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Frequency, Intrusions, and Suffix Effects in Immediate and

Delayed Recall as a Function of Aging and Alzheimer's Disease

by

Teresa A. Wiseman Griesing

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10/26/98
Date

Susan K Manning
Susan Karp Manning, Ph.D.
Chair of the Examining Committee

11/11/98
Date

Executive Officer

Supervisory Committee

Martin Chodorow, Ph.D.

Alan Kluger, Ph.D.

Victoria Luine, Ph.D.

Steven H. Ferris, Ph.D.

THE CITY UNIVERSITY OF NEW YORK

Abstract

Frequency, Intrusions, and Suffix Effects in Immediate and

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by

Teresa A. Wiseman Griesing

Advisor: Susan Karp Manning

Recent work has suggested that patients with Alzheimer's Disease (AD) have attentional deficits which may result in "rapid forgetting" and the inability to inhibit responses. The inhibition difficulties appear to be responsible for various types of intrusion errors. It has been suggested that intrusion errors, in immediate recall and delayed recall, are a useful clinical marker of early AD. The following four groups were studied: normal young, normal elderly, mild cognitively impaired (MCI) elderly, and elderly with probable AD.

Experiments 1, 2, and 3 used versions of the suffix paradigm in immediate recall and examined differences between recall of letters of the alphabet presented auditorilly as compared with visually. Experiment 1 used the "standard" version of the suffix in which the control condition requires strict serial recall of the items and the suffix condition has an extra-not-to-be-recalled item appended onto the end of the list. In Experiments 2 and 3, the "varied" suffix (also not-to-be-recalled) appears equally often in all serial positions. In Experiment 1 some letters were presented three times as often as others.

In all three experiments, participants performed recall and recognition tasks after a brief

delay. The expected decline in performance with increasing age and cognitive impairment was evident on all immediate and delayed measures.

However, the patterns differed. In immediate recall, there was no frequency effect for the letters presented three times more often, while there was a strong frequency effect in delayed recall with increasing with age and cognitive impairment. There were also varying patterns for modality and suffix effects in all experiments. Differences in performance in the "standard" suffix condition compared to "varied" suffix condition are discussed. Intrusion errors clearly differentiated the AD group from the other groups with a greater effect in delayed recall compared to immediate recall. Consistent with previous research, intrusion errors appear to be a useful clinical marker of early AD.

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Introduction

Dementia is a major health problem in the United States. It affects millions of people and costs billions of dollars. Our understanding of the epidemiology of Alzheimer's Disease (AD) has rapidly advanced in the past decade. Studies done in several countries, including but not limited to China, Japan, France, Italy, and the United States, have confirmed that the prevalence of AD increases exponentially between the ages of 65 and 85. AD, the most common cause of dementia, affects nearly 50% of the population by the age of 85 years (Evans, Funkenstein, Albert et al., 1989). It is clear that dementias, particularly those similar to AD, are progressive, are devastating for affected individuals and their families and place a tremendous burden on the health care system.

AD was first identified in 1907 by Alois Alzheimer, a German psychiatrist. He portrayed a 51-year- old patient with the following symptoms: memory deficits, naming disturbances and paraphasic substitutions, decreased comprehension, and suspiciousness. However, this patient showed no motor deficits. After a gradual decline, the patient died four and one-half years later. Upon autopsy, Alzheimer characterized the brain as atrophied, with cortical cell loss, senile plaques and neurofibrillary tangles. His description still applies to the disorder that bears his name (Cummings & Benson, 1983).

The etiology of AD is still unknown and there exists no reliable antemortem diagnosis. It is currently believed that the cause of AD is due to the accumulation of neurofibrillary tangles and beta amyloid plaques in the brain. The tangles and plaques lead to cell death which in turn interferes with the connections and communication between the remaining cells. Terry and Katzman (1983) among others, such as Alzheimer himself, have noted the presence of these plaques and tangles in post mortem studies of individuals diagnosed with AD. The well- known pathological changes (e.g., neurofibrillary tangles, neuritic plaques, loss of neurons and synapses, presence of amyloid) associated with AD appear usually to begin in the hippocampus and surrounding temporal lobe structures (Hyman, Van Hoesen, Damasio, & Barnes, 1984) and eventually the pathological changes involve all anterior and posterior cortices in both the right and left hemispheres (Terry & Katzman, 1983).

It should be mentioned that senile plaques and neurofibrillary tangles identical to those in AD are virtually always found in the brains of individuals with Downs syndrome who are older than 40 years (Wisniewski, Wisniewski, & Wen, 1985). In the higher-functioning individuals with Downs syndrome the typical presentation is the gradual onset of memory impairment, decreased verbal output, and temporal disorientation (Lai & Williams, 1989). In the more retarded individuals, the beginning signs are apathy, inattention, and decreased social interactions (Lai & Williams, 1989). The symptomotolgy found in persons with Downs syndrome is very similar to the symptomotolgy observed in others diagnosed with AD.

A variety of illnesses other than AD can produce memory loss and/or impair cognitive function. Although, AD is the most common cause of dementia (Larson, 1990) it may be confused with vascular dementia (cognitive dysfunction resulting from multiple cerebral infarcts) as well as dementia associated with Parkinson's disease, normal pressure hydrocephalus, metabolic disorders, toxic conditions, Pick's disease, frontal lobe disease, or AIDS. Nevertheless, AD is distinguishable from these other illnesses. The diagnosis of AD can be made by excluding other forms of dementia and identifying its typical clinical features. The diagnosis of AD will be discussed in more detail in the following pages.

Although there is a decline in cognitive functioning in normal aging , the decline in AD is very different. AD is broadly characterized by a global and progressive deterioration of memory, cognition, and personality (Cummings & Benson, 1992). Although there are many changes associated with the progression of AD, this paper will focus on the neuropsychological features of the memory disorders associated with the earliest manifestations of AD.

Important Definitions

Experiments 1-3 attempt to compare memory function and decline in AD, mildly impaired elderly, and normal elderly by using a memory paradigm called the suffix paradigm which will be described next. Further, we will define some important terms to be used in this paper.

When a list of items are given to individuals to remember, the items at the beginning and the end of the list, in both serial and free recall conditions, are remembered better than the items in the middle of the list. The ability to recall items which appear at the end of the list as compared with the middle items of a list is referred to as the recency effect (e.g., Crowder & Morton, 1969).

Numerous paradigms have been developed which compare the retrieval of information presented in the auditory and visual modalities. The auditory presentation refers to the presentation of stimuli through the auditory senses and the visual presentation refers to the presentation of stimuli through the visual senses. The modality effect refers to the superior recall of items presented in the auditory modality versus the recall of items presented in the visual modality. In addition, the recency effect is enhanced and more robust in the auditory modality when compared with the visual modality. The theoretical reasons for the modality effect and recency effect will be discussed in more detail in the following pages.

A suffix is defined as a not-to-be-recalled item which is appended onto a sequence of items to be recalled. The suffix reduces recall of auditory stimuli at the end of the sequence particularly when serial recall is required. The suffix acts as a minimal distractor (by creating interference) which can decrease or even eliminate the recency effect, particularly in the auditory modality. The effect of the suffix on memory performance will be examined closely in Experiments 1-3.

Following the auditory or visual presentation of stimuli for immediate recall (for example, sequences of numbers, letters, or words), participants' responses may be either serial or free. Strict serial recall requires that items be recalled in the exact order in which they were presented. Free recall means that items may be recalled in any order, regardless of the order of presentation. The present study will examine serial recall in immediate memory and free recall in delayed memory.

The recall of stimuli can be either immediate or delayed. Immediate recall requires the participants to make their responses directly after the presentation of stimuli and delayed recall requires the participants to make their responses after the performance of a distractor task or tasks, and/or after a variable time period. The present studies will examine both immediate and delayed recall as a function of age and disease.

What we will call the frequency effect will be examined in Experiment 1. The frequency effect refers to the greater expected recall performance for items presented more often compared to the recall of items presented less often. The frequency of presentation was manipulated within the experiment using a new method. Instead of varying frequency in language using norms, we varied the frequency of items within the experiment. More specifically, we used two sets of six consonants. One set appeared three times as often as the other. Experiment 1 examined the recall of both sets of letters in immediate and delayed recall to see if there was any effect of frequency on recall.

Intrusions are defined as items which participants "recall" that are not part of the to-be-recalled list of stimuli (Shindler, Caplan, & Hier, 1984). There are several types of intrusion errors which will be examined. The first type of intrusion error that will be examined in Experiments 1-3 is Extra-list intrusions. Extra-list intrusion errors are the recall of items which were never part of the stimulus sequence, and thus never presented to participants as a to-be-recalled item. This differs from Intra-list intrusions, examined in Experiments 2-3, which are intrusion errors which were part of a previously presented sequence of stimuli, but not part of the most current stimulus sequence. And finally, Experiments 1-3 will examine Suffix intrusions, which are the recall of the not-to-be-recalled suffix item appended onto each sequence.

Previous research has suggested that the examination of intrusion errors in immediate and delayed recall may provide an early cognitive marker for AD (Manning, Greenhut-Wertz, & Mackell, 1996). Since to date, it is not possible to give a definitive diagnosis of AD prior to autopsy, the present set of experiments is an attempt to find early cognitive markers of AD. Studies which attempt to find an early cognitive marker, one which can detect the earliest cognitive losses in AD and help in differentiating AD patients from those who are going through "normal aging", is extremely important. The process of finding an early cognitive marker is vital in order to target individuals who can benefit from appropriate drug treatments which are available today and those which are developed in the future.

Memory and Cognition

Theoretical Basis

In order to investigate the preservation and loss of memory, it is necessary to distinguish between different types of memory function. Memory has been classified in terms of immediate or short-term memory and long-term memory. The storage capacity of immediate memory is markedly different from that of long term memory. One way to determine the capacity of immediate memory is to measure the memory span, the number of items an individual can recall after just one presentation. For normal adults, the mean span is remarkably consistent. Whether the items are digits or letters, whether they are presented visually or auditorily, the result is essentially the same. A classic paper by George Miller (1956) has suggested that the capacity of immediate memory is seven. Although there is some question about the accuracy of Miller's "magic" number, it does suggest the capacity of immediate memory is limited, and there is a great deal of support for this view.

In contrast, the storage capacity of long term memory is enormous, and perhaps unlimited. One extremely dramatic and interesting example is that of Kasparov, the Russian chess champion who responded angrily when he lost a match to a computer named Deep Blue by its developer IBM. This computer was designed for storing chess moves and was programmed by chess playing computer programers. The fact that it has taken IBM years to developed Deep Blue and that Kasparov even now is able to win games frequently attests to the ability of certain individuals to retain enormous, perhaps unlimited, amounts of information in long term memory.

Changes with Age

As people age, they experience forgetfulness, which is often considered a benign and normal aspect of aging. The progressive decline in mental functioning, memory and intelligence, that is characteristic of dementia is not inevitable. While occurring more frequently in older adults, dementia has many causes, with some forms, such as Alzheimer's Disease (AD), are associated with specific processes that change the brain beyond critical threshold thus, causing profound cognitive impairment. The majority of older adults actually retain most of their intellectual abilities throughout the lifespan

(Selkoe, 1992).

Vocabulary is an example of an area which remains relatively stable over ones lifespan. This has been measured by using the vocabulary subtest of the Wechsler Adult Intelligence Scale - Revised (WAIS-R). Performance on this measure has been shown to remain stable, for most people, up to age 80. Although, it has also been suggested that while older adults are able to provide adequate definitions of many words, the quality of their definitions may be lower than that of younger adults. Unfortunately, the evidence on this issue of better quality definitions by younger adults, is mixed. Some studies have reported an age difference in the quality of definitions (Botwinick & Storandt, 1974b), but others have failed to find statistically significant difference (Storck & Looft, 1973) or failed to find a significant age by scoring method (quality) interaction (Botwinick, West, & Storandt, 1975). Also, it appears that when people are asked to do something more than define the words, such as classify them (Riegel, 1959) or perform verbal analogies (Farmer, McLean, Sparks, & O'Connell, 1978; Riegel, 1978), pronounced age differences are apparent and consistent.

In addition, digit span forward, the ability to repeat a long series of numbers or letters, remains relatively stable over the lifetime (Crook, Ferris, McCarthy, & Ray, 1980). Tests of arithmetic ability have yielded a mixture of results, with some indicating small differences with age (e.g., Bilash & Zubek, 1960), and others indicating more moderate differences in favor of the young (e.g., Birren & Botwinick, 1951; Gardner & Monge, 1977). Bromley (1974) points out that tests emphasizing "mechanical computation" tend to produce stable age functions (no difference) whereas tests emphasizing "thoughtful reasoning" tend to produce age-related differences. This is consistent with the findings that tests involving greater attentional demands (Rissenberg & Glanzer, 1987) or increasing task complexity (Smith, 1979, 1980) show age-related decrements.

Research in this lab has also shown this age differential when greater attentional demands are placed on participants. Work in this lab, using the suffix paradigm, has demonstrated an increased susceptibility to interference by the elderly (Manning, Greenhut-Wertz, 1990) and AD patients (Manning, Greenhut-Wertz, & Mackell, 1996). Experiments 1 - 3 will also examine the effects of interference with increasing age and cognitive decline. These differences will be examined by using not only a standard suffix paradigm in Experiment 1, but also by using a variation of the standard suffix in Experiments 2 and 3.

There are several areas in which age associated decline has been consistently found. For example, recall becomes slower, life experiences may be less accurately remembered, ability to name objects and people is reduced (Albert, Heller, & Milberg, 1988), and increased susceptibility to interference, such as background noise and irrelevant stimuli, in addition to a decline in concentration, has been observed (Reisberg, Ferris, Franssen, Kluger, & Borenstein, 1986; Winocur, 1988). In addition, there are age differences associated with both episodic memory (Craik, 1977) and semantic memory (Burke & Harrold, 1988). Young adults often perform better than older adults on episodic tasks such as recall and recognition, while older adults often perform as well or better than young adults on semantic tasks which involve access of general knowledge without reference to specific contextual details.

Hulstch, Masson, and Small (1991), further examined age differences in episodic and semantic memory and attempted to clarify some of the inconsistencies found in the literature. Hulstch et al. (1991) suggested that performance on direct memory tests such as word, text, and fact recall, rely on both semantic and episodic memory, while indirect tests, such as word stem completion, are less likely to rely on semantic or episodic memory. They, suggest that indirect tests require a participant to perform a task without reference to conceptual information or particular prior experiences. Hulstch et al. (1991) found significant age related differences, in favor of the young, in both direct (recall tasks for world knowledge, narrative texts, and word lists) and indirect (word stem completion) memory tests.

The memory deficits found in healthy older adults are not clinically impairing and they usually present no problem for daily living (Horn, 1984). For example, Metamemory does not deal with specific information, but rather with the operation of the memory system in general. Tulving (1985) describes metamemory as a individual's awareness and understanding of his or her own memory. Much speculation about possible age differences in metamemory was fueled by reports that older adults use memory strategies less often, or less effectively, than young adults. Many researchers have demonstrated that increased age is associated with a reduction in the use of memory strategies that might facilitate memory performance (i.e., Sanders, Murphy, Schmitt, & Walsh, 1980). Salthouse (1982) points out that this is of importance, since inefficient metamemory processes might exaggerate any memory differences that exist.

Although there has been no consensus on the age-related changes associated with metamemory, many agree that older adults may not be as careful as young adults in monitoring the contents of memory. Experiment 1 will examine metamemory processes in relation to the monitoring of frequency information in immediate memory. The monitoring of frequency information will be assessed by using a post-experimental questionnaire, which will ask the participants about their awareness of the frequency manipulation of the stimuli presented during immediate recall. This questionnaire will be described fully in the method section of Experiment 1.

To summarize, although most aging individuals show a decline in some areas of memory and cognition, for many individuals this decline is not significant.

Changes with Mild Cognitive Impairment

In the absence of pathology, intellectual growth and performance does not necessarily decline with advancing age, and memory may actually improve in some ways. Although this is true, it is well known that some individuals show significant decline in memory and cognition and thus, cannot be considered "normal". However, the cognitive deficits these individuals experience are not sufficient to be diagnosed as having AD. These individuals, who show signs of mild but significant decline in memory are called mild cognitively impaired (MCI) (Reisberg , Ferris, & deLeon, 1982).

But, unlike the changes in cognition that can be considered a normal part of aging, Ferris and Kluger (1996) describe the importance of diagnosing MCI which cannot be considered a normal part of the aging process. Individuals with MCI have a significant decline in memory and cognition (but not as profound as the deficits in AD) but have slight or no deficits in activities of daily living (ADL). Using psychometric measures and MRI scans Ferris, Kluger, Golomb, deLeon, Flicker, and Reisberg (1993) are able to predict future decline of MCI individuals to AD with 92% accuracy.

The diagnostic importance of this is enormous. They recommend that individuals who can be accurately diagnosed with MCI should be given the option to participate in clinical trials which test compounds with cognitive-enhancing potential (Ferris & Kluger, 1996). Early and accurate detection of AD is of great importance because it may lead to the possibility of taking medications which may not only enhance cognition but also slow the progression of the underlying disease process. Potential medications that may be useful for individuals diagnosed with MCI include Aricept developed by Eisai/Pfizer Pharmaceutical [approved by the Food and Drug Administration (FDA)], Excelon developed by Novartis and Metrifonate developed by Bayer (not yet approved by the FDA), estrogen (being studied in females), vitamin E, and a new class of anti-inflammatories called Cox-2 Inhibitors developed by Merck and Searle.

Aricept and the other agents in this class inhibit the production of acetylcholinesterase (AchE), the enzyme normally responsible for the inactivation of acetylcholine (ACh) after its release from cholinergic nerves. The principle underlying use of AchE inhibitors is to optimize the usefulness of the reduced amounts of ACh that is being released from the few remaining cholinergic neurons. These medications may help relieve the symptomatic cognitive deficits by enhancing the production of acetylcholine in the brains of AD patients and/or help slow the progression of the disease. The use of AchE inhibitors to slow the progression of the disease is still being studied, although the use of Estrogen in females, and vitamin E in both males and females, looks promising.

Changes with AD

Despite the global nature of cognitive dysfunction evident in AD, a disorder of memory is clearly the most prevalent and prominent feature of the early stages of the disease. In most cases, the presenting complaint of the patients ultimately diagnosed with AD is increased “forgetfulness”. Psychometric evaluation of these patients reveals significant declines in their ability to learn and retain new verbal or nonverbal information (anterograde amnesia), as well as deficits in the ability to recall previously well-known information from their past (retrograde amnesia) (Beatty, Salmon, Butters, Heindel, & Granholm, 1988; Wilson, Kaszniak, & Fox, 1981). In addition, memory for concepts, the meanings of words, and factual information is often impaired in patients with AD.

In the early stages of the disease, disturbances in episodic memory are generally evident to the patient, family and friends. Although memory complaints and mild declines in episodic memory are common in normal elderly individuals (Graf, 1990), recent research has shown that true episodic memory deficits are a distinctive hallmark of early stage AD and are often regarded as the most sensitive early feature of the disease (Welsh, Butters, Hughes, Mohs, & Heyman, 1992). Studies on normal age-related changes in episodic memory reveal a decrement in the availability of processing resources at the time of encoding and retrieval rather than abnormal forgetting, as observed in AD patients (Kaszniak, Poon, & Riege, 1986).

Memory impairment is apparent on clinical and experimental memory tasks which require the learning and retention of either verbal or nonverbal information over a series of trials (Carlesimo, & Oscar-Berman, 1992). It has been suggested that the severe anterograde amnesia in AD patients appears to primarily result from a failure in consolidation (i.e., transferring information form immediate to LTM) that is mediated by damage to the hippocampus (Hyman et al., 1984), and neurotransmitter changes in the cholinergic system (Drachman, 1977). This inability of AD patients to transform to-be-remembered material into a form suitable for long-term retention cannot be changed by effortful or elaborative processing at the time of acquisition (Knopman, & Ryberg, 1989). This contrasts with normal elderly, who have been shown to benefit from elaborative processing of information during the study phase of free recall tasks (Schacter, 1987).

Further evidence of the inability of AD patients to store newly acquired information is shown by their severe impairments on recognition tasks as well as on recall tasks and by their very limited improvement in acquisition over repeated learning trials (Buschke & Fuld, 1974; Moss, Albert, Butters, & Payne, 1986). Many investigators have shown that AD patients tend to recall only the most recently presented stimuli (recency effect) suggesting that AD patients have great difficulty in transferring information from immediate to LTM (Delis, Massman, Butters, Salmon, Kramer, & Cermak, 1991; Miller, 1971). In addition, many investigators using the Buschke Selective Reminding Task (SRT), have demonstrated that AD patients tend to recall items from immediate memory rather than from LTM (i.e., Buschke & Fuld, 1974).

In a study aimed at elucidating the processes underlying AD patients' failure to acquire episodic verbal information, Delis et al. (1991) compared the performance of AD patients, Huntington's disease (HD) patients, and alcoholics with Korsakoff's syndrome (KS) on the California Verbal Learning Test (CVLT). The CVLT (Delis, Kramer, Kaplan, & Ober, 1987) is a standardized memory test that assesses rate of learning, retention after short and long-delay intervals, semantic encoding ability, recognition ability, intrusion and perseveration errors, and response biases.

The CVLT consists of presenting participants with five free-recall trials (List A) of 16 shopping items (four items in each of four categories) followed by the presentation of a single trial using a second, different list (List B) of 16 items. Immediately following this final trial, participants are given a free-recall and then a cued-recall test (utilizing the names of the four categories) for the items on the first shopping list (List A). Twenty minutes later, the free-recall and cued-recall tests are repeated, followed by a "yes/no" recognition test consisting of the 16 items on the first shopping list and 28 distractor items.

Delis et al. (1991) found that, despite comparable levels of free- and cued-recall performance in all three groups, HD patients, but not AD and KS patients, substantially benefitted from recognition testing. More specifically, while AD and KS patients were severely impaired on recall and recognition measures, the HD patients performed much better on the recognition tasks than on the recall tasks. Delis et al. concluded that the severe anterograde amnesia observed in AD is not primarily due to difficulties in retrieval mechanisms, but instead reflects a deficit at the level of consolidation (transferring information from immediate to LTM). This conclusion was based on the level of performance, on recall and recognition tasks, of the AD patients. If the AD patients had stored the to-be-remembered items in LTM and were simply unable to retrieve the items, their recognition performance would have shown a level of improvement similar to that of the HD patients.

In addition to AD patients' difficulties in storing new information, they also experience what has been called "rapid forgetting". This rapid forgetting is apparent for both verbal and nonverbal information and has been shown to be more exaggerated in AD patients than in amnesia (Hart, Kwentus, & Harkins, 1988; Knopman & Ryberg, 1989; Moss et al., 1986). Recent findings suggest that "rapid forgetting" is the most important feature in the early and differential diagnosis of the disorder and can be obtained through measure of delayed recall (number of items recalled after a short delay) and savings scores (percent retained over a period of time).

Using a number of verbal memory measure (immediate recall scores for three learning trials, delayed recall, savings scores, recognition memory, and the number of intrusion errors) derived from a word-list learning task of the Consortium to Establish a Registry for Alzheimer Disease (CERAD), Welsh et al. (1990) found that recall after a 10-minute delay differentiated early AD patients from normal elderly controls with 90% accuracy or better. The only other measure which approached delayed recall in discriminative power was percent savings.

Hart et al. (1988) assessed rapid forgetting in early AD by equating matched groups of early AD patients and normal elderly individuals for initial learning. This procedure reduced the methodological problem, which was not controlled for in the study done by Welsch et al. (1991), of measuring forgetting in participants with different learning abilities. Results indicated that AD patients, despite their advantage in being allowed multiple repetitions of the material (i.e., learning to criterion), still exhibited disproportionately more rapid forgetting than matched normal elderly controls. Thus, although AD patients exhibit deficits in episodic memory, reflecting a deficit in the acquisition and storage of information, it is apparent that rapid forgetting of recently acquired information also contributes to patients' severe anterograde amnesia.

If savings does not occur in AD, then frequency (as defined in Experiment 1) should not affect delayed recall performance in AD versus the young normals, normal elderly, and mildly impaired. The AD participants, theoretically, should not benefit from the repeated exposure to the high frequency letters versus the low frequency letters. The AD group's performance should not be significantly different for HF versus LF letters, in immediate and delayed recall, as compared to the young and normal elderly who are expected to greatly benefit from the repeated exposure to the HF letters versus LF letters.

In contrast to the memory impairments of the normal elderly, which appears to be due to a decline in episodic memory, AD patients exhibit severe impairments in both episodic and semantic memory (see Nebes, 1989 for a review). For example, AD patients have a variety of word finding difficulties (Nicholas, Obler, Albert, & Helm-Estabrooks, 1985), a reduced ability to answer questions about the physical features or functions of pictured objects (Martin & Fedio, 1983), and difficulty completing sentences when the identity of the final word is insufficiently constrained by the semantic context of the sentence (Nebes, Boller, & Holland, 1986).

We will examine differences in immediate and LTM performance, by administering measures of immediate serial recall and delayed recall, between young normals, elderly normals, elderly individuals diagnosed with MCI, and AD patients. Although relative differences are hypothesized, it is expected that some of the measures will be sensitive enough to discriminate normal elderly versus elderly individuals diagnosed with MCI.

Modality and Suffix Effects

Memory tasks which require significant attentional demands are more likely to demonstrate the effects of age (Manning & Greenhut-Wertz, 1990) and AD (Miller, 1975) when compared to tasks which require less attentional demands. A task which has been shown to place significant attentional demands on young, elderly and AD participants is serial learning which includes a suffix (Manning et al., 1996). The use of a suffix, an item which is not to be recalled, requires that the participants suppress a response. Relative attentional deficits have been reported in studies which require response suppression. For example, Freund and Witte (1986) found that older participants were less able to assess the frequency of repeatedly presented items than younger participants. They suggest that this is due to older participants' increased susceptibility to distraction from nonreapted stimuli because of difficulty in suppressing and not "counting" these items in the frequency assessments made. The effects of response suppression on memory will be examined in Experiments 1-3 via the suffix paradigm in immediate serial recall. In addition, increased attentional demands will be examined via modality and the suffix paradigm.

Theoretical Basis

Modality and suffix effects have been well established with young participants, but less is known about modality and suffix effects with normal elderly participants, mild cognitively impaired participants, and AD patients. This study will examine modality and suffix effects in immediate serial recall for four groups of participants; young normal individuals, elderly normal individuals, MCI individuals, and individuals with AD.

The suffix condition, whether auditory or visual, has an extra not-to-be-recalled item appended onto each to-be-recalled sequence. When serial recall is required, the suffix acts as a minimal distractor and thus produces interference. In addition, the appended item (the suffix) which is not to be recalled, requires the participant to suppress a response. This creates a situation in which the participant must not only overcome a minimal distractor (interference) but also suppress a response.

Recency is the superior recall of final as compared with middle items. Past research has consistently shown that recency is greater for auditorily as compared with visually presented stimuli (e.g., Frick, 1988; Glenberg & Swanson, 1986; Manning, Koehler, & Hampton, 1990; Nairne, 1988). Thus, recency is one of the sources of the modality effect. The greater superiority in recall of auditorily presented stimuli as compared with visually presented stimuli is termed the modality effect (see Penney, 1989, for a review).

The theory used for many years to explain these effects was that of Crowder and Morton (1969), who postulated that auditory traces are relatively long-lived while visual traces are relatively short-lived. The presence of recency is explained by the subject's use of the extra information available in auditory as compared with visual sensory traces.

Although past research has consistently produced the modality effect, (e.g., Frick, 1988; Glenberg & Swanson, 1986; Manning, Koehler & Hampton, 1990; Nairne, 1988, 1990; Penney, 1989) at this point no adequate explanation exists for this effect. Crowder (1986), summarized and characterized the existing research by saying that although the classical auditory - visual modality effect is both large and reliable, it is still poorly understood.

A large body of research has presented challenges to Crowder and Morton's (1969) theory, which assumes the auditory specificity of recency effects. The most reliable exceptions to the auditory-visual differences are studies using lipread and/or mouthed stimuli (e.g., Campbell & Dodd, 1980; Greene & Crowder, 1984) which are visual in the first case and involve articulatory components in the second case. Studies using these stimuli generally produced recency which is similar to that produced by auditory stimuli.

A second apparent exception to the auditory specificity of those effects involves studies with American Sign Language (ASL), which is visual in modality. When ASL signs are used as stimuli to be recalled by profoundly and congenitally deaf, fluent users of ASL, recency (Krakow & Hanson, 1985; Shand & Klima, 1981) and suffix effects (Shand & Klima, 1981) are reported. Large recency effects were also produced using junior high school students with normal hearing who were taught a small set of ASL signs (eg., Campbell, Dodd & Brasher, 1983).

But Manning, Koehler, and Hampton (1990) failed to replicate the findings with ASL stimuli using college students. Also Greene (1987), after the completion of a comprehensive study, reports no evidence of visual recency or suffix effects. Greene's (1987) study employed a variety of visual stimuli and conditions. The only visual stimuli which produced consistent recency and suffix effects were the lipread stimuli.

The "changing state" view propounded first by Campbell and Dodd (1980), which suggests that lipread and ASL stimuli change over time rather than remaining static, is not an adequate explanation of recency and suffix effects. Studies which have disputed the changing state theory are Crowder (1986), using moving visual stimuli presented on a computer screen; Manning (1980), using visual stimuli presented by moving the end of a pen over a card without making any marks; and by Manning and Gmuer (1985) again using moving visual displays, also do not show major recency. Thus the change in the stimulus present in the auditory stimuli and these stimuli is not the source of recency.

Why have some studies produced recency with ASL stimuli (still and moving) and others not? At the very least one must question the method of recall in producing recency. The recency shown by Shand and Klima (1981) and Krakow and Hanson (1985) with both still and moving ASL stimuli did not require strict serial recall, instead subjects were only required to output the stimuli in any order, as long as presentation order was indicated. A study by Cohen (1972), using pictures as stimuli and the same procedure also shows U - shaped curves and small atypical suffix effects, which do not reduce recency to the degree usually found with auditory stimuli, using pictures.

The serial recall curves and suffix effects obtained by Shand and Klima (1981) with both still and moving ASL signs (which are similar to pictures) appear to be very much like those of Cohen. In an effort to test directly the effects of recall method, Manning and Schreier (1988) conducted two experiments using still pictures. In Experiment 1, modified free recall was used, and in Experiment 2, strict serial recall was used. In Experiment 1, recency was produced, thus replicating results of Cohen. In Experiment 2, recency and suffix effects disappeared entirely. This suggests that the recency produced in previous studies using this free recall procedure (e.g., Krakow & Hanson, 1985; Shand & Klima, 1981) may be a function of the recall methods rather than presentation formats.

