Order Number 9218217

Memory dissociation in Alzheimer's disease

Apter, Seth Hilton, Ph.D.
City University of New York, 1992

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

A

Memory Dissociation in Alzheimer's Disease

by

Seth H. Apter

A dissertation submitted to the Graduate Faculty
in Psychology in partial fulfillment of the
requirements for the degree of Doctor of Philosophy,
The City University of New York

1992

This manuscript has been read and accepted for
the Graduate Faculty in Psychology
in satisfaction of the dissertation requirement
for the degree of Doctor of Philosophy

1/22/92
Date

Wilma A. Winnick, Ph.D.
Chair of Examining Committee

1/24/92
Date

Executive Officer

Daniel Caputo, Ph.D.
Rhea Dornbush, Ph.D.
Philip Harvey, Ph.D.
Thomas Kay, Ph.D.

Supervisory Committee

The City University of New York

Abstract

MEMORY DISSOCIATION IN ALZHEIMER'S DISEASE

by

Seth H. Apter

Advisor: Professor Wilma A. Winnick

The present set of experiments examined the role of cognitive processing demand on dissociations between procedural and declarative memory systems in Alzheimer's disease (AD) and in normal aging. In Experiment 1, 25 AD patients and 25 age- and education-matched healthy adults were presented with a list of words to process and were subsequently administered one of two possible memory tasks: word-fragment completion or free recall. Word-fragment completion is an implicit test of memory which requires a large degree of effortful processing for successful completion. Free recall is an explicit test of memory matched to word-fragment completion in terms of relative cognitive demand. In Experiment 2, subsequent to an identical study phase, 19 AD patients and 22 age- and education-matched healthy adults were administered either a perceptual threshold measurement or a recognition test. Perceptual threshold measurement is an implicit memory task which requires automatic processing. Recognition is an explicit memory test matched to perceptual threshold measurement with regard to degree of cognitive demand. In both experiments, the implicit memory tests reflect the operation of the procedural memory system while the explicit memory tests reflect operation of the declarative memory system. Results indicate that while performance of the AD patients on both explicit tasks of memory was extremely impaired relative to the controls, a more variable pattern emerged on the implicit tests of memory. AD patients performed significantly worse relative to the controls on the effortful processing word-fragment completion task. In contrast, although AD patients had overall slower threshold durations, these subjects actually exhibited a greater degree of priming than the controls on the perceptual threshold measurement test, an automatic processing task. Performance on the implicit memory tasks was therefore dependent upon the degree of cognitive capacity demanded by each task. These findings indicate that AD patients do appear to exhibit a dissociation among systems of memory but that this dissociation appears to be mediated by cognitive processing capacity and demand. Results are discussed with respect to memory systems in general and memory functioning in AD in particular.

ACKNOWLEDGMENTS

I would like to express my appreciation and offer my endless thanks to my mentor, Wilma A. Winnick. Her enthusiasm, expertise and devotion have had a major impact on my academic and professional development. She has been everything and more that a student could hope to have in an advisor.

I thank Daniel Caputo and Rhea Dornbush for their participation in the inception, refinement, execution and writing of this research. Their contributions at every stage helped to greatly improve the final product.

Thanks to Philip Harvey and Thomas Kay who were willing to serve as outside readers on what was probably "a moment's notice." Their thoughtful and detailed review of the manuscript was greatly appreciated.

I would also like to thank Rachel Markofsky, Terena Searcey and Lizette Williams for their never-ending help with my subject sample; Jeremy Silverman for almost helping to determine my fate; Theresa Ryan for her ears and her unlimited advise and counsel; and Noreen Denny for literally being there every step of the way.

Most of all I would like to thank my family. To my newest family, Phil, Joshua, Eve, Manny and Adam, thanks for your always supportive words of encouragement - they really helped to keep me going; to my mother, Joan, and my sister and brother, Paule and Alan, thank you for your faith, support, patience and willingness to sacrifice so that I could get to where I have gotten today; and to my wife, Sari, who has never known me as a non-student. Extra-special thanks for your support, encouragement, assistance and love throughout every step of this long process - I hope I do just as well by you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

The most striking aspect of both dementing and amnesic disorders is a profound impairment in memory functioning. Unlike the amnesias, which are circumscribed syndromes generally limited to disordered memory (Squire, 1982), dementia is characterized by memory deficits and progressive impairment in intellectual, cognitive, and behavioral functioning. Despite these differences, both forms of memory disorder share in part common anatomical etiology (Corsellis, 1970; Hyman, Van Hoesen, Damasio, & Barnes, 1984) as well as common presenting symptomatology (Butters, Granholm, Salmon, Grant, & Wolfe, 1987; Kopelman, 1985). However, investigations of dementia and amnesia have rarely shared common experimental approaches. Given the existence of both etiologic and symptomatic commonalities, it may be beneficial to apply the same paradigms to both disorders. Such a strategy might be particularly useful in the study of dissociations among multiple memory systems.

Historically memory has been seen as a unitary concept (Tulving & Schacter, 1990). More recently it has been suggested that memory may in fact be made up of several, distinct components (Mitchell, 1989; Richardson-Klavehn & Bjork, 1988; Squire & Cohen, 1984; Tulving & Schacter, 1990; Weiskrantz, 1987), possibly developing as a result of evolutionary demand (Sherry & Schacter, 1987). A number of concepts have been developed to account for and describe the components of memory, including procedural and declarative memory (Cohen, 1984; Squire & Cohen, 1984), activation and elaboration (Graf, Squire, & Mandler, 1984), horizontal and vertical associative memory (Wickelgren, 1979), memory formation and habit formation (Mishkin, Malamut, & Bachevalier, 1984), perceptual and autobiographical memory (Jacoby & Dallas, 1981), semantic memory and cognitive mediation (Warrington & Weiskrantz, 1982), and unitized and nested structure (Schacter, 1985a), among others. While these systems vary somewhat in terms of specifics, in all cases memory is viewed as being made up of several dissociable components.

Recent research has established that a dissociation among the components of memory is evident in patients presenting with amnesic disorders (e.g., Cohen, 1984; Cohen & Squire, 1980; Graf, Squire, & Mandler, 1984; Jacoby & Witherspoon, 1982; Moscovitch, 1982a; Schacter, 1985a; Schacter & Graf, 1986; Shimamura, 1986). The dissociation is characterized by two distinct systems of memory which are differentially affected in amnesia (Cohen, 1984; Huppert & Piercy, 1979; Squire, 1982). One system, associated with the brain regions compromised in these patients, is impaired. These regions include diencephalic and medial temporal structures. A second system, associated with brain regions independent of the compromised areas (Shimamura, 1986; Tulving & Schacter, 1990), is unaffected. Structures hypothesized to be involved in this latter memory system include the limbic system, the basal ganglia, and the neocortex (Knopman & Nissen, 1987, 1991; Martone, Butters, Payne, Becker, & Sax, 1984; Mishkin, Malamut, & Bachevalier, 1984; Zola-Morgan & Squire, 1990).

