobiological contributions to age-related memory decrements is a complex task.

Much work remains before it can be claimed that the relationships between aging and memory are understood. No theory of memory can be complete without the inclusion of age, itself, as an important factor. The terminology surrounding aging must also be standardised so that a clear comparison can be made across studies. As discussed earlier, in the current body of available literature the term ‘old’ has been used to describe adults anywhere from 58 years of age and beyond. The looseness of this terminology must be addressed before a definitive theory of aging and memory is possible. Looseness in memory terminology, too, must be addressed, as over-lapping terminology has resulted in a plethora of different terms for very similar, but not necessarily interchangeable, concepts. A standardised description of memory types which would bring clarity to the field of memory research has yet to emerge.

Furthermore, the literature available on memory and aging (though all too little of it pertains to the oldest-old) seems to be full of conflicting results. Some find effects of certain covariates, and others do not. The amount of variance accounted for in studies that do find effects varies enormously from one study to the next. Processing speed is an example of this, where some studies have found age-related memory loss almost ameliorated by partiallling out processing speed, and others have found much smaller effects. Comparisons across studies are made difficult by differing methodologies, terminology, age bands, types of tests utilised, and differing inclusion/exclusion criteria for participants. Many studies, even those inclusive of the oldest-old, do not seem to have taken into consideration the effect of the aging brain on different memory types, yet it seems the most likely answer to account for the differences lies in the variable deterioration of specific areas of the brain.

In conclusion, in spite of the phenomenological and empirical reality of age-related memory decrement and the plethora of explanations attempting to explain it, much multidisciplinary research work will be necessary if it is to be more usefully understood.

Limitations and Future Directions

The present investigation faced a number of methodological limitations which need to be taken into account when interpreting the findings. This section covers both actual and possible limitations of the current study and directions for future investigation.

The oldest-old participants in the present study were a select group. They were cognitively intact with no history of neurological problems, and did not have long-standing illnesses. The sample included a group of well-educated elderly people who agreed to participate in this ongoing study. It is possible that less rigorous screening would have resulted in greater age-related changes in memory functioning. By screening participants for cognitive decline, neurological impairment, and mental health, it optimised the chance that the sample would be made up of adults experiencing healthy aging. While this has limited the generalisability of the results, the decision to screen participants was made to eliminate, as much as possible, the inclusion of oldest-old adults with early dementia. In addition, participants in the present study were interested, motivated, and were shown to have above average IQ scores for all age groups. Therefore, the extent to which conclusions can be generalised to people of average and below-average intellectual ability is unknown.

The wide age range utilised in this study created difficulty regarding the choice of memory tasks to be included. As shown by the high occurrence of a floor effect in the verbal and nonverbal delayed recall tasks, it is difficult to balance the difficulty of a task to allow 20-year-olds and people in their middle and late 90s to fit within a limited range of scores. Thus, making the shapes test, for example, easy enough for people in their late 80s and 90s to score reasonably well would, in all likelihood, have resulted in a ceiling effect for the young group. In retrospect, the inclusion of a few very simple shapes may have helped prevent the floor effect found in the present study. When the shapes test was pilot tested, the young pilot group attained scores up to 51 out of the possible 60, while the pilot old group scored between 12 and 40 when tested immediately after study, between 14 and 36 after a 10-minute delay, and between 5 and 26 after a 7-day delay period. The floor effect found for the oldest-old in the recall tasks was unexpected as the average score for the old group at pilot-testing was 26 when tested immediately after study. Pilot-testing had been attended to, but provided no fore-warning of the difficulty the oldest-old would encounter, even though those pilot-tested included individuals between 77 and 84 years of age. In retrospect, the proper age group (i.e., 85+ years of age) should have been used for pilot testing. The scarcity of 85+ years people who met all the screening requirements which were designed to result in a healthly oldest-old sample, led to a practical decision being made to pilot test using people 77 to 84 years of age. But a lesson has been learned: the oldest-old simply do not perform, on most memory tasks, like 77 - 84 year-olds. This again highlights a major difficulty with aging research where age bands are often very broad, or participants described as ‘old’ may be anything from 58 years-of-age upwards.

Clearly, the nonverbal recall task, as it was presented, was rather too difficult for those in the oldest-old group. Because of this, it is important that the results pertaining to the nonverbal recall task be interpreted with caution.

Another limitation regarding memory tasks concerned the design of the tasks used to measure prospective memory. Two tasks were used. The first involved participants remembering to ask two questions at a future point in time. The questions differed at Time 1 and Time 2 to avoid practice effects, although an effort was made to ensure the questions at both sessions equated in their meaningfulness to the study. Whereas the first task used different questions at each session, the second task required the participant to choose the object to be remembered, so there was no control over consistency. The development of standardised tasks for this type of memory which are suitable for the oldest-old is a matter of urgency. Because prospective memory ability is fundamental to the continued independent living during advanced aging, the two tasks were included in the present study and the scores for each task combined to create one prospective memory score rather than make a comparison of the two somewhat different tasks. Prospective memory and aging is an aspect of memory deserving of more research.

In common with many other studies, the face recognition task used only male target faces. This eliminates the potentially confounding effects of target sex (Shepherd, 1981), but also limits the external validity of the study. Further research would ideally expand the present research through the inclusion of female target faces. Additionally, it would be of interest to see whether the female advantage when recognising female faces continues into very old age.

Also, for other types of memory there is a dearth of standardised tests which are inclusive of the oldest-old. Especially if they are to be compared to young adults, it is important that appropriate tests be developed which have test-retest alternative forms, and are constructed to avoid the floor effects evident for the recall tasks in the present study when delay was included as a factor. Delay is an important variable, as it would be useful in the attempt to untangle age-related memory declines attributable to encoding, storage, or retrieval. It is apparent from the present study that something happens that changes the ability to retain the test stimuli over time at about 85 to 90 years of age. The mechanism underpinning this effect cannot begin to be understood until tasks are developed and standardised that will allow for such investigation, or norms for existing tests expanded to cover this age group. As research programmes on the oldest-old proceed, the relevance of all test materials for these people must be carefully and thoughtfully addressed. Notwithstanding the need for standardisation of tasks, there is also a danger that measuring a construct in a particular way could promote inferences about the relationship between the particular task and age-related memory change. It is important that care be taken to design tasks which do, indeed, measure what they purport to measure.

As a measure of intelligence, the present study used the NART. This test of intelligence is commonly used in aging research (e.g., Anstey et al., 2001; Bright et al., 2002; Christensen et al., 1994; Raguet, Campbell, Berry, Schmitt, & Smith, 1996; Ryan & Paolo, 1992). It is quickly and easily administered, which is important when assembling a test battery for the oldest-old when tiredness and over-load must be considered. However, it does rely on remembering how to pronounce some very uncommon irregular words, and it may be that this task is affected by memory decrements which occur in normal, healthy adults of very advanced age. The norm for the oldest group for the NART test is for those 74 years and over. As is clear from the present study results, people over the age of 85 perform very differently in many tasks than do younger adults, even those in their early 80s. Although the effects of intelligence were partialled out in the present study, the norming of the NART, or the development of another easily-administered test of intelligence for the very old, would be beneficial to aging research.

Although the present study utilised a 2-year inter-test interval, improved scores for the young and middle groups on the nonverbal recall task, may have been due to a practice effect. In contrast, it appears the oldest-old did not retain sufficient information to benefit from the test-retest design used in the present study. Lemay, Bédard, Rouleau, and Tremblay (2004) found that neuropsychological tasks were generally subject to a practice effect, although they retested after a 2-week interval and the present study used a 2-year interval. The Lemay et al. research studied participants from 52 to 80 years of age, so again there is a lack of information as to what might be expected over the age of 85 years. Mitrushina and Satz (1991) studied repeated administrations of a neuropsychological battery of tests in participants from 57 to 85 years (*M* = 70.4, *SD* = 5.0), including the Visual Reproduction sub-test of the Wechsler Memory Scale (Weschsler, 1987). The battery was administered on three occasions with a 1-year interval between probes. The finding that participants between the ages of 66 to 70 improved their scores, those 71 - 75 showed equal numbers who improved or declined, and those in the oldest group (76 - 85 years) demonstrated a decline from test to retest, is of particular interest. A similar finding is reported by Hickman et al. (2000), where a young-old group (65 - 74 years) demonstrated evidence of a practice effect on some tests, whereas an old-old group (84 - 93 years) did not. An alternate form of the shapes test, which utilised distinctive geometric shapes, could have been used to overcome the practice effect. These findings raise serious questions about the re-use of tests over short intervals of weeks or even months. The evidence from the present study suggest that a second administration of tests, even after two years, will not be independent of the first.

It is important that future aging research utilises designs which routinely include the oldest-old. Furthermore, not only is there an urgent need for more research on the elderly, but research designs that have much narrower age bands than are, at present, commonly used. From the present research it is apparent that change is measurable in the oldest-old even after two years. It seems that the older participants become the greater the need for finer and finer graduations of age groups. While the present study did include those 85 years and over, along with young and middle groups, it would be of interest to conduct research with fine age graduations from 80 or 85 years upward to ascertain the patterns of memory loss within the advanced aging years.

In the present sudy, when the covariates (processing speed, both verbal and nonverbal, and intelligence) were partialled out, the memory task scores for the oldest-old improved. What is less clear is why the young and middle people were disadvantaged by the controlling for the three covariates at both test times, with the exception of verbal recall at Time 1. This is particularly evident for the young group for nonverbal recall. One possible explanation is that processing speed is a hindrance to memory scores for the oldest-old because processing speed has slowed. On the other hand, processing speed, as a component of working memory, for example, is excellent in younger people and hence benefits memory scores. This assumes that processing speed is a factor in at least some types of memory. Thus, removing the effects of processing speed benefits the oldest-old, but penalises the younger people. This possible explanation suggests that processing speed and certain memory types are not entirely independent of each other. The high level of shared variance shown in the multiple regression analyses might be indicating this.

Hertzog et al. (2003) suggested that the multivariate measurement approach appears to be an important feature of research designs investigating memory processing given the complex interplay of multiple mechanisms involved. A problem which arose in the analyses of the present study was introducing Time as a factor and observing the longitudinal effects *after* removing covariate effects. There was no straightforward way of doing this. Two-way ANCOVA could not be used, as it did not allow for the inclusion of two sets of covariate data. It was decided to note the correlations across Time 1 and Time 2 for the covariates, and then use repeated-measure ANOVAs (with Age and Time as factors), with the covariate effects still in the data. This would not be of concern if their effects were the same at Time 1 and Time 2, as in the present study. Although this was a significant drawback it was compensated for by the fact that the design enabled both cross-sectional and longitudinal analyses. The cross-sectional analyses allowed for observation of the steep, nonlinear memory decrements for verbal and nonverbal recall, working memory, and prospective memory across the three age groups, and clearly demonstrated that short-term memory and face recognition are much better preserved in the oldest-old. The longitudinal analyses provides a picture of increasing declines in memory for the oldest-old for all memory types, although both short-term memory and face recognition are memory types better retained by the oldest-old. Longitudinal analyses demonstrates that the memory types most affected by advanced aging, when processing speed (verbal and nonverbal) and intelligence are controlled for, are nonverbal recall, verball recall, prospective memory, and working memory.

Attrition Rate

A positive aspect of the present study was the low attrition rate amongst participants. Overall, only seven participants were lost to the study in the two years between Time 1 and Time 2 testing. All young group participants completed both test times, even though it was necessary to test one male participant in the United Kingdom at Time 2, made possible because the researcher happened to be in the United Kingdom at the right time. Two of those lost to the study were in the middle group because they had moved out of the area. Perhaps the most surprising was that in the oldest-old group 42 of the original 47 participants were available for Time 2 testing. Four had died, and one was not well enough to undertake Time 2 testing – he died three weeks later.

Compared with prior longitudinal research (e.g., Hassing et al., 1988; Hickman et al., 2000) the 5.3% attrition rate overall was very low. For example, in a 4-year longitudinal study, Hickman et al. considered the attrition rate of 11.7% in their study to be extremely low. In the present study, the low attrition rate was partly due to the participants being volunteers, and therefore having an interest in the study. Particular care was taken in keeping in contact with the participants over the 2-year inter-test interval. This was because of the inclusion of the oldest-old who, because of the expected age-related memory decline, may well have forgotten they were part of the study. Contact was kept through Christmas and birthday cards, each including a ‘thank you’ and reminder of participation in the study. The low attrition rate resulted in a larger number of participants available for Time 2 testing than anticipated.