Recent work with the suffix paradigm by Baddeley and Hitch (1993) examines the relationship between the recency effect and priming. They suggest that recency may be classified as a form of implicit memory - nonconscious memory including skill and habit learning, and other instances where memory is expressed through performance rather than recollection. Baddley and Hitch argue that recency reflects the application of an explicit retrieval strategy to implicit learning. There is strong evidence that the application of the last-in-first-out recall depends on the use of a retrieval strategy. That is, in a free recall condition, participants will recall or "dump" the last items presented first. The problem with this theory is that they only consider what happens under free recall conditions. This may not hold up under strict serial recall conditions in which participants are instructed to recall the items in the order in which they were presented. More specifically, when participants are restricted from recalling the items in any order they wish, they cannot recall the final item(s) first.

Changes with Age

It has been shown that tasks involving greater complexity or difficulty are more affected by age than simpler tasks which do not seem to be affected by age (Flicker & Ferris, in Traber & Gisben, 1985; Smith, 1980). One method or way to increase the difficulty is to increase the attentional demands. When additional demands are placed on a participant, the effect of both age (Hasher & Zacks, 1988) and AD (Miller, 1975) seems to be relatively greater than in situations involving lesser attentional demands. In addition, elderly participants have also shown relative attentional deficits in tasks which require response suppression (Freund & Witte, 1986; Hasher & Zacks, 1988). The suffix condition is an example of a task which requires response suppression. The suffix condition which differs from the control condition, always contains an item appended onto the end of the to-be-remembered sequence. Participants are asked not only to recall the to-be-remembered sequence in serial order but also to omit the appended item (the suffix) from their recall of the sequence. Thus, they are asked to suppress the suffix item. The suffix condition is not only a measure of suppression but also a task which creates interference. This differs from the control condition in which there is no appended item on the sequences and thus there is no interference or suppression, the control condition becomes a span test. And as previously discussed, span tests (using WMS-R digit span) do not necessarily decline with increasing age (Crook et al., 1980) or mild AD (Flicker, Ferris, Reisberg, 1991).

Previous research, which has examined both modality and suffix effects in elderly (Greenhut-Wertz & Manning, 1994; Manning & Greenhut-Wertz, 1990) participants and AD (Manning et al., 1996) participants, has revealed some very interesting and important findings. In a study using alphabetic stimuli (Manning & Greeenhut-Wertz, 1990) and serial recall, standard suffix effects in the auditory modality were reported for young and elderly participants. In addition, young and elderly participants exhibited robust recency in the auditory control condition, while showing a significant decrement in recency in the auditory suffix condition. Interestingly, the elderly participants' performance was significantly lower across all serial positions in the auditory suffix condition. Manning and Greenhut-Wertz suggest that this overall decrement in performance is due to an increased susceptibility to interference (produced by the suffix) in the elderly participants.

Changes with AD

Manning et al. (1996), as discussed earlier, have also used the suffix paradigm in an attempt to find an early cognitive marker to aid in the diagnosis of AD. Since this is the only lab, to date, which has looked at the effect of the suffix in immediate serial recall in an AD population, the present study is an attempt to further investigate the clinical significance of using this paradigm in this population. In addition, for the first time in this lab, the present study will examine the use of the suffix paradigm in a group diagnosed with MCI.

Manning, Greenhut-Wertz, and Mackell's (1996) work on modality and suffix effects in an AD population has replicated previous findings: performance for all groups of participants was superior, in immediate serial recall, in the auditory modality as compared with performance in the visual modality. This difference in performance, between the auditory and visual modality, significantly increased in older participants when compared to the younger participants, that is, the older participants showed significantly greater performance in the auditory modality when compared to the visual modality. The auditory but not the visual suffix condition produced a significant decrease in recency for all groups (young, normal elderly, and AD) with the greatest decrement in the AD group. These findings also suggest that elderly participants are more susceptible to interference than the young and that the AD participants are the most susceptible to interference.

The findings presented above suggest that the suffix paradigm is useful for elucidating differences in memory and cognition for young, normal elderly, and AD participants. The present set of experiments, as discussed earlier, will also explore the use of this paradigm in an MCI group which has never been studied in this lab.

Frequency Judgements

Experiment 1 will explore frequency effects in immediate serial recall and delayed free recall and recognition. The effects of repetition will be closely examined in immediate and delayed memory. It is expected that all groups, except the AD group and possibly the MCI group, will benefit from multiple repetitions of the stimuli in immediate and delayed recall. In addition, a more robust frequency effect, that is the recall of HF letters is expected to be greater than the recall of LF letters, is expected in delayed recall for all groups. This effect is not expected to be as robust in the AD group given their inability to benefit from multiple presentations. In addition, since the AD group suffers from rapid forgetting and is more susceptible to interference (time between immediate and delayed recall consists of distractor memory tasks) it is expected that, although their overall performance will be significantly impaired, they may recall more HF letters compared to LF letters.

Most previous research has focused on the effect of frequency on learning, using stimuli such as English words, in which frequency can be generated independently of the experiment. The study design for Experiment 1 differs from most work on frequency, in that frequency is manipulated within the experimental design. After an exhaustive literature search, it was learned that much of the frequency literature available may not be directly related to the study design of Experiment 1. Although this is the case, many important findings can be extrapolated, and I will attempt to make the connection between previous work and Experiment 1.

Automatic processes are those which require minimal capacity and can proceed without intention or awareness (Posner & Snyder, 1975). It has been suggested that these processes encode basic information about internal and external events such as spatial, temporal, and frequency information (Hasher & Zacks, 1979). It is also thought that these processes are minimally affected by age, effort, practice, or feedback. In contrast, effortful processes are those which require both attention and effort (Hasher & Zacks, 1979). These processes have been shown to become more efficient with practice and exhibit marked developmental trends at both ends of the life span (e.g., Craik, 1977). Based on these descriptions, elderly individuals should do less well than young individuals on tasks which require effortful processing but elderly individuals should perform as well, or nearly as well, as young individuals on tasks which require automatic processing.

Hasher and Chromiak (1977) and Hasher and Zacks (1979) argue that the encoding of frequency information is an automatic process. In line with this view, several researchers have demonstrated the absence of any age deficit in making relative frequency judgements (Attig & Hasher, 1980; Kausler & Puckett, 1980; Hasher & Zacks, 1979). Leicht (1968) also demonstrated that recall and judged frequency of implicitly occurring words increases with presentation frequency.

One encoding variable that affects both recall and recognition is generation. The generation effect refers to the advantage in memory of generating verbal stimuli oneself, as compared with merely reading the stimuli. Generation appears to be a simple and effective way to increase the retention of stimuli under various conditions (Begg, Snider, Foley, & Goddard, 1989). Rabinowitz (1989) demonstrated that elderly adults benefit as much as young adults from generation effects on cued recall and recognition tasks. This is consistent with the findings of Glenberg and Fernandez (1988) who have shown that frequency judgments for repeated auditory words were better than frequency judgements for visual words. In addition, the auditory advantage increased with the frequency of presentation.

AD subjects also exhibit difficulties in concentration (e.g., Miller, 1975) which are clearly indicative of attentional deficits. Specifically, relative attentional deficits have been reported in tasks which require response suppression. Although others have not found age differences in frequency, Freund and Witte (1986) demonstrated that older participants seem less able to assess the frequency of repeatedly presented items than younger participants. They concluded that older participants have a greater susceptibility to distraction from the non-repeated stimuli because of an apparent difficulty in suppressing and not "counting" these items in the frequency assessments made. Kausler, Hakami, and Wright (1982) also found adult age differences for relative frequency judgements. They interpreted the findings in terms of an age deficit in either the storage or retrieval of memory traces.

In addition to examining the effect of frequency in immediate serial recall and free delayed recall, Experiment 1 will look at frequency judgments of young, elderly, mildly impaired elderly, and AD participants. The effect of stimulus frequency (HF and LF ratio) will be examined in immediate and delayed recall. In addition, if the processing of frequency information is automatic, as postulated by Hasher and Zacks (1979), one would expect all groups, except the AD group who has been shown not to benefit from repeated exposure to stimuli, to perform relatively well on making frequency judgments. Frequency judgements will be measured using a short questionnaire which will consist of one forced choice question and various recall/recognition questions. This questionnaire will be described in detail in the method section and can be found in Appendix A.

Intrusions

Although many investigators have discussed the value of studying intrusion errors, some investigators (i.e., Welsh et al., 1992) have argued that intrusion errors by themselves have very little predictive value in differentiating AD patients from healthy normal elderly. On the other hand, several investigators have reported that using indices of intrusion errors in conjunction with other memory measures, such as total recall, recognition memory, and rate of forgetting, can result in powerful algorithms for differentiating AD from other types of dementia (Delis et al., 1991).

As mentioned previously, three types of intrusion errors will be examined in Experiments 1, 2, and 3. The first is an extra list intrusion, defined here as an item recalled by the participant that was never presented during the test session. The second type of intrusion is a intra-list intrusion, defined here as an item recalled that was part of a previously presented stimulus set, but is not part of the to-be-recalled stimulus set. The third type of intrusion is a suffix intrusion, defined here as the recall of the suffix (the final not-to-be-recalled and redundant item) which participants were explicitly instructed to leave out in recall.

Manning et al. (1996), using the suffix paradigm, demonstrated that intrusions differentiate normals from AD. Experiments 1-3 will examine the three types of intrusion errors; extra-list, intra-list, and suffix. Since individuals with AD and MCI have been shown to have attentional deficits it is expected that these two groups will produce more extra-list and intra-list intrusion errors compared to the young and normal elderly. In addition, it is expected that the suffix will show increasing interference with increasing cognitive impairment, thus suffix intrusions are expected to increase with cognitive impairment.

Changes with AD

A prominent feature of AD patients' performances on episodic memory tests has been the frequent occurrence of intrusion errors. Although increases in intrusion errors have been associated with other neurologic disorders (Shindler & Caplan, 1984) several investigators have suggested that such errors may be of diagnostic value in the early stages of AD (Delis et al., 1991; Fuld et al., 1982; Manning et al., 1996). For example, Fuld et al. (1982) have shown that beginning- stage AD patients produce more intrusion errors than normal elderly on episodic memory tests, mental status examinations, and on several verbal sub-tests of the Wechsler Adult Intelligence Scale.

In some cases, such errors represent the intrusion of previously learned material into the attempted recall of new material (Delis et al., 1991; Fuld, 1983; Fuld, Katzman, Davies, & Terry, 1982). For example, when asked to draw a series of geometric figures presented to them previously, AD patients will incorporate components of one figure into their drawings of subsequent figures (Jacobs, Troster, Butters, Salmon, & Cermak, 1990). Normal elderly control participants typically did not produce such intrusion errors, and Huntington disease (HD) patients produced such errors only occasionally. Statistical analysis showed that AD patients produced significantly more intrusion errors than either normal control participants or equally impaired HD patients.

This tendency to produce intrusion errors has proven to be of some neurologic significance. Fuld et al. (1982) reported significant correlations between the number of intrusion errors produced by a patient and the number of plaques and amount of acetylcholine depletion in the brains of AD patients studied post mortem.

Several other investigators have also noted that AD patients have a propensity to make intrusion errors. Miller and Lewis (1977), Branconnier, Cole, Spera, and Devitt (1982), and Helkala, Laulumaa, Soininen, and Riekkinen (1989) have reported a reduced hit rate and an increased number of false alarms in AD patients compared to normal controls when tested by a yes-no recognition procedure, while a proportional (Hart, Smith, & Swash, 1986) or an absolute (Fuld et al., 1982; Helkala et al., 1989; Jacobs et al., 1990) increment of intrusions in free recall tasks has been frequently described in AD patients.

Finally, it is expected that the intrusion errors produced by any group will be category specific. This expectation comes form the work done by Manning et al. (1996) who demonstrated that both normal elderly controls and AD patients were able to maintain information regarding category. Manning et al. showed that the intrusions produced were never extra-categorical. More specifically, when normal elderly controls and AD patients were shown repeated lists of letters, they never produced responses which included words or numbers. It is expected that the present study will also find that all participants will maintain responses within the circumscribed category of information (letters of the alphabet).

Recognition Memory versus Recall Memory

Experiments 1-3 will examine delayed recall and delayed recognition. It has been demonstrated that individuals with AD suffer from rapid forgetting and are significantly more susceptible to interference. Thus, our delayed memory tasks required the retrieval of stimuli from long term memory after a short pre-set period of time (approximately 20 minutes). Experiments 1-3 not only require the retrieval of the stimuli after a pre-set period of time but also subjects the participants to interference prior to the delayed memory tasks. Under these conditions, it is expected that performance on both the delayed recall and recognition tasks will decline with increasing cognitive impairment.

In addition, the present study will examine the effect of mixed lists on immediate and delayed recall and delayed recognition in young normals, normal elderly, mildly impaired elderly, and AD patients. In Experiment 1 all immediate recall lists will have a HF to LF stimulus ratio of 3:1, respectively. The effect of mixed lists of letters (consonants) will be examined in immediate and delayed recall and recognition, taking into account previous studies based on word frequency in recall and recognition.

Theoretical Basis

In the past, there have been two general theories on the relationship between recall and recognition. One position is that the processes involved in accessing memory for recall and recognition are fundamentally the same. The strength theory assumes that recall and recognition involve the same basic process, except that recognition of an item requires a lower "threshold of strength" than does recall. Bahrick (1965) argued that the recognition of an item is less difficult because of this lower threshold. Although Tulving (1982) acknowledged that recall and recognition differ in the operations needed to convert memory output into task specific performance, he assumed that the fundamental memory access processes are identical.

The second position is that some of the processes involved in recognition and recall are fundamentally different. For example, Kintsch (1970) suggested that recognition allows direct access to memory, whereas recall does not. In the mid 80's several models were proposed that incorporated a different but still fundamental distinction between the memory access processes underlying recall and recognition; SAM model (Gillund & Shiffrin, 1984), the Minerva II model (Hunitzman, 1984), the Matrix model (Humphreys, Pike, Bain, & Tehan, 1989), and the TODAM model (Murdock, 1982). These models all suggest that a "global matching operation" (Humphreys et al., 1989) underlies single item and pair recognition, whereas a retrieval operation underlies recall.

Today a common method for measuring memory performance is by use of yes-no recognition memory tasks. These memory tests have been derived from the standard signal detection theory (SDT) method. In the yes-no form of recognition memory tests, participants are presented with a list of items which they are asked to remember (old items) and then they are presented with a list of items which include the old items and distractor items (new items). The participants' task is to decide whether each item is old (correct response = yes) or new (correct response = no). Performance is measured by the hit rate, the probability that the subject classifies an old item as old, and the false alarm rate, the probability that the subject classifies a new item as old. This measure has become popular in clinical studies assessing memory (e.g., Mohs & Davis, 1982). Itis different from the method generally used when assessing normal memory, in that, researchers often use a simpler measure of discrimination such as hits minus false alarms (e.g., Gillund & Shriffrin, 1984).

Changes with Age

Studies on verbal memory as a function of age have produced discrepant findings for recall and recognition paradigms. Recall performance has been shown to decrease with age (e.g., Harwood & Naylor, 1969; Schonfield & Robertson, 1966); however, recognition performance has been shown to remain stable with age (e.g., Schonfield & Robertson, 1966). Harwood and Naylor (1969) showed an age deficit when the recognition task was delayed for four weeks, but even then, the deficit was not as great as that found for delayed recall.

One explanation for failure to obtain an age deficit on recognition tasks may be that recognition tasks in some studies may have been much easier than the recall tasks. For example, Davies, Sutherland, and Judd (1961) systematically varied the ratio of targets to distractors, observing that as the proportion of distractor items increased, the probability of making a correct detection of old items systematically dropped. In a study by Erber (1974), difficulty was manipulated by varying the length of the study list (24 words and 60 words). She also used a five-alternative forced-choice test with all five alternatives being high-frequency words (based on Thorndike & Lorge norms, 1944) matched for number of syllables.

Under these conditions Erber found a significant difference between young and old on the recall and recognition tasks. Erber concluded that age differences were obtained due to the complexity and difficulty of the five-alternative forced-choice task rather than the study list length. Dale and Baddeley (1962) showed that the most important feature was not just the number of alternatives, but rather, the similarity between the target items and distractors. They found that the greater number of distractors, the greater the chance of including items that were very similar to the target items. Thus, it appears that performance on recognition tasks can be manipulated not only by the number of distractors and task complexity but also by the similarity between the distractors and the target items. Consistent with these findings is a study done by Rankin and Kausler (1979) who found that elderly participants, compared to young participants, had a greater false recognition effect for distractor words that rhymed (phonological) or that were synonyms (semantic) of the target words.

Colsher and Wallace (1991) reported decrements in recall and recognition performance over a six year period in a sample of 1,768 community-dwelling adults 65 years and older (M = 73.7 years). The memory tasks consisted of immediate and delayed free recall of unrelated words, followed by a recognition task. The analysis indicated that there was a significant decline in all three measures over the six year interval. In the case of immediate recall, older participants (75-84 years and 85+ years) experienced greater decline than younger participants (65-74 years). In addition, older women showed a greater decline on the recognition tasks than did younger women over the six year interval. It is important to note that several studies have reported no significant age differences in recognition performance (Craik, 1969; Smith, 1975b) while some have reported moderate to large age differences (Botwinick & Storandt, 1974b; Kausler & Puckett, 1981a; Perlmutter, 1978; Witte & Freund, 1976). The present studies will examine age differences in delayed recognition performance using a unique method (see Manning et al., 1996) which will be described in greater detail later.

Changes with AD

Recognition memory in Alzheimer's disease has also been examined and found to be defective (Miller, 1975, 1977). AD patients have been shown to produce more false positive responses than normal elderly (Hart, Smith, & Swash, 1985). A study by Helkala, Laulumaa, Soininen, and Riekkinen (1989) showed that in addition to making more false positive responses, AD patients were unable to inhibit irrelevant information and were more sensitive to interference. This is consistent with Miller's (1975, 1977) finding that AD patients' recognition ability decreases as the number of recognition alternatives is increased. In addition Shindler, Caplan, and Hier (1984) reported that intrusions (false alarms) occur more frequently in situations in which confusion between short-term and long-term memory are likely. For example, Manning et al. (1996) found that when using a delayed recognition measure, which entailed presenting participants with all the letters of the alphabet and asking them to indicate which letters were part of the testing session (stimulus set size was 6 letters), AD patients had a much greater propensity to produce intrusions as compared to normal young and elderly participants who produced virtually no intrusions. Manning et al. suggested that the mere presence of all the letters of the alphabet, now in immediate memory, caused the greatest confusion for AD patients who already have a propensity to make a greater number of intrusion errors (Fuld et al., 1982).

The Effects of Frequency on Recall and Recognition

Another component to recall and recognition is frequency. To date, all previous studies have looked at the effects of word frequency on these two types of memory tasks (see Gregg, 1976, for a review). Previous findings indicate that HF words are recalled better than LF words. However, LF words are recognized better than HF words. The HF word advantage in free recall can be reduced, eliminated (Gregg, 1976; Gregg, Montogomery, & Castano, 1980), or reversed (May, Cuddy, & Norton, 1979), when HF and LF words are mixed together within a study list. The LF advantage in recognition has been shown with both pure- and mixed frequency lists (Garton & Allen, 1968).

Gregg, et al.(1980) found a larger LF advantage for mixed lists and Dorfman and Glanzer (1988) found that the LF advantage increases as the proportion of LF words in a mixed list decreases. Although AD patients have been shown to have a tendency to make false alarms to common (HF) words, the LF advantage in recognition memory is not found in AD patients. Specifically AD patients do not show an attenuation of the rare (LF word) word advantage (Wilson, Kramer, Fox, & Kaszniak, 1983). Wilson et al. (1983) suggest that the recognition deficit found in AD patients is due to a deficit in the initial processing of the to-be-remembered verbal information.

In addition to the HF/LF effect, Bahrick and Bahrick (1964) showed that it is possible to change the level of performance on recall versus recognition tasks. They demonstrated that you can experimentally eliminate the recognition advantage simply by increasing the similarity between the distractors and target items. Bahrick and Bahrick showed that when you do this, performance on the recognition task decreases significantly. Schulman (1976) used nonword study lists to examine this phenomenon and found that this effect could be reversed. Schulman reasoned that the participants had poorer performance on the recognition tasks because the study items were so unfamiliar to them and thus, they did not have any pre-existing representations in long-term memory. This in effect, made the recognition task not only different, but more difficult. The present study will also examine a different, although similar, frequency phenomenon by using a delayed recognition task in which the distractor items are visually and auditorily (phonetically) similar to the target items.

Early Cognitive Markers of AD

Brief Summary

Since to date it is not possible to give a definitive diagnosis of AD prior to autopsy and the search for an effective drug treatment is still ongoing, it seems plausible that finding an early cognitive marker is extremely important. The marker should be one which can detect the earliest cognitive losses in AD and help in differentiating AD patients from those who are going through "normal aging." The process of finding an early cognitive marker, if successful, will be vital when an appropriate drug treatment is discovered, one which can significantly slow or halt the progression of the disease process.

In 1996, Manning et al. used the suffix paradigm, previously used to study differences in recall of visually and auditorily presented stimuli with young normal subjects (Crowder & Morton, 1969; Manning, Koehler, & Hampton, 1990), in order to examine two variables which may serve as markers of AD. The first variable assessed was the apparent deficit that exists in response suppression in AD subjects (Fuld, Katzman, Davies, & Terry, 1982). The second variable assessed was what has been called rapid memory loss. This term refers to the unusually fast loss of recently presented items - a loss which can occur in as brief a time span as a few minutes in the presence of a minimal distractor (e.g., Butters, Salmon, Cullum, Cairns, Troster, & Jacobs, 1988).

Hasher, Stoltzfus, Zacks, and Rypma (1991) conducted a recent study which supports a central assumption of the Hasher and Zacks (1988) theory: the existence of age differences in inhibition at the level of selective attention. Although selective attention is thought of as occurring during the presentation of information, mechanisms of selective attention probably play a role at the level of retrieval as well, at least in as much as choices must be made along the search path between relevant and irrelevant responses to retrieval cues. Thus, they conclude that older adults (and others such as AD patients) may be impaired both at input and retrieval by inefficient inhibitory mechanisms enabling activation of irrelevant ideas or search paths that ultimately slow or impede retrieval of target facts.

A frequently studied characteristic of AD, as well as some other dementias (e.g., Wernike's Aphasia), which suggests an inability to suppress responses is termed the "response intrusion." This term refers to a variety of phenomena, but for the context of the present paper refers to responses generated by the participants which were never presented (never part of the stimulus presentation) or responses which contain stimuli that were presented previously but were not part of the present stimuli to-be-recalled.

Fuld, Katzman, Davies, and Terry (1982) mentioned this symptomotology as part of AD. They reported that AD subjects who received an anticholinergic medication had a reduction in intrusions. Shindler, Caplan, and Hier (1984) reported intrusions in AD and aphasic subjects, with intrusions occurring most often in the AD subjects, but they also stressed that this was not limited to AD dementia. They do, however, feel that intrusions are a useful sign/symptom of AD.

In a more recent study by Manning, Greenhut-Wertz, and Mackell (1996), using three groups of subjects (young, normal elderly, and AD participants), they identified two types of intrusion errors when using the suffix paradigm, extra-list intrusions and suffix intrusions. They concluded that extra-list intrusions in both immediate and delayed recall, which were always letters of the alphabet and thus within the category of stimuli presented, provide evidence for some degree of maintenance of categorical information. Suffix intrusions, exhibited by the AD participants, illustrate an inability on the part of the participant to inhibit a response even when repeatedly told to do so. These two types of intrusions were indicative of the AD participants, which suggests that this may be a marker of AD.

Manning et al. (1996) also investigated delayed recall in the AD patients, since this has been shown in previous research to be an effective predictor of future decline. For example, Flicker, Ferris, and Reisberg (1991) showed that most elderly subjects with mild cognitive deficits will manifest the progressive mental deterioration characteristic of dementia and that psychometric predictors, such as delayed recall (Shopping List Task and Paragraph Recall), can be used to distinguish between benign and more significant underlying disorders in mildly impaired elderly subjects.

Golomb, de Leon, Kluger, George, Tarshish, and Ferris (1993) examined the prevalence of radiographically detectable hippocampal atrophy in a normal aging sample, and assessed whether such atrophy was associated with memory dysfunction. Although the study was cross-sectional, they concluded that some language based memory tasks with delayed recall were good predictors of future decline to AD. In addition, they found that poor performance on delayed verbal memory measures was correlated with hippocampal atrophy.

Delayed recall was also found by Manning et al. (1996) to be a good discriminator of normal elderly participants and AD participants. These researchers specifically looked at intrusion errors in delayed recall for all their participants. Performance on the delayed recall task was not significantly lower for any of the groups with the exception of the AD patients who did not perform as well. Although the AD group did perform relatively well and better than expected, Manning et al. attributed this to the study design. The same six letters of the alphabet were presented a total of 32 times over the course of the entire experiment. But, even more intriguing were the intrusion errors made by the AD participants. While the AD participants did relatively well in retrieving (delayed recall) and recognizing (delayed recognition) the stimuli, they also produced a significant number of intrusions in the delayed recognition task. Thus, their hit rate was significantly lower in this task than for the other two groups versus their performance in the recall task.

Manning et al's (1996) work has provided a new insight into the use of the suffix paradigm to differentiate "normal aging" and AD. This paradigm may provide insight and knowledge in relation to the subtle changes which occur early in the disease process. Further work is needed in order to study the recent findings linking intrusions and AD. But it seems likely, that using the suffix paradigm, which provides a minimal distractor and creates greater attentional demands on participants, may serve to differentiate AD patients from the "normal aging" group and the young normal group.

Experimental Hypotheses

In light of previous research, the following hypotheses' were examined for Experiments 1 - 3, unless otherwise noted:

Immediate Recall

1. The modality effect will be present for all groups (Young, Normal Elderly, MCI, and AD), that is serial recall will be better when stimuli are presented auditorily versus stimuli that are presented visually, although it is expected that overall recall in both the visual and auditory modalities will decline with increasing cognitive impairment.

Interference

2. The suffix is expected to show increasing interference with increasing age and cognitive impairment. This is based on studies done in this lab which suggest that the suffix creates increasing interference with age (Manning & Greenhut-Wertz, 1990) and AD (Mackell, 1993; Manning, Greenhut-Wertz, 1992) as compared to young participants.

Although this has not been explored for participants with MCI, the level of impairment created by the interference is expected to be greater than that seen in young participants but less than the impairment seen in AD. In addition, a serial position X condition interaction is expected since the suffix has been shown to create greater decrements at the end of the list when compared to the end of list performance in the control condition. An interaction of serial position X modality is also expected. Specifically, the suffix is expected to have a greater effect in the later serial positions in the auditory modality compared to the visual modality.

Intrusions

3. There will be very few, if any, extra-list or intra-list intrusions (only Experiment 1) produced by the young normal or elderly normal groups. But, it is expected that the number of extra-list and intra-list intrusions will increase with cognitive impairment; specifically, it is expected that the MCI and AD groups will make more intrusion errors of this type when compared to the normal groups.

4. There will be very few, if any, suffix intrusions produced by the young normal or elderly normal groups. But, it is expected, that the number of suffix intrusions will increase with cognitive impairment; specifically, it is expected that the MCI and AD groups will produce more suffix intrusion errors compared to the normal groups.

Frequency

5. The presentation of stimuli was manipulated within the experimental design, that is, some stimuli were presented more frequently than other stimuli over the course of the

experiment. The recall of the letters presented more frequently (high frequency letters) will be compared to the recall of the letters presented less frequently (low frequency letters) (Experiment 1 only). All groups are expected to be sensitive to presentation frequency although, the young and normal elderly groups are expected to benefit more than the MCI and AD groups. More specifically, the differential between HF and LF recall is expected to be larger for the young and normal elderly groups compared to the MCI and AD groups. One reason for this expected difference between the normal groups and the impaired groups is previous work which has shown that AD participants are not sensitive to repetition.

Delayed Recall

Following the immediate recall trials all participants were administered a short battery of tests, which includes the MMSE and digit span forward taken from the Wechsler Memory Scale-Revised (Wechsler, 1981) (these will be described in detail in the method section), followed by a delayed recall and delayed recognition task. The following hypotheses have been generated for the delayed measures:

6. There will be very few, if any, extra-list intrusions produced by the young normal, or elderly normal groups. But, it is expected, that the number of extra-list intrusions will increase with cognitive impairment, specifically in the MCI and AD groups.

7. The delayed recall of the letters presented more frequently (high frequency letters) will be compared to the delayed recall of the letters presented less frequently (low frequency letters). All groups are expected to be sensitive to the presentation frequency, that is, the

recall of high frequency letters is expected to be superior to the recall of low frequency letters (Experiment 1 only).

8. The delayed recognition of the letters presented more frequently (high frequency letters) will be compared to the delayed recognition of the letters presented less frequently (low frequency letters). All groups are expected to be sensitive to the presentation frequency, that is, the recognition of high frequency letters is expected to be superior to the recognition of low frequency letters (Experiment 1 only).

9. The delayed recall of high frequency and low frequency letters will be compared to the delayed recognition of high frequency and low frequency letters for all groups in Experiment 1. No significant performance differences are expected between the recall and recognition tasks for any group, with the exception of the AD group and possibly the MCI group. This difference in performance, between recall and recognition, is based on the Manning et al. (1996) finding that the AD group actually performed significantly better on the recall task compared to the recognition task. They suggest that this difference was the result of two factors: (1) The recall task, is affected by rapid forgetting in the AD group. Thus, fewer intrusions are produced. (2) According to Manning et al. (1996) the nature of the recognition task (presenting the entire alphabet and asking participants to identify all the letters which were part of the experiment) creates "confusion" for the AD group. Thus, increasing their propensity to make intrusion errors versus all other groups which make virtually no intrusion errors. This confusion may be the result of flooding the AD participants' immediate memory with irrelevant, but

category specific stimuli, making it more difficult not to produce intrusion errors.

Clinical Changes & Assessment of AD

Elderly participants were recruited and evaluated at NYUMC-ADRC for Experiments 1, 2, and 3. What follows is a brief description of the evaluation process. In the absence of a reliable biological marker, the clinical diagnosis of AD relies on inclusionary and exclusionary criteria based on clinical and laboratory information. The diagnosis of "probable" AD made at NYUMC-ADRC is based on the recommended guidelines of the National Institute of Neurological and Communicative Disease Studies-Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA)(McKhann, Drachman, Folstein, Katzman, Price, & Stadlan, 1984). In addition to meeting the NINCDS-ADRDA criteria the patients at NYUMC-ADRC must also meet another leading set of diagnostic criteria, that of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) (1994) for "primary degenerative dementia of the Alzheimer type", senile (onset after age 65) or presenile type (onset at age 65 and below). These criteria require the insidious onset of dementia with a gradual progressive deteriorating course and exclusion of all other specific causes of dementia (e.g., Korsakoff syndrome, Vascular Dementia, Depression). The diagnostic criteria for both the NINCDS/ADRDA and DSM-IV can be seen in Appendix B.