The paradigms used in research into memory dissociations in amnesic patients can be applied to other memory disordered and healthy groups as well. While a significant amount of research has also addressed dissociations of memory in healthy subjects, only recently have investigations begun to examine memory dissociations in patients presenting with dementing disorders. Furthermore, the results of these studies have not lead to consistent conclusions. At this point in time, it is not clear if the memory dissociation already well-established in amnesic patients can be reliably found in demented patients as well. The present investigation will address this and other closely related issues.

Explicit Versus Implicit Memory Tasks

In general, independence among systems of memory is supported by findings of functional dissociations in performance on distinct memory tasks. In amnesia, a dissociation has been found between tasks requiring declarative memory and those requiring procedural memory. Declarative memory is the explicit retention of facts, events, and lists. It is both the information gained from a learning experience and the memory of the actual process of learning itself. As new learning occurs, the specific outcome of each learning experience is maintained in a new data structure. Information in a declarative data base can be accessed by an individual on demand and is available to conscious awareness. The declarative memory system is aligned with the traditional view of memory (i.e., encoding, storage, retrieval) and is experimentally assessed with explicit memory tasks. Declarative memory has been found to be impaired in amnesic patients (Cohen, 1984).

Procedural memory, on the other hand, is spared in amnesic patients (Cohen, 1984). Procedural memory encompasses the acquisition of skills and is not associated with specific episodes of learning or instances in time. It includes operations and processes that are represented implicitly and accessed only by the expression of the processes or procedures themselves. Information within the procedural memory system is not explicitly accessible to the individual but is experimentally assessed through both skill learning and implicit memory tasks.

Explicit and implicit memory tasks differ, in the main, in the level of conscious awareness of the task by the subject. Explicit memory tasks require a conscious recollection or a deliberate act of remembering on the part of the subject (Graf & Schacter, 1985). The important component shared by all explicit memory procedures is the awareness of the subject at the time of retrieval that a memory task is being administered. In most cases, the subject's level of awareness is manipulated by the information presented in the task instructions. Traditional tests of memory, such as free recall and recognition, are the most common examples of explicit memory tasks. There are, however, others that also qualify as tests of explicit memory (e.g., cued recall).

The key component of implicit memory tasks is the lack of awareness on the part of the subject that memory is being assessed (Graf & Schacter, 1985). Many implicit memory tasks are concerned with the phenomenon of priming. Priming (Cofer, 1967) refers to the situation in which previous exposure to a stimulus facilitates subsequent processing of the same stimulus (direct or repetition priming) or a related stimulus (indirect or semantic priming). Priming tasks are administered without reference to the previously presented material, the memory of which is being assessed. Memory for the specific material is inferred from a facilitation in performance following repeated exposure to the stimuli.

A number of implicit memory tasks have been developed to assess procedural memory. The most commonly used tasks include perceptual threshold measurement, word-stem completion, word-fragment completion, and lexical decision (Schacter, 1987). All of these procedures include a study phase followed by a test phase. In the study phase, subjects are usually presented with a list of words, generally to rate along a specified dimension. Subjects are not informed that there is a memory component to the task.

In perceptual threshold measurement (e.g., Cermak, Blackford, O'Connor, & Bleich, 1988; Rouse & Verinis, 1962; Winnick & Daniel, 1970) the study phase is followed by a test phase in which both previously presented and new words are briefly exposed to the subject. Subjects are instructed to identify the words as they are flashed. No reference is made to the study session actually being assessed. The measure of interest is the mean identification threshold of new words versus old words. In this procedure, priming is reflected in a decreased response threshold for previously seen words compared to control words not seen before. In perceptual identification, a related paradigm, priming is measured by comparing the total number of old words as compared to new words recognized during a brief, predetermined exposure duration (e.g., Jacoby & Dallas, 1981; Murrell & Morton, 1974).

In word-stem completion (e.g., Graf & Mandler, 1984; Light & Singh, 1987; Warrington & Weiskrantz, 1978) subjects are administered the study phase and subsequently presented with the first two or three letters of a series of words (e.g., STR_ _ _ for STREAM). They are then instructed to complete each stem with the first word that comes to mind.

The stems can be completed with words seen during the study phase as well as with previously unseen, alternate words. Priming is evidenced here by the tendency to complete these items with the previously presented words rather than with previously unseen alternates.

Word-fragment completion (e.g., Light, Singh, & Capps, 1986; Tulving, Schacter, & Stark, 1982) is similar to word-stem completion in that following the study phase, subjects are presented with incomplete stimuli and asked to complete each stimulus with the first word that comes to mind. In word-fragment completion, however, random letters throughout the word are missing (e.g., C _ _ E R _ R for CATERER). In this test, priming is reflected by the tendency to complete a higher percentage of the fragments representing previously seen items than of those for items not seen before.

In lexical decision (e.g., Forbach, Stanners, & Hochhaus, 1974; Forster & Davis, 1984; Moscovitch, 1982b; Scarborough, Cortese, & Scarborough, 1977) following the study phase subjects are required in the test phase to determine if briefly presented letter-strings are words or non-words. In this task, a specified percentage of the letter strings are words which were initially presented in the study phase. Priming is evidenced by a decreased response time to items which had previously been presented (Forster & Davis, 1984; Kirsner & Smith, 1974) or to items which immediately follow semantically related stimuli

(Carroll & Kirsner, 1982).

In addition to the paradigms described above, priming has also been investigated using paired-associate learning (Cutting, 1978; Diamond & Rozin, 1984; Graf & Schacter, 1985), spelling of homophonic word pairs (Cermak, Blackford, O'Connor, & Bleich, 1988; Eich, 1984; Graf, Shimamura, & Squire, 1985), reading speed (Kolers, 1976), generation of category exemplars (Light & Albertson, 1989), degraded stimuli (Hashtroudi, Ferguson, Rappold, & Chrosniak, 1988; Parkin & Streete, 1988; Warrington & Weiskrantz, 1968, 1970), word association (Clifton, 1966), and lexical decision in sentence processing (Burke & Yee, 1984), among others.

Multiple Memory Systems

The concept of multiple systems of memory appears to be strongly supported by a variety of findings in the literature. These findings can be divided into four distinct areas: experimental variables, statistical independence, state changes, and subject performance.

Experimental Variables

Numerous studies have found a number of experimental variables that differentially affect explicit and implicit memory tasks (e.g., Carroll & Kirsner, 1982; Graf & Mandler, 1984; Graf, Mandler, & Haden, 1982; Graf, Shimamura, & Squire, 1985; Jacoby & Dallas, 1981; Scarborough, Cortese, & Scarborough, 1977; Tulving, Schacter, & Stark, 1982), strongly suggesting that declarative and procedural memory represent two distinct systems of memory. Overall, six distinct experimental variables have been identified to support the concept of multiple systems of memory: study-to-test modality changes, levels of processing, generation effect, delayed assessment, interference, and stimulus type.