Summary and Conclusions

The results of the present study support the view that there are differential decrements in memory for the oldest-old across six types of memory: verbal and nonverbal recall, short-term memory, working memory, face recognition, and prospective memory. The degree of memory loss differs, with nonverbal recall, working memory, verbal recall (tasks involving recall rather than recognition), and prospective memory (internally-initiated action) more affected by aging than are face recognition and short-term memory. In contrast to some prior research findings, such declines are not linear in nature, but show a definite, steep drop in the oldest-old.

The declines found in the oldest-old are somewhat ameliorated by taking into account verbal and nonverbal processing speed, and intelligence. Although the inclusion of these covariates helped the scores for the oldest-old they did not eliminate the decrements, and the oldest-old remain disadvantaged on memory tasks. Although the present study does not provide a definitive and complete answer as to why age differences in memory occur later in life, it does indicate that adjusting for intelligence, verbal processing, and nonverbal processing had quite a sizeable effect. The processes underlying this slowing, however, are unclear. The present study points to the role of intelligence becoming increasingly important. Even over a period of only two years, the role of intelligence appeared to increase in importance in the memory performance of the oldest-old. However, for the young and middle group participants, controlling for the covariates of verbal and nonverbal processing speed, and intelligence, generally lowered the scores across memory types.

The prime underlying factor in the onset of memory decrements in the advanced aging process is, however, age itself. Although the inclusion of the covariates attenuated the losses, age remained as the most important predictor of memory decrements. This is, at least in part, a probable result of age-related changes in the brain, as memory is distributed over many areas, structures, and neurochemical systems of the brain. For example, working memory and both episodic and semantic retrieval rely on the prefrontal area of the brain, and the encoding of verbal and nonverbal information relies on the medial-temporal lobe. Both of these areas show considerable deterioration in the ninth decade of life. Furthermore, over an inter-test interval of two years, the oldest-old participants' performance decline for all memory tasks, an effect particularly evident in prospective memory, recall tasks, and working memory.

The conclusions are based on the performance of intellectually superior groups of adults 20 to 40 years, 50 to 70 years, and 85+ years. The understanding of specific features of normal, healthy aging allows insight into the differential patterns of performance in six varying types of memory.

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APPENDIX A

Participant Information Sheet

Memory and Aging

INFORMATION SHEET

Memory is at the very core of human existence. Everything from daily activities to the smallest perception, thought, or reflection involves our memory. Our every action, speaking, writing, opening a door, driving a car – all mobilise and depend on memory.

One of the most remarkable and far-reaching demographic developments in the last century has been the 'greying' of populations. By 2051, there will be 1.18 million people aged 65 years and over in New Zealand, representing an increase of 165% since 2000 (NZ Institute for Research on Ageing). While there has been an explosion of research on memory over the past two decades, there has been little investigation of changes in the memory of community-dwelling individuals, particularly those over the age of 85.

Allison Lamont, a mature student of Massey University, will conduct the present research, for the degree of Doctor of Philosophy in Psychology. The study will investigate changes in memory across the adult life span, from young adulthood to those who are in their ninth and tenth decades of life. Many aspects of memory will be included: Recall memory for words and shapes, recognition memory for faces, working memory, short-term memory, and prospective memory – remembering to do something at a later time. This research will be carried out under the supervision of Associate Professor Dr. John Podd, Dr. Julie Bunnell, and Dr. Stephen Hill, who may be contacted at the School of Psychology, Massey University, Private Bag 11 222, Palmerston North.

For this study, about 130 volunteers will be sought. Volunteers will be in three age groups: 20-40 years of age, 50-70 years of age, and 85+ years of age in 2003. You will be asked to complete a session of varied and interesting tasks, designed to measure various aspects of memory. It will take about an hour and a half. As week later you will be asked to complete a 5-minute task. The testing will be repeated two years later, so results can be compared over time.

You will be asked to sign a consent form with your full name, but all other personal data and test results will be coded and unidentifiable to ensure confidentiality. No individual data will be used. Data from each age group will be pooled for analysis. All results of tasks and interviews will be locked into secure storage, accessible only by Allison Lamont and Associate Professor John Podd. Consent forms will be stored separately from research data, and no data will bear a participant's name to ensure anonymity and confidentiality.

You will be asked to fill in surveys relating to your health, and undertake tasks to assess your memory. These will be presented either as pencil-and-paper tasks, orally, or on a computer screen. You do not need to know how to use a computer. Each task will be fully explained, and there will be an opportunity to ask any questions.

One task, the reading aloud of a word list, will be taped. This is to allow for comparison with a master tape made by Dr. Elizabeth Gordon, linguist from the University of Canterbury, should there be any doubt about correctness of pronunciation. You have the right to ask for the tape recorder to be turned off at any time.

Your rights

You have the right

- to decline to participate
- to withdraw from the study at any time
- to refuse to answer any particular question
- to ask any questions about the study at any time during participation
- to provide information on the understanding your name will not be used
- to be given access to a summary of findings at the conclusion of the study.

If you have any queries or concerns, please contact me on (03) 354 1969, or one of the aforementioned supervisors.

Thank you for your assistance with this research – I am grateful.

Allison Lamont

This research has been reviewed, judged to be low risk, and approved by the researcher and supervisor under delegated authority from the Massey University Ethics Committee. If you have any concerns about the conduct of this research, please contact Professor Sylvia Rumball, Assistant to the Vice-Chancellor (Equity and Ethics), telephone (06) 350 5246, email S.V.Rumball@massey.ac.nz

Appendix B

Participant Consent Form

Memory and Aging

CONSENT FORM

THIS CONSENT FORM WILL BE HELD FOR A PERIOD OF FIVE (5) YEARS

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree / do not agree to the national Adult Reading Test word list only being taped.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: **Date:**

Full Name (printed):

Appendix C

Structured Screening Interview

STRUCTURED SCREENING INTERVIEW
(To be completed by the Researcher)

Participant ID:

Date of Interview:

Test Time 1 / 2

Date of Birth:

Years of education:

Years of secondary school:

Years of tertiary education:

Other:

Hearing aid:

Glasses:

Occupation (past occupation if retired)

Any recent illnesses:

Current medication:

Have you ever suffered from:

- Major depression Yes / No
- Neurological disorder (e.g., Alzheimer's, stroke, head trauma with loss of consciousness for more than 1 hour, brain tumour etc). Yes / No. If yes, please describe:
- Hereditary disease (e.g., Huntington's disease). Yes / No. If yes, please describe:
- Medical condition with known central nervous system complication. Yes / No. If yes, please describe:
- Have you ever had a neurosurgical operation? Yes / No

Appendix D

Mini Mental State Examination

MMSE

Date of Examination ____ / ____ / ____ Examiner ____________________

Name ____________________ Age ______ Years of School Completed ______

Instructions: Words in boldface type should be read aloud clearly and slowly to the examinee. Item substitutions appear in parentheses. Administration should be conducted privately and in the examinee's primary language. Circle 0 if the response is incorrect, or 1 if the response is correct. Begin by asking the following two questions:

Do you have any trouble with your memory? **May I ask you some questions about your memory?**

ORIENTATION TO TIME		RESPONSE	SCORE (circle one)	
What is the...	**year?**		0	1
	season?		0	1
	month of the year?		0	1
	day of the week?		0	1
	date?		0	1

ORIENTATION TO PLACE*

Where are we now? What is the...

state (province)?		0	1
county (or city/town)?		0	1
city/town (or part of city/neighborhood)?		0	1
building (name or type)?		0	1
floor of the building (room number or address)?		0	1

*Alternative place words that are appropriate for the setting and increasingly precise may be substituted and noted.

REGISTRATION*

Listen carefully. I am going to say three words. You say them back after I stop. Ready? Here they are... APPLE *[pause]*, **PENNY** *[pause]*, **TABLE** *[pause]*. **Now repeat those words back to me.** *[Repeat up to 5 times, but score only the first trial.]*

APPLE		0	1
PENNY		0	1
TABLE		0	1

Now keep those words in mind. I am going to ask you to say them again in a few minutes.

*Alternative word sets (e.g., PONY, QUARTER, ORANGE) may be substituted and noted when retesting an examinee.

ATTENTION AND CALCULATION *[Serial 7s]**

Now I'd like you to subtract 7 from 100. Then keep subtracting 7 from each answer until I tell you to stop.

What is 100 take away 7?	[93]		0	1
If needed, say: **Keep going.**	[86]		0	1
If needed, say: **Keep going.**	[79]		0	1
If needed, say: **Keep going.**	[72]		0	1
If needed, say: **Keep going.**	[65]		0	1

*Alternative item (WORLD backward) should only be administered if the examinee refuses to perform the Serial 7s task. →

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Substitute and score this item only if the examinee refuses to perform the Serial 7s task.
Spell WORLD forward, then backward.
Correct forward spelling if misspelled,
but score only the backward spelling. ____ (D = 1) ____ (L = 1) ____ (R = 1) ____ (O = 1) ____ (W = 1) ____ (0 to 5)

RECALL	RESPONSE	SCORE (circle one)	
What were those three words I asked you to remember? [*Do not offer any hints.*]			
APPLE	____	0	1
PENNY	____	0	1
TABLE	____	0	1
NAMING*			
What is this? [*Point to a pencil or pen.*]	____	0	1
What is this? [*Point to a watch.*]	____	0	1

*Alternative common objects (e.g., eyeglasses, chair, keys) may be substituted and noted.

REPETITION

Now I am going to ask you to repeat what I say. Ready? "NO IFS, ANDS, OR BUTS." Now you say that.
[*Repeat up to 5 times, but score only the first trial.*]

NO IFS, ANDS, OR BUTS.	____	0	1

Detach the next page along the lengthwise perforation, and then tear it in half along the horizontal perforation. Use the upper half of the page (blank) for the Comprehension, Writing, and Drawing items that follow. Use the lower half of the page as a stimulus form for the Reading ("CLOSE YOUR EYES") and Drawing (intersecting pentagons) items.

COMPREHENSION

Listen carefully because I am going to ask you to do something.
Take this paper in your right hand [*pause*], **fold it in half** [*pause*], **and put it on the floor** (*or* **table**).

TAKE IN RIGHT HAND	____	0	1
FOLD IN HALF	____	0	1
PUT ON FLOOR (*or* TABLE)	____	0	1

READING

Please read this and do what it says. [*Show examinee the words on the stimulus form.*]

CLOSE YOUR EYES	____	0	1

WRITING

Please write a sentence. [*If examinee does not respond, say:* **Write about the weather.**] 0 1

Place the blank piece of paper (unfolded) in front of the examinee and provide a pen or pencil. Score 1 point if the sentence is comprehensible and contains a subject and a verb. Ignore errors in grammar or spelling.

DRAWING

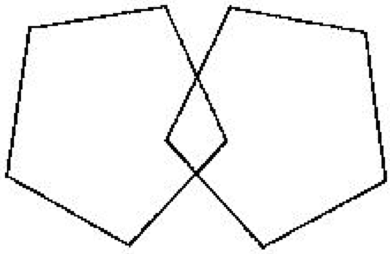
Please copy this design. [*Display the intersecting pentagons on the stimulus form.*] 0 1

Score 1 point if the drawing consists of two 5-sided figures that intersect to form a 4-sided figure.

Assessment of level of consciousness.

Alert/Responsive — Drowsy — Stuporous — Comatose/Unresponsive

Total Score = ____
(Sum all item scores.) (30 points max.)



Intersecting pentagons to be copied for the MMSE Drawing subtest

Appendix E

Beck Depression Inventory – Second Edition (BDI-II)

BDI-II

Date:

Name: ________ Marital Status: ________ Age: ______ Sex: ______

Occupation: ________ Education: ________

Instructions: This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, and then pick out **the one statement** in each group that best describes the way you have been feeling during the **past two weeks, including today.** Circle the number beside the statement you have picked. If several statements in the group seem to apply equally well, circle the highest number for that group. Be sure that you do not choose more than one statement for any group, including Item 16 (Changes in Sleeping Pattern) or Item 18 (Changes in Appetite).