In assessing AD, several clinical scales are widely used today; these include the Global Deterioration Scale (GDS) (Reisberg et al., 1982) and the Clinical Dementia Rating Scale (CDR) (Berg, 1982). The CDR is based on five degrees of impairment in performance on six categories of cognitive functioning, including memory, orientation, judgement and problem solving, community affairs, home and hobbies, and personal care. The present study used the GDS rating scale for classifying and selecting elderly participants. The GDS (Reisberg et al., 1982), which is used at NYUMC-ADRC, is a staging scale based on an individual's cognitive abilities, as well as some functional aspects, but memory being the most prevalent feature. The GDS is a seven stage scale and can be seen in Appendix C.

The use of a seven stage scale, which was designed to delineate all stages throughout the course of the disease from normal aging to severe dementia, enables a clinician to make a relatively objective and reliable decision about whether an individual is normal or suffering from some form of dementia. The GDS is based on five areas of functioning: (1) concentration, (2) recent memory, (3) remote memory, (4) orientation, and (5) self-care and functioning. The progression of the disease is divided into seven clinically identifiable stages, with Stage 1 representing normal (no cognitive decline), to Stage 7 representing severe cognitive decline. Each stage of the GDS encompasses specific criteria which are assessed during the course of a clinical interview with the patient and the patient's primary caregiver. The GDS ratings have demonstrated excellent test/retest and inter-rater reliability in several studies (i.e., Dura, Haywood-Niler, & Kiecolt-Glaser, 1990; Reisberg, Ferris, Steinberg, Shulman, deLeon, & Sinaiko, 1989).

The GDS ratings can be briefly described as follows: GDS 1, normal cognitive capacity, in the absence of either subjective or objective evidence of cognitive or functional deficit; GDS 2, subjective complaints of cognitive and/or functional impairment in the absence of clinically objective examinations; GDS 3, subtle, clinically apparent cognitive or functional impairment which may not be of sufficient magnitude to interfere with complex occupational or social tasks; GDS 4, moderate cognitive and functional deficits which are clearly evident on a detailed clinical interview which are generally of sufficient magnitude to interfere with complex activities of daily living (e.g., management of personal finances, planning an activity outside the home, planning and preparing a meal); GDS 5 through GDS 7, cognition and functioning decrease significantly with increasing levels of severity.

In addition to receiving a psychiatric interview in which a GDS rating is assigned, the patient also receives a complete medical examination, neurologic and neuroradiologic examinations (either an MRI or CT is obtained), and cognitive psychometric assessments (see Appendix A for a complete list of psychometric measures administered at the NYUMC-ADRC). After all the examinations are completed, a team of physicians and psychologists meet to review each case individually, and it is at this time that a diagnosis is assigned. In addition to examining college student participants, the present studies will examine individuals classified as GDS 1 or 2 (Normal Elderly), GDS 3 (mild cognitive impairment or MCI), and GDS 4 ("probable" AD).

Method

Experiment 1

Participants

All participants (Experiments 1 and 2) spoke English as a first language, although some participants may have learned English simultaneously with another language. There were 48 participants in this experiment, 12 participants in each group. These groups will be called young normals, elderly normals, MCI, and probable AD. Each group will be described below. The young normal participants were college and graduate students from Hunter College (HC) of the City University of New York (CUNY). The elderly normal participants, MCI participants, and AD participants were recruited at NYUMC-ADRC.

The 12 young normal participants (10 male, 2 female) were undergraduate and graduate students ranging in age from 20 - 29 (M = 24.1) and all had a minimum of 13 years of education. The total number of years of education was not specifically collected for this group, but students were recruited in classes attended by sophomores through seniors at the college level and graduate students at all levels. The 12 normal elderly participants (8 male, 4 female), classified as either GDS 1 or GDS 2 at NYUMC-ADRC, ranged in age between 60 - 83 years (M = 72.0). They had an average of 16.3 years of education. The MCI participants (6 male, 6 female), classified as GDS 3 at NYUMC-ADRC, ranged in age between 61 - 81 years (M = 72.6). They had an average of 14.7 years of education. The 12 AD participants, classified as GDS 4 (6 male, 6 female) at NYUMC-ADRC, ranged in age between 71 - 90 years (M = 79.4). They had an average of 12.6 years of education. The demographic/characteristic information for all participant groups (gender, age, education, and MMSE) can be seen in Table 1.

There is a high correlation between GDS ratings, discussed earlier, and an independently developed mental status examination (MMSE) (Folstein, Folstein, & McHugh, 1975). Reisberg et al. (1989) found a strong correlation between the MMSE and GDS level (Pearson correlation coefficient = 0.89). AD patients (GDS 4) score an average of 20 points (out of a possible score of 30 points) on the MMSE (Reisberg et al., 1989) with a range of points between 16-23 (Reisberg et al., 1985). In the present study the MMSE scores for the young normal participants were between 28 and 30 points (M = 29.3). The MMSE scores for the normal elderly participants were between 28-30 points (M = 29.5). The MMSE scores for the MCI participants were between 27 and 30 points (M = 28.7). The MMSE scores for the AD participants were between 20-27 points (M = 24.1). The mean MMSE score for the AD participants is consistent with previous findings (Reisberg et al., 1989), although the range of scores is higher for this sample than reported by Reisberg et al. (1989). Since years of education have been shown to have an impact on MMSE performance (Uhlmann & Larson, 1991), a one-way ANOVA was performed comparing years of education for the elderly groups (normal elderly, MCI, and AD). The ANOVA revealed that there are significant differences in the level of education between the three groups of elderly participants, F (2, 44) = 3.689, MSE = 55.33. The level of education, assessed as number of years of education, declined with increasing level of impairment. This is consistent with current studies which show that

Table 1

Mean, Range, and Standard Deviation (SD) for Participants Age, Years of Education, and Mini-Mental Status Examination (MMSE).

		Young	Elderly	MCI	AD
Age					
	Mean	24.1	72.0	72.6	79.4
	SD	3.6	8.4	7.2	5.3
	Range	20-29	60-83	61-86	71-91
Education					
	Mean	>13.0[a]	16.3	14.7	12.6
	SD		2.1	2.7	2.3
	Range		12-20	10-18	8-16
MMSE					
	Mean	29.3	29.5	28.7	24.1
	SD	.74	.76	.92	2.6
	Range	28-30	28-30	27-30	20-27

[a] Although it is known that all the participants graduated high school and many were advanced college students, the exact education data for this group is unknown.

the onset of dementia is correlated with the number of years of education - more specifically, individuals who have more education may be "protected" from the disease (or at least the onset of the disease is delayed). Since the mean years of education for all groups exceeded 12, it is unlikely that education had a great impact on MMSE. Specifically, it is unlikely that the AD participants decline in mean MMSE is due to level of education.

Stimuli and Experimental Design for Immediate Recall Task

The experiment consisted of four conditions each with 12 trials: visual suffix, visual control, auditory suffix, and auditory control. Each trial required strict serial recall of six stimuli. The stimuli were letters of the alphabet. Each of the 12 letters were chosen to minimize both visual and auditory similarity, using norms established by Manning (1977). Over the course of the entire experiment, half of the letters classified as high frequency letters (HF) were presented three times as often as the other half of the letters, classified as low frequency letters (LF). This 3:1 ratio of letter presentation was created using balanced Latin Squares. The six HF letters were C, F, J, M, L, S and the six LF letters were H, K, N, Q, R, T. Thus, in each condition (consisting of 12 trials) there was a total of 72 letters used. More specifically, the six HF letters appeared a total of nine times each in each serial position and three of the LF letters appeared a total of three times in each serial position. Since there were four conditions, three of the LF letters (T, N, K) appeared in two of the conditions and the remaining three LF letters (H, Q, R) appeared in the other two conditions. Because the LF letters were separated into two groups of three letters, each one appeared, on average, 1.5 times in each serial position over the entire experiment. None of the letters, HF or LF appeared in the same serial position in the preceding or following trial.

Apparatus and Procedure

The auditory and/or visual stimuli, letters of the alphabet, were presented in the center of a monochrome computer screen at a rate of one per second. The stimuli were on the screen for 0.5 seconds and off the screen for 0.5 seconds. The stimuli were 0.4 centi meters (cm) in size and were always capital letters. The tone used in the control condition was 1000 Hertz (Hz).

Participants were explicitly instructed before the start of each condition of the procedure to be followed. The instructions for the immediate recall conditions can be seen in Appendix D. Participants were instructed to either read each letter aloud as it appeared on the screen (auditory conditions) or they were instructed to read each letter silently without mouthing the letters as they appeared on the screen (visual conditions). Participants were required to recall each letter sequence in strict serial order by writing on a response sheet which was provided by the tester. The response sheet can be seen in Appendix D. After each trial, the participants were given 30 seconds for recall and were prompted for the start of each new trial by a tone. Every trial in the control condition ended with a tone, which was sufficiently different from the tone used to indicate the start of a new trial, while every trial in the suffix condition ended with the letter "Y" appended to each sequence, the tone and the letter "Y" indicated the end of the sequence to the participants, respectively.

Each participant received all sequences and the order of administration of conditions was formed by using three balanced squares. One half of the participants received the auditory conditions (suffix and control) first, and the visual conditions (suffix and control) second while the other half of the participants received the visual conditions first and the auditory conditions second. Within each modality (visual and auditory), one half of the participants received the suffix condition first and the control condition second and the other half of the participants received the control condition first and the suffix condition second.

Following the immediate recall experiment, participants were administered several measures which are described in more detail below, and they appear in the order in which they were administered to each participant. The additional cognitive tests described below, MMSE and Digit Span Forwards, were utilized for several reasons: (1) MMSE was used as an intervening task, between the immediate recall trials and delayed recall and delayed recognition, and as a test for magnitude of dementia (Folstein et al.,1975) (2) The Digit Span Forwards was also used as an intervening task and as a measure of short-term memory (Wechsler, 1958). These psychometric tests can be see in Appendix A.

A) The **MMSE** (Folstein, Folstein, & McHugh, 1975) was administered to each participant as a measure of global cognition. The MMSE assesses several domains of cognition and includes measures of initial and delayed recall, orientation, concentration and calculation, language, comprehension, and praxis.

B) The **Auditory Digit Span**, taken from the Wechsler Adult Intelligence Scale-Revised (WAIS-R) (Wechsler, 1981) was administered to each participant. Each digit was spoken at rate of one per second, and the participant was asked to recall each sequence in the order in which it was presented (backwards digit span was not assessed at this time). The first trial consisted of three items, increasing by one item with each subsequent presentation. The test was discontinued when the participant failed to recall correctly two successive trials of a given sequence length.

C) A **Delayed Recall Task** was also given to each participant. Each participant was given a blank sheet of paper and asked to recall as many letters as they could from the lists used during the testing session. This test was not timed and participants could have as much time as they needed. The test was ended when the participant stated that they were finished.

D) A **Delayed Recognition Task** was given to each participant directly following the delayed recall test. Participants were presented with all the letters of the alphabet printed on a sheet of paper. They were asked to circle as many letters as they could recall as being part of the lists used during the testing session. Participants did not have access to their responses from the delayed recall test. This test was not timed and participants could have as much time as they needed. Again, the test was ended when the participant stated that they were finished.

E) Finally, a **Post-Test Questionnaire** was given to each participant (Experiment 1 only). The questionnaire contained five questions pertaining to the presentation frequency of the stimuli. Participants were asked whether (1) they remembered seeing some letters more frequently than others, (2) they were then asked to indicate which letters were presented more frequently, (3) and which letters were presented less frequently, (4) participants were then asked to decide how frequently the HF (given to 6 participants per group) or LF (given to 6 participants per group) letters were presented, (5) and finally, participants were presented with the list of stimuli used in the experiment and asked to indicate which letters were presented more frequently (given to 6 participants per group) or less frequently (given to 6 participants per group).

Results and Discussion

For all conditions the data were scored by calculating the number of correct responses for each serial position, over 12 trials for each participant. A strict serial recall scoring method was used, thus, a response was scored as correct only if it was correct and in the appropriate serial position. In addition to the usual scoring procedures for serial recall data, the number of correct HF and LF responses were calculated for each serial position over the 12 trials. Since the ratio of HF letters to LF letters was 3:1, each serial position had a HF maximum score of nine and a LF maximum score of three. In order to make HF letters and LF letters comparable, the total LF score for each serial position was multiplied by three, thus the adjusted maximum score for LF letters is nine. These data are summarized in Appendix A, which shows the mean number of items correct at each serial position for all groups as a function of frequency, condition, and modality.

Immediate Recall Analysis - (Control Condition Only)

Many studies with young normal adult participants have shown superior performance in immediate serial recall, when stimuli are presented auditorily compared to visually, in control conditions (e.g., Crowder & Morton, 1969; Manning et al., 1990). In addition, young normal participants have been shown to be more sensitive to auditory suffixes than visual suffixes. Auditory suffixes, in most cases, reduce recall of auditorily presented stimuli at the end of the sequence, whereas visual suffixes generally have no effect on recall of comparable visual sequences (Crowder & Morton, 1969; Manning et al., 1990).

A small number of studies have shown greater recall performance for auditory as compared with visual stimuli in immediate recall to be relatively greater in elderly compared to young normal participants (e.g., Arenberg, 1977; Manning et al., 1990; Manning et al., 1996). Manning and Greenhut-Wertz (1990) have suggested that the relative differences in performance may be due to a relative deficit, in the elderly, in recoding visual stimuli. In addition, Manning et al. (1996) found that AD participants performed very much like the normal elderly in showing a relative visual decline in performance. This difference was no greater for AD participants than normal elderly participants. Manning et al. suggest that age may be more relevant than AD in this immediate recall deficit.

In order to further examine group differences, modality effects, recency effects, and frequency effects, independent of interference from the suffix condition, an analysis was performed using only the data from the control condition. The analysis was a 4 (Group) X 2 (Modality) X 2 (Frequency) X 6 (Serial Position) ANOVA. The analysis revealed a significant main effect of Group, F (3, 44) = 4.35, MSE = 275.743, $p < .00005$. As expected, this effect is due to the decrease in performance, summed over all conditions and modalities, with increasing impairment in the order listed, young normal participants, elderly normal participants, MCI participants, and AD participants (M = 7.104, M = 6.135, M = 5.767, M = 4.736, respectively). The main effect of Serial Position was also significant, F (5, 220) = 56.08, MSE = 263.283, $p < .00005$. The main effect of Serial Position represents the usual irregular effects summed over condition.

A modality effect was expected but was not significant. Although there have been studies which have not found this auditory advantage, most previous research has shown an auditory advantage. In the present study there was not a significant advantage for the auditory modality (M = 5.88) compared to the visual modality (M = 5.99). Figure 1 clearly shows that the auditory advantage was eliminated by the superior performance in the visual modality at the beginning of the sequence (positions 1 - 4) when summed over all groups and frequency.

The Modality X Serial Position interaction was highly significant, F (5, 220) = 11.42, MSE = 32.927, $p < .00005$. This interaction reflects superior performance summed across all groups, in the visual modality compared to the auditory modality for positions one through four and a reversal in performance for positions five and six, with superior performance in the auditory modality at positions five (M = 4.73) and six (M = 6.21) compared to the performance in the visual modality at positions five (M = 4.51) and six (M = 4.80). As one would expect, recall was better at the end of the sequence in the auditory modality compared to the visual modality. This effect will be examined more closely in the recency section.

The main effect of Frequency was also not significant. As mentioned in the introduction, the frequency portion of the study appears to be novel with respect to immediate serial recall. Robert Greene (personal communication, May 4, 1998) has suggested that these results are consistent with the standard theories of repetition effects on memory. Since immediate serial recall requires the retrieval of one particular memory trace and the location of where the item occurred, the memory traces formed for each letter are irrelevant unless the participant can also recall the location of each letter on the most current trial. If every occurrence of a particular letter leaves a separate memory trace, one would expect that at the time of free recall you are more likely to recall items which have more memory traces. Thus, it seems more plausible to expect a frequency effect in delayed free recall compared to immediate serial recall.

The Group X Frequency interaction was significant, $F(3, 44) = 2.79$, MSE = 5.830, $p < .05$. This interaction is the result of the superior performance for LF items compared to HF items for the young normal group (M = 7.23 and 6.98, respectively), MCI group (M = 5.84 and 5.69, respectively), and the AD group (M = 4.89 and 4.57, respectively), while the normal elderly group showed superior performance for HF (M = 6.29) compared to LF (M = 5.98) letters. The lack of superior performance for LF letters compared to HF letters in the normal elderly group is difficult to explain and is likely to be a chance aberration. There will be further evidence, in the immediate recall (Control and Suffix) section, that this interaction is an aberration. The nonsignificant, but superior recall of LF items compared to HF items for the young, MCI, and AD groups and the superior recall of HF items compared to LF items for the elderly normal group does not appear to be suggestive of anything. It may be that since immediate recall task required strict serial recall, the memory traces formed for each letter were irrelevant if the participants could not also recall the location of each letter.

<u>**Evaluating the Recency Effect**</u>

Research has demonstrated rapid forgetting (the unusually quick loss of recently presented items), in the presence of even minimal interference, is very powerful in differentiating normal participants from those with AD (Butters, 1988). Since it has been suggested that the suffix acts as a minimal distractor, performance at the end of the sequence (recency) should be better in the control condition compared to the suffix condition, particularly for the AD participants. The effect of the suffix, interference, will be examined for all four groups by examining the effect of the suffix on recency. Although all of the groups performance is expected to decrease in the presence of the suffix, the AD group is expected to be the most effected, particularly in the auditory modality.

Since the main effect of frequency was not significant, and the interaction of group and frequency appears to be an aberration, recency was assessed by generating serial position curves which collapsed over the frequency scores. The maximum score for these new serial position curves is 9.0. Based on these new serial position curves, which can be seen in Table 2 and Figure 1, recency was assessed by performing individual t-tests between position five and position six in the control condition in both the auditory and visual modalities. Consistent with previous research, the young normals, elderly normals, and MCI groups showed a significant recency effect in the auditory control condition ($p = .01$), while the AD group showed marginally significant recency ($p = .10$) in the auditory control condition. Consistent with previous research no group, except the MCI group ($p = .05$), showed a significant recency effect in the visual control condition. In addition, as can be seen in Appendix A when HF and LF performance is combined, the AD group appears to be the most effected by the presence of a suffix (visual or auditory). When the AD group was examined more closely, it was clear that they showed the most recency in the auditory control condition and the least in the visual suffix condition. Although previous work in this lab has suggested that the auditory suffix is more deleterious than the visual suffix, it appears in the present study, that the AD group was effected by the auditory and visual suffix. Finally, although all groups were effected by the presence of the suffix, the AD group showed relatively more rapid forgetting in the presence of a minimal distractor - visual and auditory.

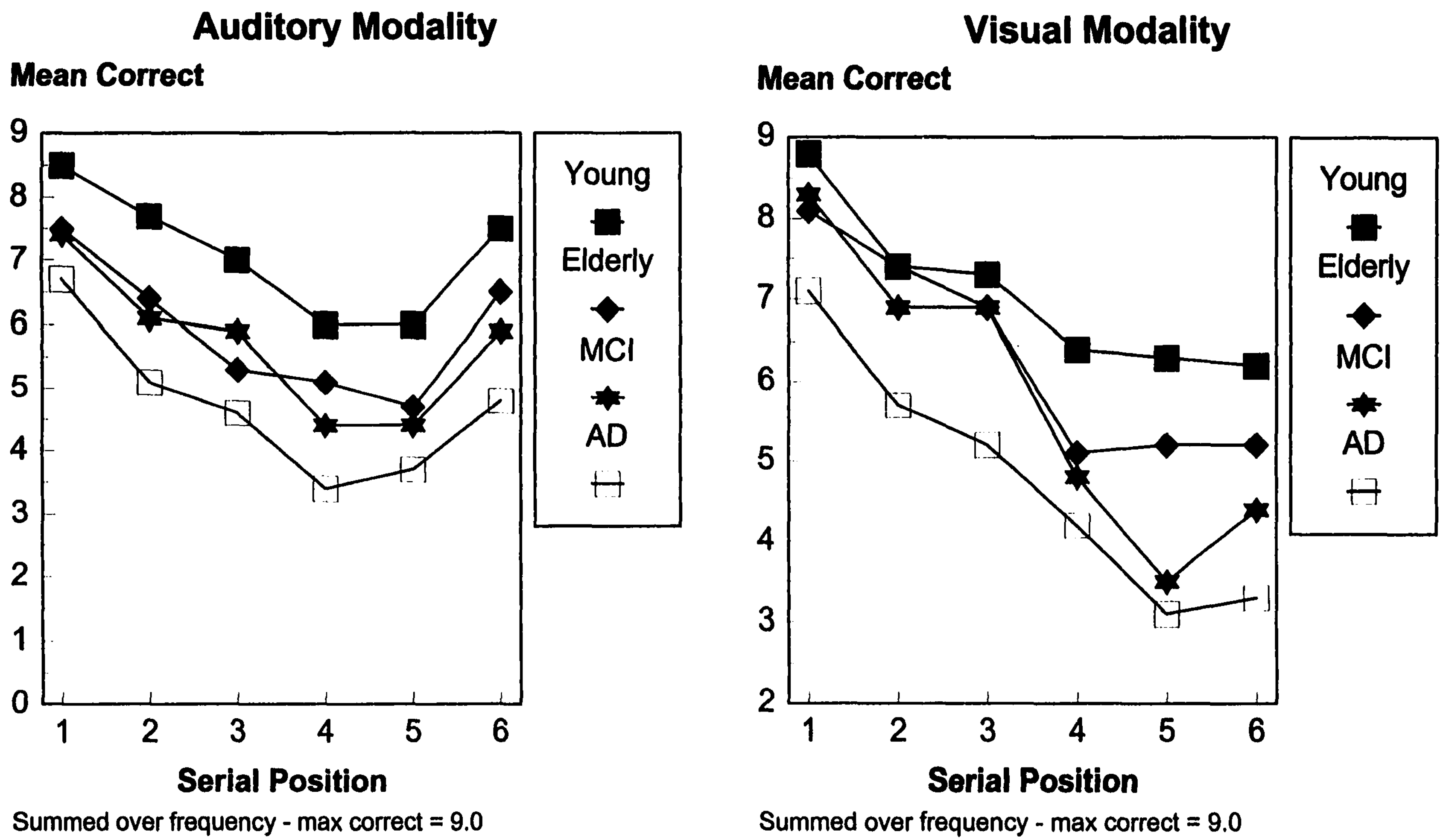
Table 2

Mean Number of Items Recalled in the Control Condition as a Function of Group and Modality

	1	2	3	4	5	6
Young						
Auditory	8.5	7.8	7.0	6.0	6.0	7.5*
Visual	8.6	7.5	7.3	6.4	6.3	6.2
Normal Elderly						
Auditory	7.5	6.4	5.3	5.1	4.7	6.5*
Visual	8.1	7.4	6.9	5.1	5.2	5.2
MCI						
Auditory	7.4	6.1	5.9	4.4	4.4	5.9*
Visual	8.3	6.9	6.9	4.8	3.5	4.4
AD						
Auditory	6.7	5.1	4.6	3.4	3.7	4.8†
Visual	7.1	5.7	5.2	4.2	3.1	3.3

Note: Maximum Score is 9.0 for all serial positions.
* Represents a significant one-tailed t-test between position five and position six.
† Represents a marginally significant one-tailed t-test between position five and position six.

Figure 1: Serial Position Curves for the Control Condition Analysis as a Function of Group & Modality.



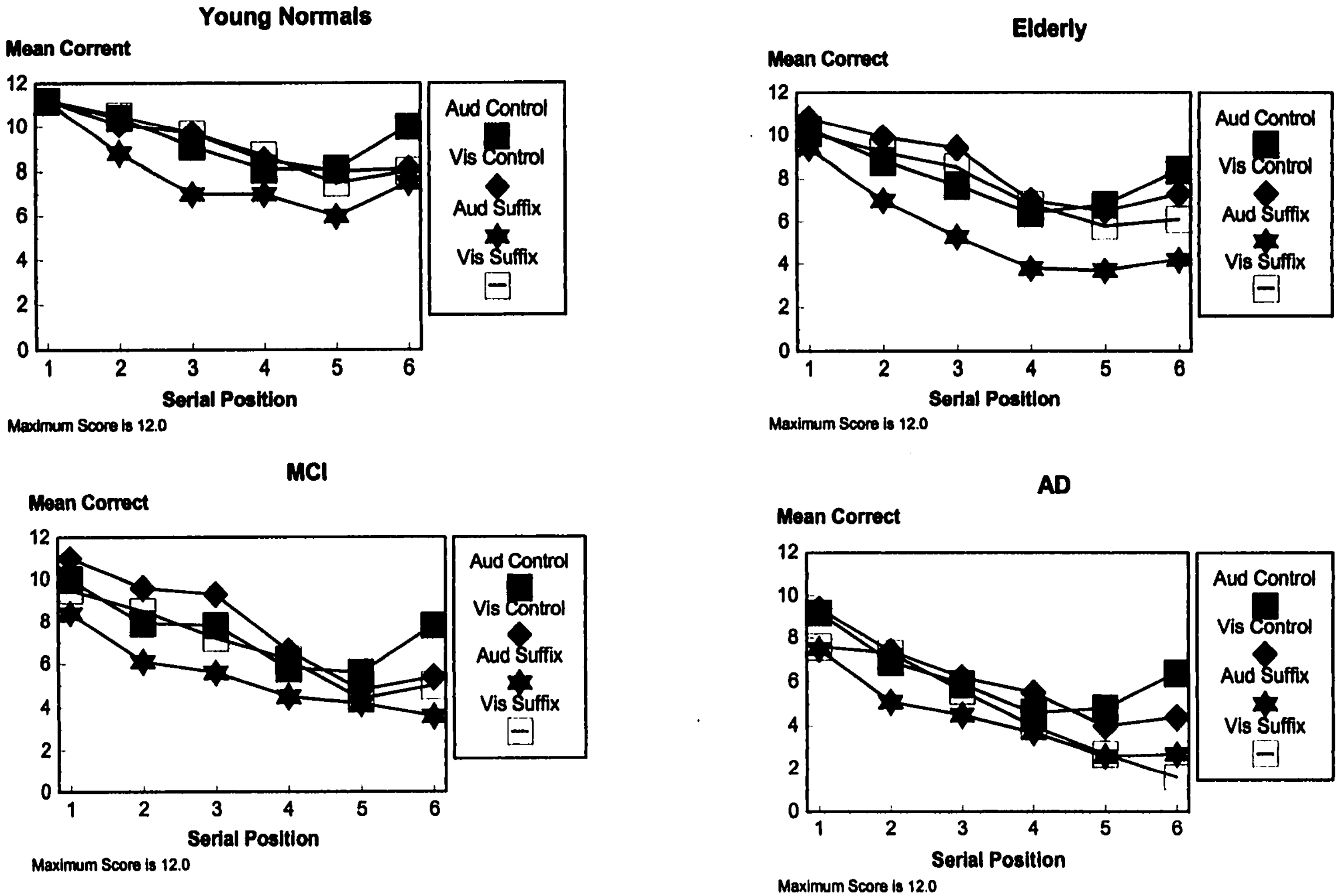
Immediate Recall Analysis (Control & Suffix)

Since the suffix is known to have a great impact, particularly in the auditory modality, the previous analysis was done using the control condition alone to examine modality and frequency effects. The present analysis contains the suffix data as well as the control data. The Experiment was a 4 (Group: Young, Normal Elderly, MCI, and AD) X 2 (Condition: Control, Suffix) X 2 (Frequency: HF, LF) X 2 (Modality: Auditory, Visual) X 6 (Serial Position) factorial design, with all variables being within subject except Group which is a between subject variable. The mean number of HF and LF letters recalled as a function of group, condition, and modality are summarized in Appendix A. As one would expect the main effects of Group, $F(3, 44) = 6.82$, $MSE = 734.53$, Condition, $F(1, 44) = 64.06$, $MSE = 660.92$, Modality, $F(1, 44) = 11.82$, $MSE = 157.29$, and Serial Position, $F(5, 220) = 101.59$, $MSE = 598.99$, were all significant. The main effect of Frequency was not significant.

The main effect of Group is the result of the superior performance of the young as compared with the normal elderly, the MCI, and especially the AD group. The main effect of condition reflects the superior performance of all groups, summed over all serial positions, for the control condition ($M = 5.93$) compared to the suffix condition ($M = 4.86$). The main effect of Serial Position represents the usual irregular effects summed over condition.

Although the main effect of Modality was significant, as in the previous analysis, the effect was due to the superior performance in the visual modality ($M = 5.66$), rather

Figure 2: **Serial Position Curves for Immediate Serial Recall as a Function of Condition and Modality for each group: Young, Normal Elderly, MCI, and AD.**



than the usual and expected superior performance, in the auditory modality (M = 5.14). This finding is not surprising since the analysis of the control condition did not show an auditory advantage and the current analysis also contained the suffix data, which is known to decrease performance in the auditory modality which creates an even greater visual superiority. The superior performance in the visual modality appears to be largely due to the greater recall of the items in the middle of the curve (positions 3 and 4), see Figure 2 and Table 3, in both the suffix and control conditions in the visual modality compared to the auditory modality when summed over frequency. Since the control condition analysis revealed that there is no significant difference between the auditory modality and the visual modality, the main effect of modality in the current analysis must be largely due to the addition of the suffix condition which has been shown to decrease or eliminate any effect of auditory superiority, particularly when the suffix is auditory.

A significant Modality X Condition interaction was found, $F(1, 44) = 14.9$, $MSE = 95.9$. As expected, the overall performance in the auditory and visual modality was better in the control condition (M = 5.88 and 5.99, respectively) compared to the suffix condition (M = 4.40 and 5.33, respectively). As expected, this effect is more robust in the auditory condition because of the more deleterious effect of the suffix in the auditory modality.