Modality Effects. Several investigations have assessed the effect of a study-to-test modality change on both procedural and declarative memory. For example, Graf, Shimamura, and Squire (1985) presented amnesic and control subjects with word lists administered in either the visual or auditory modalities. Following this, subjects completed both a free recall and a word-stem completion task in the visual modality. While switching modalities from study (auditory) to test (visual) had no effect on free recall, performance on the word-stem completion task was significantly impaired as a result of the modality change. Such differential effects suggest that explicit and implicit memory tests reflect different memory systems. Similar modality effects have also been found when comparing explicit memory tasks to other types of implicit memory tasks, including lexical decision (Kirsner, Milech, & Standen, 1983; Kirsner & Smith, 1974; Scarborough, Gerard, & Cortese, 1979), perceptual learning (Jacoby & Dallas, 1981; Kirsner, Milech, & Standen, 1983; Morton, 1979), word-fragment completion (Roediger & Blaxton, 1987), and paired word-stem completion for new associations (Schacter & Graf, 1989).

Levels of Processing. A second variable whose effects support a dissociation between declarative and procedural memory is related to the level of processing which occurs at the time of encoding. Graf, Mandler, and Haden (1982) compared the effects of both elaborative and non-elaborative processing on subsequent performance on implicit and explicit tasks of memory. Healthy subjects were required either to rate their liking of individual words on a list (elaborative) or to determine whether a target word shared a vowel with the previously presented word (non-elaborative). Subjects were then tested with a word-stem completion test and a free recall task. Performance on the free recall task was significantly better following semantic elaboration than when following non-elaborative processing. No differences were seen, however, in word-stem completion as a result of level of processing at encoding. This finding has been replicated in other studies looking at word-stem completion (Graf & Mandler, 1984; Light & Singh, 1987) and in studies comparing explicit memory tasks to lexical decision (Carroll & Kirsner, 1982), perceptual identification (Carroll, Byrne, & Kirsner, 1985; Jacoby & Dallas, 1981), degraded stimuli (Hashtroudi, Ferguson, Rappold, & Chrosniak, 1988), naming latency (Carroll, Byrne, & Kirsner, 1985), and reading speed (Masson, 1984).

In a recent study, further evidence was found for a dissociation between procedural and declarative memory based on the level of processing at encoding (Schacter, Cooper, & Delaney, 1990). In a series of experiments, subjects were presented with unfamiliar, three-dimensional objects that could or could not exist in three-dimensional space. They were required to either rate each item using a three-dimensional structural description (e.g., is the object facing left or right?) or a two-dimensional nonstructural description (e.g., are there more vertical or horizontal lines in the object?).

Subjects were then assessed with both implicit and explicit memory tasks. Procedural memory was assessed with an object decision task. Previously viewed and new objects were presented for a duration of 100ms and the subject was required to determine if the object could exist in the real world. Declarative memory was assessed through a yes/no recognition paradigm. Results indicate that while performance on the implicit object decision task was enhanced by structural descriptive processing, performance on the explicit recognition task was not at all affected by the type of processing.

Generation Effect. A third experimental variable supporting a dissociation among memory systems is the generation effect, in which better recall occurs for items generated rather than named by a subject. Jacoby (1983) presented subjects with a series of paired items and subsequently administered either a perceptual identification or a recognition task. The initial presentation of study items varied based on context and was divided into four conditions. In the no context condition, the second member of an antonym pair was presented, preceded by a series of X's. In the context condition, both members of an antonym pair were presented. In the generate condition, the first member of a pair was presented followed by a series of question marks. The subject was then required to generate the second member. Finally, in the new condition, two non-antonym words were presented. Following the study phase, memory for the second member of each word pair was assessed by perceptual identification or recognition.

As expected, a generation effect emerged on the recognition test; words which had been initially generated by the subject were more likely to be correctly identified than words presented under all other conditions. In contrast, a reverse generation effect emerged on the test of perceptual identification; words which had been initially read out of context were more likely to be identified than all other words. This effect was also reported by Roediger and Blaxton (1987) and McClelland and Pring (1991), who investigated the generation effect in free recall and word-stem completion.

Delayed Assessment. A fourth experimental variable supporting the dissociation between systems of memory is related to the time course of the effect. Jacoby and Dallas (1981) compared both immediate and delayed recognition and perceptual identification in healthy subjects. While a delay had no effect on perceptual identification, recognition performance was significantly worse following the delay. Similar results were also found in an experiment comparing perceptual threshold measurement and recognition performance in Korsakoff's amnesics (Cermak, Talbot, Chandler, & Wolbarst, 1985).

Tulving, Schacter, and Stark (1982) presented healthy subjects with a word list and assessed recognition and word-fragment completion performance both immediately and following a seven day delay. Recognition performance was significantly reduced at delayed assessment. Word-fragment completion performance, on the other hand, did not differ from immediate to delayed testing.

Komatsu and Ohta (1984) also compared delayed assessment for both recognition and word-fragment completion but extended delays to a period of five weeks. Results show that, as expected, recognition memory performance consistently declined from eight minute to one week to five weeks delayed assessment. In contrast, performance on word-fragment completion showed no decrements across the same span of time; only a minimal 10% decrease in priming was seen after a five week delay. This effect has also been found when utilizing implicit tasks involving lexical decision (Scarborough, Cortese, & Scarborough, 1977), word-stem completion (Chiarello & Hoyer, 1988), reading inverted text (Cohen & Squire, 1980), reading speed (Kolers, 1976), picture naming (Mitchell & Brown, 1988; Mitchell, Brown, & Murphy, 1990), degraded stimuli (Hashtroudi, Ferguson, Rappold, & Chrosniak, 1988), and solving sentence puzzles (McAndrews, Glisky & Schacter, 1987).

Interference. A fifth variable supporting a dissociation between declarative and procedural memory is the effect of interference. Graf and Schacter (1987) presented healthy college students with a list of unrelated word pairs to study. One half of the subjects then received an explicit memory test (cued recall or pair-matching) followed by an implicit memory test (word-stem completion). The remaining subjects were administered the same tests but were first presented with an interference task. Results indicate that while interference negatively affected performance on both explicit memory tasks, it had no effect on implicit memory performance.

Stimulus Type. Finally, a sixth type of variable supporting the dissociation between procedural and declarative memory is related to the type of stimuli utilized in the memory task. Winnick and Daniel (1970) presented subjects with a series of both words and pictures. Subjects were subsequently administered either a free recall task (explicit) or a tachistoscopic perceptual threshold measurement task (implicit). Results indicate that free recall of items initially presented as pictures was superior to recall of stimuli initially presented as words. In contrast, on the perceptual threshold measurement task, subjects exhibited a lower threshold for items originally presented as words than for items initially presented as pictures. This effect has since been replicated by Morton (1979) and by Roediger and Weldon (1987).