1. Sadness

0 I do not feel sad.
1 I feel sad much of the time.
2 I am sad all the time.
3 I am so sad or unhappy that I can't stand it.

2. Pessimism

0 I am not discouraged about my future.
1 I feel more discouraged about my future than I used to be.
2 I do not expect things to work out for me.
3 I feel my future is hopeless and will only get worse.

3. Past Failure

0 I do not feel like a failure.
1 I have failed more than I should have.
2 As I look back, I see a lot of failures.
3 I feel I am a total failure as a person.

4. Loss of Pleasure

0 I get as much pleasure as I ever did from the things I enjoy.
1 I don't enjoy things as much as I used to.
2 I get very little pleasure from the things I used to enjoy.
3 I can't get any pleasure from the things I used to enjoy.

5. Guilty Feelings

0 I don't feel particularly guilty.
1 I feel guilty over many things I have done or should have done.
2 I feel quite guilty most of the time.
3 I feel guilty all of the time.

6. Punishment Feelings

0 I don't feel I am being punished.
1 I feel I may be punished.
2 I expect to be punished.
3 I feel I am being punished.

7. Self-Dislike

0 I feel the same about myself as ever.
1 I have lost confidence in myself.
2 I am disappointed in myself.
3 I dislike myself.

8. Self-Criticalness

0 I don't criticize or blame myself more than usual.
1 I am more critical of myself than I used to be.
2 I criticize myself for all of my faults.
3 I blame myself for everything bad that happens.

9. Suicidal Thoughts or Wishes

0 I don't have any thoughts of killing myself.
1 I have thoughts of killing myself, but I would not carry them out.
2 I would like to kill myself.
3 I would kill myself if I had the chance.

10. Crying

0 I don't cry anymore than I used to.
1 I cry more than I used to.
2 I cry over every little thing.
3 I feel like crying, but I can't.

Subtotal Page 1

Continued on Back

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11. Agitation
0 I am no more restless or wound up than usual.
1 I feel more restless or wound up than usual.
2 I am so restless or agitated that it's hard to stay still.
3 I am so restless or agitated that I have to keep moving or doing something.

12. Loss of Interest
0 I have not lost interest in other people or activities.
1 I am less interested in other people or things than before.
2 I have lost most of my interest in other people or things.
3 It's hard to get interested in anything.

13. Indecisiveness
0 I make decisions about as well as ever.
1 I find it more difficult to make decisions than usual.
2 I have much greater difficulty in making decisions than I used to.
3 I have trouble making any decisions.

14. Worthlessness
0 I do not feel I am worthless.
1 I don't consider myself as worthwhile and useful as I used to.
2 I feel more worthless as compared to other people.
3 I feel utterly worthless.

15. Loss of Energy
0 I have as much energy as ever.
1 I have less energy than I used to have.
2 I don't have enough energy to do very much.
3 I don't have enough energy to do anything.

16. Changes in Sleeping Pattern
0 I have not experienced any change in my sleeping pattern.
1a I sleep somewhat more than usual.
1b I sleep somewhat less than usual.
2a I sleep a lot more than usual.
2b I sleep a lot less than usual.
3a I sleep most of the day.
3b I wake up 1–2 hours early and can't get back to sleep.

17. Irritability
0 I am no more irritable than usual.
1 I am more irritable than usual.
2 I am much more irritable than usual.
3 I am irritable all the time.

18. Changes in Appetite
0 I have not experienced any change in my appetite.
1a My appetite is somewhat less than usual.
1b My appetite is somewhat greater than usual.
2a My appetite is much less than before.
2b My appetite is much greater than usual.
3a I have no appetite at all.
3b I crave food all the time.

19. Concentration Difficulty
0 I can concentrate as well as ever.
1 I can't concentrate as well as usual.
2 It's hard to keep my mind on anything for very long.
3 I find I can't concentrate on anything.

20. Tiredness or Fatigue
0 I am no more tired or fatigued than usual.
1 I get more tired or fatigued more easily than usual.
2 I am too tired or fatigued to do a lot of the things I used to do.
3 I am too tired or fatigued to do most of the things I used to do.

21. Loss of Interest in Sex
0 I have not noticed any recent change in my interest in sex.
1 I am less interested in sex than I used to be.
2 I am much less interested in sex now.
3 I have lost interest in sex completely.

_____ Subtotal Page 2
_____ Subtotal Page 1
_____ Total Score

Appendix F

SF-36 Health Survey

SF-36 HEALTH SURVEY

INSTRUCTIONS: This questionnaire asks for your views about your health, how you feel and how well you are able to do your usual activities.

Answer every question by marking the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can.

1. In general, would you say your health is:

(circle one)

Excellent 1

Very good 2

Good 3

Fair 4

Poor 5

2. <u>Compared to one year ago</u>, how would you rate your health in general <u>now</u>?

(circle one)

Much better now than one year ago 1

Somewhat better now than one year ago 2

About the same as one year ago 3

Somewhat worse now than one year ago 4

Much worse now than one year ago 5

3. The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

(circle one number on each line)

ACTIVITIES	Yes, Limited A Lot	Yes, Limited A Little	No, Not Limited At All
a. **Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
b. **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
c. Lifting or carrying groceries	1	2	3
d. Climbing **several** flights of stairs	1	2	3
e. Climbing **one** flight of stairs	1	2	3
f. Bending, kneeling or stooping	1	2	3
g. Walking **more than one kilometre**	1	2	3
h. Walking **half a kilometre**	1	2	3
i. Walking **100 metres**	1	2	3
j. Bathing or dressing yourself	1	2	3

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

(circle one number on each line)

	YES	NO
a. **Cut down on the amount of time** you spent on work or other activities	1	2
b. **Accomplished less** than you would like	1	2
c. Were limited in the **kind** of work or other activities	1	2
d. Had **difficulty** performing the work or other activities (for example, it took extra effort)	1	2

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

(circle one number on each line)

	YES	NO
a. Cut down on the **amount of time** you spent on work or other activities	1	2
b. **Accomplished less** than you would like	1	2
c. Didn't do work or other activities as carefully as usual	1	2

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups?

(circle one)

Not at all 1

Slightly 2

Moderately 3

Quite a bit 4

Extremely 5

7. How much bodily pain have you had during the past 4 weeks?

(circle one)

No bodily pain 1

Very mild 2

Mild 3

Moderate 4

Severe 5

Very severe 6

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

(circle one)

Not at all 1

A little bit 2

Moderately 3

Quite a bit 4

Extremely 5

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks -

(circle one number on each line)

	All of the Time	Most of the Time	A Good Bit of the Time	Some of the Time	A Little of the Time	None of the Time
a. Did you feel full of life?	1	2	3	4	5	6
b. Have you been a very nervous person?	1	2	3	4	5	6
c. Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
d. Have you felt calm and peaceful?	1	2	3	4	5	6
e. Did you have a lot of energy?	1	2	3	4	5	6
f. Have you felt down?	1	2	3	4	5	6
g. Did you feel worn out?	1	2	3	4	5	6
h. Have you been a happy person?	1	2	3	4	5	6
i. Did you feel tired?	1	2	3	4	5	6

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?

(circle one)

All of the time 1

Most of the time 2

Some of the time 3

A little of the time 4

None of the time 5

11. How TRUE or FALSE is each of the following statements for you?

(circle one number on each line)

	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
a. I seem to get sick a little easier than other people	1	2	3	4	5
b. I am as healthy as anybody I know	1	2	3	4	5
c. I expect my health to get worse	1	2	3	4	5
d. My health is excellent	1	2	3	4	5

Appendix G

The National Adult Reading Test

National Adult Read Test (NART)

chord
ache
depot
aisle
bouquet
psalm
capon
deny
nausea
debt
courteous
rarefy
equivocal
naïve
catacomb
gaoled
thyme
heir
radix
assignate
hiatus
subtle
procreate
gist
gouge

superfluous
simile
banal
quadruped
cellist
facade
zealot
drachm
aeon
placebo
abstemious
detente
idyll
puerperal
aver
gauche
topiary
leviathan
beatify
prelate
sidereal
demesne
syncope
labile
campanile

Appendix H

Words used in the verbal recall task

Table H.1: *Words used in the verbal recall task, and their frequency in the English language.*

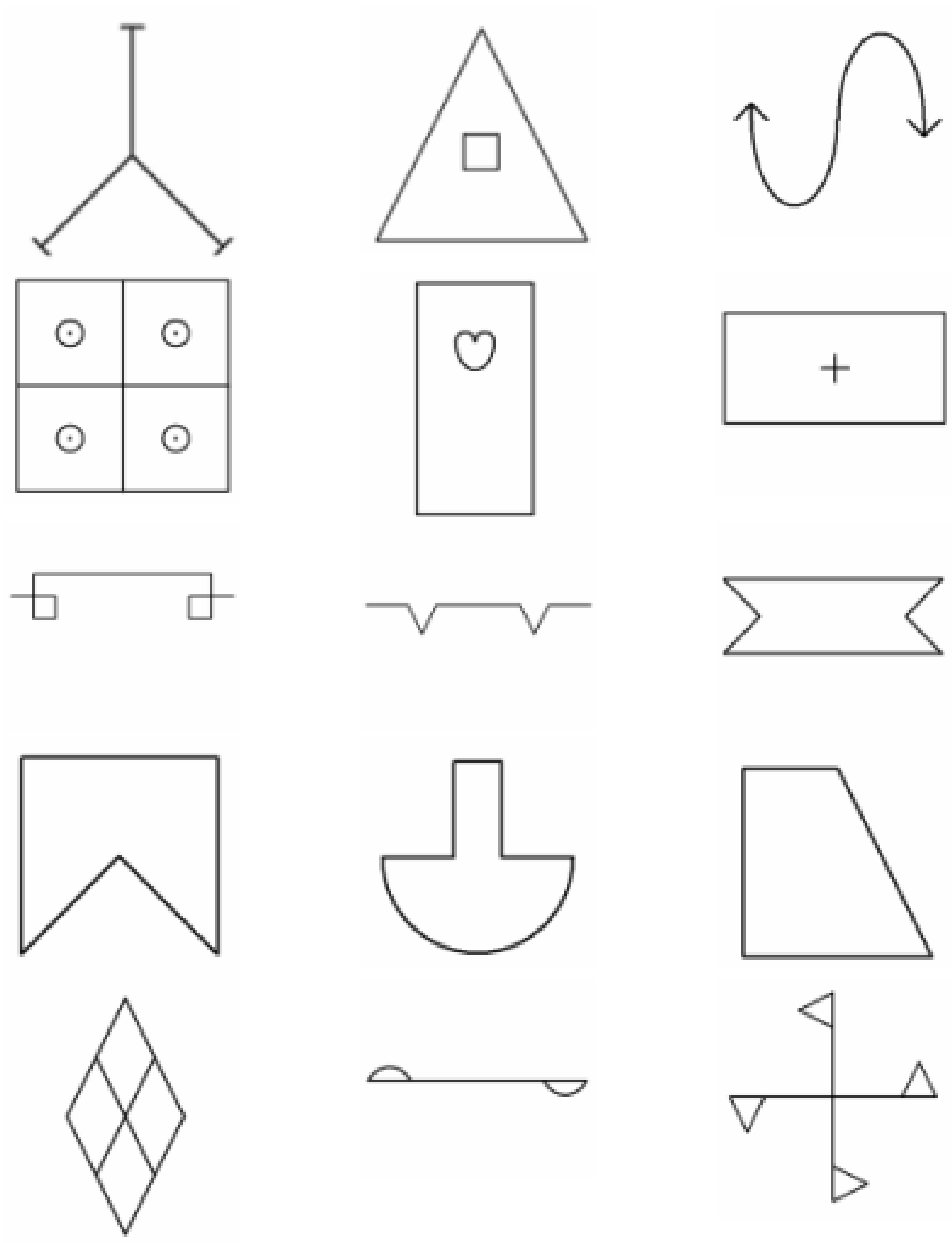
Word	**Frequency[a]**
maze	6
rite	8
dusk	70
tune	10
soul	47
stair	2
minor	58
candle	18
loot	3
bug	4
beach	61
kite	1
dream	64
ski	5
peace	198
waist	11
hall	152
gate	37
lamb	7
broom	2
sheet	45
lion	17
mouth	103
creek	14
breath	53

[a]Kucera-Francis frequency is the number of occurrences in a corpus of 1,014,232 words.