A significant Modality X Serial Position interaction was found, $F(5, 220) = 9.24$, $MSE = 37.30$. As can be seen in Figure 2, this effect may be due to the superior end of sequence recall, positions five and six, for all groups in the auditory modality compared

Table 3

Mean Number Correct During Immediate Serial Recall as a Function of Condition, Modality, Age and Cognitive Impairment

	Serial Position					
	1	2	3	4	5	6
Young						
Auditory Suffix	11.2	8.8	7.0	7.0	6.0	7.5
Auditory Control	11.2	10.4	9.1*	8.1	8.1*	10.0*
Visual Suffix	11.2	10.5	9.7	8.7	7.5	8.0
Visual Control	11.2	10.1	9.7	8.5	8.0	8.1
Normal Elderly						
Auditory Suffix	9.4	7.0	5.3	3.8	3.7	4.2
Auditory Control	10.3	8.8	7.7*	6.4*	6.8*	8.4*
Visual Suffix	10.1	9.2	8.5	6.8	5.8	6.1
Visual Control	10.8	9.9	9.4	7.0	6.5	7.3
MCI						
Auditory Suffix	8.4	6.1	5.6	4.5	4.2	3.6
Auditory Control	10.0	7.9	7.8*	5.8	5.6	7.8*

Visual Suffix						
	9.5	8.5	7.2	6.2	4.4	5.0
Visual Control						
	11.0	9.6	9.3	6.6	4.8	5.4
AD						
Auditory Suffix						
	7.5	5.1	4.5	3.7	2.6	2.7
Auditory Control						
	9.2	6.9	5.9	4.6	4.8*	6.4*
Visual Suffix						
	7.6	7.3	5.6	4.0	2.7	1.6
Visual Control						
	9.4	7.4	6.2	5.5	4.0	4.4*

Note: Maximum Score is 12.0 for all serial positions.
* represents a significant Dunnett test, C - E = 1.97.

to the visual modality in the control condition and the lack of such a robust end of sequence effect for the visual control conditions and the auditory and visual modality suffix conditions. In addition, there is a generalized suffix effect, for the auditory and visual modality, with the greatest effect occurring at the end of the sequence. This is consistent with previous research which has demonstrated a robust recency effect for auditorily compared to visually presented stimuli (e.g., Frick, 1988; Manning, Koehler, & Hampton, 1990; Nairne, 1988). In addition, most previous research has shown a lack of any recency effect in suffix conditions. The suffix has been shown to act as an interference, thus eliminating the recency effect, particularly in the auditory modality (e.g., Manning & Greenhut-Wertz, 1990).

The main effect of Frequency was not significant, that is, HF letters were not recalled better than LF letters in immediate recall. Interestingly, the recall of HF ($M = 5.4$) and LF ($M = 5.4$) letters was exactly the same when summed over condition and modality. As discussed earlier, this may be due to the nature of the immediate recall task. Since participants were instructed to use a strict serial recall method they could not recall the letters in any order, as is done when participants are given free recall instructions. The nature of serial recall places greater attentional demands on the participants, since they are required to not only retrieve the letters but also recall the letters in the same order in which they were presented. It may be that if participants were instructed to use a free recall method, a frequency effect would have been observed. But, due to the nature of strict serial recall, the participants did not have this advantage.

A significant Group X Frequency interaction was found, $F(3, 44) = 4.84$, $MSE = 14.0$, $p < .005$. This interaction is the result of the superior performance for LF items compared to HF items for the young normal group (M = 6.91 and 6.70, respectively), and the MCI group (M = 5.39 and 5.07, respectively), while the elderly normal group showed superior performance for HF compared LF letters (M = 5.71 and 5.32, respectively) and the AD group did not show any frequency effect (M = 4.05 and 4.05, respectively). As discussed in the control condition analysis, the differences in frequency recall is not significant (main effect of Frequency was not significant in either analysis) and the differences between the groups from the two analyses' are further evidence that these findings are likely to be an aberration.

A highly significant Condition X Serial Position effect was found $F(5, 220) = 6.69$, $MSE = 18.35$ as well as a highly significant Modality X Condition X Serial Position effect, $F(5, 220) = 5.34$, $MSE = 13.37$. These interactions are important since one would expect that the superior performance at the end of the sequence for the auditory modality to be more pronounced in the control condition compared to the suffix condition.

Preplanned Dunnett tests comparing the control condition to the suffix condition, using the error term for the Modality X Condition X Frequency X Serial Position interaction, C -E = 1.97, were performed to clarify the difference between the control condition and the suffix condition for all groups. Table 3 highlights the serial positions where a significant difference between the control condition and the suffix condition can be seen. Consistent with previous work in this area all groups showed a significant difference between the control and suffix conditions at position five and position six in the Auditory modality with the exception of the MCI group which showed it only at position six.

In addition, no significant differences between the control and suffix conditions were found in any group for the visual modality, with the exception of one significant difference at position six in the AD group. This is also consistent with previous work in this lab, in which normal young and elderly participants seem to be able to block out or ignore the visual suffix (e.g, Manning et al., 1997, Manning & Greenhut-Wertz, 1990). Although all of the other groups were successful in blocking out the interference created by the visual suffix, including the MCI participants, this phenomenon does not hold for the AD participants. The AD participants show a significant decrement in performance at position six. Although this decrement in performance is only at position six, it strongly suggests that AD participants are unable to successfully block out the visual suffix. Although this is not consistent with previous work in this lab, it is further evidence to support the theory that participants with AD show signs of attentional deficits and an inability to suppress irrelevant information.

Intrusions in Immediate Recall

Intrusions, defined as letters incorrectly included in recall which are not part of the sequence to be recalled, were divided into one of three types: extra-list, intra-list and suffix intrusions. Table 4 shows the total number of intrusion errors by type and group. As previously discussed, a prominent feature of AD patients' performance on memory

Table 4

Total Number of Extra-List, Intra-List, and Suffix Intrusions as a Function of Group, Condition and Presentation Modality.

Presentation	**Young**	**Elderly**	**MCI**	**AD**
Extra-List Intrusions				
Auditory Control	3	0	0	8
Auditory Suffix	1	7	8	15
Auditory Total	**4**	**7**	**8**	**23**
Visual Control	7	6	5	12
Visual Suffix	0	5	3	16
Visual Total	**7**	**11**	**8**	**28**
Intra-List Intrusions				
Auditory Control	1	1	2	6
Auditory Suffix	0	5	4	0
Auditory Total	**1**	**6**	**6**	**6**
Visual Control	1	7	11	20
Visual Suffix	2	10	8	11
Visual Total	**3**	**17**	**19**	**31**
Suffix Intrusions				
Auditory Control	0	0	0	2
Auditory Suffix	1	4	6	17
Auditory Total	**1**	**4**	**6**	**19**
Visual Control	0	0	0	2
Visual Suffix	0	1	6	11
Visual Total	**0**	**1**	**6**	**13**
COMBINED TOTAL	**16**	**46**	**53**	**120**

tests has been the frequent occurrence of intrusion errors. Several investigators have suggested that such errors may be of diagnostic value in the early stages of AD (e.g, Delis et al., 1991; Manning et al., 1996). The present study will examine intrusion errors in order to further explore their usefulness in the clinical diagnosis of AD. For each type of intrusion a 4 (Group) X 2 (Modality) X 2 (Condition) X 6 (Serial Position) ANOVA was performed with all variables being within subject except group.

Extra-List Intrusions

The total number of extra-list intrusions produced by each group as a function of modality and condition can be seen in Table 4. The extra-list intrusion analysis revealed a significant main effect of Group, $F(3, 44) = 2.68$, $MSE = 1.42$, $p < .05$. Consistent with previous research (Manning et al., 1996), this effect was due to the large number of extra-list intrusions produced by the AD group (Total = 51) as compared to the young (Total = 11), normal elderly (Total = 18), and MCI (Total = 16) groups.

Although the main effect of Modality was not significant, the interaction of Modality X Condition was, $F(1, 44) = 4.34$, $MSE = .4201$ $p < .04$. This interaction is the result of the production of less extra-list intrusions in the auditory control condition ($M = .0521$) compared to the auditory suffix condition ($M = .1076$) and the reverse effect in the visual modality, with the production of more extra-list intrusions in the visual control condition ($M = .1042$) compared to the visual suffix condition ($M = .0833$).

Manning et al. (1996) found a significant main effect of serial position which was attributed to the increased number of intrusions in the later serial positions, particularly in the visual modality. This finding was not replicated in the present study and may be due to the stimulus set size differences. In the Manning et al. study, the stimulus set size was six and all six letters were used in every sequence compared with the present study which used a stimulus set size of 12 and used only six of the letters in every sequence. The use of 12 letters of the alphabet compared to six which reduces the chances of extra-list intrusions, in general. It may be the case that participants generated more intra-list intrusion errors, which were not possible in the Manning et al. study, compared to extra-list intrusion errors in the later serial positions. This will be explored in the next section.

Intra-List Intrusions

Although some aspects of extra-list intrusion analysis did not replicate previous work in this lab the examination of intra-list intrusions may reveal new information not previously studied in this lab. Possibly due to the stimulus set size, the examination of extra-list intrusions did not replicate previous work, but the examination of intra-list intrusions may reveal more information about each group, for this very same reason. Keep in mind that the LF letters were divided into two sets, balanced over the entire experiment, thus not all LF letters were used during a particular condition. The number of intra-list intrusions produced by each group as a function of modality and condition can be seen in Table 4.

Although the main effect of Group was not significant, there was a trend toward significance ($p = .09$) with the AD (Total = 37) group producing the greatest total number on intra-list intrusion errors compared to the young (Total = 4), normal elderly (Total =

23) and MCI (Total = 24) groups. The analysis revealed a significant main effect of Modality, $F(1, 44) = 19.8$, $MSE = 2.26$, $p < .0001$. This effect was due to the greater mean number of intra-list intrusions produced in the visual modality ($M = .1233$) compared with the mean number of intra-list intrusion errors produced in the auditory modality ($M = .0347$). The main effect of Serial Position was also significant, $F(1, 220) = 3.52$, $MSE = .342$, $p < .004$. As seen in the Manning et al. (1996) study, this effect is the result of the generally increasing number of intrusions in the later serial positions, see Table 5, particularly for the AD group compared to the other groups.

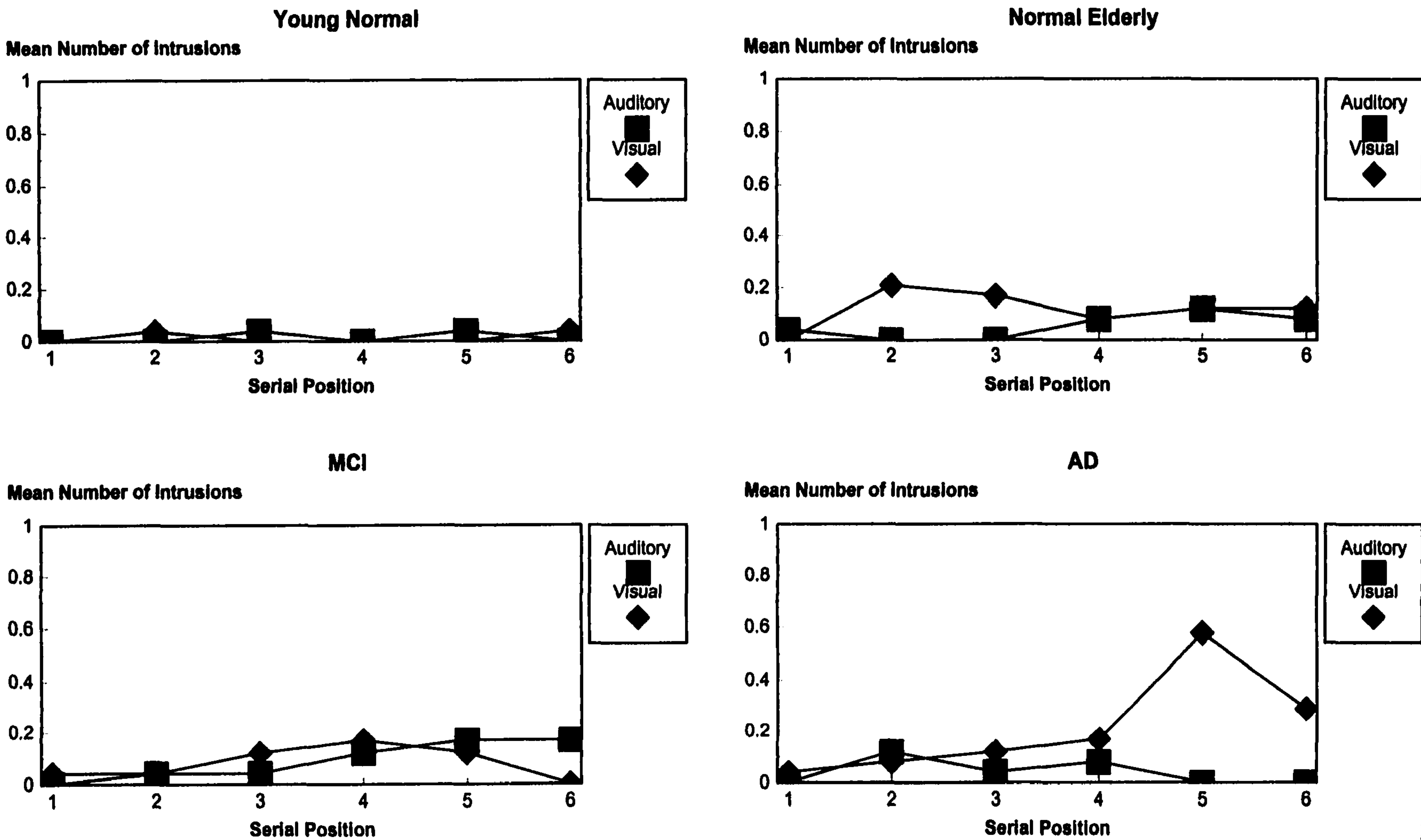
In addition, there was a significant Modality X Serial Position interaction, $F(5, 220) = 2.84$, $MSE = .349$, $p < .02$. The interaction being mainly driven by the AD group, see Figure 3, who show an increase in intrusion errors at positions five and six in the visual modality compared to the auditory modality. In addition, when summed over all groups the mean number of intrusion errors is greater at all serial positions, except position three, in the visual modality compared to the auditory modality. This suggests that participants, particularly the AD group, were more likely to make intra-list intrusion errors in latter serial positions in the visual modality.

Table 5

Mean Number of Intra-list Intrusions as a Function of Presentation Modality, Condition, and Serial Position for the AD Participants.

	Serial Position					
	1	2	3	4	5	6
Presentation						
Auditory						
Control	.00	.25	.08	.17	.00	.00
Suffix	.00	.00	.00	.00	.00	.00
Visual						
Control	.00	.17	.17	.33	.67	.33
Suffix	.08	.00	.08	.00	.50	.25

Figure 3: The Interaction of Modality X Serial Position for Intra-List Intrusion Errors.



The Group X Modality interaction was also significant, F (3, 44) = 2.73, MSE = .342, $p < .05$. All groups made more intra-list intrusion errors in the visual modality compared with the auditory modality. But as can be seen in Table 4, the total number of intrusion errors increases with increasing impairment. The young make virtually no intrusion errors in either modality, the normal elderly and MCI groups make some intrusion errors, but as expected the AD group makes more than any other group. These results are similar to those found by Manning et al. (1996) for extra-list intrusions. In the present study all groups, although mainly the AD group, made intra-list intrusions with greater frequency in the visual modality and at the later serial positions.

As Manning et al. suggest, the increase in the end of sequence intrusion errors may be the result of the serial recall paradigm. Since the first items are always recalled prior to the later items, the AD participants who already rapidly forget, actually forget not only temporal information but also forget the actual items presented. In addition, it appears that when the AD participants reached the end of the list, and they could not recall what letters had appeared, they had difficulty suppressing previously presented stimuli. Also consistent with Manning et al's study is the Modality X Serial Position interaction. This may be due to the standard modality effect, more robust recency in the auditory modality, which may lead to more "filled in" guesses and intrusions at the end of the sequence in the visual modality compared to the auditory modality.

The Combination of Extra-List & Intra-List Intrusions

In order to further explore intrusion errors in immediate recall, extra-list and intra-list intrusion errors were combined in one analysis. As seen in Table 4, there appears to be an effect of condition, modality, and position when these two types of intrusion errors are collapsed, with an increase in the total number of intrusion errors occurring in the suffix condition and visual modality, for all groups.

A 4(Group) X 2 (Modality) X 2 (Condition) X 6 (Serial Position) ANOVA was performed. The mean number of intrusion errors made by each group as a function of modality, condition, and serial position can be seen in Table 6.

The analysis revealed a significant main effect of Groups, $F (3, 44) = 4.09$, $MSE = 3.396$, $p < .01$. This effect is driven by the AD group's increase in intrusion errors (Total = 88) compared to the young, normal elderly, and MCI groups (Total = 15, 41, and 41 respectively). As expected, when intrusion type was collapsed, the main effect of Condition was highly significant, $F (1, 44) = 7.78$, $MSE = 2.722$, $p < .008$. This is due to the increase in intrusion errors in the suffix condition ($M = .211$) compared to the control condition ($M = .114$). The greater attentional demands placed on participants in the suffix condition appears to contribute to the increase in intrusion errors made by all groups, and particularly the AD group.

The main effect of Serial Position was also highly significant, $F (5, 220) = 3.69$, $MSE = 1.132$, $p < .003$. This is due to the increase of intrusion errors at the later part of the curve, position five and six. Manning et al. (1996) have suggested that the increase in intrusion errors at the end of the curve is due to participants "guessing" when they reach

Table 6

The Mean Number of Combined Extra-List and Intra-List Intrusion Errors as a Function of Group, Condition, Modality, and Serial Position.

Position	1	2	3	4	5	6
Auditory Modality						
Control Condition						
Young	0.0	0.0	.25	0.0	.08	0.0
Elderly	0.0	0.0	0.0	0.0	.08	0.0
MCI	0.0	0.0	0.0	.08	.08	0.0
AD	.33	.58	.08	.42	0.0	.08
Suffix Condition						
Young	0.0	0.0	0.0	.83	.25	.33
Elderly	.08	0.0	.08	.33	.25	.33
MCI	0.0	.08	.17	.17	.25	.67
AD	0.0	.17	.42	.42	.83	.67
Visual Modality						
Control Condition						
Young	0.0	0.0	0.0	0.0	0.0	.08
Elderly	0.0	.25	.08	0.0	.33	.42
MCI	0.0	.17	.25	.08	.25	.25
AD	.33	0.0	.17	.33	.33	.08
Suffix Condition						
Young	0.0	.08	0.0	0.0	0.0	.08
Elderly	0.0	.33	.25	.33	.08	.25
MCI	.08	.08	.17	.25	.17	.17
AD	.08	.08	.25	.25	1.0	.58

the end of the sequence and can no longer recall any of the items. The main effect of Modality was not significant.

The interaction of Condition X Serial Position was significant, F (1, 220)= 2.98, MSE = .770, $p < .01$. This interaction is the result of an increase in intrusion errors in the latter serial positions in the visual modality compared to the auditory modality. This is consistent with the findings of Manning et al. (1996) who also found that the decrease in recency in the visual modality leads to more "filled in guesses", and thus there is an increase in extra-list and, in this study, intra-list intrusion errors at the end of the sequence in the visual modality compared to the auditory modality.

Finally the Group X Condition X Serial Position interaction was also highly significant, F (15, 220) = 2.20, MSE = .570, $p < .007$. This interaction is mainly due to the increase in intrusion errors in the suffix condition compared to the control condition across all serial positions, with a few exceptions, see Table 6. This effect is present for all groups with the strongest effect seen in the AD group, particularly at positions five and six in the auditory and visual modalities.

When you look at intrusion errors in immediate recall, and particularly when you combine extra-list and intra-list intrusion errors, the AD group once again emerges as being different from all other groups. The AD group made a total of 59 intrusion errors while the young made only 10, the least number of intrusion errors. Interestingly, the MCI group looks exactly the same as the normal elderly. The normal elderly made 28 intrusion errors while the MCI group made 27 intrusion errors. The AD group made almost double the number of intrusion errors compared to the normal elderly and MCI groups. Consistent with previous work in this lab and others, intrusions errors appear to be a potential marker of early AD, while they do not appear to be a marker of MCI.

Suffix Intrusions

The presence of suffix intrusion errors by any group, which is an item participants are explicitly told to ignore, is thought to be a result of their inability to inhibit responses. This type of intrusion error was discussed as a possible identifying feature of AD by Manning et al. (1996). They found that AD participants generated significantly more suffix intrusion errors than young and normal elderly participants, in both the auditory and visual suffix conditions.

The present analysis revealed a significant main effect of Group, $F(3, 44) = 7.43$, $MSE = .7046$, $p < .0004$. This effect is due to the expected increase in suffix intrusion errors with increasing impairment, from young normals to AD (Total = 1, 5, 12, and 32 respectively). Consistent with the findings of Manning et al. (1996), the AD group made the greatest number of suffix intrusion errors in both the visual and auditory modalities, see Table 4, compared to the other groups.

The main effect of Modality was not significant. This is surprising given that previous research (Manning et al., 1996) has shown that there is an increase in suffix intrusion errors in the auditory modality. Manning et al. found that auditory suffixes intrude more than visual suffixes, particularly in an AD group. Although there were more suffix intrusions overall, see Table 4, in the auditory modality (Total = 30) compared to the visual modality (Total = 20), the present study did not find such a robust effect. The lack of a modality effect may be do to a floor effect or the low number of intrusion errors by this group.

As can be seen in Table 7, the interaction of Modality X Serial Position was not significant, although there was as expected, an increase of suffix intrusion errors in the auditory modality compared to the visual modality at serial position six. Although not significant, the AD group made more suffix intrusion errors at position six in the auditory and visual modalities compared to the other groups. This is consistent with Manning et al's (1996) study which found that suffix intrusions are more robust at the later serial positions in the AD group. These intrusion errors are likely to be the result of the AD group's inability to inhibit responses.

The highly significant main effect of Condition, $F(1, 44) = 13.43$, $MSE = 1.4592$, $p < .0007$, is the result of the mean number of suffix intrusion errors in the control condition ($M = .0087$) compared to the suffix condition ($M = .0799$). As can be seen in Table 4, the production of suffix intrusion errors was greatest in the suffix condition (Total Auditory and Visual = 46) compared to the control condition (Total Auditory and Visual = 4) for all groups. The main effect of serial position was also highly significant, $F(5, 220) = 10.28$, $MSE = .8474$, $p < .00005$. This effect is due to the large number of suffix intrusion errors occurring at serial position six for all groups. Although the normal elderly and MCI groups make very few suffix intrusion errors, they too tend to make them at serial position six.

Table 7

Mean Number of Suffix Intrusions as a Function of Group, Modality, Condition, and Serial Position.

Position	1	2	3	4	5	6
Auditory Modality						
Control Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	0.0
MCI	0.0	0.0	0.0	0.0	0.0	0.0
AD	0.0	0.0	0.0	0.0	.08	.08
Suffix Condition						
Young	0.0	0.0	0.0	0.0	.08	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	.33
MCI	0.0	0.0	0.0	0.0	0.0	.50
AD	0.0	.08	.17	.08	.17	.92
Visual Modality						
Control Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	0.0
MCI	0.0	0.0	0.0	0.0	0.0	0.0
AD	0.0	0.0	0.0	.08	0.0	.08
Suffix Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	.08	0.0
MCI	0.0	0.0	0.0	.17	0.0	.33
AD	0.0	.08	0.0	.08	.17	.58

The interaction of Group X Condition, $F(3, 44) = 2.97$, $MSE = .3226$, $p < .04$, and Group X Serial Position, $F(15, 220) = 2.69$, $MSE = .2219$, $p < .0009$ were both significant. As previously discussed, all groups made more suffix intrusion errors in the suffix conditions compared to the control conditions. The interaction of Group X Condition is being driven by the number of suffix intrusion errors made by the AD group in the suffix conditions (Total = 28) compared to the control conditions (Total = 4). It should also be noted that no other group made suffix intrusion errors in the control conditions. The interaction of Group X Serial Position, see Table 7, is being driven by the large increase in suffix intrusion errors at position six for the AD group, in both the auditory and visual modalities.

In addition, the interaction of Condition X Serial Position was significant, $F(5, 220) = 8.74$, $MSE = .6863$, $p < .0005$. This effect is due to the large and concentrated number of suffix intrusion errors at serial position six, particularly by the AD group, in the suffix conditions (auditory and visual) compared to the control conditions.

Finally, the interactions of Group X Condition X Serial Position, $F(15, 220) = 1.98$, $MSE = .1553$, $p < .02$, and Modality X Condition X Serial Position, $F(5, 220) = 2.28$, $MSE = .0904$, $p < .05$ were significant. The interaction of group, condition, and serial position data are summarized in Table 7. This effect is due to the increase of suffix intrusion errors, particularly by the AD group, in the latter serial positions in the suffix conditions and the lack of suffix intrusion errors for the latter serial positions in the control conditions. The interaction of modality, condition, and serial position is being driven mainly by the increase in suffix intrusion errors at position six for the auditory suffix condition (M = .4375) compared to the visual suffix condition (M = .2292), when summed over all participant groups. It should also be noted here that as the number of suffix intrusion errors increase at the end of the sequence, the likelihood of other types of intrusion errors (e.g., extra-list or intra-list) at the end of the sequence decreases.

A closer look at suffix intrusion errors revealed that the actual number of participants who made suffix intrusion errors, was also greatest in the AD group. A total of 32 suffix intrusions were made by 17 AD participants in the auditory and visual modalities compared to only 1 participant in the young normal group, 5 in the normal elderly group, and 6 in the MCI group. A suffix serves not only as a minimal distractor but also, in the case of suffix intrusions, is a further example that AD participants have great difficultly inhibiting irrelevant material, even when repeatedly asked to do so. These findings are consistent with previous work by Manning et al. (1996) in which the AD participants were unable to inhibit the suffix item compared to a normal elderly group. Once again the MCI group looked very similar to the normal elderly group, but suffix intrusions continue to look like a useful clinical marker of early AD.

Delayed Recall Results

Several investigators have demonstrated that the hippocampus is damaged in AD (Ball, 1977; deLeon et al., 1993, Hyman, et al., 1984). Recent studies have hypothesized that hippocampal damage should manifest itself in terms of rapid forgetting. The results of many studies suggest that clinical measures that capitalize on loss of information over brief delays (anywhere from 2-10 minutes) are the most useful for differentiating AD patients from normal controls and from other patient groups (e.g., Butters et al., 1988; Manning et al., 1996; Moss, Albert, Butters, & Payne, 1986). A study by Welsh, Butters, Hughes, Mohs, and Heyman (1991) found that among very mildly impaired AD patients (MMSE score of 24 or greater), the memory measure that best differentiated patients and normal controls was delayed recall. The present study was designed to examine delayed recall and recognition in order to further support the research discussed above and also to look at an MCI population.

As previously discussed, two delayed memory tasks were administered in this study; delayed recall and delayed recognition. These measures were administered after a short delay, approximately 15-20 minutes, following the immediate recall portion of the experiment. The mean correct, mean number of intrusion errors, and mean hit rate for the delayed recall and delayed recognition tasks are reported in Table 8. The data presented for both delayed memory tasks include the mean number correct responses for the HF letter set and LF letter set, the mean number of intrusion errors, and the mean hit rate. The number correct, for both tasks, was calculated as the total number of items recalled for both HF and LF stimuli (the maximum correct for each is 6.0), and due to the ambiguity of whether the suffix should be given as an appropriate response it was eliminated from all calculations. The number of intrusion errors was calculated as the number of extra-list items given. The hit rate was calculated by using the standard method, taking the number of correct responses and dividing it by the sum of the number of correct responses plus

Table 8

Mean Number of Correct Responses, Mean Number of Intrusions, and Mean Hit Rate for HF and LF Letters as a Function of Group and Delayed Memory Task

Task	Young	Elderly	MCI	AD
Mean Number Correct				
Delayed Recall				
HF	5.8	5.5	5.1	4.4
LF	4.9	3.7	3.8	3.0
Delayed Recognition				
HF	5.9	5.5	5.6	4.5
LF	5.7	4.3	5.2	3.1
Mean Number of Intrusions				
Delayed Recall	0.0	0.5	.42	.75
Delayed Recognition	0.0	1.0	. 67	1.75
Mean Hit Rate				
Delayed Recall				
HF	1.0	.92	.92	.85
LF	1.0	.88	.90	.80
Delayed Recognition				
HF	1.0	.85	.89	.72
LF	1.0	.81	.89	.64

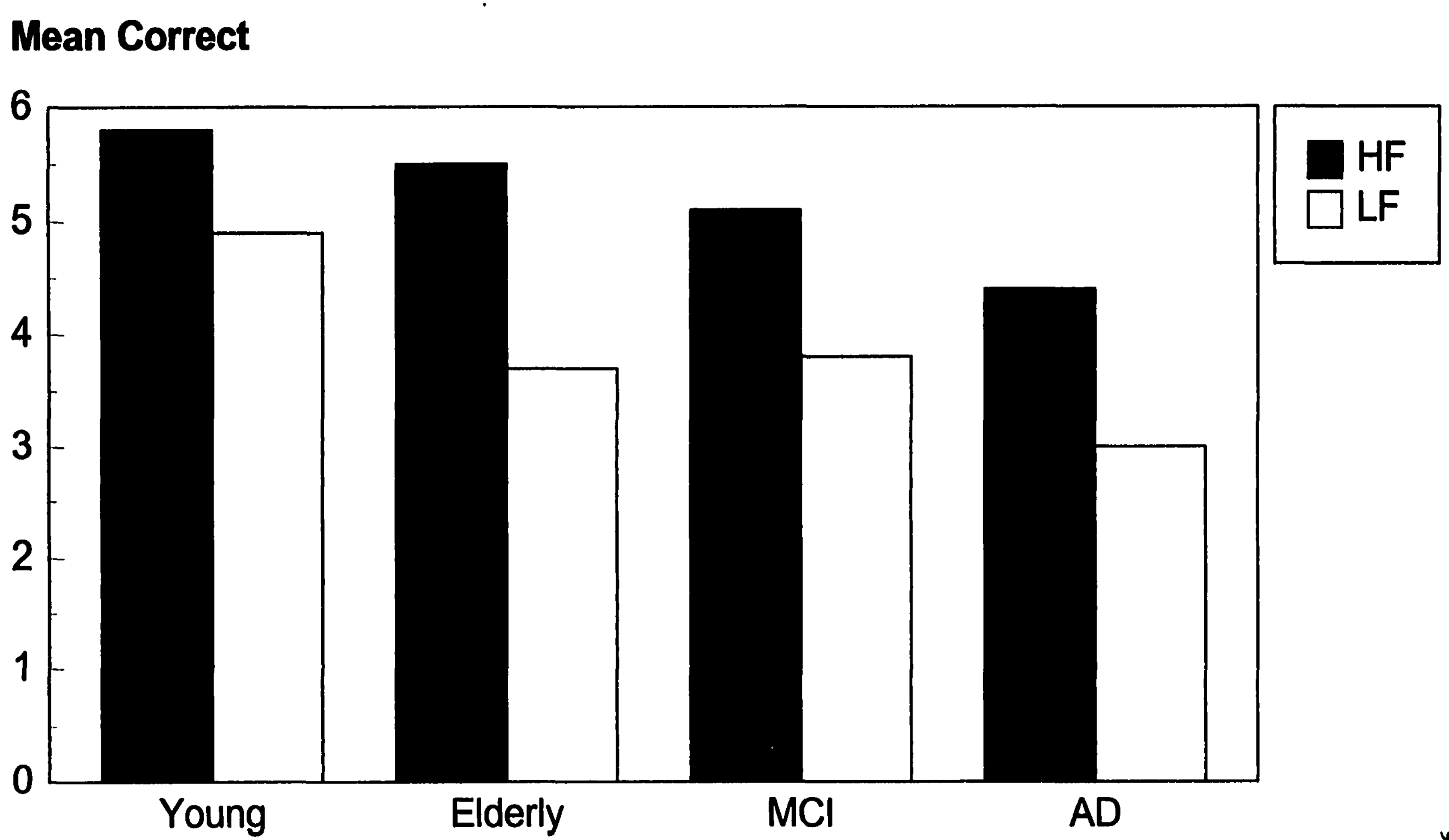
Mean Number of Items Recalled - Maximum = 6.0 (for HF and LF)
Mean Number of Items Recognized - Maximum = 6.0 (for HF and LF)
Mean Hit Rate for Recall and Recognition - Maximum = 1.00 (for HF and LF)

the number of intrusions (hits ÷ [hits + false alarms]).