In a series of experiments, Scarborough, Gerard, and Cortese (1979) presented undergraduate subjects with a set of concrete words as either pictures to be named or words to be pronounced. Subjects were subsequently administered a lexical decision task or a standard recognition test. Subjects who were initially presented with pictures to be named evidenced good recognition but poor lexical decision performance. In contrast, subjects who were initially required to pronounce the target items displayed poor recognition but good lexical decision performance. These results mirror those found by Winnick and Daniel (1970) and lend additional support to a distinction between procedural and declarative memory.

Stochastic Independence

The second general area of research which supports the concept of multiple systems of memory is statistical in nature. Stochastic independence (Tulving, 1985) has been demonstrated between tests of explicit and implicit memory. Stochastic independence refers to the fact that performance on measures of explicit memory are statistically independent of performance on implicit tasks (i.e., success on one is in no way correlated to success or failure on the other). Finding statistical independence between these two types of memory tasks further supports the distinction between procedural and declarative memory systems. Stochastic independence has been demonstrated between explicit tests and such implicit measures as word-fragment completion (Light, Singh, & Capps, 1986; Tulving, Schacter, & Stark, 1982), homophonic spelling (Eich, 1984; Jacoby & Witherspoon, 1982), lexical decision (Burke & Yee, 1984), picture completion (Parkin & Streete, 1988), object decision (Schacter, Cooper, & Delaney, 1990), and picture naming (Mitchell & Brown, 1988; Mitchell, Brown, & Murphy, 1990).

State Changes

The third area of study involves experimentally-induced or naturally occurring changes in the subject's state or level of consciousness. To date, memory dissociations have been studied following the ingestion of alcohol (Hashtroudi, Parker, DeLisi, Wyatt, & Mutter, 1984; Nilsson, Backman, & Karlsson, 1989), the induction of a hypnotic state (Kihlstrom, 1980; Williamsen, Johnson, & Eriksen, 1965) and the administration of scopolamine (Nissen, Knopman, & Schacter, 1987), diazepam (Danion, Zimmermann, Willard-

Schroeder, Grange, & Singer, 1989), lorazepam (Brown, Brown, & Bowes, 1989), and electroconvulsive therapy (ECT) (Graf, Squire, & Mandler, 1984; Squire, Shimamura, & Graf, 1985). Dissociations have also been studied in multiple personality disorder (Nissen, Ross, Willingham, Mackenzie, & Schacter, 1988).

Hashtroudi, Parker, DeLisi, Wyatt, and Mutter (1984) compared both acutely intoxicated and sober subjects on explicit (free recall, recognition) and implicit (identification of visually degraded words) tasks. Performance on free recall was significantly impaired in the intoxicated group relative to the sober controls. In contrast, the performance of the sober and the intoxicated subjects did not differ on the implicit task of identification of visually degraded words. These results therefore lend support to the concept of multiple systems of memory.

Interestingly, no differences were seen between the two groups on the recognition task; recognition performance was not impaired by intoxication due to the acute ingestion of alcohol. While the authors were unable to completely account for this finding, they suggest that intact recognition performance may be one way to distinguish between acute alcoholic amnesia and the more chronic amnesia due to long-term abuse.

Nilsson, Backman, and Karlsson (1989) compared alcohol intoxicated subjects to three other groups, young healthy controls, elderly healthy controls, and sleep deprived subjects, on both implicit and explicit memory tasks. All four groups were presented with a series of both weakly and strongly related word pairs. This was followed by tests of lexical decision and cued recall. No differences were found among the groups on the lexical decision task. In contrast, when compared to the young controls, the performance of the elderly and intoxicated subjects on weakly related cued recall was impaired. The sleep deprived subjects also performed more poorly than the young controls, but not significantly so. These findings support a dissociation between procedural and declarative memory systems. Finally, no differences were evident among the groups on the strongly related cued recall task. The authors partly attribute this finding to the varying degree of processing and retrieval effort required by each specific task. This particular interpretation may also explain the finding, described above, by Hashtroudi, Parker, DeLisi, Wyatt, and Mutter (1984) of intact recognition with impaired recall performance in acutely intoxicated subjects.

Williamsen, Johnson, and Eriksen (1965) compared subjects with post-hypnotic amnesia to control subjects on a wide variety of memory measures (recall, recognition, word association, and partial word completion). Hypnotized subjects were divided into two groups: high susceptibility

(HS) and low susceptibility (LS). While hypnotized, subjects were presented with a list of words followed by a suggestion for post-hypnotic amnesia. Both the HS and the LS subjects evidenced impaired recall performance following hypnosis when compared to the control subjects. In contrast, neither the HS nor the LS subjects differed from the control subjects on either word association or partial word identification, two implicit tests of memory. Although not defined in such terms by the authors, intact priming was evident in the hypnotized subjects. In the partial word test, for example, all subjects showed a significantly greater response to fragments of words that had been previously seen relative to new control words.

Kihlstrom (1980) also compared a test of explicit memory (recall) to tests of implicit memory (word association, Experiment 1; category-instances, Experiment 2) in post-hypnotic amnesics. In both experiments, hypnotized subjects evidenced impaired recall performance but intact implicit memory performance. Subjects in Experiment 1 were more likely to offer word associations from a list of words presented to them while hypnotized than from a list of equally viable control words. Similarly, in Experiment 2, subjects were more likely to respond with a category-instance (e.g., elephant for animal) that had been previously presented.

Memory dissociations induced by the presentation of scopolamine, a drug which is known to block the peripheral and central action of acetylcholine, have also been explored (Nissen, Knopman, & Schacter, 1987). Scopolamine has previously been shown to negatively affect explicit memory functioning (Drachman & Leavitt, 1974). Healthy subjects were subcutaneously administered either scopolamine or normal saline. Following administration, subjects were given a series of explicit memory tasks (recall, recognition, cued recall) reflecting declarative memory and implicit memory tasks (serial reaction time task within an embedded repeating sequence and word-fragment completion) reflecting procedural memory.

Results indicated that, relative to the effects of saline, scopolamine led to significantly impaired performance on all explicit tasks of declarative memory. In comparison, no differences were found in the performance of the two groups on the implicit serial reaction time task; equal levels of priming ability were found. Similarly when word-fragment completion was administered five minutes post study, both groups showed an equivalent priming effect; words which were previously studied were more likely to be completed as fragments than were new words.

When the word-fragment completion test was administered following a 60, rather than 5, minute delay, however, subjects receiving saline showed a greater priming effect than did scopolamine subjects. The authors attribute this to the possibility that performance on word-fragment completion tasks can be attributed to both implicit and explicit memory abilities. It is thus suggested that delayed word-fragment completion performance was impaired by the administration of scopolamine because of the inability of the subjects to utilize explicit procedures rather than as a result of impaired implicit memory per se (also see Schacter, 1985a).

Danion, Zimmermann, Willard-Schroeder, Grange, and Singer (1989) assessed the effects of diazepam on explicit, implicit, and knowledge memory in a double-blind study. Diazepam is a benzodiazepine known to have adverse effects on memory performance. Following oral administration of either diazepam or a placebo, subjects were presented with a word-stem completion test, a free recall test, and a category-generation task in which subjects were required to name as many instances of two general categories as possible. Diazepam was found to have no effect on the performance of subjects on word-stem completion or category-generation. Performance on free recall, on the other hand, was significantly impaired by diazepam administration.