Appendix I

The Shapes Test – Stimuli, Development, and Scoring Criteria

The Individual Stimuli Used in the Shapes Test



The Shapes Test – Development

As no test was available which met the parameters considered desirable for the present study, it was decided to devise a nonverbal recall task which would meet the requirements. It was considered desirable that the verbal and nonverbal recall tasks would allow for cross-test comparison as to which, of either, of the recall skills would show the greatest decrements in the oldest-old. In the shapes test, participants were required to study, and then reproduce, 15 geometric shapes of varying complexity. The shapes used in the task were chosen from an original pool of 25 shapes, by eliminating those that could be confused with other shapes used because of similarity. The final 15 chosen were distinct from one another (see next section).

Geometric shapes were chosen to minimise the likelihood of verbal encoding, although it is not possible to eliminate this possibility entirely. It was thought that geometric shapes would be less prone to verbal encoding than commercially available tests for the elderly such as the Kendrick Object Learning Task (Kendrick, 1985), which uses pictures of common objects as stimuli. Riege and Inman (1981) assert that common objects constitute easily verbally-encoded material, and this may mask age decrements in nonverbal memory. The Shapes test was designed to address this issue.

To ensure the test would be unlikely to produce either floor or ceiling scoring difficulties, the Shapes test was piloted with a group of 15 university students (M = 23.1, SD = 6.39), and a group of 15 older adults between 77 and 84 years of age (M = 79.5, SD = 2.48). This was particularly important as the research design incorporated 10-minute and 7-day delay periods as well as the recall immediately after study of the target stimuli. As can be seen in Table I-1, no floor or ceiling problems in the scores were found, although the oldest of the old pilot group was 84 years old.

However, despite the careful pilot testing, a high occurrence of a floor effect was found in the oldest-old during Time 1 and Time 2 testing, and this issue will need to be addressed if the shapes test is to be used again. Piloting with an ‘old’ group who were not quite as old as the oldest-old participants in the present study, led to an unexpected difficulty with floor effects for the shapes test. As we now know, advanced old age really decreases performance on this recall test.

Table I.1. *The results of pilot testing of the shapes test for the young and old groups, for recall immediately after study, and at 10-minute delay and 7-day delay periods.*

	Minimum	Maximum[a]	Mean	Std.Deviation
Young Group – Immediate recall	17	51	37.73	9.58
Young Group – 10-minute delay	18	47	37.00	9.52
Young Group – 7-day delay	18	47	30.60	8.50
Old Group – Immediate recall	12	40	26.00	8.39
Old Group – 10-minute delay	14	36	22.60	6.38
Old Group – 7-day delay	5	26	17.33	2.48

[a] The maximum score possible was 60.

Test-Retest Reliability for the Shapes Test

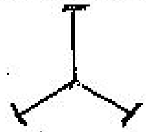
The test-retest correlation for the geometric shapes test was .91 for a group of 15 young people (M = 23.1, SD = 6.39), and .89 for a group of 20 older people (M = 79.5, SD = 2.48) over a 2-week period.

The Scoring Criteria for the Shapes Test

The scoring criteria utilised in the scoring of the test, and for the inter-rater reliability are set out on the next several pages. While every possible permutation of errors in reproducing the shape could not be listed, the criteria resulted in an inter-rater reliability of 0.95 when scored by two independent raters over 135 shapes.

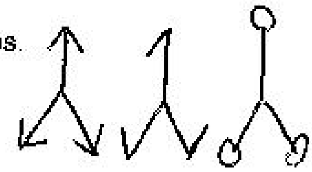
Proposed Scoring Criteria for Geometric Shapes Test

Shape 1: inverted 'Y' – lines on ends



4 = Correct shape

3 = Lines on replaced by another element e.g. arrowheads, circles.



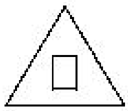
OR figure correct but inverted

2 = inverted and lines on ends replaced by another element

1 = Only inverted Y drawn

0 = Missing or unrecognizable as inverted Y or Y.

Shape 2: Outer triangle with inner square



4 = Correct figure

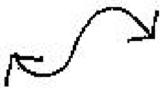
3 = Outer triangle and inner square, but figure inverted

2 = Outer triangle, but inner square replaced by another elemente.g. circle, triangle.

1 = Only one element drawn – large triangle or small square

0 = Missing

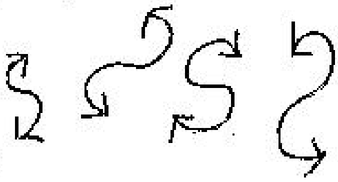
Shape 3: Reclining 'S', arrowheads.



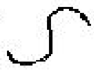
4 = Correct figure

3 = Correct 'S', but another element replaces arrowheads, e.g. straight lines, inverted arrowheads.

OR figure correct, but inverted, or incorrect alignment e.g.

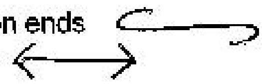


2 = Only 'S' correctly aligned, with no element on ends.



OR Line curved, but incorrectly, with arrowheads.

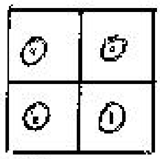
1 = Straight line with arrowheads, inverted arrowheads, or lines on ends



OR only an upright 'S'

0 = Missing or unrecognizable

Shape 4: Divided square, with quarters containing circles with dot



4 = Correct figure

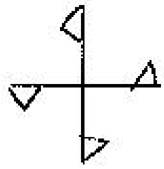
3 = Outer square correctly with intersecting lines creating four squares with circles OR dots present OR dots have become small inner circles.

2 = Outer square correct with intersecting lines.

1 = Outer square with at least two circles or dots – intersecting lines may be missing.

OR only circles or dots

0 = Missing or unrecognisable.

Shape 5: Intersecting poles with flags. 

4 = Two poles – vertical and horizontal alignment – intersected in centre with pole ends approximately equal. Four triangular flags correctly placed to left side of pole, sharing a side with end of pole.

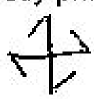
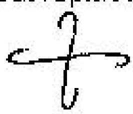
3 = Two poles correctly intersected as above. Triangular flags replaced by another shaped element e.g. half circles, squares, but in correct alignment to poles

OR poles correctly intersected. At least two triangular flags in correct position

OR poles correctly intersected, and triangular flags present, but separated from poles

2 = Two poles intersected, but may be misaligned as X with four triangular flags at least two of which are correctly placed.

OR Two poles intersected but may be misaligned as X, with four flags Correctly placed but replaced by another element eg. Half circles, squares.

e.g.  

1 = Intersecting poles only

OR flags only

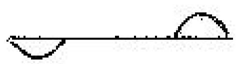
OR one pole with flags

0 = Missing or unrecognisable.

Shape 6: Horizontal line with half circles at end. Left end half circle upward Facing, Right end half circle downward facing. 

4 = Correct figure

3 = Line correct and two half circles in any alignment to line – e.g. both half circles upward facing, both half circles downward facing. Half circles attached to line e.g.

OR Line correct and another closed element e.g. squares, oblongs, triangles attached with R facing down, and L facing up, correctly aligned.

e.g. 

2 = Line correct. Half circles replaced by another element, e.g. squares, oblongs, triangles in incorrect position at ends line. E.g. both facing up, both facing down. Element attached to line.

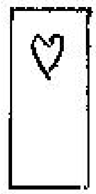
e.g. 

1 = Half circles replaced by an open element and aligned in any way to ends of line. Attached to line.

e.g. 

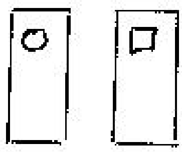
0 = Missing or unrecognisable.

Shape 7: Upright rectangle, with heart centred at upper end.



4 = Correct figure

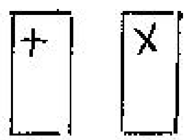
3 = Correct upright rectangle, but heart replaced by another similar element e.g. square, circle, oval. Replacement element must not be composed only of lines eg. Hyphen, cross.



OR foreshortened rectangle more akin to square, with heart correctly Placed.

OR heart placed other than in upper 25% of figure.

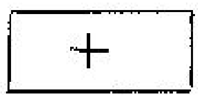
2 = Correct upright rectangle, but heart replaced by element composed of lines, e.g. hyphen, cross (either + or x),



1 = Only one element – either upright rectangle, or heart

0 = Missing or unrecognisable.

Shape 8: Horizontal rectangle with + centrally placed



4 = Correct figure

3 = Correct horizontal rectangle, with + replaced by similar element composed of lines e.g. - , = , x

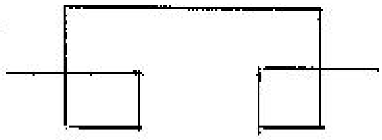
OR Foreshortened rectangle more akin to square, with + correctly placed.

2 = Correct horizontal rectangle, with + replaced with dissimilar element, e.g. square, circle, heart, triangle.

1 = One element only – either horizontal rectangle or +

0 = Missing or unrecognisable.

Shape 9: horizontal line figure with squares and tails.

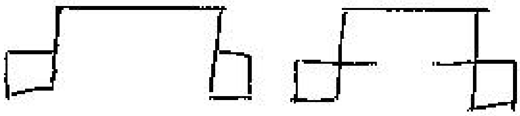


4 = Correct figure

3 = Correct with the exception of no tails

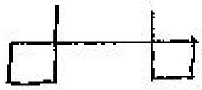
OR Correct figure but inverted

2 = Squares facing outward, with or without tails



1 = Main horizontal line and two downward lines

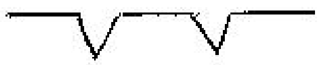
OR Squares directly attached under line, with tails



OR Recognisable element which is not only horizontal line

0 = Missing or straight line only

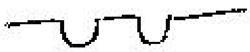
Shape 10: Horizontal figure – line with two 'valleys'



4 = Correct figure

3 = Correct figure but inverted

OR figure correct configuration and orientation, but valleys have been rounded



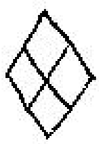
2 = Only 1 valley

OR figure correct configuration, but valleys rounded, and figure inverted

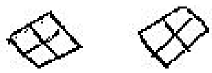
1 = A horizontal line with a definite deviation partially recognizable as correct Figure

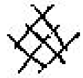
0 = Missing or straight line

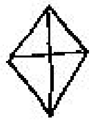
Shape 11: Intersected Diamond



4 = Correct figure

3 = Diamond with correctly intersecting lines but incorrectly aligned. 

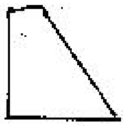
OR Correct figure, but lines do not meet 

2 = Diamond with two lines intersecting, but incorrectly aligned e.g. lines starting and finishing at 'points' of diamond 

1 = Diamond only, at any orientation

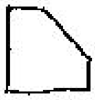
OR X only

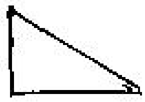
0 = Missing or unrecognisable.

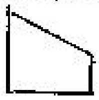
Shape 12: Unequally sided figure 

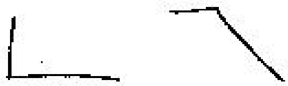
4 = Correct figure

3 = Shape correct but facing opposite direction

OR addition of extra vertical line e.g. 

2 = Vertical and horizontal lines, joined with 45 degree sloping line but facing opposite direction 

OR Vertical and horizontal lines correct, but sloping line joined directly to vertical line, plus extra vertical. E.g. 

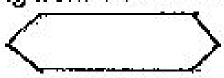
1 = Incomplete but with at least two lines correctly placed 

0 = Missing or unrecognisable.

Shape 13: Horizontal Rectangle with 'valley' at each end. 

4 = Correct shape

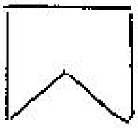
3 = Horizontal shape correct, but valleys rounded or squared or uneven. E.g 

2 = Horizontal shape correct, but V shapes protruding from end of horizontal shape instead of being valleys. 