In order to examine the delayed recall (HF and LF) and the delayed recognition (HF and LF) data, 4 (Group) X 2 (Frequency) ANOVA's were performed. The analysis for the delayed recall task revealed a significant main effect of Groups, $F(3, 44) = 7.47$, $MSE = 11.177$, $p < .0004$. This effect is due to the decline in performance for HF and LF letters with increasing impairment, specifically the young ($M = 5.37$), normal elderly ($M = 4.58$), and MCI ($M = 4.47$) compared to the AD group ($M = 3.71$). As seen in Table 8, the AD group did relatively well in recalling the stimuli ($M = 7.4$ out of 12.0). This is consistent with the work of Manning et al. (1996) who also found that the AD group did relatively well in the delayed recall task. As in the Manning et al. study, these findings are surprising given the rapid forgetting associated with AD. It has been suggested that the multiple repetitions help facilitate their learning and retention over a short delay, and given that the AD group recalled more HF letters than LF letters suggest that the more repetitions they are given the more likely they will be able to retain some of the information.

The main effect of Frequency is also highly significant, $F(3, 44) = 51.13$, $MSE = 44.01$, $p < .00005$. As expected there was a frequency effect in delayed recall. As can be seen in Table 8 and Figure 4, all groups recalled more HF letters than LF letters. If it is true that every occurrence of a particular letter leaves a separate memory trace, one would expect that at the time of free recall you are more likely to recall items which have more memory traces (HF letters). Thus, it seems more plausible to expect a frequency effect in

Figure 4: Mean Number of HF and LF Letters Recalled in Delayed Memory as a Function of Group.

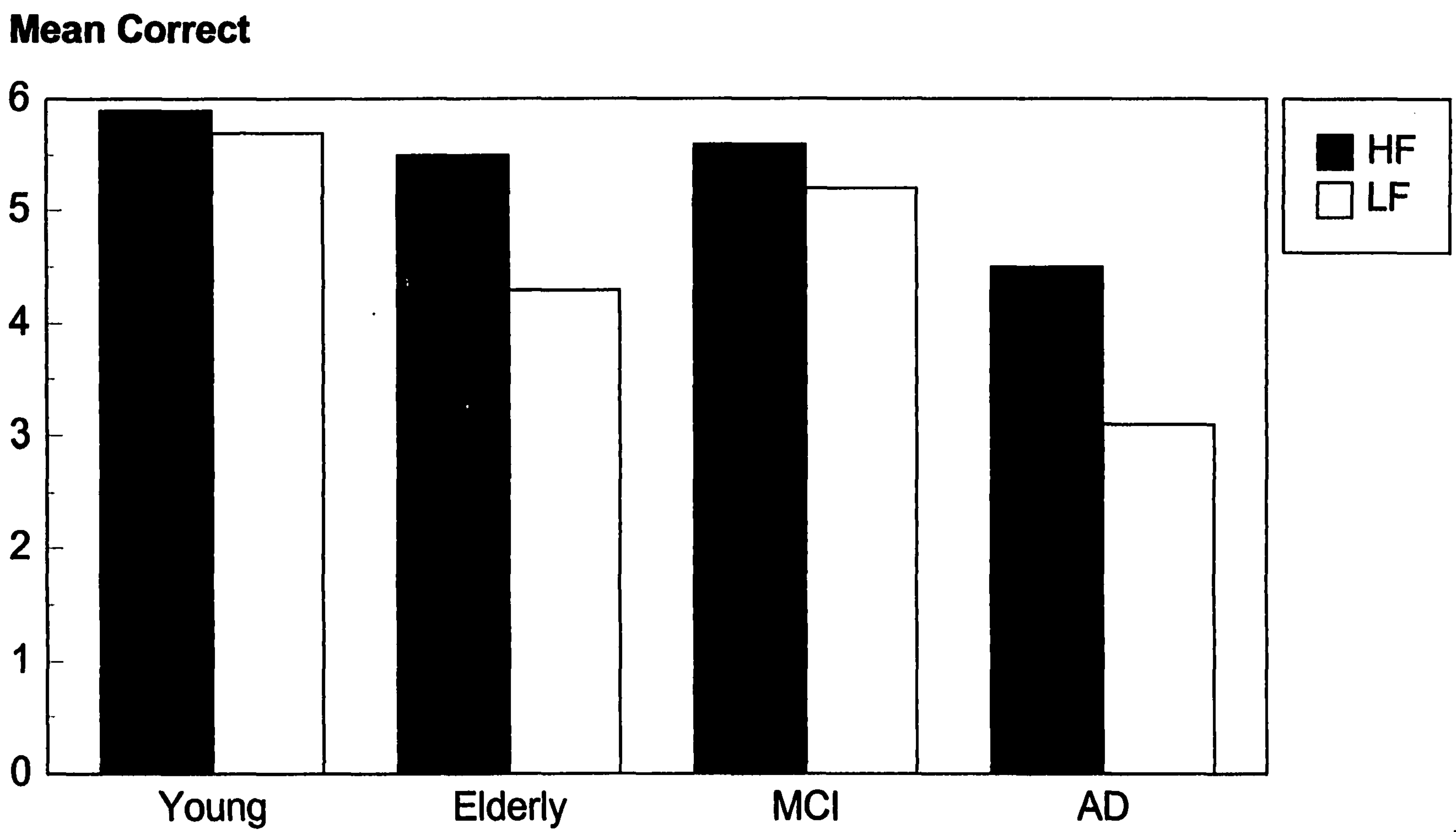


delayed free recall compared to immediate serial recall, as was found in the present study. The interaction of Group X Frequency was not significant.

The analysis for the delayed recognition task also revealed a highly significant main effect of Groups, $F(3, 44) = 16.29$, $MSE = 18.68$, $p < .00005$. As can be seen in Table 8, this effect is due to the superior performance of all groups, specifically the young ($M = 5.83$), normal elderly ($M = 4.92$), and MCI ($M = 5.42$) groups, compared to the AD group ($M = 3.79$). As expected the AD group's performance was poorer compared to the other groups, although they did perform relatively well ($M = 7.6$ out of 12.0). Once again this finding is consistent with Manning et al. (1996) who also found that although the AD group performed relatively worse than the other groups they performed surprisingly well.

The main effect of Frequency is also highly significant, $F(3, 44) = 19.95$, $MSE = 14.260$, $p < .0001$. This effect is due to the superior recognition of HF letters ($M = 5.37$) compared to LF letters ($M = 4.60$), when summed across all groups. In addition, as can be seen in Figure 5, all groups showed this frequency effect. There was also a significant Group X Frequency interaction, $F(3, 44) = 3.16$, $MSE = 2.260$, $p < .03$. Although all groups recognized more HF letters than LF letters, the effect was mainly due the differential performance between the recognition of HF letters compared to LF letters. Specifically, this differential is highest for the normal elderly (HF - LF = 1.2) and AD (HF - LF = 1.4) groups compared to the young normal (HF - LF = .2), who also approach ceiling, and the MCI (HF - LF = .4) groups.

Figure 5: Mean Number of HF and LF Letters Recognized in Delayed Memory as a Function of Group.



A 4 (Groups) X 2 (Task: Recall, Recognition) X 2 (Frequency: HF, LF) ANOVA was performed to further examine the frequency effect in delayed recall and delayed recognition. The main effect of Group was highly significant, $F(3, 44) = 14.39$, $MSE = 28.229$, $p < .00005$. This effect is due to the superior performance of the young (M = 5.60), normal elderly (M = 4.75), and MCI 3 (M = 4.94) compared the AD group (M = 3.75) who as expected performed below all other groups.

The main effect of Task, $F(1, 44) = 14.77$, $MSE = 10.08$, $p < .0004$, and Frequency, $F(1, 44) = 53.13$, $MSE = 54.19$, $p < .00005$, were highly significant. The main effect of Task is due to the superior performance in the delayed recognition task (M = 4.99) compared to the delayed recall task (M = 4.53), summed across all groups. The main effect of Frequency is due to the superior performance for HF letters (M = 5.29) compared to LF letters (M = 4.23), when summed over recall and recognition.

Interestingly, the interaction of Task X Frequency was also significant, $F(1,44) = 7.35$, $MSE = 4.083$, $p < .01$. This interaction is due to the differences in performance between the recall and recognition tasks. As can be seen in Table 8, the differential performance between LF recall and LF recognition is greater than the differential performance for HF recall and HF recognition, for all groups. This means that all groups benefitted more in the recognition paradigm when trying to retrieve LF items compared with HF items. It should be noted that performance for the young, normal elderly, and MCI groups was close to ceiling in both the recall and recognition tasks. The MCI group appears to have benefitted the most, with a 1.4 letter mean improvement for retrieving LF items, in the recognition task compared to the recall task. This suggests that the MCI group did not totally lose the memory traces for the LF items as might be suggested by their recall performance. In addition, the AD group was unable to benefit from the recognition paradigm suggesting that they lost the memory traces for the LF items probably due to both rapid forgetting and interference.

Delayed Recall Versus Delayed Recognition

In order to further evaluate the performance of delayed recall compared to delayed recognition, individual t-tests were done for each group of participants. The young normal participants performed significantly better on the delayed recognition task (M = 11.7) compared to the delayed recall task (M = 10.7), $t(11) = 2.56$, $p < .05$. The normal elderly participants did not perform significantly better on the delayed recognition task (M = 9.8) compared to the delayed recall task (M = 9.2), although the trend for better performance on the delayed recognition task is evident. The MCI participants performed significantly better on the delayed recognition task (M = 10.8) compared to the delayed recall task (M = 8.9), $t(11) = 3.73$, $p < .01$. As mentioned previously, the MCI participants benefitted the most from the delayed recognition task. The AD participants did not perform significantly better on the delayed recognition task (M = 7.5) compared to the delayed recall task (M = 7.4).

The inability for the AD participants to benefit from a recognition paradigm, is consistent with previous studies using the same delayed recall and recognition paradigm (Manning et al, 1997). Manning et al. (1997) demonstrated, using the delayed recall and recognition paradigm described for this experiment, that not only do AD participants not benefit from recognition tasks, they are adversely affected by the them. Using Manning et al.'s delayed task the AD group actually performed worse on the recognition task (M = 4.12 out of 6.0) compared to the recall task (M = 4.75 out of 6.0). They attributed this difference to AD patients' increased propensity to produce intrusion errors during the recognition task, thus reducing their hit rate. When presented with all the letters of the alphabet and asked to identify the experimental stimulus set, their immediate memory may be flooded with stimuli - this situation creates a "state" of confusion in the AD group causing them to produce more intrusion errors, and thus their performance is decreased. In addition, Rosen, Mohs, and Davis (1984) have also demonstrated AD participants' inability to benefit from repeated exposure to stimuli using both an immediate and delayed recall task and a forced choice recognition task (immediate only).

The present experiment did not show a significant decline in performance for the recognition task compared to the recall task for the AD group as was found in the Manning et al. (1996) study. One reason the hit rate may not have declined significantly in the recognition task in the present study may have to do with the number of stimuli used. The Manning et al. study used only six letters versus the present study which used 12 letters. The chances of producing intrusion errors is much less due to the increase in the number of stimuli used.

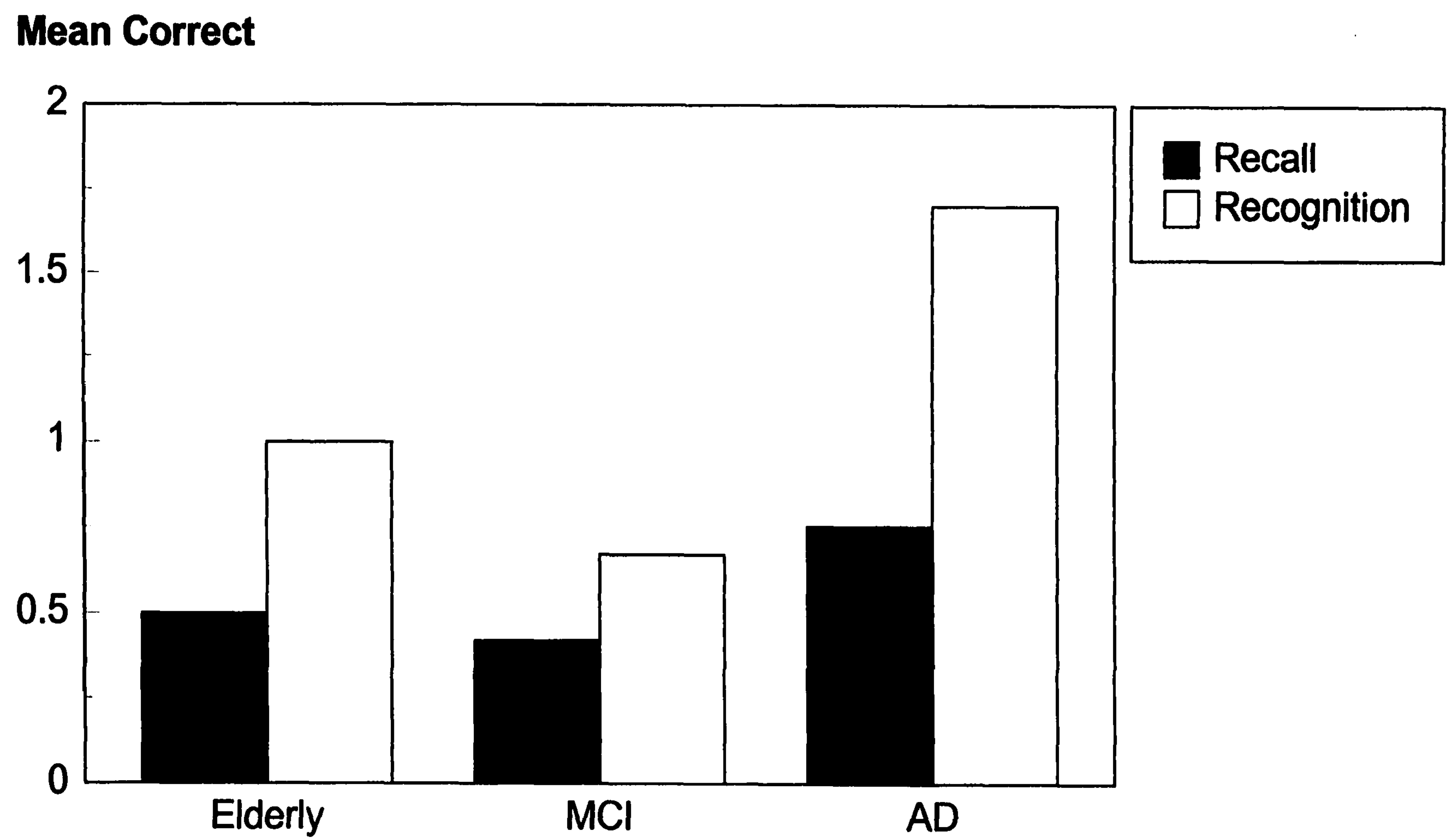
Intrusions in Delayed Memory Tasks

Although Manning et al. (1996) demonstrated that AD participants can perform relatively well on delayed recall measures with multiple repititions, they also demonstrated that they also produce the greatest number of intrusion errors. A 4 (Group) X 2 (Task: Recall and Recognition) ANOVA was performed to examine intrusion errors in both delayed memory tasks. The data for the mean number of intrusion errors in delayed memory tasks are summarized in Table 8.

The analysis shows a main effect of Task, $F(1, 44) = 17.39$, $MSE = 4.594$, $p < .0001$. This effect is due to the greater number of intrusion errors produced (summed across groups) in the delayed recognition task ($M = .854$) compared to the delayed recall task ($M = .417$). All groups, with the exception of the young, who did not produce any intrusions errors in either task, produced more intrusion errors in the recognition task compared to the recall task. The AD group, as expected, produced more intrusion errors than any group and, as can be seen in Figure 6, also had the largest differential between recall and recognition compared to the other groups.

This finding is consistent with Manning et al. (1996) who also showed that the AD group produced a greater number of intrusion errors in the recognition task compared to the recall task. Although this effect is not as large, compared to the Manning et al. findings, the size of the effect could be due, in part, to the size of the stimulus set. The Manning et al. study used a stimulus set of six letters compared with the present study which has a stimulus set size of 12 letters. Thus, it is conceivable that by increasing the number of targets the number of intrusion errors would decrease. The likelihood of making intrusion errors in the recognition task, which seems to create great confusion for

Figure 6: Mean Number of Intrusion Errors in Delayed Memory as a Function of Group.



the AD group, seems greater when there are fewer targets. Random guesses, due to confusion, are more likely to create intrusion errors in the recognition task as the number of target items decreases. Experiments 2 and 3 will address this issue further since the stimulus sets used in these experiments consist of six letters.

There is also a significant interaction for Group X Task, F (3, 44) = 4.14, MSE = 1.094, $p < .01$. This interaction is, in part, due to the lack of intrusion errors by the young in delayed recall and delayed recognition. In addition, the normal elderly had a larger differential in intrusion error rates between recall and recognition compared to the MCI group. This finding, as will also be supported in the next analysis, is likely to be an aberration since the overall difference (see Table 8) between the intrusion error rates between these two groups is fairly small. Finally, as expected, the AD group had the largest differential in intrusion error rates between recall and recognition compared to the normal elderly and MCI groups. A t-test, for the AD group, showed that the number of intrusion errors produced in the recognition task was significantly greater than the number of intrusion errors produced in the recall task, t (11) = 3.07, $p < .01$.

Finally, as was discussed previously, the young did not produce any intrusion errors in delayed memory. This led to the exclusion of the young normals from the next analysis. A 3 (Group) X 2 (Task) ANOVA was performed. The main effect of Task was still significant, F (1, 33) = 17.39, MSE = 6.125, $p < .0002$. The main effect was due to the higher number of intrusion errors in the recognition task compared to the recall task. The main effect of Group and the interaction of Group X Task was not significant. This lends support that the significant interaction of Group X Task, in the previous analysis, was an aberration.

Post Questionnaire Results

The post test questionnaire, which can be seen in Appendix D, was done in order to evaluate the effects of frequency in the young, normal elderly, MCI, and AD groups. As discussed earlier, Hasher and Zacks (1979) suggest that the encoding of frequency information is automatic. In addition, several investigators have found that making relative frequency judgements is independent of age (e.g., Attig & Hasher, 1980). Question 1 asked participants to make a relative assessment of frequency - they were asked if they recalled seeing some letters more frequently than others. The percentage correct is based on the responses of the 12 participants from each group. The percentage correct for the young normal group was 83%, for the normal elderly group 92 %, for the group MCI 100%, and for the AD group 83%. Thus, there does not appear to be an effect of age or level of impairment. All of the groups did very well.

Questions 2 and 3 were recall questions which asked the participants to try to recall the letters they remember seeing more frequently (question 2) and the letters they remember seeing less frequently (question 3). These questions were scored for number correct, number incorrect, and number of intrusions. The number incorrect was calculated based on the number of inter-list intrusion errors and the number of intrusion errors was calculated as the number of extra-list intrusions. The mean number of HF and LF letters correctly recalled, as well as the mean number of items incorrectly recalled for each

Table 9

Mean Number of Correct Responses, Mean Number of Incorrect Responses, and Mean Number of Intrusion Errors as a Function of Age and Level of Impairment.

	Young	Elderly	MCI	AD
Recall (Questions 2 and 3)				
Mean Number Correct				
HF	3.2	2.8	2.9	2.7
LF	2.4	1.3	1.0	.83
Mean Number Incorrect				
HF	1.5	1.2	1.2	1.2
LF	.92	.83	.58	1.3
Mean Number of Intrusions				
HF	0.0	.08	0.0	.50
LF	.08	.08	.17	1.2
Mean Hit Rate				
HF	.68	.68	.70	.61
LF	.71	.60	.57	.61
Recognition (Question 5)				
HF	3.8	3.8	4.0	.92
LF	3.3	2.0	2.6	3.0
Mean Number Incorrect				
HF	1.6	1.0	.80	.83
LF	.86	1.4	1.3	1.3
Mean Hit Rate				
HF	.70	.79	.80	.83
LF	.86	.59	.67	.70

Mean Number of Items Recalled - Maximum = 6.0 (for HF and LF)
Mean Hit Rate for Recall and Recognition - Maximum = 1.00 (for HF and LF)
Mean Number Recognized for HF is based on five participants per group.
Mean Number Recognized for LF is based on seven participants per group.

question can be seen in Table 9. The mean number of intrusion errors can also be seen in Table 9.

One would expect the number of items correctly recalled to decline with level of impairment (MCI and AD), especially for the LF letters. In order to evaluate this, One-way ANOVA's were performed. The analysis for the recall of HF letters was not significant. The analysis for the number of items incorrectly recalled (in this case the number of LF letters recalled) was also not significant. The analysis for intrusions was significant, $F(3, 44) = 3.82$, $MSE = .687$, $p < .02$. This was due to the increase in the number of intrusion errors for the AD group ($M = .50$) compared to the young ($M = 0$), normal elderly ($M = .08$), and MCI ($M = 0$) groups.

Unlike the analysis for HF letters, the analysis for the LF letters was significant, $F(3, 44) = 3.46$, $MSE = 1.76$, $p < .02$. As expected, the AD group recalled fewer LF letters ($M = .83$) compared to the young ($M = 2.4$), normal elderly ($M = 1.3$) and MCI ($M = 1.0$) groups. The analysis for the number of items incorrectly recalled (in this case the number of HF letters recalled) was not significant. The analysis for the number of intrusion errors was significant, $F(3, 44) = 4.56$, $.858$, $p < .007$. Once again this effect is due to the increase in intrusion errors for the AD group ($M = 1.2$) compared to the young $M = .08$), normal elderly ($M = .08$), and MCI ($M = .17$) groups.

The hit rate for the recall of HF and LF items, seen in Table 9, was calculated by taking the mean number of correct responses and dividing it by the sum of the number of correct responses plus the number of intrusions (in this case inter-list and extra-list intrusions). All groups had a hit rate of 70% or below for both the HF and LF recall questions, with a decline in the hit rate, for most groups, for the LF letters compared to the HF letters. These scores reflect the difficulty of these tasks for all groups.

Overall, performance for all groups was relatively low on this task (both HF and LF). Although participants were aware of the frequency during the immediate recall portion of the test session they had difficulty specifically recalling and differentiating between the HF and LF stimuli.

In order to further evaluate frequency in this questionnaire a 4 (Groups) X 2 (Frequency) ANOVA was performed on the recall of HF and LF letters. Although the main effect of Groups was not significant, the main effect of Frequency was highly significant, $F(3, 44) = 40.96$, $MSE = 55.51$, $p < .00005$. Although overall performance on this task was poor for all groups, the effect was due to the better performance (recall) for HF letters ($M = 2.9$) versus LF letters ($M = 1.4$).

Another difficult task for all groups was identifying how often they actually saw either the HF letters or the LF letters using a multiple choice format (Question 4). One half of the participants in each groups were asked to identify how often they saw the HF letters and the other half was asked to identify how often they saw the LF letters. The young normal group had a score of 58% correct, the normal elderly group had a score of 75% correct, the MCI group had a score of 42% correct, and the AD group had a score of 50%correct. Once again when the specific frequency information was requested all groups had some level of difficulty.

The questionnaire also contained a recognition task (Question 5) in which the participants were presented with the list of letters (stimulus set) that were used during the test session. One-half of the participants were asked to identify the letters which appeared more frequently, but due to an error only five participants were given this version in each participant group. The other one-half of the group was asked to identify the letters which appeared less frequently, but once again due to an error seven participants were given this version of the test. The number of incorrect responses, in this case extra-list intrusion, were also scored. These data can be seen in Table 9.

The recognition data was analyzed by performing One way ANOVA's. The ANOVA's for the recognition of HF letters and LF letters were not significant. In addition, the ANOVA's for intrusion errors in the HF recognition task and the LF letter recognition task were not significant. Although the analysis was not significant (probably due to the N) there appears to be an effect for HF letters with the young, normal elderly, and MCI groups recognizing 3.8 (out of 6.0) HF letters and the AD group recognizing less than 1.0.

The questionnaire provided some interesting results but overall most of the questions appeared to be difficult for all of the groups. Future studies should look at refining these questions.

General Discussion

Immediate Recall Highlights

Consistent with previous work in this lab, with regard to strict serial recall and immediate memory, performance showed an attenuation with age and a further decline with AD. The suffix and varied suffix also showed increasing effects with age and cognitive impairment. What was interesting, in immediate serial recall performance, was the lack of a modality effect. Previous work in this lab and others (e.g., Arenberg, 1977; Manning & Greenhut-Wertz, 1990) have shown the superior performance for auditory as compared to visual stimuli to be relatively greater in elderly compared to young participants. Manning et. al (1990) have suggested that the relatively poorer performance with visual stimuli compared to auditory stimuli, in the elderly, may be due to a deficit in recoding visual stimuli (research has suggested that visual stimuli are processed in a way that they are recoded, see Manning et al., 1990 for a review). The present study seems to suggest that this is not the case. The analyses of the control condition data suggests that all groups seemed to be able to process auditory and visual stimuli at the same level. There does not appear to be a relative deficit for processing visual stimuli, even in the elderly groups. These findings will need to be explored more closely in future analyses.

The present study also examined the effects of repetition/frequency on immediate recall. Surprisingly, there was no frequency effect in immediate recall. One possible explanation is the strict serial recall restraints placed on the participants during recall. Responses needed to be correct and placed in the correct temporal position. In addition, the scoring method may have contributed to a lack of a frequency effect in immediate recall. No group showed a frequency effect, and in some groups there was a minimal advantage for stimuli presented less frequently. If the scoring method employed was less restrictive, i.e., dropping the temporal order requirements, it is possible that a frequency effect would emerge. The present analysis did not further explore this possibility, although future work will.

Intrusion errors were also examined, and once again they provided interesting results. The design of this study allowed the examination of three types of intrusion errors; extra-list, intra-list, and suffix. Consistent with previous research the AD group made the greatest number of intrusion errors, of all types. This particular measure does not seem to be a good clinical discriminator of MCI. These findings are of importance since previous work in this lab and others, have suggested that a prominent feature of AD is the frequent production of intrusion errors on episodic memory tasks. Several investigators have suggested that such errors may be of diagnostic value in the early stages of the disease (e.g., Fuld et al., 1996 & Manning et al., 1996).

Delayed Recall & Recognition

Previous work in this lab by Manning et al. (1996) has shown that AD patients appear to benefit from multiple repetitions in delayed recall, but their performance in delayed recognition decreases due to an increase in intrusion errors. Performance on the delayed recall task in the present study was consistent with previous work. There was an overall decline in the number of items recalled with increasing age. The young recalled more HF and LF letters compared to the normal elderly, MCI, and AD groups. The normal elderly and MCI groups recalled less than the young but more than the AD group. This is consistent with the theory of reduced storage with age, rapid forgetting in AD, and increased concentration deficits with age and AD (Hart et al, 1988; Salmon et al., 1989; Waugh et al., 1978). The MCI group performed almost as well as the normal elderly, suggesting that performance on delayed memory is not only influenced by impairment, as seen in AD, but age (these two groups were also very similar demographically) as well.

The frequency effect, not seen in immediate recall, was clearly present for all groups in delayed recall. All groups recalled more HF letters compared to LF letters. The effects of repetition, which were not present in immediate memory, are present here. It appears that the presentation of each letter does leave a separate memory trace which is reinforced with repetition, thus HF letters are more easily retrievable compared to LF letters.

Consistent with the findings of Manning et al. (1996) the AD group also produced the greatest number of intrusion errors compared to the other groups. It should be mentioned that intrusion errors, overall, were down. This decrease in intrusion errors by all groups appears to be due to the stimulus set size of 12 letters compared to the stimulus set size of six letters in previous studies in this lab. Since there were 12 correct responses, intrusion errors based on probability alone, were more difficult to make in this study, even for the AD group.

It has been demonstrated that recall tasks require more processing resources than recognition tasks (Craik & McDowd, 1987). Craik and McDowd (1987) also reported that age differences, typically found in recall tasks, are minimized in recognition tasks when comparing young and elderly participants. But, regardless of the method of assessment, recognition memory performance has been consistently shown to be age dependent on tests associated with episodic memory (e.g., Hultsch et al., 1991; Salthouse, 1988), because older adults have a smaller pool of processing resources available to them.

Recognition performance in the present study also declined with age. The young performed better than the normal elderly, MCI, and AD participants on both HF and LF letters. Interestingly, the MCI group did slightly better than the normal elderly but, overall they performed almost the same. Once again the AD group recognized the fewest letters, although their overall performance was relatively good.

The frequency effect seen in delayed recall was also present in delayed recognition. As expected, all groups recognized more HF letters compared to LF letters. This finding is consistent with the idea previously discussed, that is, every presentation of a letter leaves a separate memory trace which is reinforced with repetitions. Since HF letters were presented more often than LF letters they were reinforced 3 times more often than LF letters. The effects of repetition made the HF letters more easily recognized than LF letters for all groups.

Intrusion errors in delayed recognition are consistent with previous work in this lab (Manning et al., 1996). The AD group once again made the greatest number of intrusion errors compared to the other groups. Work in this lab suggests that the recognition task, in which each participant is presented with all the letters of the alphabet at once compared to a forced-choice recognition task, overloads immediate memory, particularly for impaired groups. This task seems to generate confusion for the AD group which leads to the production of more intrusion errors. Although this tasks appears to be a good clinical marker of AD it does not seem to discriminate between normal elderly and MCI groups.

Brief Introduction for Experiments 2 and 3

Although Experiments 2 and 3 were designed to look at many of the same variables (e.g., recency, suffix effects, and delayed memory) as Experiment 1, the experimental design differs significantly. The first major difference is that Experiment 1 was a within-subject experimental design, while Experiments 2 and 3 are a between-subject experimental design (reasons for this difference will be discussed later). Thus, experiments 2 and 3 are exactly the same with the exception of Modality (Auditory and Visual). The between-subject design will allow, for the first time in this lab, an analysis of both Delayed Recall and Delayed Recognition within each Modality, since Experiment 2 is in the Auditory modality and Experiment 3 is in the Visual modality. The effects of modality on delayed memory will be examined within each of the four groups. It is expected that, as in immediate memory, delayed recall and delayed recognition performance will be better in the auditory modality compared to the visual modality.