The effects of lorazepam, another benzodiazepine, on procedural and declarative memory have also been studied (Brown, Brown, & Bowes, 1989). Lorazepam produces a clinical state that mimics amnesia. In a series of experiments, subjects received either lorazepam or placebo.

In Experiment 1, four tasks were administered: implicit word-stem completion, implicit word generation, explicit recognition presented in the context of the implicit task, and explicit recognition of an independent word list. Experiment 2 replicated a more standard paradigm and consisted of a word-stem completion test and a recognition test. The results of this study are both interesting and unexpected. When compared to the placebo group, the lorazepam group was significantly impaired in the implicit tasks of memory. In contrast, although lorazepam subjects were also impaired on recognition relative to the placebo group, the performance of the lorazepam subjects was greater than chance.

The authors compare these findings to the results of studies with organic amnesic patients and highlight the emergence of a double dissociation. While lorazepam amnesia leads to impaired implicit and intact (at least relative to chance performance) explicit memory, organic amnesia leads to intact implicit memory with impaired explicit memory. The finding of this double dissociation convincingly supports the dissociation between declarative and procedural memory systems.

Memory dissociations have also been studied in patients with amnesia due to ECT treatment. Graf, Squire, and Mandler (1984) compared memory functioning in a group of depressed patients undergoing a course of ECT treatment to a group of depressed controls. ECT patients were tested between 45 and 90 minutes following their fourth or fifth treatment. Subjects were presented with a list of words and required to either rate the words on a scale of liking or to determine if each successive pair of words shared any vowels. Subsequent to this study phase, subjects were given a free recall task followed by a word-fragment completion test. While ECT subjects were impaired relative to the controls on free recall, no differences were seen on the word-fragment completion test. This conclusion was further supported by Squire, Shimamura, and Graf (1985) who found equivalent results in ECT patients when comparing word-fragment completion performance to recognition performance.

Dissociations between procedural and declarative memory have also been explored in patients with multiple personality disorder. Nissen, Ross, Willingham, Mackenzie, and Schacter (1988) studied a 45-year-old woman with 22 different personalities. The majority of personalities were all unaware of the other personalities and had no overt memory of their experiences. A series of explicit and implicit memory tasks were administered to the subject. In all cases, the study phase was presented to one personality while the test phase was administered to an alternate personality. Performance on tests of explicit memory was impaired. Both cued recall and recognition tasks were failed by one personality when the initial target material had been presented to an alternate personality. In contrast, performance on the majority of implicit memory measures was intact, suggesting that there was access across personalities. Among other tasks, perceptual identification, word-fragment completion, and sequence learning in a serial reaction time task all revealed unimpaired priming ability. Thus, a clear dissociation emerged among memory tasks in this multiple personality disorder patient.

Subject Performance

The fourth general area supporting the concept of multiple memory systems is actual subject performance. The finding of differences in performance in distinct tasks of memory within a single group is a powerful indicator of the existence of multiple, dissociable memory systems. To date, dissociations of memory have been studied in a number of subjects, most notably amnesic patients and healthy controls, and, to a lesser extent, demented subjects.

Amnesic Subjects

Memory dissociations have been examined in a wide variety of amnesic groups. The majority of studies in this area have used Korsakoff patients. However, a number of other amnesic patients of differing etiologies have been assessed, including patients with amnesia due to encephalitis (Brooks & Baddeley, 1976; Cermak, Blackford, O'Connor, & Bleich, 1988), closed head injury (Mutter, Howard, Howard, & Wiggs, 1990), aneurysm (Corkin, 1982), ECT treatments (Graf, Squire, & Mandler, 1984; Squire, Shimamura, & Graf, 1985), tumor (Graf & Schacter, 1985), anoxia (Moscovitch, 1982b), and temporal lobe resection (Cohen & Corkin, 1981).

By definition, patients presenting with any form of amnesic disorder are viewed as evidencing impaired "memory." This is clearly the case when these patients are assessed with standard explicit memory tasks. However, recent examination of memory functioning in amnesic populations has generated evidence suggesting that not all aspects of memory performance are impaired.

Amnesic patients were initially shown to evidence intact skill learning ability. Some of the tasks on which these patients are unimpaired include, but are not limited to, identifying Gollin Figures (Milner, Corkin, & Teuber, 1968), solving jigsaw puzzles (Brooks & Baddeley, 1976), solving the Tower of Hanoi puzzle (Cohen & Corkin, 1981; Cohen, Eichenbaum, Deacedo, & Corkin, 1985), reading inverted text (Cohen & Squire, 1980; Martone, Butters, Payne, Becker, & Sax, 1984), generating category exemplars (Graf, Shimamura, & Squire, 1985), utilizing a new arithmetic rule (Kinsbourne & Wood, 1975), playing new songs on the piano (Starr & Phillips, 1970), identifying fragmented pictures (Nissen, Cohen, & Corkin, 1981), generating idioms in a word association task (Schacter, 1985b), producing common associates after exposure to related word pairs (Shimamura & Squire, 1984), and spelling homophones (Jacoby & Witherspoon, 1982).

In the tasks listed, amnesic patients reliably reveal savings in performance across repeated exposure to the measures. In contrast, when tested with procedures which require awareness on the part of the patient (i.e., explicit memory tasks), impairment is obvious and severe. In fact, some patients may not recall the study session at all while still showing an improvement in performance after repeated experience.

More recently, amnesic patients have been shown to exhibit intact memory when assessed with priming procedures. This result has been found with a variety of implicit memory tasks including word-stem completion (Graf, Shimamura, & Squire, 1985; Graf, Squire, & Mandler, 1984; Squire, Shimamura, & Graf, 1985; Warrington & Weiskrantz, 1970), lexical decision (Glass & Butters, 1985; Moscovitch, 1982a, 1982b; Verfaellie, Cermak, Blackford, & Weiss, 1990), perceptual threshold measurement (Cermak, Blackford, O'Connor, & Bleich, 1988; Cermak, Talbot, Chandler, & Wolbarst, 1985), perceptual identification (Murrell & Morton, 1974), paired-associate learning (Diamond & Rozin, 1984; Shimamura & Squire, 1984; Winocur & Weiskrantz, 1976), degraded stimuli (Warrington & Weiskrantz, 1968, 1970), word-stem completion in paired associates (Cermak, Blackford, O'Connor, & Bleich, 1988; Graf & Schacter, 1985; Mutter, Howard, Howard, & Wiggs, 1990; Schacter & Graf, 1986), fictional-statement memory (Schacter, Harbluck, & McLachlan, 1984), and sentence puzzles (McAndrews, Glisky, & Schacter, 1987).