1 = Top line longer than bottom line, joined by inwardly sloping side lines 

0 = Missing or no recognisable elements.

Shape 14: Horizontal rectangle with triangular 'cut-out' removed from bottom line



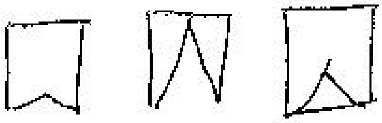
4 = Correct shape

3 = Correct horizontal orientation but with 'cut-out' rounded or squared

OR very elongated. 

2 = 'Cut out' triangle under- or over-sized

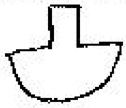
OR with an underline.



1 = Flattened shape

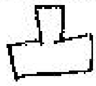
0 = Missing or unrecognisable.

Shape 15: **'Shovel'** – made up of top element 'handle', and bottom half circle.



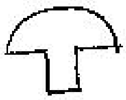
4 = Correct shape

3 = Top element – handle and horizontal lines – correct with half circle replaced with similar element, e.g. squared.

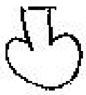


OR Correctly rounded bottom element with 'handle' rounded.

OR Correct shape but inverted

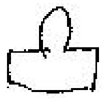


OR Horizontal lines rounded

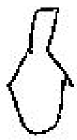


2 = Two elements present with more than one error

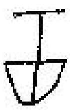
e.g. bottom element squared *and* handle rounded,



OR sloping 'shoulders' to top element, and bottom half circle elongated.



OR A handle and 'shovel' but two errors in one element. e.g.



1 = One element correct.

0 = Missing or unrecognisable.

Appendix J

The Digit Span subtest from the WAIS-III (Wechsler, 1997a)

DIGIT SPAN FORWARD

Discontinue after a score of 0 on both trials of any item.

	Trial	Item / Response	Time 1	Time 2
1	**1**	1 - 8		
	2	7 - 4		
2	**1**	6 – 9 - 3		
	2	5 – 8 - 4		
3	**1**	7 – 5 – 4 - 8		
	2	8 – 3 – 6 - 5		
4	**1**	4 – 1 – 6 – 2 - 9		
	2	6 – 4 – 7 – 2 - 5		
5	**1**	7 – 2 – 8 – 5 – 6 - 4		
	2	2 – 8 – 1 – 7 – 3 - 6		
6	**1**	4 – 8 – 1 – 6 – 3 – 2 - 9		
	2	5 – 2 – 8 – 9 – 4 – 7 - 6		
7	**1**	3 – 9 – 1 – 8 – 2 – 6 – 4 - 7		
	2	4 – 9 – 3 – 8 – 6 – 1 – 7 - 3		
8	**1**	2 – 7 – 1 – 9 – 6 – 2 – 5 – 8 - 4		
	2	7 – 8 – 1 – 3 – 9 – 5 – 2 – 4 – 6		
		Total Raw Score		

Appendix K

The Letter-Number Sequencing Task from the WAIS-III (Wechsler, 1997a)

Letter-Number Sequencing Task

Discontinue after a score of 0 on three items of the same level.

	Trial	Item / Response	Time 1	Time 2
1	1	**M – 3** (3 – M)		
	2	**7 – Q** (7 – Q)		
	3	**A – 4** (4 – A)		
2	1	**G – 8 – M** (8 – G – M)		
	2	**S – 5 – D** (5 – D – S)		
	3	**H – 2 – 9** (2 – 9 – H)		
3	1	**S – 8 – A – 4** (4 – 8 – A – S)		
	2	**V – 2 – K – 5** (2 – 5 – K – V)		
	3	**8 – N – 4 – L** (4 – 8 – L – N)		
4	1	**9 – C – 6 – H – 1** (1 – 6 – 9 – C – H)		
	2	**K – 1 – C – 8 – S** (1 – 8 – C – K – S)		
	3	**4 – P – 2 – Y – 8** (2 – 4 – 8 – P – Y)		
5	1	**M – 4 – E – 6 – P – 2** (2 – 4 – 6 – E – M – P)		
	2	**X – 7 – H – 4 – F – 3** (3 – 4 – 7 – F – H – X)		
	3	**5 – H – 9 – A – 1 – T** (1 – 5 – 9 – A – H – T)		
6	1	**R – 2 – B – 6 – Z – 1 – C** (1 – 2 – 6 – B – C – R – Z)		
	2	**4 – T – 8 – J – 1 – X – 7** (1 – 4 – 7 – 8 - J – T – X)		
	3	**F – 2 – H – 7 – S – 3 – D** (2 – 3 – 7 – D – F – H – S)		
7	1	**5 – H – 8 – S – 1 – N – 7 – A** (1 – 5 – 7 – 8 – A – H – N - S)		
	2	**C – 2 – R – 8 – B – 4 – L – 3** (2 – 3 – 4 – 8 – B – C – L – R)		
	3	**6 – N – 1 – T – 5 – F – 2 – Z** (1 – 2 – 5 – 6 – F – N – T – Z)		
		Total Raw Score		

Appendix L

Sample stimulus face from the Face Recognition task

SAMPLE STIMULUS FACE

Permission was obtained from the above participant
to include his photograph in this thesis

Appendix M

ANOVA for all memory types at Time 1 testing

ANOVA FOR ALL MEMORY TYPES AT TIME 1

Verbal Recall – Words Time 1

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	510.522	2	255.261	28.262	<.001
WITHIN GROUPS	1110.964	123	9.032		
TOTAL	1621.468	125			

Nonverbal Recall – Shapes Time 1

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	9336.255	2	4668.128	88.628	<.001
WITHIN GROUPS	6478.546	123	52.671		
TOTAL	15814.802	125			

Short-term Memory – Digit Span Time 1

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	61.915	2	30.976	7.346	<.001
WITHIN GROUPS	518.683	123	4.217		
TOTAL	580.635	125			

Working Memory – Letter-Number Sequencing Time 1

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	780.641	2	390.321	81.742	<.001
WITHIN GROUPS	587.327	123	4.775		
TOTAL	1367.968	125			

Face Recognition Time 1

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	739.781	2	369.890	34.622	<.001
WITHIN GROUPS	1314.092	123	10.684		
TOTAL	2053.873	125			

Prospective Memory Time 1

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	186.100	2	93.050	47.176	<.001
WITHIN GROUPS	242.606	123	1.972		
TOTAL	428.706	125			

Appendix N

ANOVA for all memory types at Time 2 testing

ANOVA FOR ALL MEMORY TYPES AT TIME 2

Verbal Recall – Words Time 2

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	861.734	2	430.867	35.181	<.001
WITHIN GROUPS	1506.401	123	12.247		
TOTAL	2368.135	125			

Nonverbal Recall – Shapes Time 2

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	13994.779	2	6997.389	85.172	<.001
WITHIN GROUPS	10105.190	123	82.156		
TOTAL	24099.968	125			

Short-term Memory – Digit Span Time 2

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	171.128	2	85.564	17.308	<.001
WITHIN GROUPS	608.078	123	4.944		
TOTAL	779.206	125			

Working Memory – Letter-Number Sequencing Time 2

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	1146.468	2	573.234	124.738	<.001
WITHIN GROUPS	565.247	123	4.596		
TOTAL	1711.714	125			

Face Recognition Time 2

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	1491.199	2	745.600	62.946	<.001
WITHIN GROUPS	1456.936	123	11.845		
TOTAL	2948.135	125			

Prospective Memory Time 2

	Sum of Squares	df	Mean Square	F	Sig
BETWEEN GROUPS	518.749	2	259.374	112.051	<.001
WITHIN GROUPS	284.720	123	2.315		
TOTAL	803.468	125			

Appendix O

Mixed Design ANOVA with Time as the within groups factor, and Age as the between groups factor

Verbal Recall – Words

Tests of within-groups effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Time	3.500	1	3.500	.836	.36	.01	.148
Time*group	33.108	2	16.554	3.955	.02	.06	.701
Error(time)	514.781	123	4.185				

[a] Computed using alpha = .05 for all tests in Appendix O

Tests of between-group effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Intercept	17804.197	1	17804.197	1041.544	<.001	.89	1.00
Agegroup	1339.148	2	669.574	39.170	<.001	.39	
Error	2102.567	123	17.094				

Nonverbal Recall – Shapes

Tests of within-groups effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Time	201.595	1	201.595	8.507	<.01	.07	.83
Time*group	261.120	2	130.560	5.509	<.01	.08	.84
Error(time)	2914.900	123	23.698				

Tests of between-group effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Intercept	134832.605	1	134832.605	1213.301	<.001	.91	1.00
Agegroup	23069.914	2	11534.957	103.798	<.001	.63	
Error	13668.836	123	111.129				

Short-term memory – digit span

Tests of within-groups effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Time	1.711	1	1.711	1.409	.24	.01	.22
Time*group	13.984	2	6.992	5.755	<.01	.09	.86
Error(time)	149.429	123	1.215				

Tests of between-group effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Intercept	28850.000	1	28850.000	3630.852	<.001	.97	1.00
Agegroup	219.096	2	109.548	13.787	<.001	.18	.99
Error	977.333	123	7.946				

Working Memory – letter-number sequencing

Tests of within-groups effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Time	10.736	1	10.736	6.494	.01	.05	.72
Time*group	17.915	2	8.957	5.418	<.01	.08	.84
Error(time)	203.355	123	1.653				

Tests of between-group effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Intercept	24832.011	1	24832.011	3217.740	<.001	.96	1.00
Agegroup	1090.194	2	954.597	123.697	<.001	.67	1.00
Error	949.218	123	7.717				

Face Recognition

Tests of within-groups effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Time	.070	1	.070	.027	.87	.00	.05
Time*group	67.437	2	33.718	13.252	<.001	.18	.99
Error(time)	312.964	123	2.544				

Tests of between-group effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Intercept	295616.742	1	295616.742	14792.478	<.001	.99	1.00
Agegroup	2163.543	2	1081.772	54.131	<.001	.47	1.00
Error	2458.064	123	19.984				

Prospective Memory

Tests of within-groups effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Time	23.818	1	23.818	15.996	<.001	.12	.98
Time*group	41.717	2	20.858	14.009	<.001	.19	.99
Error(time)	183.140	123	1.489				

Tests of between-group effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Intercept	8560.809	1	8560.809	3059.336	<.001	.96	1.00
Agegroup	663.132	2	331.566	118.490	<.001	.66	1.00
Error	344.186	123	2.798				

Appendix P

ANCOVA for all memory types at Time 1 testing

ANCOVA FOR ALL MEMORY TYPES AT TIME 1

Tests of Between-Subjects Effects

Verbal Recall – Words

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[5]
Corrected Model	662.005	5	132.401	16.559	<.001	.408	1.000
Intercept	6.091	1	6.091	.762	.385	.006	.139
WaisFS1	80.502	1	80.502	10.068	.002	.077	.883
IDPics1	4.751	1	4.751	.594	.442	.005	.119
FindA1	38.242	1	38.242	4.783	.031	.038	.583
Agegroup	140.985	2	70.492	8.816	<.001	.128	.968
Error	959.464	120	7.996				
Total	10759.000	126					
Corrected Total	1621.468	125					

Nonverbal Recall – Shapes

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Corrected Model	10269.605	5	2053.921	44.448	<.001	.649	1.000
Intercept	28.227	1	28.227	.611	.436	.005	.121
WaisFS1	242.213	1	242.213	5.242	.024	.042	.622
IDPics1	442.617	1	442.617	9.578	.002	.074	.867
FindA1	3.200	1	3.200	.069	.793	.001	.058
Agegroup	1175.300	2	587.650	12.717	<.001	.175	.996
Error	5545.196	120	46.210				
Total	77815.000	126					
Corrected Total	15814.802	125					

[5] Power was computed at $p = .05$ for all ANCOVAs.