Previous research has also suggested that the elderly are more susceptible to interference than the young (Manning & Greenhut-Wertz, 1990). Manning and

Greenhut-Wertz (1990) found that standard suffix effects, a decrease in recency, interact with age, and, modality-specific (auditory) attentional deficits were found for the elderly group. Except for studies in this laboratory (e.g., Manning et al., 1996), the suffix paradigm has not been used with AD patients to examine the effects of interference on immediate recall. Although, concentration deficits seen in AD, in terms of intrusion errors (extra-list and prior-list), would suggest that the suffix would have a more deleterious effect on recall in AD patients (Beatty, Butters, & Janowsky, 1988; Manning et al., 1996), compared to young and even normal elderly and MCI participants. The following set of experiments were designed to examine the effect of attentional demands and interference, via the suffix and varied suffix conditions. The varied suffix condition was created for the following set of experiments, in order to place greater attentional demands, on all participants, as compared to the classic suffix condition. The varied suffix condition will be described fully in the Method section.

Method

Experiment 2

Participants

There were forty-eight participants in this experiment. Each group consisted of 12 participants. The four groups, although demographically different, are from the same populations defined in Experiment 1.

The 12 young normal participants (3 male, 9 female) were undergraduate and graduate students ranging in age from 23 years to 35 years (M = 28.2) and all had a minimum of 13 years of education (M = 15.7). The 12 normal elderly participants (6 male, 6 female), were classified as either GDS 1 or GDS 2 at NYUMC-ADRC, and ranged in age between 60 and 75 years (M = 66.2). They had an average of 15.5 years of education. The MCI participants (6 male, 6 female), classified as GDS 3 at NYUMC-ADRC, ranged in age between 63 and 86 years (M = 76.0). They had an average of 15.1 years of education. The 12 AD participants, classified as GDS 4 (7 male, 5 female) at NYUMC-ADRC, were ranged in age between 60 and 86 years (M = 75.0). They had an average of 14.3 years of education. The characteristics of all the participant populations (gender, age, education, and MMSE) can be seen in Table 10.

As discussed in Experiment 1 there is a high correlation between GDS ratings and an independently developed mental status examination (MMSE). In the present study the MMSE scores for the young normal participants were between 28 and 30 points (M = 29.1). The MMSE scores for the normal elderly participants were between 28 and 30 points (M = 28.9). The MMSE scores for the MCI participants were between 27 and 30 points (M = 28.6). The MMSE scores for the AD participants were between 21 and 29 points (M = 24.5). It should be noted that it appears that the AD group in the present study is not as cognitively impaired compared to the AD group in the Manning et al. (1996) study. The AD group in the Manning et al. study had a mean MMSE score of 22.4 and a range of 17-26 compared to the present study AD group which has a mean MMSE of 24.5 and a higher range of scores between 21-29.

Since years of education have been shown to have an impact on MMSE performance (Uhlmann & Larson, 1991) a one-way ANOVA was performed comparing years of education for all elderly participant groups. The ANOVA revealed that there were no significant differences in the level of education between the three groups of elderly participants.

Table 10

Mean, Range, and Standard Deviation (SD) for Participants Age, Years of Education, and Mini-Mental Status Examination (MMSE).

	Young	Elderly	MCI	AD
Age				
Mean	28.2	66.2	76.0	75.0
SD	3.5	4.6	7.1	6.9
Range	23-35	60-75	63-86	60-86
Education				
Mean	15.7	15.5	15.1	14.3
SD	.94	3.7	2.7	2.5
Range	15-18	08-22	12-20	09-18
MMSE				
Mean	29.1	28.9	28.6	24.5
SD		0.86	1.2	2.2
Range	28-30	28-30	27-30	21-29

Stimuli and Experimental Design for Immediate Recall Task

The experiment consisted of three conditions each composed of 14 trials: auditory control, auditory suffix, and auditory varied suffix. Each condition required the strict serial recall of stimuli. The experiment consisted of 84 trials in which the following eight letters were used J, Q, R, L, S, M, G, and Y. These letters were used for all stimulus sequences and none of the letters appeared in the same serial position in the preceding or following trial.

The stimulus lists for the control and suffix conditions were generated by using seven 6 X 6 Latin Squares and the mirrors. Thus, there were a total of six stimulus lists containing 14 trials each which were balanced across the experiment. The varied suffix stimulus sequences were generated by using two 7 X 7 Latin Squares, and the mirrors were used to generate a total of two lists containing 14 trials each. Each participant received only one varied suffix stimulus list so that the two lists were balanced across the experiment.

Apparatus and Procedure

The stimuli were presented in the center of a monochrome computer screen and followed the protocol described in Experiment 1. Participants were explicitly instructed before the start of each condition of the procedure to be followed, these instructions are exactly the same as the auditory modality instructions described in Experiment 1 and can be seen in Appendix D. The only deviation from Experiment 1 was the introduction of the varied suffix condition. This condition contained the letter "Y" distributed over all serial positions. The letter "Y" appeared in each trial only once and in each serial position twice over the 14 trials. Participants were instructed to recall the stimulus sequence, using strict serial recall, but were asked to leave a *blank space* in the position that the letter "Y" appeared and, for letters that they could not recall participants were asked to either guess or place a dash to indicate that they could not recall the letter. By using a dash to indicate that they could not recall a letter or series of letters it could be distinguished from the blank space used to indicate where the letter "Y" appeared.

Following the three immediate recall conditions all participants were administered the MMSE (Folstein, Folstein, & McHugh, 1975) and the Forward Digit Span (Wechsler, 1981). These tests were followed by a delayed recall and delayed recognition task, the format of these tasks was exactly the same as described in Experiment 1, and can be seen in Appendix B. In the delayed recall task, which was always administered first, participants were asked to write down on a plain sheet of paper all the letters that they could recall as being part of the experiment. In the delayed recognition task, participants were presented with the alphabet and asked to circle the letters that they recalled as being part of the experiment (it should be noted that the participants did not have access to their previous responses on the delayed recall task).

Scoring the Varied Suffix Data

In order to make the data for the varied suffix condition, which consisted of seven serial positions, comparable to the control condition and suffix condition, which consisted of six serial positions, a different scoring method was used for this condition in both

Experiment 2 and Experiment 3. Although a strict serial recall scoring method was used for each trial, the varied suffix position was eliminated for each trial, thus creating six serial positions per trial. For example, if a trial was presented in which the varied suffix appeared in position two, when scored using the new method, position three became position two because the varied suffix position was eliminated. This scoring method will still enable us to determine the effect of the varied suffix across all serial positions.

Results and Discussion

Immediate Recall

In order to examine the effects of the suffix and the varied suffix on immediate memory a 4 (Young Normal, Elderly Normal, MCI, and AD) X 3 (Control, Suffix, and Varied Suffix) X 6 (Serial Position) ANOVA was performed. As one would expect the main effects of Group, $F(3, 44) = 4.18$, $MSE = 304.659$, $p < .01$, Condition, $F(2, 88) = 26.65$, $MSE = 234.594$, $p < .00005$, and Serial Position, $F(5, 220) = 69.51$, $MSE = 423.602$, $p > .00005$, were all highly significant. The main effect of Group is due to the superior performance of the young (M = 11.05) as compared with the normal elderly (M = 9.61), the MCI (M = 9.33), and especially the AD group (M = 8.16). The main effect of Condition reflects the superior performance, summed over all groups and all serial positions, for the control condition (M = 10.57) compared to the suffix condition (M = 9.15) and the varied suffix condition (M = 8.89), respectively. Although perfromance was the lowest in the varied suffix condition, it should be mentioned, that all groups did

Table 11

Mean Number Correct During Immediate Serial Recall (Auditory) as a Function of Condition, Age and GDS Rating

Serial Position

1	2	3	4	5	6
Young					
Control					
13.1	12.3	11.2	10.9	11.2	13.1
Suffix					
13.3	11.6	10.5	9.6	9.0*	10.1*
Varied Suffix					
13.1	11.3	9.2*	7.9*	9.2*	12.2
Normal Elderly					
Control					
13.0	11.6	10.2	8.7	8.5	11.8
Suffix					
12.4	10.5	9.2	8.3	6.7*	8.5*
Varied Suffix					
12.1	9.0*	7.7*	7.1*	6.9*	10.7
MCI					
Control					
12.9	11.0	9.6	8.2	7.6	10.4
Suffix					
12.7	10.1	8.4	8.4	6.8	7.7*
Varied Suffix					
11.9	10.3	8.2	7.3	7.7	8.5*

AD

Control					
12.2	10.2	8.9	7.5	8.3	11.2
Suffix					
11.1	9.3	7.0*	6.5	5.4*	6.5*
Varied Suffix					
10.0*	8.6*	5.9*	6.0*	5.3*	6.8*

Note: The maximum correct at each serial position is 14.0.
* represents a significant Dunnett test, C - E = 1.46.

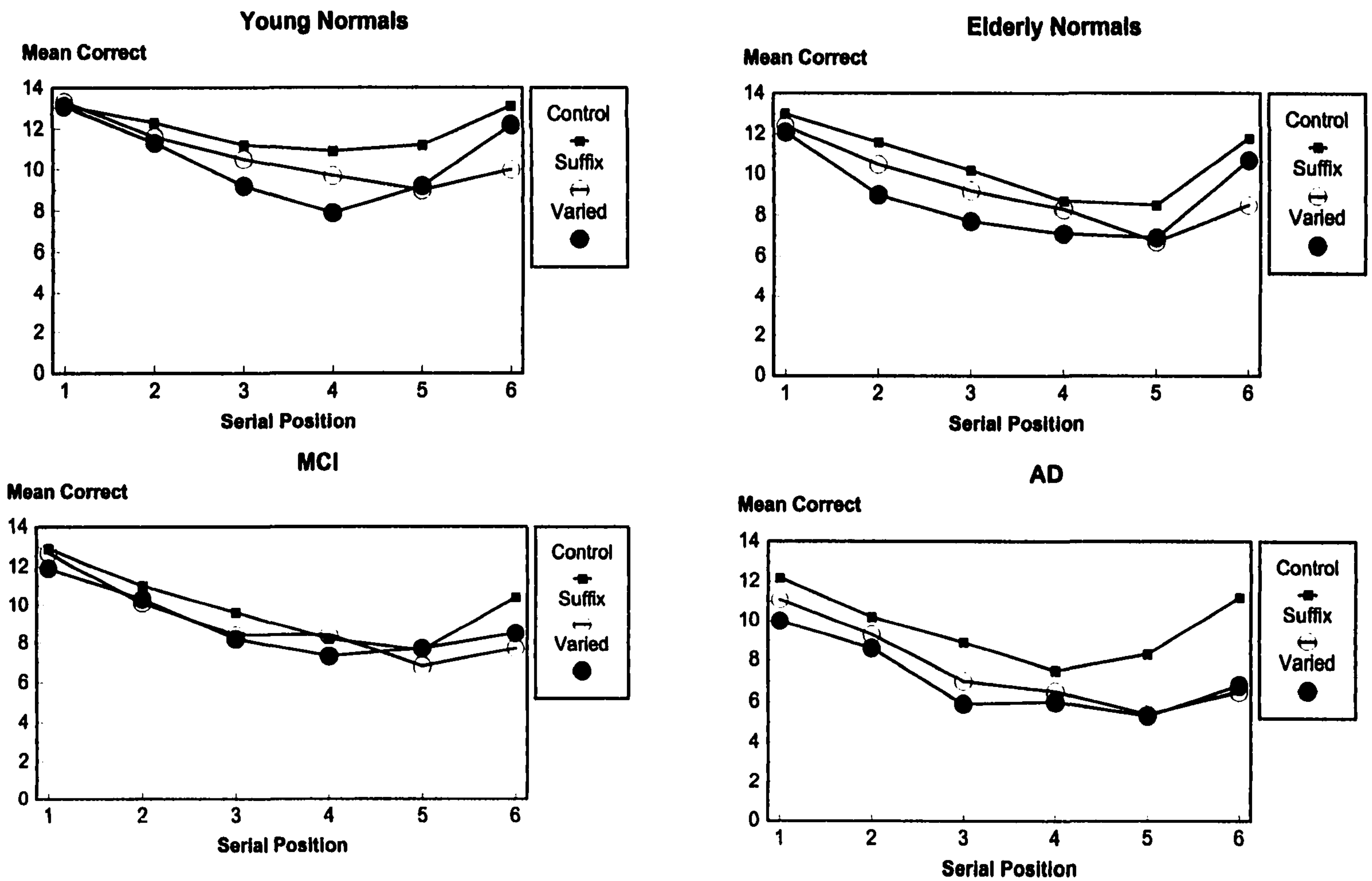
relatively well given the demands placed on the participants for this condition. And the main effect of Serial Position represents the usual irregular effects when summed over condition.

Finally, the analysis revealed a highly significant Condition X Serial Position interaction, $F(10, 440) = 6.81$, $MSE = 18.556$, $p < .00005$. This interaction is being driven by the superior performance in the control, suffix, and varied suffix, respectively, for positions one through four and the superior performance in the control, varied suffix, and suffix condition, respectively for positions five and six. As expected, there appears to be a significant recency effect in the control condition and interestingly in the varied suffix condition, compared to the suffix condition. Recency will be examined more closely in the following section.

Recency Effects

In order to evaluate recency effects, in the auditory modality, t-tests were performed between serial position five and serial position six for each group and condition. The serial position curves for each group by condition can be seen in Table 11 and Figure 7. The young showed a significant recency effect in the control condition ($p = .01$) and the varied suffix condition ($p = .01$). The normal elderly group showed a significant recency effect in the control condition ($p = .01$) and the varied suffix condition ($p = .01$). The MCI group showed significant recency in the control condition ($p = .02$) and no significant recency effect in the varied suffix condition. Finally, the AD group showed a significant recency effect in the control condition ($p = .01$) and the varied suffix

Figure 7: Mean Number Correct During Immediate Serial Recall for the Auditory Modality as a Function of Condition.



condition (p = .05). The recency effects observed in the control condition are consistent with previous research (e.g., Frick, 1988; Nairne, 1988). The presence of a strong recency effect in all groups, except the MCI group, is interesting. This task required more attention than the control and standard suffix conditions, and this attentional demand was apparent for the items in the middle of the serial position cure, but the participants were still able to maintain a strong recency effect. The overall performance for the varied suffix condition look like an exaggerated contol condition, strong primacy and recency but a greater decline in performance for the middle items due to the increased attentional demands.

Preplanned Dunnett tests comparing the control condition to the suffix condition and the varied suffix condition, using the error term for the Group X Condition X Position interaction, C -E = 1.46, were performed to clarify the difference between the control condition, the suffix condition, and the varied suffix condition for all groups across all serial positions. Table 11 highlights the serial positions where a significant difference between the control condition and the varied suffix and standard suffix conditions can be seen. All groups, with the exception of the young normal group (although the difference between the control and suffix condition is in the expected direction) and the elderly normal group (although, once again, the difference between the control and suffix condition is in the expected direction), showed a significant difference between the control condition and the suffix and varied suffix conditions at position five and position six in the Auditory modality.

With the exception of the MCI group, the varied suffix condition appears to have an across the board effect starting at position three for all groups. In addition, the AD group performed relatively worse across all serial positions, including position 1, in the varied suffix condition. As mentioned earlier, the AD participants performed significantly worse on the suffix condition and the varied suffix condition, respectively, compared to the control condition. This decline in performance is significant at serial positions three, five, and six for the suffix condition and is significant for serial positions one through six for the varied suffix condition. As discussed earlier, the varied suffix condition was designed to place greater attentional demands on all participants, and, as expected, the AD participants were most effected by the increased attentional demands placed on them. These findings are consistent with theories which suggest that AD patients suffer from attentional deficits.

Intrusions in Immediate Recall

As previously discussed Experiments 2 and 3 examine two types of intrusion errors; extra-list intrusions and suffix intrusions. Experiment 2 will examine intrusion errors as a function of the Auditory modality only, since the Visual modality was not a part of this esperiment.

For each type of intrusion, in the control and suffix conditions, a 4 (Group) X 2 (Condition: Control & Suffix) X 6 (Serial Position) ANOVA was performed. Since the varied suffix condition consisted of seven serial positions compared to the control condition and suffix condition which consisted of six serial positions, a separate analysis was performed for the varied suffix condition. For the varied suffix condition a 4 (Group) X 7 (Serial Position) ANOVA was performed for each type of intrusion error.

Extra-List Intrusions (Control and Suffix Conditions)

The total number of extra-list intrusion errors produced in immediate recall can be seen in Table 12 and the mean number of intrusion errors as a function of serial position can be seen in Table 13. The extra-list intrusion analysis, for the control and suffix conditions, did not reveal any significant main effects or interactions. It appears that the lack of significance is because only the control (Total = 15) and suffix condition (Total = 19) could be included in the analyses.

The analysis for the varied suffix condition (Total = 24) may reveal more information about group differences, since the total number of intrusions is very high for the MCI group (Total = 10) and the AD group (Total = 12) compared to the young (Total = 2) and the normal elderly (Total = 0). Table 12 illustrates that the combined total number of intrusion errors for the AD group over all three conditions is higher (Total = 30) than the total number of intrusion errors produced by the MCI group (Total = 24), although these two groups look very similar. The young normal and elderly normal groups made relatively few intrusion errors over the three conditions (Total = 4 and 0, respectively).

Extra-List Intrusions (Varied Suffix Condition)

As previously mentioned a 4 (Groups) X 7 (Serial Position) ANOVA was performed for the varied suffix condition. The mean number of extra-list intrusion errors

Table 12

Total Number of Extra-List and Suffix Intrusions in Immediate Memory as a Function of Group, Modality, and Condition.

Presentation	Young	Elderly	MCI	AD
Extra-List Intrusions				
Auditory Control	0	0	6	9
Auditory Suffix	2	0	8	9
Auditory Varied	2	1	10	15
Auditory Total	**4**	**1**	**24**	**33**
Visual Control	2	0	3	11
Visual Suffix	0	1	9	36
Visual Varied	2	5	6	30
Visual Total	**4**	**6**	**18**	**77**
COMBINED EXTRA-LIST INTRUSION TOTAL	**8**	**7**	**42**	**110**
Suffix Intrusions				
Auditory Control	0	0	0	0
Auditory Suffix	0	3	10	28
Varied Suffix	2	0	6	30
Auditory Total	**2**	**3**	**16**	**58**
Visual Control	0	0	0	0
Visual Suffix	1	0	12	16
Visual Varied	2	1	5	29
Visual Total	**3**	**1**	**17**	**45**
COMBINED SUFFIX INTRUSION TOTAL	**5**	**4**	**33**	**103**

Table 13

Mean Number of Extra-List and Suffix Intrusions in Immediate Memory as a Function of Age, Impairment, Condition, and Serial Position.

Serial Position	1	2	3	4	5	6
Extra-List Intrusions						
Control Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	.08	0.0	0.0	.08
MCI	.08	0.0	0.0	.08	.08	.25
AD	.08	.25	.17	.08	.08	.08
Suffix Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	.08	0.0
MCI	.08	.08	.33	.17	.08	.25
AD	0.0	.17	.08	0.0	.25	.08
Suffix Intrusions						
Control Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	0.0
MCI	0.0	0.0	0.0	0.0	0.0	0.0
AD	0.0	0.0	0.0	0.0	0.0	0.0
Suffix Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	.17
MCI	0.0	0.0	0.0	0.0	0.0	.50
AD	0.0	0.0	.08	.17	.17	1.9

made by each group as a function of serial position can be seen in Table 14. The varied suffix condition contained a not-to-be-recalled suffix which appeared in a different position for each trial, rather than at its standard end-of-sequence position. The main effect of groups was significant, $F(3, 44) = 3.77$, $MSE = .623$, $p < .02$. This effect is due to the propensity of the AD ($M = .18$) group to make intrusion errors more frequently than the young ($M = 0.0$), normal elderly ($M = .012$) and MCI ($M = .119$) groups. The main effect of Serial Position was not significant. The lack of significance is the result of the lack of a concentration of extra-list intrusion errors at any serial position, even in the AD group.

Brief Discussion of Extra-List Intrusion Errors

It should be mentioned again that the sequences used in the study contain six letters of the alphabet, which occur once in each sequence in random order. Previous work in this laboratory, and others, have suggested that the production of intrusion errors on episodic memory tasks may be a good clinical marker of early AD. In the present study, the AD and MCI groups looked very similiar when compared to the young and normal elderly groups. When you look at the total number of intrusion errors (combined from all 3 conditions) the AD group made a total of 33 intrusion errors and the MCI group made 24 intrusion errors compared to the young who made 4 and the normal elderly who did not make any. Unlike Experiment 1, which did not seem to differentiate between the MCI group and the normal elderly, the findings here suggest that in the auditory modality, the MCI participants are more prone to making intrusion errors

Table 14

Mean Number of Extra-List and Suffix Intrusions in the Varied Suffix Condition as a Function of Age, Impairment, and Serial Position.

Serial Position	1	2	3	4	5	6	7
Extra-List Intrusions							
Young	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	.08	0.0	0.0
MCI	0.0	.17	0.0	.08	.25	.25	.08
AD	0.0	.33	.25	.17	.17	0.0	.33
Suffix Intrusions							
Young	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MCI	.08	0.0	0.0	0.0	.25	.08	.08
AD	.25	.33	.67	.08	.67	.17	.33

compared to the normal elderly participants. This finding needs to be explored more fully in future studies. It should also be mentioned that, consistent with the work of Manning et al. (1996), extra-list intrusion errrors are likely to be due to forgetting which item was presented. Evidence for this comes from the fact that all groups, including the AD group, made extra-list intrusion errors which were catergory specific. All groups maintained the caterogory, letters of the alphabet, when making intrusion errors.

Suffix Intrusions (Control and Suffix Conditions)

As discussed in Experiment 1, suffix intrusions are a sign of a lack of inhibition since the suffix is a stimulus item which participants are explicitly asked to ignore. Manning et al. (1996) found that AD patients had the greatest difficulty with this type of task, probably due to the increase in attention that it requires. The total number of suffix intrusions can be seen in Table 12, and in Table 13 as a function of serial position. The analysis revealed a significant main effect of Groups, $F(3, 44) = 5.95$, $MSE = 1.13$, $p < .002$. This was due to the increase in suffix intrusions with increasing impairment: young participants ($M = 0.0$), normal elderly participants ($M = .02$), MCI participants ($M = .04$), and AD participants ($M = .19$). The main effect of Condition was also significant, $F(1, 44) = 12.56$, $MSE = 2.38$, $p < .0009$. As expected, suffix intrusions were produced significantly more, and in this case only in, the suffix condition compared to the control condition, by all groups. The main effect of position was also significant, $F(5, 220) = 8.10$, $MSE = 1.55$, $p < .00005$. This effect is due to the concentration of suffix intrusion errors at the end of the sequence in the suffix condition.

The interaction of Group X Condition was highly significant, F (3, 220) = 5.95, MSE = 1.13, $p < .002$. This interaction is the result of the lack of any suffix intrusion errors in the control condition by any group, while the normal elderly ($M = .04$), MCI ($M = .08$), and AD ($M = .39$) groups made suffix intrusion errors in the suffix condition. The interaction of Group X Serial Position was also highly significant, F (15, 220) = 3.71, MSE = .7087, $p < .00005$. This interaction is being driven by the lack of or small number of suffix intrusion errors by the young (Total = 0), normal elderly (Total = 3), and MCI (Total = 10) groups compared to the AD group (Total = 28), who made the greatest number of suffix intrusion errors. In addition, the intrusion errors made by the normal elderly and MCI groups were only at position six compared to the AD group who made intrusion errors at positions three through six, with the greatest concentration of intrusions at position six.

The interaction of Condition X Serial Position was highly significant, F (5, 220) = 8.10, MSE = 1.55, $p < .00005$. This interaction is significant because there were no suffix intrusions made by any group at any serial position in the control condition, whereas there were a varying number of suffix intrusion errors made at position two through position six in the suffix condition. Finally, the interaction of Group X Condition X Serial Position was also highly significant, F (15, 220) = 3.71, MSE = .7087, $p < .00005$. Once again this interaction is the result of the differing position of suffix intrusion errors for the various groups. There were suffix intrusion errors made by the normal elderly participants at positions two and six, by the MCI participants at position six, and by the AD participants at positions two through six in the suffix condition while there were no suffix intrusion errors made at any serial position, by any group, in the control condition.

Suffix Intrusions (Varied Suffix Condition)

A 4 (Groups) X 6 (Serial Position) analysis was also done for suffix intrusions in the varied suffix condition. The mean number of suffix intrusions made by each group as a function of condition can be seen in Table 12 and as a function of serial position in Table 14. Once again the main effect of Groups was highly significant, $F(3, 44) = 12.06$, $MSE = 2.43$, $p < .00005$. Like extra-list intrusions, the AD ($M = .38$) group made more suffix intrusion errors, which is probably due to a lack of inhibition, in the task which required the most attention, compared to the young ($M = 0.0$), normal elderly ($M = 0.0$) and MCI ($M = .07$) groups. It is worth pointing out that the MCI group did have some difficulty with this task when compared to the young and elderly groups. Although the main effect of Serial Position is generally significant when looking at suffix intrusions in the standard Suffix condition, the main effect of Position was not significant in the present analysis. This lack of significance is likely due to the changing location of the suffix item, which in turn created suffix intrusions at various locations, rather than at the only at the end of the sequence as generally seen with the standard suffix condition.

Brief Discussion of Suffix Intrusion Errors

As previously discussed, suffix intrusions are thought to be due to a lack of inhibition, particularly in and AD population. Manning et al. (1996) suggest that the increase in suffix intrusion errors may be a good clinical marker of AD.

In the present study, the AD group made significantly more suffix intrusion compared to all other groups. They made a total of 58 intrusions compared to the MCI group who made 16, the normal elderly who made 3 and the young who made only 2. It should also be pointed out that all AD patients made suffix intrusion errors. This finding is consistent with previous work in this lab and is further evidence that this may be a good clinical marker of early AD.

Delayed Memory Tasks

As in Experiment 1, a Delayed Recall and Delayed Recognition task was administered to all participants. These delayed memory tasks were administered after a short delay, at which time the MMSE and Digit Span Measures were administered, following the immediate recall portion of the experiment. The mean correct, mean number of intrusions, and mean hit rate can be seen in Table 15.

In order to examine Delayed Recall and Delayed Recognition a One-Way ANOVA was performed for each task. The Delayed Recall analysis revealed a significant main effect of Groups, $F(3, 44) = 3.80$, $MSE = 1.64$, $p < .02$. As expected the AD (M = 5.2) group recalled significantly fewer items than the young (M = 6.0), normal elderly (M = 5.8), and MCI (M = 5.8) groups. But it should be stressed that the AD group did very well. They recalled on average 87% of the stimuli after a short delay, which is very good given that performance on delayed memory tasks in AD are generally very poor. Manning et al. (1996) found that the AD group recalled an average of 4.75 or 79% on the

Table 15

Mean Number Correct, Mean Number of Intrusions, and Mean Hit Rate as a Function of Group and Delayed Memory Task.

Task	Young	Elderly	MCI	AD
Mean Number Correct				
Delayed Recall	6.0	5.8	5.8	5.2
Delayed Recognition	6.0	6.0	5.8	4.7
Mean Number of Intrusions				
Delayed Recall	0.0	0.0	.17	.50
Delayed Recognition	0.0	.08	.58	1.9
Mean Hit Rate				
Delayed Recall	1.0	1.0	.97	.91
Delayed Recognition	1.0	.99	.91	.72

Mean Number of Items Recalled - Maximum = 6.0
Mean Number of Items Recognized - Maximum = 6.0
Mean Hit Rate for Recall and Recognition - Maximum = 1.0

same delayed recall task . Thus, the performance of the AD group in the current study is even better than the group used in the Manning et al. study. On e possible explanation is that the current study was done in the auditory modality only and the Manning et al. study was done in both the visual and auditory modality. One would expect better performance in the auditory modality given previous research on immediate memory. This will be explored further when delayed recall is examined in the visual modality.

The Delayed Recognition analysis also revealed a highly significant main effect of Groups, $F(3, 44) = 24.2$, $MSE = 4.35$, $p < .00005$. As expected the AD ($M = 4.7$) group recognized significantly fewer items then the young ($M = 6.0$), normal elderly ($M = 6.0$), and MCI ($M = 5.8$) groups. The main effect of Groups is more robust in the recognition task compared to the recall task. This might be expected given the findings of Manning et al. (1996), who showed that AD participants performed better than expected on the recall task but performed worse than expected on the recognition task. Manning et al. showed that the decrease in performance for the AD group in the recognition task was due to their increased propensity to make intrusion errors, thus decreasing their hit rate and overall performance. This phenomenon will also be examined in this study in the following section on intrusion errors.

Intrusions in Delayed Memory Tasks

In order to examine intrusion errors in Delayed Recall and Delayed Recognition One-Way ANOVA's were performed for each task. The mean number of intrusion errors made by each group as a function of task can be seen in Table 15. The Delayed Recall analysis revealed a significant main effect of Groups, F (3, 44) = 2.75, MSE = .667, $p <$ .05. This effect is due to the increase in intrusion errors with increasing impairment, with the AD group (M = .50) making the greatest number of intrusions compared to the young (M = 0.0), normal elderly (M = 0.0) and MCI (M = .17) groups. Although the AD group made more intrusion errors than the other groups, they still managed to have a relatively high hit rate (.91). The main effect of Groups was significant, but it was not as robust as the findings of Manning et al. (1996), who found a hit rate of .76 in this task. Some possible explanations for this difference will be discussed later.

The Delayed Recognition analysis also revealed a significant main effect of Group, F (3, 44) = 6.02, MSE = 9.41, $p < .002$. Once again the main effect of Groups is more robust in the recognition task compared to the recall task. As expected, the AD group made more intrusion errors (M = 1.9) in the recognition task compared to the young (M = 0.0), normal elderly (M = .08), and MCI (M= .58) groups. Due to the number of intrusion errors made by the AD group, their hit rate was only .72%. Although Manning et al. showed a much lower hit rate of .57, the current study shows a .19 mean hit rate difference between the recall and recognition tasks, this is the same differential found by Manning et al. One possible explanation for the differences, in hit rate scores, between the two studies is the level of impairment of the AD group. It appears that the AD group in the present study is not as impaired as the AD group used in the Manning et al. (1996) study. The AD group in the Manning et al. study had a mean MMSE score of 22.4 and a range of 17-26 versus the present group which had a mean MMSE = 24.5 and a range of 21-29.