In all of these studies, amnesics evidenced intact procedural memory but impaired declarative memory as measured by recognition, free recall, and/or cued recall. In one of the early studies, for example, Warrington and Weiskrantz (1970) presented amnesic and control subjects with a list of words. Memory was subsequently assessed under four conditions: free recall, recognition, degraded presentation and word-stem completion. In the degraded presentation task, subjects were presented with stimuli which were physically fragmented to a certain degree (i.e., parts of each letter were physically missing). Results indicate that while the amnesic subjects were impaired relative to the control subjects on explicit memory tasks (recall and recognition), there was no difference among the groups in implicit memory performance (degraded presentation and word-stem completion).

Graf, Squire, and Mandler (1984) presented both control and amnesic subjects with a list of study words. Following this, subjects were presented with a series of three letter word-stems, some of which when complete had been previously presented as study words. Subjects were instructed either to use the stems as cues to recall the study list words (cued recall, explicit memory task) or simply instructed to generate the first word that came to mind which completed the stem (word-stem completion, implicit memory task). It should be noted that these two tasks are identical except for the instructions. Subjects were also administered a free recall task.

Results revealed a dissociation in performance on the memory tasks. Both the control and the amnesic groups exhibited intact performance on the implicit memory task. The controls, however, performed significantly better than the amnesics on cued recall and free recall, both explicit memory measures.

Cermak, Talbot, Chandler, and Wolbarst (1985) presented a list of study words to Korsakoff patients and to alcoholic controls. Subjects were then presented with a perceptual threshold measurement task (implicit) and a standard recognition test (explicit). While the amnesic patients exhibited poor performance on the recognition task, their performance on the perceptual threshold measurement task was relatively unimpaired.

In summary, many investigations have found a dissociation between procedural memory (as assessed by implicit memory tasks) and declarative memory (as assessed by explicit memory tasks) in amnesic populations. This dissociation is evident in a wide variety of patient types (e.g., Korsakoff patients, ECT patients) and across a wide variety of different implicit (e.g., word-stem completion, word-fragment completion, perceptual identification) and explicit (e.g., cued recall, free recall, recognition) tasks.

Control Subjects

Procedural and declarative memory systems have been examined in non-amnesic, control subjects as well. Not surprisingly, healthy young adults evidence unimpaired priming ability as assessed by a variety of implicit memory tasks including perceptual identification (Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982; Murrell & Morton, 1974), perceptual threshold measurement (Morton, 1979; Neisser, 1954; Rouse & Verinis, 1962; Winnick & Daniel, 1970), lexical decision (Forbach, Stanners, & Hochhaus, 1974; Kirsner & Smith, 1974; McKoon & Ratcliff, 1979; Meyer & Schvaneveldt, 1971, 1976; Neely, 1976; Scarborough, Cortese, & Scarborough, 1977; Swinney, Onifer, Prather, & Hirshkowitz, 1979), word-fragment completion (Light, Singh, & Capps, 1986; Tulving, Schacter, & Stark, 1982), newly formed paired-associates (Graf & Schacter, 1987), word-stem completion (Graf & Mandler, 1984; Graf, Mandler, & Haden, 1982; Light & Singh, 1987), word association (Clifton, 1966), sentence repetition (Collins & Quillian, 1970), category cuing (Loftus, 1973), attitudinal enhancement (Wilson, 1979), generation of category exemplars (Light &

Albertson, 1989), picture naming (Mitchell & Brown, 1988), degraded stimuli (Hashtroudi, Ferguson, Rappold, & Chrosniak, 1988), reading speed (Masson, 1984), and perceptual priming of novel visual stimuli (Musen & Treisman, 1990).

At least two studies (Carroll, Byrne, & Kirsner, 1985; Parkin & Streete, 1988) have also shown that priming ability is evident in young children as well, even as early as age 3. Carroll et al. assessed priming in children ages 5, 7, and 10 years. Following the presentation of a series of target pictures, subjects saw another series of both old and new pictures on a screen and were required to name them as quickly as possible. Results indicate that subjects exhibited a facilitative effect of priming; previously seen stimuli were named faster than new stimuli. In a separate experiment, after the initial study presentation, tachistoscopic identification was measured for both old and new pictures. Again, subjects exhibited priming; more previously seen than new words were identified at the predetermined exposure duration.

Parkin and Streete (1988) presented three groups of children (ages 3, 5, and 7 years) and one group of adults with a series of incomplete (i.e., physically degraded) pictures of common objects. Subjects were subsequently presented with less degraded pictures until the object was correctly identified. Following this study phase, at either a one hour or a two week delay, subjects were again presented with a picture completion task containing equal numbers of both new and previously seen pictures. At the same time, subjects were also administered a test of recognition memory.

The data indicate that at all ages, a facilitative effect of priming was found following both delays. In contrast, while all four subject groups performed accurately on the recognition task after the one hour delay, the 3-year olds' recognition memory was impaired following the two week delay. This suggests that while children appear to have significant procedural memory functions as early as age three, declarative memory capacity is not fully developed, leading to impaired performance on explicit memory tasks following a delay.

Recently, studies have focused on the dissociation of procedural and declarative memory in the elderly (e.g., Chiarello & Hoyer, 1988; Light & Singh, 1987; Light, Singh, & Capps, 1986). Most previous research in this area had been limited to relatively young control groups, primarily college-aged adults. Since elderly persons without pathology have been shown to evidence impaired declarative memory (e.g., Craik, 1977), it is of both theoretical and practical interest to determine if procedural memory is also compromised in elderly subjects. Such information will enable investigators to develop more accurate models of memory.

Howard, McAndrews, and Lasaga (1981) administered a lexical decision task to both young and elderly adults. All subjects were presented with two letter-strings and were required to determine if both strings were words. In some cases, the pairs were category-member associates (e.g., rain, snow) and in other cases, the pairs were descriptive-property associates (e.g., rain, wet). Following the lexical decision task, a free recall task was administered.

Results indicate that while elderly subjects performed significantly worse than young subjects on free recall, no differences were seen between the groups on lexical decision, regardless of the type of association between the letter-strings.

In a follow-up study (Howard, 1983) young and elderly subjects were administered a lexical decision task in which one of two items presented to the subject was a category name and the other item was an exemplar. The dominance of the exemplar varied across trials (high dominance = bird, robin; low dominance = bird, duck). A free recall task was also administered.

Once again, although no differences were found between the groups on lexical decision, regardless of the level of dominance of the word pairs, young subjects significantly outperformed elderly subjects on free recall. Similar results were also found in three additional studies assessing lexical decision performance in young and elderly adults (Burke, White, & Diaz, 1987; Cerella & Forzard, 1984; Moscovitch, 1982b).

Burke and Yee (1984) presented both young and older control subjects with a novel lexical decision task. Subjects were shown a series of sentences followed by a related word, an unrelated word, or a nonword. Subjects were required to make a speeded lexical decision as to whether or not the letters following the sentence were a word. Three types of related words were presented: (a) words related to the episode described in the sentence, (b) words that were instruments implied by the action of the sentence, and (c) words related to a single word in the sentence. Subjects also received a test of recognition memory.