Short-term Memory – Digit Span

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Corrected Model	123.839	5	24.768	6.506	<.001	.213	.997
Intercept	5.975	1	5.975	1.570	.213	.013	.237
WaisFS1	34.549	1	34.549	9.076	.003	.070	.848
IDPics1	.689	1	.689	.181	.671	.002	.071
FindA1	8.723	1	8.723	2.292	.133	.019	.324
Agegroup	5.740	2	2.870	.754	.473	.012	.176
Error	456.796	120	3.807				
Total	15260.000	126					
Corrected Total	580.635	125					

Working Memory – Letter-Number Sequencing

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Corrected Model	842.482	5	168.496	38.478	<.001	.616	1.000
Intercept	4.306	1	4.306	.983	.323	.008	.166
WaisFS1	28.782	1	28.782	6.573	.012	.052	.720
IDPics1	1.497	1	1.497	.342	.560	.003	.089
FindA1	11.408	1	11.408	2.605	.109	.021	.360
Agegroup	171.214	2	85.607	19.549	<.001	.246	1.000
Error	525.487	120	4.379				
Total	14290.000	126					
Corrected Total	1367.968	125					

Face Recognition

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Corrected Model	869.627	5	173.925	17.624	<.001	.423	1.000
Intercept	493.925	1	493.925	50.050	<.001	.294	1.000
WaisFS1	20.184	1	20.184	2.045	.155	.017	.295
IDPics1	27.638	1	27.638	2.801	.097	.023	.382
FindA1	29.955	1	29.955	3.035	.084	.025	.409
Agegroup	86.481	2	43.241	4.382	.015	.068	.748
Error	1184.246	120	9.869				
Total	149894.000	126					
Corrected Total	2053.873	125					

Prospective Memory

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Corrected Model	198.468	5	39.694	20.688	<.001	.463	1.000
Intercept	10.853	1	10.853	5.657	.019	.045	.655
WaisFS1	.868	1	.868	.453	.502	.004	.102
IDPics1	9.481	1	9.481	4.941	.028	.040	.597
FindA1	.013	1	.013	.007	.935	.000	.051
Agegroup	30.565	2	15.282	7.965	<.001	.117	.951
Error	230.238	120	1.919				
Total	5171.000	126					
Corrected Total	428.706	125					

Appendix Q

ANCOVA for all memory types at Time 2 testing

ANCOVA FOR ALL MEMORY TYPES AT TIME 2

Tests of Between-Subjects Effects

Verbal Recall – Words

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[6]
Corrected Model	1247.118	5	249.424	26.700	<.001	.527	1.000
Intercept	105.512	1	105.512	11.295	.001	.086	.915
WAIS2	202.011	1	202.011	21.624	<.001	.153	.996
IDPics2	4.168	1	4.168	.446	.505	.004	.102
FindA2	37.773	1	37.773	4.043	.047	.033	.514
Agegroup	80.398	2	40.199	4.303	.016	.067	.740
Error	1121.017	120	9.342				
Total	11035.000	126					
Corrected Total	2368.135	125					

Nonverbal Recall – Shapes

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power(a)
Corrected Model	16294.753	5	3258.951	50.104	<.001	.676	1.000
Intercept	226.227	1	226.227	3.478	.065	.028	.456
WAIS2	455.188	1	455.188	6.998	.009	.055	.747
IDPics2	423.300	1	423.300	6.508	.012	.051	.716
FindA2	242.831	1	242.831	3.733	.056	.030	.483
Agegroup	1161.263	2	580.631	8.927	<.001	.130	.970
Error	7805.215	120	65.043				
Total	96580.000	126					
Corrected Total	24099.968	125					

[6] Power was computed at $p = .05$ for all ANCOVAs.

Short-term Memory – Digit Span

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power(a)
Corrected Model	327.904	5	65.581	17.438	<.001	.421	1.000
Intercept	2.486	1	2.486	.661	.418	.005	.127
WAIS2	92.695	1	92.695	24.647	<.001	.170	.998
IDPics2	.350	1	.350	.093	.761	.001	.061
FindA2	13.433	1	13.433	3.572	.061	.029	.466
Agegroup	14.229	2	7.114	1.892	.155	.031	.387
Error	451.302	120	3.761				
Total	15030.000	126					
Corrected Total	779.206	125					

Working Memory – Letter-Number Sequencing

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power(a)
Corrected Model	1276.262	5	255.252	70.341	<.001	.746	1.000
Intercept	.064	1	.064	.018	.895	.000	.052
WAIS2	28.199	1	28.199	7.771	.006	.061	.790
IDPics2	13.053	1	13.053	3.597	.060	.029	.469
FindA2	22.291	1	22.291	6.143	.015	.049	.691
Agegroup	144.935	2	72.467	19.970	<.001	.250	1.000
Error	435.453	120	3.629				
Total	13602.000	126					
Corrected Total	1711.714	125					

Face Recognition

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power(a)
Corrected Model	1823.304	5	364.661	38.903	<.001	.618	1.000
Intercept	355.741	1	355.741	37.951	<.001	.240	1.000
WAIS2	61.126	1	61.126	6.521	.012	.052	.717
IDPics2	37.345	1	37.345	3.984	.048	.032	.508
FindA2	61.389	1	61.389	6.549	.012	.052	.719
Agegroup	146.291	2	73.145	7.803	<.001	.115	.947
Error	1124.830	120	9.374				
Total	151131.000	126					
Corrected Total	2948.135	125					

Prospective Memory

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power(a)
Corrected Model	566.418	5	113.284	57.347	<.001	.705	1.000
Intercept	1.493	1	1.493	.756	.386	.006	.139
WAIS2	24.599	1	24.599	12.453	.001	.094	.938
IDPics2	8.778	1	8.778	4.444	.037	.036	.552
FindA2	.053	1	.053	.027	.870	.000	.053
Agegroup	85.889	2	42.945	21.739	<.001	.266	1.000
Error	237.050	120	1.975				
Total	4637.000	126					
Corrected Total	803.468	125					

Appendix R

Raw data for all memory types, covariates, and screening tests for all age groups

Table R.1. *Key to test titles used in all raw data tables.*

Abbreviation	Full Title
Part	Participant
Age1, Age 2	Age at Time 1 & Time 2 testing
Ed1, Ed 2	Years of Education, Time 1 & Time 2
IQ1, IQ2	Intelligence(measured by NART), Time 1 & Time 2
WR1, WR2	Word Recall, no delay, Time 1 & Time 2
WR101, WR102	Word Recall, 10 minute delay, Time 1 & Time 2
WR71, WR72	Word Recall, 7 day delay, time 1 & Time 2
Shp1, Shp2	Shape Recall, no delay, Time 1 & Time 2
Shp101, Shp102	Shape Recall, 10 minute delay, Time 1 & Time 2
Shp71, Shp 72	Shape Recall, 7 day delay, Time 1 & Time 2
DS1, DS2	Digit Span, Time 1 & Time 2
LNS1, LNS2	Letter-number sequencing task, Time 1 & Time 2
Face 1, Face 2	Face recognition, Time 1 & Time 2
Pros1, Pros2	Prospective memory, Time 1 & Time 2
IP1, IP2	Identical Pictures task, Time 1 & Time 2
FA1, FA2	Finding A's, Time 1 & Time 2
MSE1, MSE2	Mini-Mental State Examination, Time 1 & Time 2
BDI1, BDI2	Beck Depression Inventory -II, Time 1 & Time 2
PF1, PF2	SF-36 Physical Function scale, Time 1 & Time 2
MH1, MH2	SF-36 Mental Health scale, Time 1 & Time 2

Table R.2. *Raw data for the Young group for all tests at Time 1 and Time 2.*

Raw data for the Young group continued

Part	Age1	Age2	Ed1	Ed2	IQ1	IQ2	WR1	WR2	WR101	WR102	WR71	WR72
1	27.2	29.2	14	14	120	120	12	12	10	9	6	5
2	23.9	25.9	17	17	108	108	12	10	9	10	6	6
3	27.9	30.0	16	16	108	110	10	10	7	8	4	4
4	38.2	40.2	17	17	112	117	13	21	11	18	7	12
5	20.6	22.6	15	15	121	123	11	14	11	9	7	5
6	24.5	26.5	14	15	108	108	6	6	5	6	4	5
7	32.0	34.0	14	14	92	92	5	5	4	3	2	3
8	20.6	22.6	12	13	105	103	8	7	6	4	1	6
9	36.9	38.9	17	17	106	107	7	10	6	8	2	5
10	37.6	39.6	13	14	117	117	11	10	6	10	1	5
11	24.2	26.2	17	17	102	102	13	4	13	12	9	8
12	34.5	36.5	16	16	110	110	6	7	6	6	3	5
13	34.1	36.2	16	16	111	111	12	8	12	7	6	5
14	34.5	36.5	15	15	117	117	7	8	8	8	7	8
15	40.0	42.0	13	13	90	90	8	8	6	6	4	4
16	33.9	35.9	15	15	92	98	7	6	6	3	4	1
17	34.5	36.5	18	18	127	126	18	23	16	22	15	19
18	32.9	34.9	17	17	108	110	7	11	3	9	2	3
19	20.1	22.2	17	18	123	123	10	10	9	9	6	7
20	36.1	38.1	12	13	113	113	9	12	8	9	3	3
21	29.8	31.8	16	16	128	128	12	18	11	16	8	12
22	20.2	22.2	15	17	126	124	9	9	6	5	7	6
23	27.8	29.8	14	14	100	100	6	7	6	5	3	3
24	27.8	29.8	17	17	121	124	13	15	12	13	10	10
25	30.0	32.1	14	14	117	117	15	6	10	11	8	8
26	36.7	38.6	14	15	122	122	15	6	12	11	9	10
27	28.7	30.7	22	22	116	122	6	6	5	5	3	2
28	23.5	25.5	18	18	111	113	8	9	6	6	4	5
29	31.1	33.1	12	12	107	107	9	9	8	7	10	8
30	31.0	33.0	11	12	98	98	11	10	9	8	6	8
31	33.4	35.4	17	17	108	110	7	8	5	6	1	2
32	25.3	27.3	12	12	105	105	15	13	13	11	8	5
33	39.5	41.5	11	12	103	103	9	7	7	4	1	1
34	27.0	29.0	16	16	122	122	12	12	10	11	7	6
35	27.6	29.6	11	12	100	100	15	16	11	12	8	10
36	33.6	35.6	23	23	122	123	12	11	8	8	1	4
37	30.8	32.8	20	20	112	113	9	9	8	9	5	5
38	32.8	34.8	11	11	96	96	15	4	10	9	5	5
39	24.9	26.9	13	14	111	122	15	18	13	18	6	14
40	31.2	33.2	16	16	111	111	10	11	8	9	5	6

Part	Shp1	Shp2	Shp101	Shp102	Shp71	Shp72	DS1	DS2	LNS1	LNS2
1	33	31	27	25	21	19	15	16	10	10
2	33	33	28	35	23	29	12	10	14	13
3	36	37	30	30	26	27	13	13	13	12
4	34	37	26	34	27	30	10	8	11	9
5	42	34	40	34	35	21	16	14	16	15
6	20	18	17	15	15	13	9	9	9	9
7	18	17	22	21	18	17	9	9	10	9
8	29	31	23	20	21	23	11	12	13	9
9	25	34	26	33	9	20	14	12	12	14
10	29	34	27	26	17	24	13	13	14	12
11	37	33	26	22	21	17	10	10	11	11
12	29	40	25	36	17	24	10	11	10	11
13	34	18	35	17	28	14	12	9	12	12
14	45	39	41	33	41	32	8	8	11	11
15	19	16	19	16	11	9	10	10	10	10
16	22	27	18	23	18	23	9	8	9	11
17	33	52	25	48	22	26	11	14	11	15
18	25	32	22	30	15	15	14	14	14	13
19	30	28	25	23	20	18	14	14	15	15
20	26	34	27	26	15	5	8	11	12	13
21	19	30	19	30	14	14	11	10	13	13
22	39	39	47	47	23	23	10	10	12	12
23	31	33	26	24	18	16	9	9	13	11
24	23	28	22	33	23	24	11	12	14	14
25	35	35	25	25	18	18	13	13	15	15
26	35	35	32	32	21	21	13	13	14	14
27	28	29	25	25	18	17	8	9	9	11
28	29	30	26	23	22	18	12	12	11	11
29	31	30	28	27	19	18	13	13	14	14
30	42	43	37	42	39	40	9	9	11	12
31	39	50	45	50	33	45	9	12	11	14
32	36	41	28	45	20	28	8	6	11	11
33	28	30	20	28	16	7	12	8	11	12
34	41	40	42	39	32	29	14	14	15	15
35	28	27	30	29	20	18	12	12	16	16
36	35	38	35	32	14	31	11	11	12	11
37	22	46	23	46	15	28	11	10	12	9
38	30	28	27	27	10	10	10	10	14	14
39	23	48	25	48	14	14	12	15	14	14
40	26	28	24	24	19	18	11	12	14	14