In order to further examine the difference in performance between the recall and recognition tasks, especially in the AD group, a 4 (Groups) X 2 (Recall, Recognition) ANOVA was performed. As expected the analysis revealed a significant main effect of Groups, $F(3, 44) = 5.71$, $MSE = 7.54$, $p < .002$ and Task, $F(1, 44) = 11.34$, $MSE = 5.51$, $p < .002$. More interesting is that the interaction of Groups X Task was also significant, $F(3, 44) = 5.22$, $MSE = 2.54$, $p < .004$. This interaction is due mainly to the increase in intrusion errors by the AD group in recognition task ($M = 1.92$) compared to the recall task ($M = .50$). The recognition task (in which all the letters of the alphabet are presented at one time) for the AD group, appears to overload immediate memory with stimuli, thus creating a sense of confusion. This overload, in addition to their propensity to make intrusion errors, seems to be driving both their decline in performance and their increase in intrusion errors in the Delayed Recognition task. All of the other groups, including the MCI group, made relatively few, if any, intrusion errors on the recall and recognition tasks.

Brief Discussion Of Experiment 2

Many studies of young normals have demonstrated superior performance, in immediate serial recall, for auditory stimuli compared to visual stimuli (e.g., Crowder & Morton, 1969; Penney, 1975). A small group of studies have shown this modality effect to be relatively larger in elderly as compared with the young (e.g., Arenberg, 1977; Manning & Greenhut-Wertz, 1990; Taub, 1975). In addition to modality specific differences in performance, the elderly have also been shown to be more susceptible to distraction (Freund & Witte, 1986). In spite of the evidence that the elderly have been shown to be more imparied by interference, whether this relative distractability is modality specific has never been tested. Although, there is data which shows that young normals are more disrupted by auditory distractors in immediate recall of auditory stimuli as compared with visual distractors in immediate recall of visual stimuli (e.g., Crowder & Morton, 1960). In addition, Manning and Greenhut-Wertz (1990) suggest that modality differences in performance in the elderly are not due to attentional deficits, in the general sense. Instead, they suggest that they are modality specific. Manning anf Greenhut-Wertz propose that visual stimuli need to be recoded into an auditory representation, and it is this process that they suggest is impaired in the elderly.

For the first time in this laboratory, the difference in performance between modalities can be examined more easily. This is because Experiments 2 and 3 are a between subject design, which allows for the examination of performance within each modality, without interference from using both modalities, as is the case in within subject designs.

Experiment 2 examined immediate and delayed memory as a function of the audiotory modality, only. The results from immediate memory were consistent with previous research. There was a decline in overall performance as cognitive impairment increased, with the AD group performing below all the other groups. As expected, as the attentional demands increased, performance decreased, for all groups. Performance was best in the control condition and declined in the suffix and varied sufix conditions, respectively. All groups showed a significant recency effect in the control condition and interestingly, all groups except the MCI group, showed a significant receny effect in the varied suffix condition.

As for delayed recall and recognition, the AD group performed relatively well compared to the other groups, but their hit rate was effected due to an increase in intrusion errors, especially in the recognition task. The MCI group also had an increase in intrusion errors in the recall and recognition task. Thus, their overall hit rate was lower in these two tasks - they looked very similiar to the AD group in ther delayed recall task.

Consistent with previous work in this lab, there was an increase in intrusion errors in the delayed recognition task compared to the recall task. Differences in performance and intrusion errors will also be examined in the visual modality, Experiment 3. It will be interesting to see if there are any modality specific differences between the groups in immediate and/or delayed memory.

Experiment 3

Participants

There were 48 participants in this experiment. Each group consisted of 12 participants. The four groups, although demographically different, were recruited from the same populations described in Experiment 1.

The 12 young normal participants (12 females) were undergraduate and graduate students ranging in age between 18 and 34 (M = 22.2). They had an average of 14.8 years of education. The 12 normal elderly participants (3 male, 9 female), were classified as either GDS 1 or GDS 2 at NYUMC-ADRC, and ranged in age between 60 and 77 years (M = 67.4). They had an average of 14.7 years of education. The MCI participants (5 male, 7 female), were classified as GDS 3 at NYUMC-ADRC, and ranged in age between 61 and 85 years (M = 76.7). They had an average of 14.8 years of education. The 12 AD participants, were classified as GDS 4 (5 male, 7 female) at NYUMC-ADRC, and ranged in age between 60 and 86 years (M = 74.6). They had an average of 13.5 years of education. The characteristics of all the participant populations (gender, age, education, and MMSE) can be seen in Table 16.

As discussed in Experiments 1 and 2 there is a high correlation between GDS ratings, discussed earlier, and an independently developed mental status examination (MMSE). In the present study the MMSE scores for the young normal participants were between 28 and 30 points (M = 29.1). The MMSE scores for the normal elderly participants were between 28 and 30 points (M = 29.3). The MMSE scores for the MCI participants were between 26 and 29 points (M = 27.7). The MMSE scores for the AD participants were between 21 and 27 points (M = 24.7). As in Experiment 2, the AD group in the present study does not appear to be as cognitively impaired compared to the AD group in the Manning et al. (1996) study.

Since years of education have been shown to have an impact on MMSE performance (Uhlmann & Larson, 1991), a one-way ANOVA was performed comparing years of education for all four groups. The ANOVA revealed that there were no significant differences in the level of education between the normal elderly, MCI, and AD participant groups.

Table 16

Mean, Range, and Standard Deviation (SD) for Participants Age, Years of Education, and Mini-Mental Status Examination (MMSE).

	Young	Elderly	MCI	AD
Age				
Mean	22.2	67.4	76.7	74.6
SD		6.4	8.2	8.2
Range	18-34	60-77	61-85	60-86
Education				
Mean	14.8	14.7	14.8	13.5
SD	-----	2.9	2.0	3.4
Range	13- 16	12-18	12-18	9-18
MMSE				
Mean	29.1	29.3	27.7	24.7
SD		0.62	0.85	1.92
Range	28-30	28-30	26-29	21-27

Experimental Design and Procedure

The experiment consisted of three conditions each comprised of 14 trials: visual control, visual suffix, and visual varied suffix. The experimental design was exactly the same as described for Experiment 2, with the exception of modality which was Auditory for Experiment 2 and was Visual for Experiment 3.

Apparatus and Procedure

The apparatus and procedure were exactly the same as described in Experiment 2.

Results and Discussion

In order to examine the effects of the suffix and the varied suffix in immediate recall a 4 (Young Normal, Elderly Normal, MCI, and AD) X 3 (Control, Suffix, and Varied Suffix) X 6 (Serial Position) ANOVA was performed. As one would expect the main effects of group, $F(3,44) = 12.13$, $MSE = 812.003$, $p < .00005$, condition, $F(2, 88) = 23.58$, $MSE = 237.446$, $p < .00005$, and serial position, $F(5, 220) = 91.31$, $MSE = 335.446$, $p < .00005$, were all highly significant. The main effect of group is due to the superior performance of the young ($M = 11.29$) as compared with the normal elderly ($M = 11.34$), the MCI ($M = 9.42$), and especially the AD group ($M = 7.24$). The main effect of condition reflects the superior performance summed over all groups and all serial positions, for the control condition ($M = 10.82$) compared to the suffix condition ($M = 9.60$) and the varied suffix condition ($M = 9.04$), respectively. The main effect of serial position represents the usual irregular effects summed over condition. These data are summarized in Table 17 and Figure 8, which shows the mean number of correct items at

Table 17

Mean Number Correct During Immediate Serial Recall (Visual) as a Function of Condition and Group

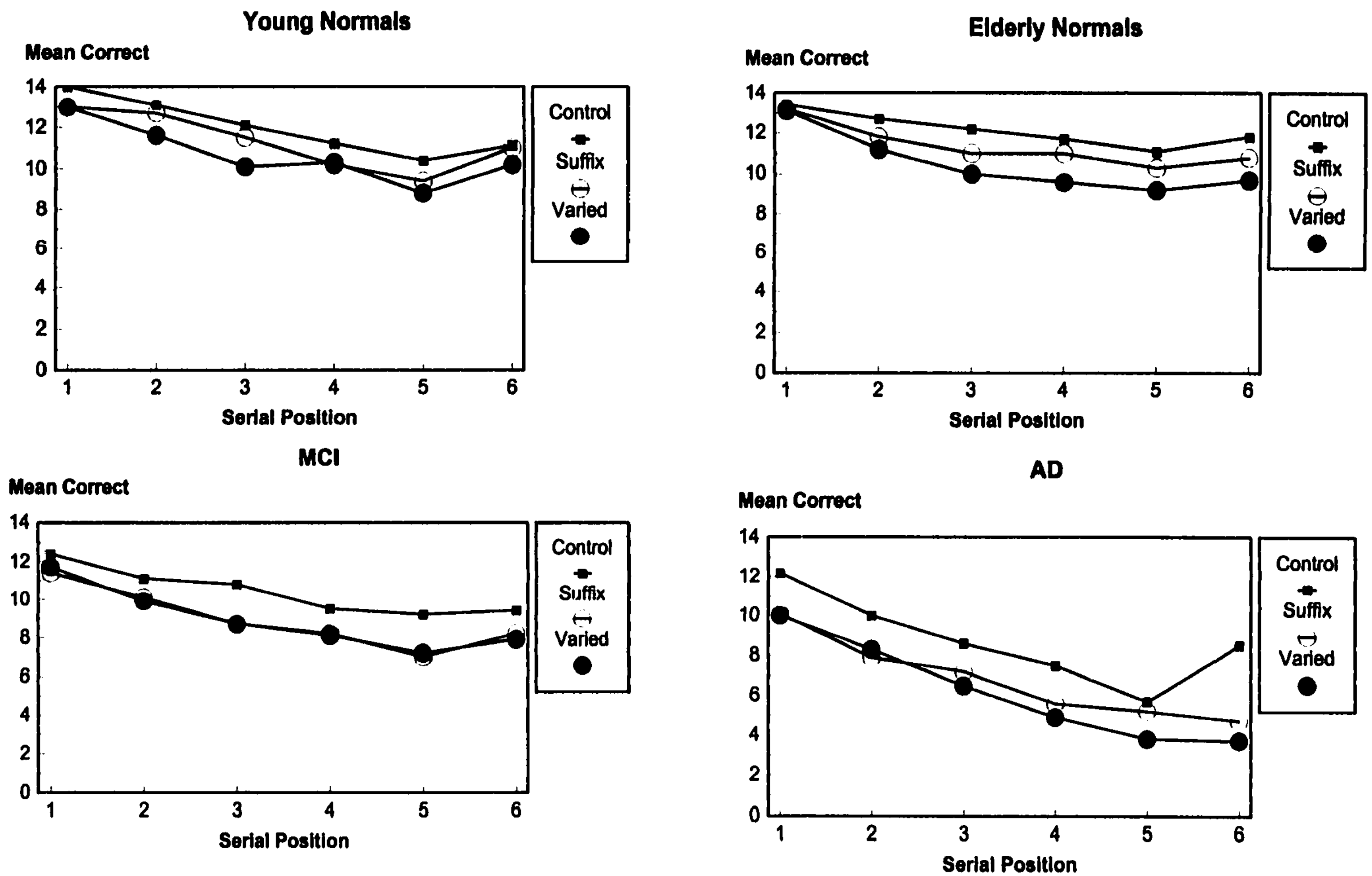
	Serial Position					
	1	2	3	4	5	6
Young						
Control	14.0	13.1	12.1	11.1	10.4	11.1
Suffix	13.0	12.7	11.5	10.2	9.4	11.0
Varied Suffix	13.0	11.7*	9.8*	10.1	8.7*	10.2
Normal Elderly						
Control	13.4	12.7	12.2	11.7	11.1	11.8
Suffix	13.2	11.8	11.0	11.0	10.3	10.8
Varied Suffix	13.1	11.2*	10.0*	9.6*	9.2*	9.7*
MCI						
Control	12.4	11.1	10.8	9.5	9.2	9.4
Suffix	11.4	10.1	8.7*	8.2*	7.0*	8.2
Varied Suffix	11.6	9.9	8.7*	8.1*	7.2*	7.9*

AD

Control					
12.2	10.0	8.6	7.5	5.7	8.5
Suffix					
10.1*	7.9*	7.2*	5.6*	5.2	4.7*
Varied Suffix					
10.0*	8.3*	6.5*	4.9*	3.8*	3.7*

Note: The maximum correct at each serial position is 14.0.
* represents a significant Dunnett test, C - E = 1.32.

Figure 8: **Mean Number Correct During Immediate Serial Recall for the Visual Modality as a Function of Condition.**



each serial position for all groups as a function of condition.

Finally, the analysis revealed that there is a significant Group X Serial Position interaction, F (15, 220) = 2.60, MSE = 9.553, p < .0013. This interaction is due to the superior performance of the young, normal elderly, MCI, and AD groups, respectively, for serial positions one through six with the exception of position four and five. Specifically, the performance of the normal elderly was better compared to the young at positions four and five.

Recency Effects

In order to evaluate recency effects, t-tests were performed between serial position five and serial position six for each group and condition. The serial position curves for each group and each condition can be seen in Table 17 and Figure 8. The young showed a significant recency effect in the varied suffix condition (p = .01). There was no significant recency found in the control condition. The normal elderly group did not show significant recency effects in the control condition or the varied suffix condition. The MCI group did not show significant recency effects in the control condition or the varied suffix condition. Finally, the AD group showed a significant recency effect in the control condition (p = .01) and no significant recency in the varied suffix condition. These results are consistent with previous research which has shown a lack of recency in the visual modality for the control condition. As previously discussed, the prescence of a strong recency effect in the auditory modality compared to the visual modality is known as the modality effect.

Preplanned Dunnett tests comparing the control condition to the suffix condition and the varied suffix condition, using the error term for the Group X Condition X Position interaction, C -E = 1.32, were performed to clarify the difference between the control condition, the suffix condition, and the varied suffix condition for all groups across all serial positions. Table 17 highlights the serial positions where a significant difference between the control condition and the suffix condition can be seen. As can be seen in Table 17 no groups (although the difference between the control and suffix condition is in the expected direction), except the AD group, showed a significant difference between the control condition and the suffix condition at position six in the Visual modality. Also, the varied suffix condition appears to have an across the board effect starting at position two for all groups, with the exception of the MCI group who did show this across the board effect of the varied suffix beginning at serial position three. In addition, the AD group performed relatively worse across all serial positions, including position 1, in the varied suffix condition. This decline in performance is significant at all serial positions with the exception of position 5 for the suffix condition, and is significant for serial positions one through six for the varied suffix condition.

The varied suffix condition was designed to place greater attentional demands on all participants, and as expected the AD participants were the most affected by these additional attentional demands. This is consistent with Experiment 2, in which there was an across the board decrease in performance for the varied suffix condition. It appears that all groups had greater difficulty in the Visual modality compared to the Auditory modality when the attentional demands were increased (varied suffix condition). These findings are also consistent with theories of attentional deficits in AD.

Intrusions in Immediate Recall

As previously mentioned, Experiment 3 examines two types of intrusion errors; extra-list intrusions and suffix intrusions. Once again, since the Varied Suffix condition consisted of seven serial positions (which could not be reduced to six positions) and the Control and Suffix conditions consisted of six serial positions, separate analyses were performed. For each type of intrusion, in the Control and Suffix conditions, a 4 (Groups) X 2 (Condition) X 6 (Serial Position) ANOVA was performed. For each type of intrusion error in the Varied Suffix condition, a 4 (Groups) X 7 (Serial Position) ANOVA was performed.

Extra-List Intrusions

The total number of extra-list intrusion errors produced in immediate recall can be seen in Table 12 and as a function of serial position in Table 18. As in Experiment 2, the extra-list intrusion analysis, for the Control and Suffix conditions, did not reveal any significant main effects or interactions. Although the analysis did not reveal a significant main effect of Groups as can be seen in Table 12, the AD group made almost four times the number of intrusion errors (Total = 47) compared to the MCI group (Total = 12) in the control and suffix conditions. The young and normal elderly made relatively few intrusion errors in the control and suffix conditions (Total = 2 and 1, respectively). In addition, the AD group made more extra-list intrusion errors in the suffix condition (Total

Table 18

Mean Number of Extra-List and Suffix Intrusions in Immediate Memory as a Function of Age, Impairment, Condition, and Serial Position.

Serial Position	1	2	3	4	5	6
Extra-List Intrusions						
Control Condition						
Young	0.0	0.0	0.0	0.0	.08	.08
Elderly	0.0	0.0	0.0	0.0	0.0	0.0
MCI	0.0	.08	0.0	0.0	.08	.08
AD	.17	0.0	0.0	.25	.08	.08
Suffix Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	.08
MCI	0.0	.08	.17	.42	.08	0.0
AD	0.0	.75	.42	.08	.59	.92
Suffix Intrusions						
Control Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	0.0
MCI	0.0	0.0	0.0	0.0	0.0	0.0
AD	0.0	0.0	0.0	0.0	0.0	0.0
Suffix Condition						
Young	0.0	0.0	0.0	0.0	0.0	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	.08
MCI	0.0	0.0	.17	.08	0.0	.33
AD	.58	0.0	0.0	0.0	.50	.67

= 36) compared to the control condition (Total = 11).

Extra-List Intrusions (Varied Suffix Condition)

As in Experiment 2, a 4 (Groups) X 6 (Serial Position) ANOVA was performed for the Varied Suffix condition. The mean number of extra-list intrusions made as a function of serial position can be seen in Table 19. As previously discussed, the Varied Suffix condition contained a not-to-be-recalled suffix which appeared in a different position for each trial, rather than its standard end-of-sequence position for every trial. The main effect of groups was not significant, although it was very close ($p = .06$). Although not significant the AD group did show an increased propensity ($M = .36$) to make intrusion errors more frequently than the young ($M = .02$), normal elderly ($M = .07$), and MCI ($M = .07$) groups. There were relatively few extra-list intrusions made by any group, with the exception of the AD group. As can be seen in Table 19, intrusion errors were not concentrated at any specific serial position. Thus, the main effect of Serial Position was not significant.

Brief Discussion of Extra-List Intrusion Errors

Previous work in this laboratory and others have suggested that intrusion errors on episodic memory tests, may be a good clinical marker of early AD (see Introduction for a complete discussion). In the present study, the AD group made a total (combine the three conditions) of 77 intrusion errors compared to the MCI group which made 18, the normal elderly group which made 6, and the young normal group which made only 4. These findings lend further support to this theory. In addition, this finding may be more

Table 19

Mean Number of Extra-List and Suffix Intrusions in the Varied Suffix Condition as a Function of Age, Impairment, and Serial Position.

Serial Position	1	2	3	4	5	6	7
Extra-List Intrusions							
Young	0.0	0.0	0.0	0.0	.08	.08	0.0
Elderly	0.0	0.0	.08	0.0	.08	0.0	.33
MCI	0.0	.08	0.0	.17	0.0	.25	0.0
AD	.08	.42	.08	.50	.50	.33	.58
Suffix Intrusions							
Young	0.0	0.0	0.0	.08	0.0	.08	0.0
Elderly	0.0	0.0	0.0	0.0	0.0	.08	0.0
MCI	.08	.08	0.0	.08	0.0	.08	.17
AD	.33	.42	.58	.25	.42	.25	.25

apparent in the visual modality. The AD group made a total of 30 intrusion errors in the auditory modality compared to 77 intrusion errors in the visual modality. This is a new finding in this lab, since the work of Manning et al. (1996) did not find a significant main effect of modality. This may be due to the experimental design, as previously discussed, of the present studies. Since the present set of studies are a between subject design it is difficult to make direct comparisons with previous work by Manning et al. This modality difference will need to be explored further.

Suffix Intrusions (Control and Suffix Conditions)

The total number of suffix intrusions can be seen in Table 12 and can also be seen as a function of serial position in Table 18. The main effect of Groups was not significant, although there was a strong trend toward significance ($p = .06$). Although not significant, there was an increase in intrusion errors with increasing impairment: young ($M = .00$), normal elderly ($M = .00$), MCI ($M = .05$), and AD ($M = 1.5$). The main effect of Condition was significant, $F(1, 44) = 6.02$, $MSE = 1.46$, $p < .02$. As expected, suffix intrusions were produced significantly more, and in this case only, in the Suffix condition compared to the Control condition by all groups. The effect of condition, although significant, was not as robust as that seen in Experiment 2 (Auditory Modality). This is expected since the suffix creates more interference and is more difficult to ignore in the Auditory Modality compared to the Visual Modality. Although the main effect of Serial Position was not significant there is a trend, as can be seen in Table 18 which illustrates the mean number of suffix intrusions as a function of serial position, with a greater concentration of suffix intrusion errors in serial positions five and six.

Suffix Intrusions (Varied Suffix Condition)

A 4 (Groups) X 7 (Serial Position) ANOVA was performed to evaluate suffix intrusion errors in the Varied Suffix condition. The mean number of suffix intrusion errors made by each group can be seen in Table 12 and as a function of serial position in Table 19. Once again the main effect of Groups was highly significant, $F(3, 44) = 4.23$, $MSE = 2.26$, $p < .01$. Like extra-list intrusions, the AD group ($M = .36$) made more suffix intrusion errors than the young ($M = .02$), normal elderly ($M = .01$), and MCI ($M = .06$) groups. The suffix intrusion errors produced by the AD groups is likely due to their lack of inhibition or their inability to suppress a response. As seen in Experiment 2, there was no significant main effect of Serial Position. This is due to the lack of suffix intrusion errors concentrated at a particular serial position, which is probably due to the changing location of the suffix in this condition.

Brief Discussion of Suffix Intrusions

Consistent with previous work in this lab, there was not a significant group difference in suffix intrusion errors in the control and standard suffix conditions. Manning et al. (1996) demonstrated that auditory suffixes not only cause large decrements in recall compared to visual suffixes which have little effect, they also intrude more than visual suffixes, although visual suffixes did intrude. The AD group made 58 suffix intrusion errors in the auditory modality compared to 45 suffix intrusion errors in the visual modality. The difference in intrusion errors between the two modalities may not be significant, but the difference is in the expected direction.

Interestingly, the number of suffix intrusion errors in the varied suffix condition was virtually the same in both modalities for the AD group. They made 30 intrusion errors in the auditory and 29 in the visual modality. The attentional demands placed on participants seems to be the same in both modalities. The AD group seems unable to inhibit the suffix item, no matter what the modality is. This id different from the findings in the standard suffix condition, which seems to suggest that the AD group has more difficulty in inhibiting the suffix in the auditory modality. Future analyses will look at these differences more closely.

Delayed Memory Tests

As in Experiment 2, a Delayed Recall and Delayed Recognition task was administered to all participants. These delayed memory tasks were administered after a short delay, at which time the MMSE (Folstein, Folstein, & McHugh, 1975) and the Digit Span (Wechsler, 1981) measures were administered, following the immediate recall portion of the experiment. The mean correct, mean number of intrusions, and the mean hit rate can be seen in Table 20.

In order to examine Delayed Recall and Delayed Recognition, a One-Way ANOVA was performed for each task. The Delayed Recall analysis revealed a significant main effect of Groups, $F(3, 44) = 5.61$, $MSE = 5.50$, $p < .002$. As expected, the AD group ($M = 4.6$) recalled significantly fewer items than the young ($M = 6.0$), normal elderly ($M = 6.0$), and MCI ($M = 5.7$) groups. But it should be stressed that the AD group did fairly

Table 20

Mean Number Correct, Mean Number of Intrusions, and Mean Hit Rate as a Function of Group and Delayed Memory Task.

Task	Young	Elderly	MCI	AD
Mean Number Correct				
Delayed Recall				
	6.0	6.0	5.7	4.6
Delayed Recognition				
	6.0	5.8	5.3	4.7
Mean Number of Intrusions				
Delayed Recall	.17	0.0	.33	1.0
Delayed Recognition	.08	.08	1.1	2.6
Mean Hit Rate				
Delayed Recall	.97	1.0	.84	.82
Delayed Recognition	.99	.99	.83	.64

Mean Number of Items Recalled - Maximum = 6.0
Mean Number of Items Recognized - Maximum = 6.0
Mean Hit Rate for Recall and Recognition - Maximum = 1.0

well; they recalled on average 76% of the letters after a short delay. This is very good considering that AD participants generally perform very poorly on tasks of delayed memory. Unlike Experiment 2 (87% recall), the results are more similar to the findings of Manning et al. (1996) who found that the AD group recalled an average of 4.75 or 76% on the same recall task. Once again it needs to be pointed out that the Manning et al. study used both the visual and auditory modality within one experiment compared to the present study which used only the visual modality. The poorer performance in delayed recall in Experiment 3 compared to Experiment 2, is likely due to the visual modality; this is consistent with modality differences commonly found in immediate recall tasks.

The Delayed Recognition analysis also revealed a significant main effect of Groups, $F(3, 44) = 4.03$, $MSE = 4.30$, $p < .01$. As expected the AD group ($M = 4.7$) recognized significantly fewer letters than the young ($M = 6.0$), normal elderly ($M = 5.8$), and MCI ($M = 5.3$) groups. The AD group actually performed slightly better on the recognition task compared to the recall task (4.6) which is not consistent with the previous work done in this lab. Manning et al. (1996) and Experiment 2, showed that the AD group's performance actually decreased in the recognition task relative to the recall task. This difference is likely due to the experimental design, specifically, using only the visual modality.

The main effect of Groups is not more robust, although it is significant, in the recognition task compared to the recall task, as was seen in Experiment 2. But, the difference in performance between the recall and recognition tasks, in the AD group, is not as robust as that seen previously in Experiment 2. This difference may be a function of modality. The number of intrusion errors in the recognition task is still greater than the number of intrusion errors in the recall task, thus once again the hit rate for the recognition task is lower (.64) compared to the recall task (.82) for the AD group. The decline in the hit rate for the AD group in the recognition task is slightly greater in the visual modality (Experiment 3) compared to the auditory modality (Experiment 2). In addition, the differential in the hit rates between recall and recognition is .18 which is consistent with Manning et al. (1996) who showed a .19 mean difference in hit rates between recall and recognition.

Due to the between subject study design this is the first opportunity to explore the differences in delayed memory as a function of modality. It appears that the differences between delayed recall and recognition previously seen by Manning et al. (1996) and in Experiment 2, are even more enhanced in the visual modality. The AD group produced more intrusion errors in the delayed recognition task in the visual modality than in the auditory modality. Thus, the overall performance for the AD group on delayed memory measures was better in the auditory modality compared to the visual modality. These differences will be explored in more detail in future analyses.

Intrusions in Delayed Memory Tasks

In order to examine intrusion errors in Delayed Recall and Delayed Recognition, One-Way ANOVA's were performed for each task. The mean number of intrusion errors made by each group can be seen in Table 20. The Delayed Recall analysis did not find a significant main effect of Groups, although there was a strong trend towards significance (p = .06). Although the main effect of Groups was not significant, the AD (M = 1.0) group made the greatest number of intrusion errors compared to the young (M= .17), normal elderly (M = 0.0) and the MCI (M = .33) groups. The AD group's hit rate in this task was .82 which is relatively good, and consistent with the Manning et al. (1996) findings. Compared to Experiment 2 in the Auditory modality, the AD groups performance was lower in Experiment 3 in the Visual modality. In addition, the MCI group also showed a decline in overall hit rate in the Visual modality (.84) compared to the Auditory modality (.97). The modality differences observed between Experiment 2 and 3, in the MCI and AD groups, need to be further explored.

The Delayed Recognition analysis revealed a robust main effect of Groups, F (3, 44) = 8.22, MSE = 16.75, $p < .0002$. As expected, the AD (M = 2.6) group made more intrusion errors in the recognition task compared to the young (M = .08), normal elderly (M= .08), and the MCI (M= 1.1) groups. It should also be noted that the MCI group showed an increase in the mean number of intrusion errors compared to the two normal groups. Due to the number of intrusion errors made by the AD group, their hit rate was very low (.64) compared to their hit rate in the recall task. This is also consistent with previous work in this lab which has shown that AD participants generate more intrusion errors in the recognition task compared to the recall task, thus decreasing their hit rates.

As was seen in the delayed recall task, the MCI and AD group, showed a decline in overall hit rate in the Visual modality compared to the Auditory modality for the delayed recognition task. The MCI groups hit rate in the in the Auditory modality was .91 and declined to .83 in the Visual modality. The AD groups hit rate was .72 in the Auditory modality and declined to .64 in the Visual modality. The MCI and AD groups showed what appear to be significant changes due to modality. There appears to be a decline in delayed memory performance, in the Visual modality compared to the Auditory modality. These findings are consistent with the modality differences seen in immediate memory. Future analyses will examine these differences more closely.

A 4 (Groups) X 2 (Recall, Recognition) ANOVA was also performed to further examine intrusion errors in delayed memory. The analysis revealed a significant main effect of Groups, $F(3, 44) = 6.37$, $MSE = 15.62$, $p < .001$. As previously discussed, this was due to the increase in intrusion errors, in the recall and recognition task, for the AD group ($M = 1.8$) compared to the young ($M = .12$), normal elderly ($M = .04$), and MCI ($M = .72$) groups. As expected, the main effect of task was also highly significant, $F(1, 44) = 26.34$, $MSE = 6.51$, $p < .00005$. This is due to the increase in intrusion errors in the recognition task (.89) compared to the recall task (.37). The interaction of Groups X Task was also significant, $F(3, 44) = 13.64$, $MSE = 3.75$, $p < .00005$. This is due to the increase in intrusion errors in the recognition task compared to the recall task in the following three groups: normal elderly (.08 and 0.0, respectively), MCI (.83 and .33, respectively), and AD (2.6 and 1.0, respectively) groups.

Finally, to further examine the differences in performance on the delayed memory tasks (recall versus recognition), a 4 (Groups) X 2 (Recall, Recognition) ANOVA was performed. As expected the analysis revealed a significant main effect of Groups, $F(3, 44) = 5.71$, $MSE = 7.54$, $p < .002$ and Task, $F(1,44) = 11.34$, $MSE = 5.51$, $p < .002$. More interesting in the significant interaction of Group X Task, $F(3, 33) = 5.22$, $MSE = 2.54$, $p < .004$. This interaction is due mainly to the increase in intrusion errors by the AD group in the recognition task ($M = 1.92$) compared to the recall task ($M = .50$). The recognition task, for the AD group, appears to overload their immediate memory thus creating a sense of "confusion", creating a situation in which they make more intrusion errors than is expected. This difference between recall and recognition appears to be a strong indicator of AD, and lends support to the findings of Manning et al. (1997), since all of the other groups made very few, if any, intrusion errors in the recall or recognition tasks.

Combined Analysis for Experiment 2 and Experiment 3 (Immediate Recall)

As previously discussed, Experiments 2 and 3 were originally designed as one within subject experiment, but due to the length of time needed to complete all of the conditions (fatigue), it was decided that a between subject design would be the best option. This design allowed us, as mentioned earlier, to look at things we were unable to examine in the past, such as performance on the Delayed memory tasks as a function of modality. Although new types of data were obtained, the loss of other interesting data (e.g., interaction of modality) lead to the next analysis. Experiments 2 and 3 were combined to perform a 4 (Groups) X 2 (Modality) X 3 (Condition) X 6 (Serial Position) ANOVA.