The data indicate that age had no effect on lexical decision ability. Priming was evident only in the instrument condition and was present to the same degree in both age groups. In contrast, the older subjects were impaired relative to the young subjects on the test of recognition memory.

Light, Singh, and Capps (1986) assessed procedural and declarative memory in both young and elderly healthy adults. Subjects were presented with 40 words to study and subsequently tested on the words with both a yes/no recognition test and a word-fragment completion test.

Memory was assessed at two points: immediately following study and after a seven-day delay. Results indicate that while age of subject had a significant impact on recognition performance, with young subjects performing better than elderly subjects, age had no effect on word-completion performance. After a seven-day delay, performance accuracy decreased for both tasks in both groups. The results of this study suggest that, like amnesics, healthy elderly subjects show impairment on explicit tasks of memory but evidence intact performance on implicit memory tasks.

The effects of aging on the priming of newly learned associations has also been explored (Howard, Heisey, & Shaw, 1986). Both young and elderly adults were presented with a series of sentences in the form of NOUN 1-VERB-NOUN 2 (e.g., the spider consumed the stew). A cued recall and an item-recognition priming task followed. In the priming task, subjects saw a series of nouns and were required to determine if they had been presented within the study sentences. On primed trials, two nouns from the same sentence were tested consecutively (e.g., stew followed spider). The number of target item presentations as well as the number and order of the memory tests varied. Data indicate that while the young outperformed the elderly on cued recall, both groups showed equivalent priming when tested following the two-presentation condition.

Light and Singh (1987) conducted a series of three experiments focusing on memory dissociation in normal aging. The performances of both young and elderly adults were compared on recall and recognition, and on word-stem completion (Experiment 1) or degraded stimuli (Experiment 3). Subjects were presented with 20 words and required either to rate the pleasantness of each word on a seven-point scale (elaborative processing) or to determine if the word presented shared any vowels with the previous item (non-elaborative processing).

In Experiment 2, young and elderly subjects rated a list of 20 words for pleasantness. Half of the subjects in each group then performed a word-stem completion task while the other half performed a cued-recall task. The procedure of each task was identical; only the instructions given to the subjects varied. In cued-recall, subjects were told to use the word-stems as cues to recall the previously presented target words (declarative memory). In word-stem completion, subjects were simply told to complete each item with the first word that came to mind (procedural memory). In addition, both groups subsequently received a recognition test.

In all three experiments, performance on implicit memory tasks (word-stem completion and degraded stimuli) did not vary as a function of age of subject or type of processing. However, young adults performed significantly better than the elderly subjects on the explicit memory tasks (recall, recognition, and cued recall) which followed elaborative processing at encoding. When words were studied under non-elaborative conditions, individual elderly subjects actually performed significantly better than or at least equal to the young adults on some measures of declarative memory (e.g., recognition).

Light and Albertson (1989) compared the performance of both young and older adults on an implicit memory test involving generation of category members in a controlled word association task and an explicit memory task involving cued recall. Subjects were initially presented with a list of words and required to rate each item for pleasantness. Embedded in the list were a series of exemplars from a number of categories. Following this, subjects were administered the implicit generation task, which required subjects to generate members from a series of categories (some of which had been previously represented on the study list), and the explicit cued recall task, which simply required that the subjects attempt to recall the initial study list with category names serving as cues.

Results of this study support the existence of a memory dissociation in normal aging. The data indicate that there were no significant differences in performance on the implicit generation task as a function of age: both young and older adults showed equivalent evidence of priming. In contrast the older adults were impaired on the explicit, cued recall task in comparison to the young subjects.

Mitchell, Brown, and Murphy (1990) studied the effects of both age and delay on procedural and declarative memory. Young and older adults were presented with a series of line drawings of common objects. Subjects were then administered a picture naming task followed by a test of recognition. In the picture naming task subjects were required to name as quickly as possible a group of pictures, half of which had been previously presented. This memory assessment was completed at one of four possible intervals: immediately or after a delay of one day, one week, or three weeks.

Following a delay of at least 24 hours, picture naming performance was stable while recognition performance began to decline. More importantly, while the older cohort evidenced impaired recognition ability compared to the young subjects, no differences were evident between the groups on picture naming.

In a comprehensive study addressing the concept of multiple memory systems, Mitchell (1989) administered 11 different memory tasks to young and older healthy adults. Three forms of memory were assessed based on Tulving's (1985) tertiary concept of the memory system: episodic memory (e.g., free recall, recognition), semantic memory (e.g., vocabulary test, picture naming errors), and procedural memory (e.g., repetition priming). All tasks were presented in the context of a picture naming test and were administered within-subject in a fixed-order format.

Results were highly consistent. While the older adults performed significantly more poorly than the young adults on all episodic tasks, no differences emerged as a function of age on either the semantic or the procedural tasks. Thus a clear dissociation in memory ability as a function of age emerged. In addition, a factor analysis applied to the 11 memory tasks revealed three distinct factors, further supporting the concept of a multiple memory system.

Results from the investigations described above suggest that the memory dissociation evident in amnesic populations can also be seen in normal aging. These studies indicate that, compared to healthy young adults, healthy elderly subjects perform significantly worse on explicit tasks of memory while performing equally as well on implicit memory measures.

However, results from two studies suggest that this conclusion may not always be valid. Chiarello and Hoyer (1988) presented a series of words to both young and elderly adults. Immediately following presentation, subjects were administered either a word-stem completion task or a cued recall task. After delays of 13 and 46 minutes, subjects were again administered the same memory task. Results indicate that at all test delays, the elderly adults performed significantly more poorly than the young adults on both implicit and explicit tasks.

Rose, Yesavage, Hill, and Bower (1986) administered a test of general information to both young and elderly adults. Embedded within this test was a series of less frequent units from a group of homophonic word pairs (e.g., write versus right). This presentation was followed by a spelling test (implicit task) in which subjects were presented with a word from a homophonic word pair and required to give one spelling. A test of recognition memory was subsequently administered. Unexpectedly, the data indicate that while homophones were more correctly recognized than nonhomophones by both groups, only the young adult subjects evidenced a significant priming effect.

One possible explanation for these results is the difference between the young and the elderly subjects in terms of education; the elderly subjects had significantly higher levels of education as well as higher vocabulary scores than did their younger counterparts. Possibly as a result of their greater education, the elderly subjects in the present experiment used the less frequent spelling on non-primed homophones more often than the younger subjects, thus effectively eliminating the priming effect. Had the two groups been more closely matched for education, this effect may have disappeared.

In summary, most research into memory dissociations in elderly control subjects suggests that while elderly adults show impairment on explicit memory tasks relative to young controls, their performance on implicit memory tasks is largely intact.