Raw data for the Young group continued

Part	Face1	Face2	Pros1	Pros2	IP1	IP2	FA1	FA2	MSE1	MSE2	BDI1	BDI2
1	35	35	8	8	80	81	46	44	29	29	2	2
2	34	34	8	6	87	72	52	56	29	30	1	2
3	34	36	8	8	78	77	52	51	30	30	0	0
4	39	40	8	7	92	87	68	71	30	29	12	4
5	35	36	8	8	95	93	46	47	30	30	2	2
6	32	32	7	7	65	66	38	39	29	29	1	1
7	30	30	5	8	68	68	40	40	30	30	3	3
8	36	39	8	6	87	61	33	49	27	28	7	7
9	33	33	7	7	83	85	50	63	29	30	5	5
10	38	40	7	8	81	88	89	63	30	29	6	4
11	37	37	7	7	92	92	54	54	30	30	1	1
12	37	37	6	8	65	64	58	58	30	30	1	1
13	39	40	8	8	73	81	41	40	28	30	2	2
14	38	38	4	6	74	74	61	60	30	30	2	2
15	34	34	8	8	59	59	51	49	28	28	7	7
16	32	31	8	8	65	62	38	28	30	30	7	0
17	38	39	8	8	93	98	73	66	30	30	8	0
18	36	37	8	7	81	89	73	77	30	30	2	8
19	38	39	8	8	81	82	61	61	30	30	1	1
20	39	38	7	6	79	79	69	72	30	30	8	10
21	39	39	6	6	70	79	81	75	30	29	4	8
22	35	36	7	7	72	73	56	57	30	30	2	2
23	27	31	6	6	93	89	57	56	29	30	4	3
24	35	36	8	8	55	67	43	62	30	28	10	8
25	37	36	6	6	66	67	62	61	30	30	2	2
26	40	40	6	6	50	51	52	53	29	29	0	0
27	33	34	7	8	85	74	45	43	30	30	1	0
28	40	40	8	7	73	74	50	50	30	30	4	4
29	33	33	8	8	61	61	51	52	29	29	0	0
30	38	39	8	8	86	88	51	50	30	30	5	8
31	35	38	6	8	91	94	50	59	30	30	0	0
32	40	39	8	8	50	56	52	52	30	29	0	3
33	36	40	8	6	82	90	67	67	30	30	2	3
34	38	38	8	8	76	76	58	57	30	30	2	2
35	39	39	7	7	82	81	65	66	30	30	2	2
36	39	40	8	6	75	66	57	48	30	30	7	11
37	36	35	8	7	88	89	47	58	30	30	6	3
38	39	39	7	8	82	82	65	63	30	30	5	5
39	37	35	4	8	66	73	47	59	28	30	11	3
40	36	36	7	7	80	80	48	48	30	29	1	3

Raw data for the Young group continued

Part	PF1	PF2	MH1	MH2
1	28	28	24	25
2	30	30	26	23
3	29	29	27	26
4	28	27	16	19
5	30	30	23	20
6	30	30	26	25
7	30	30	27	27
8	30	30	25	22
9	27	30	27	23
10	30	30	27	20
11	28	28	23	23
12	27	27	27	27
13	30	30	19	20
14	28	28	26	26
15	29	29	25	25
16	29	30	22	22
17	28	28	21	21
18	30	24	20	22
19	30	30	28	28
20	25	28	24	21
21	30	30	27	20
22	30	30	28	27
23	28	27	24	24
24	30	30	19	15
25	29	29	22	22
26	28	28	26	21
27	30	30	25	21
28	30	30	24	23
29	30	30	25	25
30	30	30	27	21
31	30	30	26	22
32	28	25	22	19
33	19	30	25	18
34	30	30	27	27
35	30	30	27	27
36	29	28	25	20
37	30	30	21	21
38	28	28	24	24
39	27	30	17	19
40	29	28	27	26

Table R.3. *Raw data for the Middle Group (50 – 70 years) for all tests at Time 1 and Time 2 testing.*

Part	Age1	Age2	Ed1	Ed2	IQ1	IQ2	WR1	WR2	WR101	WR102	WR71	WR72
41	51.3	53.3	20	20	115	124	10	16	7	12	5	9
42	63.1	65.1	18	18	118	121	12	14	10	11	9	7
43	57.9	59.9	14	14	97	97	2	6	1	4	0	0
44	62.4	64.4	19	19	129	128	13	16	13	16	12	16
45	63.1	65.1	16	16	121	128	14	13	10	12	9	11
46	60.9	62.9	19	19	128	126	9	16	9	14	3	8
47	60.1	62.1	16	16	131	128	13	11	11	11	5	4
48	51.7	53.7	13	16	103	103	4	9	4	7	1	3
49	59.0	61.0	19	19	121	121	5	6	7	7	3	3
50	58.2	60.2	11	11	111	110	6	8	5	6	4	3
51	55.8	57.8	21	21	123	120	7	8	7	5	4	3
52	56.0	58.0	11	11	112	108	14	14	14	13	10	11
53	68.4	70.4	12	12	101	98	11	9	5	4	1	0
54	57.8	59.8	11	11	105	107	9	9	7	9	2	8
55	56.4	58.4	16	16	124	122	11	11	10	8	3	1
56	62.9	65.0	14	14	117	106	6	6	0	0	0	0
57	50.8	52.9	17	17	124	124	10	8	6	6	2	5
58	60.5	62.5	21	21	121	121	16	16	10	15	5	12
59	61.1	63.0	15	15	100	100	12	11	11	9	4	7
60	51.2	53.3	22	22	124	124	9	7	9	6	3	4
61	51.2	53.2	24	24	112	121	14	16	11	16	6	15
62	54.8	56.8	15	15	122	120	9	10	6	7	3	1
63	55.9	57.9	15	15	103	103	8	6	4	5	0	0
64	60.7	62.7	11	13	111	111	8	8	5	5	2	3
65	65.1	67.1	20	20	126	124	9	9	6	7	3	3
66	65.8	67.8	11	11	110	110	9	11	7	10	6	3
67	56.8	58.8	24	24	126	126	12	12	13	8	5	6
68	56.4	58.4	14	14	115	117	13	11	11	10	7	6
69	60.1	62.1	19	19	120	124	4	5	5	5	0	1
70	69.9	71.9	11	11	107	107	12	9	8	8	7	7
71	56.6	58.7	21	21	113	117	5	4	3	0	1	0
73	58.2	60.2	20	20	117	123	10	12	7	10	2	2
75	58.0	60.0	14	14	106	103	7	5	6	5	0	2
76	67.1	69.1	16	16	120	118	14	13	12	14	9	7
77	56.1	58.1	12	12	100	100	10	7	8	1	2	1
78	59.2	61.2	17	17	131	124	7	14	6	12	2	2
79	67.6	69.6	19	19	128	128	8	11	8	10	5	4
80	62.5	64.5	15	15	126	124	14	17	10	15	1	3

81	52.1	54.1	18	18	112	112	10	10	9	8	5	4
82	68.9	70.9	10	10	102	102	5	7	2	6	0	0
83	56.9	58.9	18	18	98	98	8	10	4	7	0	0
84	58.4	60.4	16	16	117	116	9	9	8	8	4	5
85	59.0	61.0	17	19	124	111	12	7	8	4	5	1
86	59.1	61.1	16	16	120	120	8	9	4	7	3	4

Continued over

Raw data for the Middle group continued

Part	Shp1	Shp2	Shp101	Shp102	Shp71	Shp72	DS1	DS2	LNS1	LNS2
41	38	56	43	55	36	58	15	14	13	13
42	37	39	33	49	28	43	8	10	11	12
43	10	11	12	7	10	3	12	11	9	9
44	25	26	25	21	21	18	14	12	10	11
45	32	43	23	40	31	35	11	11	11	11
46	19	21	12	21	10	14	14	14	10	11
47	37	29	34	31	17	9	10	12	11	12
48	32	42	27	34	21	25	13	15	13	12
49	10	14	13	12	5	11	8	8	10	10
50	16	25	12	21	13	17	11	10	9	13
51	18	23	19	23	12	9	10	10	11	10
52	33	38	32	34	26	28	10	11	10	11
53	18	23	18	16	17	10	9	7	15	12
54	27	33	27	28	12	15	8	9	12	12
55	27	41	24	35	16	30	11	10	14	14
56	2	7	7	0	0	5	15	14	11	10
57	25	41	22	36	13	28	11	11	14	17
58	34	40	34	39	29	35	10	13	13	13
59	30	31	25	30	17	24	9	9	12	12
60	22	20	21	20	14	13	9	14	9	11
61	35	33	39	33	13	33	15	15	12	11
62	20	19	20	27	17	16	11	12	15	15
63	32	46	25	45	8	37	12	14	10	13
64	23	27	21	23	12	12	13	14	12	13
65	26	39	20	36	14	35	11	12	10	10
66	33	33	32	32	24	24	11	9	10	13
67	21	23	20	15	13	18	14	15	13	13
68	24	23	21	20	11	16	11	13	10	11
69	34	27	23	32	0	6	12	14	11	11
70	24	34	20	33	21	25	15	13	12	12
71	17	20	14	14	7	10	10	10	3	10
73	18	22	17	19	10	8	8	10	12	9
75	19	22	18	20	11	13	11	9	10	9
76	22	41	23	34	20	15	10	14	13	12
77	21	17	21	0	14	0	12	11	15	12
78	34	43	35	32	9	14	13	15	15	11
79	36	35	36	38	32	27	14	15	14	13
80	24	29	24	26	20	25	12	11	10	8
81	36	46	32	42	17	36	15	13	15	13

82	31	38	33	34	0	29	8	11	9	9
83	27	22	22	28	0	10	10	8	8	10
84	31	28	24	20	15	11	12	12	13	11
85	33	7	31	7	22	5	13	10	15	9
86	31	24	24	21	14	16	10	11	9	9

Continued over

Raw data for the Middle group continued

Part	Face1	Face2	Pros1	Pros2	IP1	IP2	FA1	FA2	MSE1	MSE2
41	37	39	7	8	70	65	104	108	30	29
42	39	39	8	6	66	67	52	52	29	29
43	30	29	5	6	48	49	21	31	27	27
44	36	39	8	8	63	71	58	54	30	30
45	37	37	6	8	69	76	83	78	30	27
46	30	39	7	6	42	41	46	44	29	28
47	38	38	5	8	62	57	81	72	30	27
48	38	38	7	6	88	94	57	66	30	30
49	38	38	8	8	61	61	66	66	30	30
50	28	33	6	8	43	48	55	49	30	27
51	37	38	5	7	71	54	59	54	29	30
52	38	39	8	4	74	65	48	59	29	30
53	38	38	8	4	40	51	55	63	30	28
54	35	37	8	8	57	48	57	61	29	29
55	39	40	8	8	63	69	50	59	28	30
56	32	30	8	4	63	63	66	55	29	27
57	35	35	6	7	69	68	84	66	30	28
58	37	39	6	6	56	53	61	49	30	27
59	33	36	7	8	48	60	59	49	30	30
60	36	37	6	7	71	56	65	66	30	29
61	39	39	4	7	55	55	72	68	30	30
62	35	35	6	8	60	68	67	66	28	30
63	37	33	7	6	63	56	43	48	29	29
64	35	35	8	6	77	52	53	58	29	30
65	34	35	7	8	45	47	57	52	30	30
66	38	40	8	6	57	47	63	53	30	28
67	35	36	6	8	55	59	79	83	29	30
68	35	40	8	8	69	54	111	98	30	28
69	40	38	7	8	91	71	53	33	30	30
70	36	40	7	8	40	40	43	32	28	30
71	38	37	6	6	47	52	37	31	30	28
73	31	38	6	7	56	66	51	57	30	30
75	38	36	8	4	54	44	58	49	30	29
76	37	38	8	7	69	66	63	84	30	29
77	33	37	6	0	50	42	68	71	30	28
78	35	34	8	8	54	54	51	53	30	29
79	40	40	8	8	56	50	62	58	28	27
80	35	36	5	6	45	48	40	48	30	29
81	35	38	8	7	57	68	89	81	30	30
82	37	36	5	6	44	47	58	64	27	30