The main effects of groups was highly significant, $F(3, 88) = 14.14$, $MSE = 991.56$,

$p < .00005$. This effect was due to the decrease in performance with increasing impairment; young ($M = 11.2$), normal elderly ($M = 10.5$), MCI ($M = 9.0$), and AD ($M = 7.7$). The main effect of Modality was not significant. This may be due to the combination of the between subject experimental design and the presence of the suffix and varied suffix data in the analysis. The main effect of Condition was highly significant, $F(2, 176) = 48.90$, $MSE = 461.56$, $p < .00005$. This effect was due to the decrease in performance for the conditions which required increased attention; Control condition ($M = 10.7$), Suffix condition ($M = 9.4$), and Varied Suffix condition ($M = 9.0$) respectively. The main effect of Serial Position was also significant, $F(5, 440) = 148.09$, $MSE = 720.08$, $p < .00005$. The main effect of serial position represents the usual irregular effects summed over condition.

The interaction of Modality X Serial Position was highly significant, $F(5, 440) = 7.31$, $MSE = 35.37$, $p < .00005$. This interaction is due mainly to the better performance in the visual modality for positions two through five and the better performance in the auditory modality for positions one and six. This is consistent with previous work on primacy and recency effects in the auditory modality.

The interaction of Condition X Serial Position was also highly significant, $F(10, 880) = 5.19$, $MSE = 11.828$, $p < .00005$. This interaction is due to the superior performance in the control condition for positions one through six compared to the suffix and varied suffix conditions. In addition, the performance in the suffix condition is superior to the varied suffix condition for positions one through five.

Finally, the interaction of Modality X Condition X Serial Position was highly significant, F (10, 880) = 3.76, MSE = 8.560, $p < .0001$. This interaction is due to several things. First, performance in the control and suffix conditions are superior to performance in the varied suffix condition for positions one through five in the visual modality versus the auditory modality. Secondly, performance in the varied suffix condition is superior in the visual modality for positions one through four only with superior performance for positions five and six in the auditory modality.

General Discussion of Experiments 2 and 3

The combined analysis for immediate recall in Experiment 2 and 3 failed to show a significant modality effect. This may just be due to combining these two experiments but it may be more than that. The results in the present analyses are also likely to be effected by the suffix and varied suffix conditions. Performance in the Visual modality may be better since there is less interference created by the visual suffix in the visual suffix conditions compared to the auditory suffix in the auditory suffix conditions.

When visual and auditory performance are compared (see Tables 11 and 17), it becomes apparent that the visual superiority is being driven mainly by the young, normal elderly, and to a lesser degree the MCI group. For these three groups, performance is better in the visual modality for positions one through four in the control condition and there appears to be an across the board effect in the suffix and varied suffix conditions. The auditory suffix appears to have a greater effect on overall performance for these groups compared to the visual suffix. The AD group performs better in the auditory modality no matter what the condition is, suggesting that, although their overall performance is compromised in the presence of a suffix, the input in the auditory modality overrides it effects to a greater degree compared to the visual modality.

These findings are, in many ways, consistent with previous studies which suggest that auditory suffixes create a greater decrement in performance (e.g., Manning et al, 1990). Manning et al. (1996) suggest that auditory suffixes create large decrements in overall performance compared to visual suffixes which have little or no effect on overall performance. The lack of a standard modality effect appears to be due to the overall performance differences, seen previously, in the presence of auditory and visual suffixes.

Experiments 2 and 3 also revealed new information about modality and delayed memory. It appears that delayed memory (recall and recognition) performance is enhanced when only the auditory modality is used compared to the visual modality. These set of experiments are the first opportunity, in this lab, to examine modality differences in delayed memory since all previous work used within subject experimental designs.

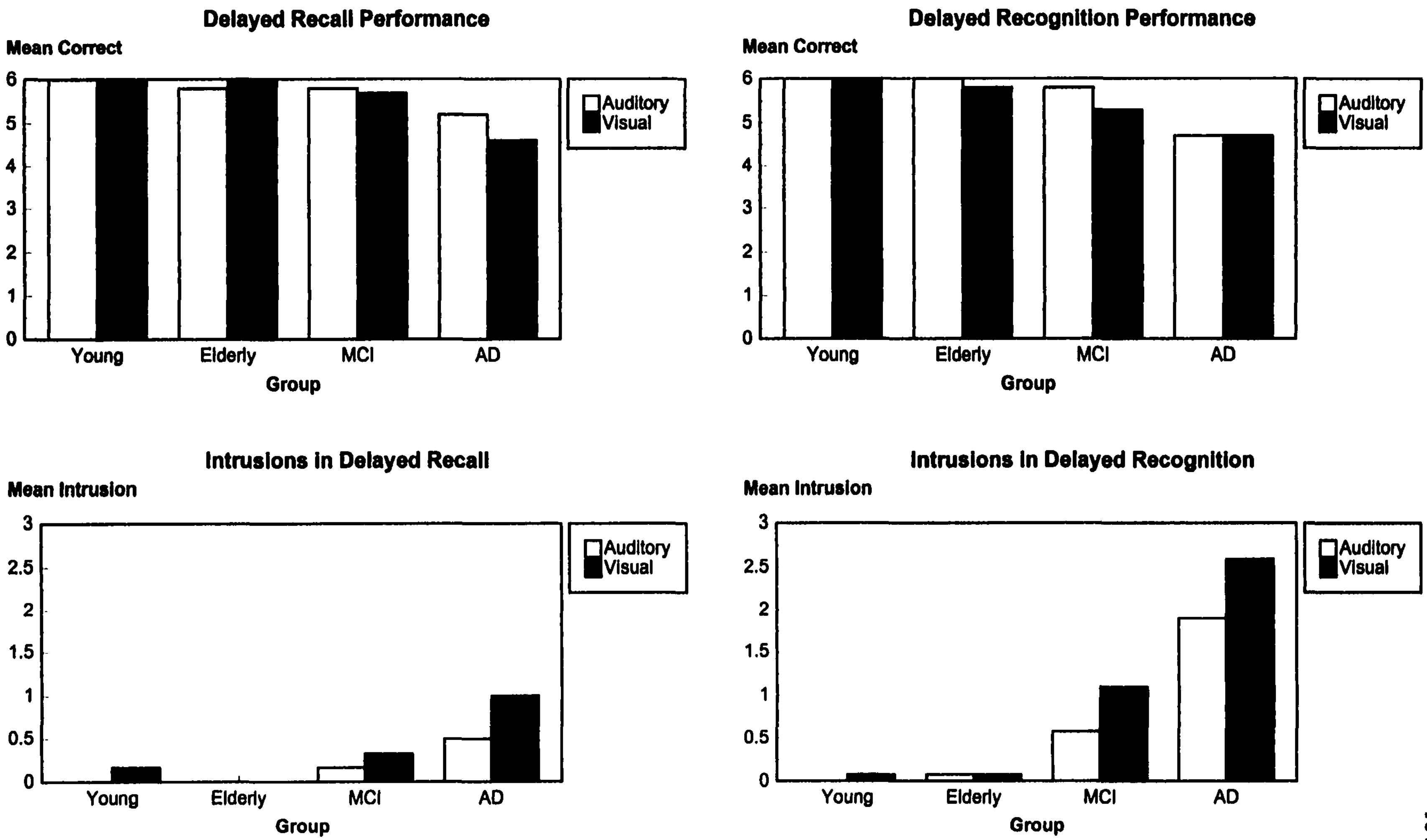
The findings of an apparent auditory superiority in delayed memory is consistent with modality differences seen in immediate memory. As previously discussed, at length, the majority of research to date, supports the view that in immediate recall stimuli are better recalled when they are presented auditorily compared to visually. Various explanations for this effect, such as the recency effect, are provided in the introduction.

Although no formal analyses have been done, between Experiment 2 and 3, to compare delayed memory performance, Figure 9 illustrates some of the differences that future analyses will be look at more closely. All groups, except the AD group, are close to ceiling performance in delayed recall in the auditory and visual modalities. The AD groups performance is better in the auditory modality compared to the visual modality but what is more interesting is what happens to the hit rate in each modality. Due to a sharp increase in intrusion errors in the visual modality, for the AD group and to a lesser degree the MCI group, the hit rate declines. For example, the AD groups hit rate in the auditory modality was very good (.91), considering that they are more likely to experience rapid forgetting in the presence of interference. This is compared to the hit rate in the visual modality which declines to .82. These differences need to be looked at more closely taking into account the between subject experimental design.

The same pattern appears for delayed recognition in Experiment 2 and 3. Performance for the young, normal elderly, and MCI groups are close to ceiling compared to the AD groups performance. The AD group shows a slight advantage in the auditory modality compared to the visual modality, but this difference is not likely to be significant. The MCI and AD groups also showed an increased in the visual modality compared to the auditory modality, thus the hit rates declined. For example, the AD group had a .72 hit rate in the auditory modality compared to a hit rate of only .64 in the visual modality.

In addition, these studies have confirmed the findings of Manning et al. (1996). The delayed recognition task seems to be much harder than the delayed recall task,

Figure 9: **A Comparison of Delayed Memory as a Function of Modality.**



particularly for the AD group, who made more intrusion errors in the recognition task. The use of such a delayed recognition task needs to be explored further in light of these modality differences.

Clinical Applications & Future Directions

As previously discussed, it is not possible to give a definitive diagnosis of AD prior to autopsy. To date, there is still not an effective drug treatment which can halt, indefinitely, or slow the progression of the disease. Thus, finding an early cognitive marker, one which can detect the earliest cognitive losses and help in differentiating AD from those going through the normal aging process, is very important. Once an appropriate drug treatment is available, one which can slow or halt the progression, an early cognitive marker will be essential in identifying patients who need early treatment.

One of the goals of the present set of experiments was to further explore previous findings in this lab, which have suggested potential cognitive markers of early AD. Manning et al. (1996) have suggested that suffix and extra-list intrusion errors in immediate and delayed memory are potential early markers of AD. Their findings strongly suggested that these measures can strongly differentiate early AD from normal aging. The results from the present set of experiments supports these findings. Intrusion errors in immediate and delayed memory appear to be useful in the early clinical diagnosis of AD. Unfortunately, these measure do not seem sensitive enough to pick up the very subtle cognitive losses associated with MCI. Although, the differences seen in delayed recall and recognition in Experiments 2 and 3, for the MCI group, needs to be further explored. There may be some subtle differences in performance and the production of extra-list intrusion errors with respect to modality. This will be explored further as well.

Future research will focus on the subtle differences seen in immediate and delayed memory for the MCI and AD groups, especially with respect to modality. Future studies should also take time into consideration. For example, each experiment took about 1 hour to complete with each patient. Many clinicians do not have this much time to screen a patient for memory or cognitive impairments. If the total length of the battery could be considerably shortened, it may have more clinical application and relevance in todays healthcare environment. Finally, future studies need to determine if these markers can also differentiate between dementias, as suggested by other work on intrusion errors.

APPENDIX A

Mean Number of High and Low Frequency Letters Recalled During Immediate Serial Recall as a Function of Condition, Modality, Age and Cognitive Impariment

	Serial Position					
	1	2	3	4	5	6
Young						
Auditory Suffix						
HF	8.3	6.6	5.3	5.0	4.2	5.8
LF	8.7	6.7	5.0	6.0	5.5	5.0
Auditory Control						
HF	8.3	7.8	6.7	6.1	6.1	7.5
LF	8.7	7.7	7.2	6.0	6.0	7.5
Visual Suffix						
HF	8.5	7.8	7.3	6.5	5.9	5.7
LF	8.2	8.0	7.2	6.7	4.7	7.0
Visual Control						
HF	8.2	7.7	7.2	6.3	5.8	5.9
LF	9.0	7.2	7.5	6.5	6.7	6.5
Normal Elderly						
Auditory Suffix						
HF	7.1	5.2	4.1	2.8	3.1	3.3
LF	7.0	5.5	3.7	3.0	1.7	2.7
Auditory Control						
HF	8.0	6.7	6.3	4.5	5.5	6.1
LF	7.0	6.2	4.2	5.7	4.0	7.0
Visual Suffix						
HF	7.9	7.0	6.3	5.2	4.5	4.9
LF	6.7	6.5	6.7	4.7	4.0	3.5
Visual Control						
HF	8.1	7.4	7.2	5.4	4.6	5.7
LF	8.0	7.5	6.7	4.7	5.7	4.7

MCI						
Auditory Suffix						
HF	6.3	4.5	4.4	3.0	3.0	2.7
LF	6.2	4.7	3.7	4.5	3.5	2.7
Auditory Control						
HF	7.6	5.7	5.8	4.3	3.9	5.7
LF	7.2	6.5	6.0	4.5	5.0	6.2
Visual Suffix						
HF	7.1	6.0	5.1	4.5	3.2	3.5
LF	7.2	7.0	6.2	5.2	3.5	4.5
Visual Control						
HF	8.3	7.4	7.1	5.1	3.7	3.6
LF	8.2	6.5	6.7	4.5	3.2	5.3
AD						
Auditory Suffix						
HF	5.6	3.9	3.4	2.8	1.8	1.8
LF	5.7	3.7	3.2	2.7	2.5	2.7
Auditory Control						
HF	7.1	5.2	4.2	3.5	3.6	4.7
LF	6.2	5.0	5.0	3.2	3.7	5.0
Visual Suffix						
HF	6.2	5.6	4.5	3.3	2.0	1.2
LF	4.2	5.0	3.2	2.2	1.7	1.2
Visual Control						
HF	7.0	5.4	4.1	4.1	2.9	3.2
LF	7.2	6.0	6.2	4.2	3.2	3.5

Note: Maximum Score is 9.0 for all serial positions

APPENDIX B: PSYCHOMETRIC EVALUATIONS

1. Mini-Mental Status Examination
2. Digit Span Task (WMS-R)
3. Guild Paragraph Recall (Form A and B)

MINI MENTAL STATE (MMSE)

Orientation Score

What is the (year) (season) (month) (day) (date) (5 points)
Where are we? (state) (county) (town) (hospital) (floor) (5 points)

Registration

Name 3 objects from list: Apple, Telephone, River, Book, Horse, Chair. 1 second to say each. Then ask the patient to repeat all three after you have said them. 1 point for each correct. (3 points)

Attention and Calculation

Serial 7s. 1 point for each correct. Stop at 5 answers. Or spell "world" backwards. (Number correct equals letters before first mis-take- i.e., dlorw = 2 correct). (5 points)

Recall

Ask for the objects above. 1 point for each correct. (3 points)

Language Tests

Name- pencil, watch (2 points)
Repeat- no ifs, ands or buts (1 point)
Follow a 3 stage command: "Take the paper in your right hand, fold it in half, and put it on the floor." (3 points)
Read and obey the following:

CLOSE YOUR EYES. (***Show statement printed on prior page.***) (1 point)

Write a sentence spontaneously on the next page. (1 point)

Copy the design on the next page (Two intersecting pentagons). (1 point)

TOTAL (30 POINTS) ______

DIGIT SPAN (Forwards)

(Discontinue after failure on both trials of any item. Administer both trials of each item, even if the first trial is passed.)

DIGITS FORWARD

Item	Trial I	PassFail	Trial II	Pass Fail	WAIS Score Max correct for item	WMS-R Score 2, 1, or 0
1.	6-2-9		3-7-5			
2.	5-4-1-7		8-3-9-6			
3.	3-6-9-2-5		6-9-4-7-1			
4.	9-1-8-4-2-7		6-3-5-4-8-2			
5.	1-2-8-5-3-4-6		2-8-1-4-9-7-5			
6.	3-8-2-9-5-1-7-4		5-9-1-8-2-6-4-7			
			WMS-R Total Forward Max=12			

If patient completes either trial of item # 6 then go on to item # 7. Include scoring of item # 7 for WAIS digit span only.

Item	Trial I	Pass Fail	Trial II	Pass Fail	WAIS Score Max=9
7.	2-7-5-8-6-2-5-8-4		7-1-3-9-4-2-5-6-8		

GUILD MEMORY TEST (Form A)

I'm going to read you a short paragraph. I'd like you to remember the paragraph because I'll ask you to repeat it to me when I'm done, verbatim, if you can.

PARAGRAPH 1

NEW YORK, / SEPTEMBER / 28TH, / THE CENTURY / THEATER / ON COLUMBUS / STREET / WILL OFFER / A FESTIVAL / OF OLD TIME / FAVORITES / OF SILENT / FILM / DAYS. / MANY WELL-KNOWN / ACTORS / AND ACTRESSES / OF BY- GONE YEARS / WILL PUT IN/ A PERSONAL / APPEARANCE. /

Tell me everything you can remember from that paragraph. SCORE: ____________

(Read Paragraph 1 again for delayed recall, then go immediately to PAIRED ASSOCIATES.)

GUILD MEMORY TEST (Form B)

I'm going to read you a short paragraph. I'd like you to remember the paragraph because I'll ask you to repeat it to me when I'm done, verbatim, if you can.

PARAGRAPH 1

BOSTON, / OCTOBER / 14TH, / THE APOLLO / THEATER / ON CENTER / AVENUE / WILL PRESENT / A NEW / PLAY / BY JOHN MILNER / THE FAMED / SOCIAL / PLAYWRIGHT. / THE COMEDY / DEALS / AMUSINGLY / WITH LOCAL / SOCIAL CONDITIONS. /

Tell me everything you can remember from that paragraph. SCORE: ____________

APPENDIX C: DIAGNOSTIC CRITERIA AND RATING SCALES FOR AD

1. **DSM-IV DIAGNOSTIC CRITERIA**
2. **NINCDS/ADRDA DIAGNOSTIC CRITERIA**
3. **GLOBAL DETERIORATION SCALE (GDS)**

Diagnostic criteria for Dementia of the Alzheimer's Type

A. The development of multiple cognitive deficits manifested by both

(1) memory impairment (impaired ability to learn new information or to recall previously learned information)

(2) one (or more) of the following cognitive disturbances:

(a) aphasia (language disturbance)

(b) apraxia (impaired ability to carry out motor activities despite intact motor function)

(c) agnosia (failure to recognize or identify objects despite intact sensory function)

(d) disturbance in executive functioning (i.e., planning, organizing, sequencing, abstracting)

B. The cognitive deficits in Criteria A1 and A2 each cause significant impairment in social or occupational functioning and represent a significant decline from a previous level of functioning.

C. The course is characterized by gradual onset and continuing cognitive decline.

D. The cognitive deficits in Criteria A1 and A2 are not due to any of the following:

(1) other central nervous system conditions that cause progressive deficits in memory and cognition (e.g., cerebrovascular disease, Parkinson's disease, Huntington's disease, subdural hematoma, normal-pressure hydrocephalus, brain tumor)

(2) systemic conditions that are known to cause dementia (e.g., hypothyroidism, vitamin B_{12} or folic acid deficiency, niacin deficiency, hypercalcemia, neurosyphilis, HIV infection)

(3) substance-induced conditions

E. The deficits do not occur exclusively during the course of a delirium.

F. The disturbance is not better accounted for by another Axis I disorder (e.g., Major Depressive Disorder, Schizophrenia).

Code based on type of onset and predominant features:

With Early Onset: if onset is at age 65 years or below

290.11 With Delirium: if delirium is superimposed on the dementia

290.12 With Delusions: if delusions are the predominant feature

290.13 With Depressed Mood: if depressed mood (including presentations that meet full symptom criteria for a Major Depressive Episode) is the predominant feature. A separate diagnosis of Mood Disorder Due to a General Medical Condition is not given.

290.10 Uncomplicated: if none of the above predominates in the current clinical presentation

With Late Onset: if onset is after age 65 years

290.3 With Delirium: if delirium is superimposed on the dementia

290.20 With Delusions: if delusions are the predominant feature

290.21 With Depressed Mood: if depressed mood (including presentations that meet full symptom criteria for a Major Depressive Episode) is the predominant feature. A separate diagnosis of Mood Disorder Due to a General Medical Condition is not given.

290.0 Uncomplicated: if none of the above predominates in the current clinical presentation

Specify if:

With Behavioral Disturbance

Coding note: Also code 331.0 Alzheimer's disease on Axis III.

CLINICAL DIAGNOSIS OF ALZHEIMER'S DISEASE

NINCDS-ADRDA CRITERIA

A. Criteria for Dementia Syndrome

Dementia is the decline of memory and other cognitive functions in comparison with the patient's previous level of function as determined by a history of decline in performance and by abnormalities noted from clinical examination and neuropsychological tests. A diagnosis of dementia cannot be made when consciousness is impaired by delirium, drowsiness, stupor, or coma or when other clinical abnormalities prevent adequate evaluation of mental status. Dementia is a diagnosis based on behavior and cannot be determined by computerized tomography, electroencephalography, or other laboratory instructions, although specific causes of dementia may be identified by these means.

B. Criteria for Alzheimer's Disease

Alzheimer's Disease is a progressive, dementing disorder, usually of middle or late life. The clinical criteria for the diagnosis of PROBABLE, POSSIBLE and DEFINITE Alzheimer's Disease are outlined in Table 1. A clinical diagnosis of probable Alzheimer's Disease can be made with confidence if there is a typical insidious onset of dementia with progression and if there are no other systemic or brain diseases that could account for the progressive memory and other cognitive deficits. Among the disorders that must be excluded are manic depressive disorder, Parkinson's disease, multiinfarct dementia, and drug intoxication; less commonly encountered disorders that may cause dementia include thyroid disease, pernicious anemia, luetic brain disease and other chronic infections of the nervous system, subdural hematoma, occult hydrocephalus, Huntington's disease, Creutzfeldt-Jakob disease, and brain tumors.

A diagnosis of definite Alzheimer's Disease requires histopathologic confirmation. A clinical diagnosis of possible Alzheimer's Disease may be made in the presence of other significant diseases, particularly if, on clinical judgment, Alzheimer's Disease is considered the more likely cause of the progressive dementia. The clinical diagnosis of possible rather than probable Alzheimer's Disease may be used if the presentation or course is somewhat aberrant. The information needed to apply these criteria is obtained by standard methods of examination: the medical history; neurologic; psychiatric, and clinical examinations; neuropsychological tests; and laboratory studies.

Global Deterioration Scale (GDS) for Age-Associated Cognitive Decline and Alzheimer's Disease.

GDS Stage	Clinical Characteristics	Diagnosis
1 No cognitive decline	No subjective complaints of memory deficit. No memory deficit evident on clinical interview.	Normal
2 Very mild cognitive decline	Subjective complaints of memory deficit, most frequently in following areas: (a) forgetting where one has placed familiar objects; (b) forgetting names one formerly knew well. No objective evidence of memory deficit on clinical interview. No objective deficit in employment or social situations. Appropriate concern with respect to symptomatology.	Normal Aging
3 Mild cognitive decline	Earliest clear-cut deficits. Manifestations in more than one of the following areas: (a) patient may have gotten lost when traveling to an unfamiliar location. (b) co-workers become aware of patient's relatively poor performance. (c) word and name finding deficit become evident to intimates. (d) patient may read a passage or book and retain relatively little material. (e) patient may demonstrate decreased facility remembering names upon introduction to new people. (f) patient may have lost or misplaced an object of value. (g) concentration deficit may be evident on clinical testing. Objective evidence of memory deficit obtained only with an intensive interview. Decreased performance in demanding employment and social settings. Denial begins to become manifest in patient. Mild to moderate anxiety frequently accompanies symptoms.	Mild Neurocognitive Disorder
4 Moderate cognitive decline	Clear-cut deficit on careful clinical interview. Deficit manifest in following areas: (a) decreased knowledge of current and recent events. (b) may exhibit some deficit in memory of one's personal history. (c) concentration deficit elicited on serial subtractions. (d) decreased ability to travel, handle finances, etc. Frequently no deficit in following areas: (a) orientation to time and place. (b) recognition of familiar persons and faces. (c) ability to travel to familiar locations. Inability to perform complex tasks. Denial is dominant defense mechanism. Flattening of affect and withdrawal from challenging situations occur.	Mild Alzheimer's Disease
5 Moderately severe decline	Patient can no longer survive without some assistance. Patient is unable during interview to recall a major relevant aspect of their current life, e.g.: (a) their address or telephone number for many years. (b) the names of close members of their family (such as grandchildren). (c) the name of the high school or college from which they graduated.	Moderate Alzheimer's Disease

GDS: Continued

	Frequently some disorientation to time (date, day of the week, season, etc.) or to place. An educated person may have difficulty counting back from 40 by 4s or from 20 by 2s. Persons at this stage retain knowledge of many major facts regarding themselves and others. They invariably know their own names and generally know their spouse's and children's names. They require no assistance with toileting or eating, but may have difficulty choosing the proper clothing to wear.	
6 Severe cognitive decline	May occasionally forget the name of the spouse upon whom they are entirely dependent for survival. Will be largely unaware of all recent events and experiences in their lives. Retain some knowledge of their surroundings; the year, the season, etc. May have difficulty counting by 1s from 10, both backward and sometimes forward. Will require some assistance with activities of daily living: (a) may become incontinent. (b) will require travel assistance but occasionally will be able to travel to familiar locations. Diurnal rhythm frequently disturbed. Almost always recall their own name. Frequently continue to be able to distinguish familiar from unfamiliar persons in their environment. Personality and emotional changes occur. These are quite variable and include: (a) delusional behavior, e.g., patients may accuse their spouse of being an impostor; may talk to imaginary figures in the environment, or to their own reflection in the mirror. (b) obsessive symptoms, e.g., person may continually repeat simple cleaning activities. (c) anxiety symptoms, agitation, and even previously non-existent violent behavior may occur. (d) cognitive abulia, e.g., loss of willpower because an individual cannot carry a thought long enough to determine a purposeful course of action.	Moderately severe Alzheimer's Disease
7 Very severe cognitive decline	All verbal abilities are lost over the course of this stage. Early in this stage words and phrases are spoken but speech is very circumscribed. Later there is no speech at all - only grunting. Incontinent of urine; requires assistance toileting and feeding. Basic psychomotor skills (e.g. ability to walk) are lost with the progression of this stage. The brain appears to no longer be able to tell the body what to do. Generalized and cortical neurologic signs and symptoms are frequently present.	Severe Alzheimer's Disease

Source: B. Reisberg, et al., "The Global Deterioration Scale for Assessment of Primary Degenerative Dementia." *American Journal of Psychiatry,* 139 (1982).

APPENDIX D: TEST MATERIALS FOR EXPERIMENTS 1, 2 AND 3

1. Immediate and Serial Recall Instructions for Control, Suffix, and Varied Suffix Condition.

2. Response Sheet

3. Delayed Recall Instructions

4. Delayed Recognition Instructions

5. Post Test Questionnaire

Serial Recall Instructions - Suffix Condition (Visual & Auditory)

* Your task will be to recall several letters. You will hear a tone at the start of each sequence.
* All letters will appear in the center of the screen one at a time, as they appear read them *ALOUD/SILENTLY.*
* Each sequence will end with the letter Y.
* This is your cue to begin recalling the letters in the order in which they appeared.
* You are not required to recall the letter Y.
* Write the letters from left to right and do not go back to fill in blank spaces once you have proceeded to the next space.
* If you cannot remember a letter, please guess.
* You will have twenty seconds for recall. At the sound of the tone stop writing, the next sequence is about to begin.

Serial Recall Instructions - Control Condition (Visual & Auditory)

* Your task will be to recall several letters. You will hear a tone at the start of each sequence.

* All letters will appear in the center of the screen one at a time, as they appear read them *ALOUD/SILENTLY.*

* Each sequence will end with a BEEP.

* This is your cue to begin recalling the letters in the order in which they appeared.

* You are not required to recall the letter Y.

* Write the letters from left to right and do not go back to fill in blank spaces once you have proceeded to the next space.

* If you cannot remember a letter, please guess.

* You will have twenty seconds for recall. At the sound of the tone stop writing, the next sequence is about to begin.

Delayed Recall and Recognition Questions

Delayed Recall:

1. Write down as many letters, in any order, that you can recall from the session/experiment.

Delayed Recognition:

1. Please circle all the letters that were used during this session/experiment.

A	B	C	D	E	F	G
H	I	J	K	L	M	N
O	P	Q	R	S	T	U
V	W	X	Y	Z		

Frequency Judgment Questionnaire (Post Test) in Condensed Form

1. In the experiment you just completed, do you remember seeing some letters more frequently than others?

2. You have seen some letters more frequently than others, which ones were they?

3. You have seen some letters less frequently than others, which ones were they?

4. In each condition set (each page), some letters appeared less (or more) frequently than other letters. How frequently would you say they were presented? (Choices: ½, 1/3, 1/4, or 1/5 as often)

5. Listed below are the letters presented in the experiment. Which of the letters were presented less (or more) frequently than others?

Appendix E: Neuropsychological Tests Administered at NYUMC-ADRC

The Cognitive Assessment Battery is administered by a trained psychometrician at the NYUMC-ADRC. In order to provide a profile of cognitive and neuropsychological functioning the test battery consists of several examinations. The battery assesses several aspects of memory, immediate and delayed, remote memory, language, attention, spatial ability, and psychomotor processes. The exams included in NYUMC-ADRC battery include the following:

Immediate Memory

(1) Digit Span (Forward and Backward) (Wechsler, 1981)

Recent Memory

(1) Paragraph Recall (Gilbert, Levee, & Catalano, 1968; Wechsler, 1981)
Paired Associates Immediate Recall
Designs (only Gilbert et al., 1968)

(2) Shopping List Task (McCarthy, Ferris, Clark, & Crook, 1981)

(3) Delayed Spatial Recall Task (Flicker, Bartus, Crook, & Ferris, 1984)

(4) Misplaced Objects Task (Crook, Ferris, & McCarthy, 1979)

(5) Visual Recognition Span (Flicker, Ferris, Crook, & Bartus, 1989)

(6) Figural Memory (Wechsler, 1981)

Remote Memory

(1) Remote Memory Questionnaire (Flicker, Ferris, Crook, & Bartus, 1989)

Language

(1) Vocabulary (Wechsler, 1981)

(2) Category Retrieval (Mens First Names & Types of Footwear) (Battig & Montague, 1969)

(3) Object Naming (Flicker, Ferris, Crook, & Bartus, 1987)

(4) Object Function Recognition (Flicker, Ferris, Crook, & Bartus, 1987)

(5) Object Identification (Flicker, Ferris, Crook, & Bartus, 1987)

Concept Formation

(1) Object Sorting Task (Flicker, Ferris, Crook, & Bartus, 1987)

Visuospatial Praxis

(1) Digit Symbol Substitution (Wechsler, 1981)

Visuoperceptual Function

(1) Judgement of Line Orientation (Benton, Hamsler, Varney, & Spreen, 1983)

Psychomotor Speed

(1) Finger Tapping (Dominant & Non-Dominant Hand)

Attention and Concentration

(1) Digit Span (Forward and Backwards) (Wechsler, 1981)

(2) Visual Memory Span (Forward and Backward) (Wechsler, 1981)

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IMAGE EVALUATION TEST TARGET (QA-3)

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1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989