83	34	34	5	6	61	73	57	60	29	29
84	36	35	7	7	61	61	53	52	29	29
85	35	35	7	7	60	60	57	57	30	30
86	36	34	8	6	60	63	47	36	29	30

Continued over

Raw data for the Middle group continued

Part	BDI1	BDI2	PF1	PF2	MH1	MH2
41	4	5	28	28	25	16
42	3	5	30	29	25	21
43	2	6	26	27	27	24
44	5	10	28	26	23	21
45	0	3	26	26	27	21
46	0	1	22	19	25	20
47	5	14	28	29	27	24
48	0	7	30	28	28	23
49	2	2	25	25	19	19
50	0	5	25	25	25	19
51	2	4	26	28	25	23
52	6	7	26	27	25	20
53	18	12	18	28	19	21
54	1	6	30	29	26	20
55	1	0	30	27	27	22
56	9	12	28	26	23	20
57	7	4	29	29	28	23
58	7	1	13	12	22	21
59	0	1	30	28	30	21
60	0	0	30	29	24	19
61	0	0	30	30	28	19
62	2	1	28	28	27	21
63	2	8	20	21	23	23
64	3	15	24	25	25	20
65	2	4	28	20	22	19
66	4	4	30	28	25	19
67	2	5	29	27	27	20
68	1	5	26	25	25	21
69	0	1	21	19	23	19
70	2	4	27	27	26	22
71	0	0	23	29	26	23
73	0	2	29	29	18	19
75	5	7	28	29	28	21
76	1	1	28	30	28	19
77	13	8	24	24	21	19
78	3	6	27	29	26	19
79	0	1	26	25	27	20
80	2	5	26	28	25	20
81	5	2	28	29	27	21
82	1	15	27	28	28	26
83	0	5	28	29	21	20

84	2	2	28	28	25	25
85	1	1	27	23	26	21
86	3	4	28	25	25	22

Table R.4. *Raw data for the Oldest-old group for all tests*

Part	Age1	Age2	Ed1	Ed2	IQ1	IQ2	WR1	WR2	WR101	WR102	WR71	WR72
87	85.8	87.8	14	14	113	107	7	6	3	2	2	1
88	86.7	88.7	10	10	102	98	4	3	2	2	0	0
89	87.2	89.4	10	10	98	98	4	3	3	2	2	1
90	85.7	87.8	14	14	108	105	5	4	3	0	1	0
93	90.1	92.1	14	14	120	118	7	8	7	7	5	7
94	85.8	87.8	9	9	95	87	3	1	2	1	0	0
95	88.9	90.0	11	11	126	121	6	6	2	5	2	6
96	88.4	90.4	12	12	107	107	2	1	2	0	1	0
98	93.7	95.8	14	14	118	113	7	6	4	3	4	3
99	85.7	87.7	7	7	110	110	4	3	3	4	0	0
100	86.8	88.8	10	10	106	103	7	6	4	2	3	3
101	88.6	90.6	9	9	113	100	3	3	0	0	0	0
102	85.9	87.9	12	12	115	115	5	6	4	6	3	5
103	86.8	88.9	11	11	110	103	1	1	0	0	0	0
104	85.7	87.7	10	10	121	122	7	10	4	6	2	2
105	85.8	87.8	12	12	108	105	6	5	4	3	2	2
106	86.7	88.7	12	12	115	108	6	5	4	4	0	1
107	87.2	89.2	17	17	116	115	4	5	2	3	1	3
108	92.7	94.7	15	15	128	124	9	7	7	2	6	2
109	89.0	91.0	10	10	100	96	4	4	0	0	0	0
110	93.9	95.9	14	14	117	113	8	7	2	1	0	0
111	90.1	92.2	16	16	106	105	10	8	7	3	3	1
112	85.8	87.9	12	12	112	107	7	3	6	1	3	1
113	88.9	90.0	11	11	106	106	5	2	2	0	0	0
114	88.4	90.6	8	8	108	105	4	4	3	3	0	0
115	90.2	92.2	12	12	107	106	10	9	5	5	3	3
116	93.7	95.7	10	10	103	91	5	4	4	3	0	0
117	85.7	87.7	16	16	120	120	11	6	6	4	4	3
118	86.8	88.8	9	9	113	112	3	1	0	0	0	0
119	88.6	90.7	16	16	122	118	9	7	6	6	6	5
120	90.6	92.6	13	13	111	110	7	7	2	2	0	0
121	85.1	87.4	23	23	128	122	7	3	7	1	2	0
122	85.5	87.6	19	19	110	100	1	1	1	0	1	0
123	85.2	87.4	9	9	100	91	2	1	2	0	0	0
124	86.8	89.0	9	9	100	98	7	5	2	1	0	0
125	87.8	89.8	9	9	115	110	7	7	3	3	0	0
126	85.3	87.3	18	18	129	126	5	4	4	3	2	2
127	87.7	89.7	9	9	97	91	7	7	0	4	1	1
128	87.8	90.0	10	10	108	98	8	1	4	0	0	0

130	85.9	88.0	15	15	118	118	7	4	5	2	1	1
131	87.7	89.7	21	21	113	110	7	3	4	0	1	0
132	85.2	87.4	10	10	111	111	2	6	2	0	1	0

Continued over

Raw data for the Oldest-old group continued

Part	Shp1	Shp2	Shp101	Shp102	Shp71	Shp72	DS1	DS2	LNS1	LNS2
87	9	9	0	4	2	4	9	8	7	6
88	6	5	3	2	0	0	9	8	6	6
89	13	7	11	4	4	2	7	7	5	4
90	4	0	2	0	6	0	8	8	3	2
93	6	6	0	4	6	5	12	10	5	4
94	3	2	0	0	0	0	7	5	5	3
95	31	30	26	27	15	24	8	7	10	11
96	5	4	5	1	6	0	7	7	3	2
98	10	6	10	5	14	4	9	8	5	5
99	11	10	7	10	0	10	9	10	9	5
100	11	8	8	5	11	7	9	8	6	5
101	4	3	0	0	0	0	11	11	6	5
102	16	18	11	21	17	18	9	8	8	6
103	0	0	0	0	0	0	10	9	12	7
104	25	23	14	24	12	11	12	14	7	10
105	6	4	2	0	0	0	9	7	6	5
106	10	7	10	0	2	0	8	8	10	6
107	11	6	3	3	8	5	11	9	8	6
108	8	17	8	16	15	8	15	12	11	12
109	8	5	0	2	0	3	12	10	5	4
110	14	7	6	6	0	0	12	10	7	6
111	21	17	14	22	12	4	13	14	5	4
112	7	4	4	3	3	2	10	8	5	5
113	2	5	0	1	0	0	12	10	5	3
114	11	4	7	3	0	0	9	9	8	6
115	15	6	8	4	10	4	11	9	6	5
116	4	7	0	3	0	2	9	9	6	6
117	15	21	14	19	14	14	10	12	5	3
118	1	2	0	0	0	0	12	11	6	5
119	8	6	7	6	15	7	9	8	8	7
120	18	18	10	8	0	0	10	9	9	8
121	17	11	17	6	14	0	11	12	5	3
122	7	3	0	0	0	0	7	7	4	4
123	8	0	7	0	5	0	10	6	3	2
124	7	8	5	3	0	0	9	8	5	3
125	13	11	6	3	4	11	10	9	7	6
126	14	17	14	11	11	10	14	14	8	12
127	10	18	10	14	8	8	7	5	6	4
128	5	2	8	0	0	0	8	6	7	4

130	18	17	13	17	17	10	8	10	10	10
131	16	25	15	18	9	9	11	10	10	8
132	4	9	4	9	4	0	9	9	7	2

Continued over

Raw data for the Oldest-old group continued

Part	Face1	Face2	Pros1	Pros2	IP1	IP2	FA1	FA2	MSE1	MSE2
87	35	33	5	5	34	30	34	31	30	27
88	34	33	4	2	29	27	29	28	25	25
89	32	30	3	2	27	26	27	24	27	27
90	32	31	4	0	31	25	41	35	30	25
93	29	32	5	3	50	48	75	60	29	30
94	26	23	3	0	20	14	20	16	27	25
95	37	37	8	4	39	47	40	35	30	30
96	33	32	6	2	27	36	50	39	29	28
98	30	29	3	2	39	38	40	38	27	26
99	34	35	5	4	18	22	31	37	27	26
100	29	29	4	4	39	36	34	32	26	26
101	28	28	3	3	26	26	58	38	27	27
102	31	29	4	4	47	37	40	40	26	27
103	24	23	3	0	30	26	51	44	26	25
104	36	36	6	6	54	53	49	52	28	29
105	25	24	2	1	32	30	31	28	28	26
106	38	36	3	0	55	46	36	39	28	30
107	25	21	3	0	26	22	25	23	27	24
108	29	29	6	6	40	41	35	45	29	30
109	33	27	0	4	35	22	38	33	29	25
110	31	30	7	6	43	42	35	34	29	27
111	38	36	7	4	41	37	73	53	27	25
112	31	30	7	3	40	36	41	40	27	26
113	33	28	4	0	19	16	31	21	26	25
114	34	33	3	2	19	19	40	38	27	27
115	26	25	5	0	39	16	24	25	27	24
116	36	26	8	3	41	26	31	24	29	27
117	31	33	4	5	39	42	48	45	30	30
118	25	18	3	2	26	23	58	49	29	28
119	28	28	4	3	29	28	35	34	29	27
120	29	29	4	4	29	29	39	38	28	27
121	31	29	2	2	27	24	26	24	29	25
122	21	25	2	0	32	18	37	19	27	24
123	31	24	4	0	31	17	46	19	27	24
124	31	30	8	6	14	14	26	25	28	27
125	28	23	4	3	27	18	27	27	30	26
126	35	34	6	5	47	48	63	63	29	28
127	27	26	4	2	32	33	26	30	29	29
128	32	31	3	2	17	16	47	38	27	24

130	34	35	7	4	44	41	49	43	29	30
131	36	37	5	2	50	60	55	57	26	28
132	27	29	5	2	27	25	38	25	28	26

Continued over

Raw data for the Oldest-old group continued

Part	BDI1	BDI2	PF1	PF2	MH1	MH2
87	3	6	25	18	22	20
88	3	3	13	13	28	24
89	3	3	17	15	22	21
90	3	3	17	10	29	25
93	2	3	20	12	28	21
94	9	3	13	13	28	22
95	7	8	20	19	26	22
96	3	3	21	14	26	18
98	5	4	22	18	24	21
99	1	4	17	18	28	21
100	4	3	14	13	30	24
101	2	2	20	20	30	26
102	8	6	14	13	25	21
103	0	7	26	21	30	21
104	3	3	16	25	26	20
105	5	8	24	19	25	21
106	1	0	22	20	29	30
107	5	9	18	19	24	21
108	3	2	29	28	30	20
109	3	17	25	28	20	18
110	2	5	16	14	30	26
111	0	4	25	23	30	20
112	4	7	21	18	20	19
113	6	7	24	28	25	18
114	1	3	17	16	24	22
115	4	5	14	10	30	19
116	8	11	19	13	29	14
117	8	8	22	24	25	22
118	2	0	20	21	30	20
119	3	3	26	23	28	25
120	3	5	17	16	25	23
121	1	6	21	19	24	21
122	2	2	27	13	20	21
123	9	6	20	12	23	19
124	7	6	20	20	28	24
125	2	4	25	28	26	19
126	8	12	21	21	27	20
127	5	6	26	25	36	20
128	2	5	27	22	28	21

130	0	1	22	24	30	20
131	0	2	28	27	30	22
132	0	0	27	20	24	19