Alzheimer's Disease Subjects

While the dissociation among systems of memory has been repeatedly supported in both amnesic and healthy, elderly subjects, the existence of such a dissociation has not yet been firmly established in dementia. As stated previously, although dementia shares with the amnesic disorders both cognitive and anatomical characteristics, only limited research has addressed the possibility of a memory dissociation in demented populations. Dementia is a disorder characterized by a gradual, progressive deterioration in cognitive, social, and intellectual functioning. The majority of cases of dementia appear to be caused by Alzheimer's disease (AD) (Terry & Katzman, 1983). A number of cognitive features, in addition to memory impairment, are prominent in AD (Coblentz, Mattis, Zingesser, Kasoff, Wisniewski, & Katzman, 1973). There is a progressive decline in intellectual functioning (Botwinick & Birren, 1951). A defect in both abstract thinking and judgment is evidenced (Thal, 1988). Perceptual deficits can appear and are characterized by visual-spatial relation defects (Thal, 1988) as well as difficulties in route finding. Deficits in verbal fluency (Rosen & Mohs, 1982) and word finding (Nebes, 1989) are also evident.

Behavioral, emotional, and psychiatric changes can occur in AD (Lipowski, 1978). There is often an accentuation of premorbid personality traits or the development of new personality characteristics (Miller, 1977). An apathetic attitude may be evidenced (Burns, Jacoby, & Levy, 1990a; Miller, 1977). Depression (Burns, Jacoby, & Levy, 1990b; Kaszniak, Wilson, Lazarus, Lessor, & Fox, 1981; Rosen & Zubenko, 1991) or aggression (Burns, Jacoby, & Levy, 1990a) can be seen. Hallucinations (Burns, Jacoby, & Levy, 1990c; Rosen & Zubenko, 1991) and delusions (Burns, Jacoby, & Levy, 1990d; Rosen & Zubenko, 1991) are evident in a small percentage of AD patients. In addition, paranoia and suspiciousness may develop as a result of the memory loss (Thal, 1988).

As the disorder progresses, aphasic, apraxic and agnosic syndromes may appear (Coblentz, Mattis, Zingesser, Kasoff, Wisniewski, & Katzman, 1973). Eventually, AD results in profound intellectual deterioration, rigidity, incontinence and immobility (Burns, Jacoby, & Levy, 1990a). Gross neurological signs and reflexes (e.g., the snout and grasp reflexes) eventually emerge.

There are four primary neuropathological changes associated with AD which distinguish it from normal aging. (a) Dramatic pyramidal cell loss is found throughout the hippocampal complex. (b) Neurofibrillary tangles, large bundles of neurofilaments twisted into the form of a double-helix, are found in greater number in both cortical and hippocampal regions (Tomlinson, 1977). (c) Neuritic plaques, patches of degenerating neuronal processes surrounded by a fibrillary or granular zone and containing a central core of amyloid, form in the cortex and in subcortical structures as well (Tomlinson, 1977). It appears that the severity of the cognitive impairment is related to the quantity of plaques and tangles found (Blessed, Tomlinson, & Roth, 1968; Perry, Tomlinson, Blessed, Bergmann, Gibson, & Perry, 1978). (d) Granulovacular degeneration occurs primarily in the pyramidal cells of the hippocampus and subiculum and is a result of argyrophilic granule within the processes of degenerating neurons (Tomlinson, 1977; Tomlinson, Blessed, & Roth, 1970).

Investigations in a variety of areas have collectively led to the development of what has been termed the "cholinergic hypothesis." Simply stated, the cholinergic hypothesis asserts that the decline in memory and cognitive functions occurring in demented patients is directly associated with functional disturbances of the cholinergic system.

According to Davies (1985), findings from three specific areas of research have lent support to this theory. First, research has indicated that certain anticholinergic agents, such as scopolamine, lead to significant deficits in memory functioning when administered to healthy volunteer subjects (e.g., Drachman & Leavitt, 1974; Kopelman & Corn, 1988).

Second, studies investigating the biochemical aspects of dementia have indicated that the most dramatic biochemical change associated with AD involves the cholinergic system (e.g., Davies & Maloney, 1976). Choline acetyltransferase and acetylcholinesterase may be reduced by as much as 90% within the hippocampus, mid-temporal gyrus and parietal cortex (Perry, Tomlinson, Blessed, Bergmann, Gibson, & Perry, 1978). A less dramatic loss is seen in other regions as well. Further, deficiency in choline acetyltransferase activity has been correlated with decline in cognitive functioning (Fuld, Katzman, Davies, & Terry, 1982) and with increased plaque count (Perry, Tomlinson, Blessed, Bergmann, Gibson, & Perry, 1978).

Third, the administration of certain cholinergic agonists, such as physostigmine, appears to lead to reliable, albeit mild, increases in cognitive functioning (Davis, Mohs, Rosen, Greenwald, Levy, & Horvath, 1983; Peters & Levin, 1979; Thal, Fuld, Masur, & Sharpless, 1983). Taken together, these lines of evidence suggest an important role for the cholinergic system in the development of cognitive impairment in dementia.

A number of investigators have recently highlighted the importance of amyloid in the development of AD. Beta-amyloid precursor protein (Beta-APP), a 695-amino-acid molecule that anchors itself to cell membranes via amino acids 625 through 648, is found in the normal brain. In AD, an abnormal 42-amino-acid protein, amyloid beta-protein, is also found (Kang, Lemaise, Unterbeck, Salbaum, Masters, Grzeschik, Multhaup, Beyreuther, & Muller-Hill, 1987). This protein is cleaved from the Beta-APP between amino-acids 597 through 638, the 28 amino-acids just outside the cell membrane and the initial 14 amino-acids within the membrane.

The gene for Beta-APP has been found to be located on chromosome 21 (Kang, Lemaise, Unterbeck, Salbaum, Masters, Grzeschik, Multhaup, Beyreuther, & Muller-Hill, 1987), also known to be associated with Down's syndrome (with an extra 21st chromosome and brain lesions typically seen in AD) and familial Alzheimer's disease (FAD; a form of AD in which a clear genetic transmission is evident). This finding has served to strengthen the relationship between AD and the amyloid-beta protein.

Goate, Chartier-Harlin, Mullan, Brown, Crawford, Fidani, Giuffra, Haynes, Irving, James, Mant, Newton, Rooke, Roques, Talbot, Pericak-Vance, Roses, Williamson, Rossor, Owen, and Hardy (1991) found two families with AD who had a particular DNA pattern in the Beta-APP gene (amino-acid 642 substitution from Valine to Isoleucine) and Murrell, Farlow Ghetti, and Benson (1991) found a different amino-acid substitution (Valine to Phenylalanine) at the same position in other affected families. These findings indicate that this position is integral in the development of both amyloid deposits and AD.

Selkoe (1991) speculates that this DNA mutation increases the amount of Beta-APP proteins synthesized. These proteins are further cleaved by proteases over time to release large amounts of amyloid-beta protein, which then accumulates as diffuse plaques in the brain. Eventually, amyloid beta-protein begins to have toxic and trophic effects on the surrounding cells, resulting in the transformation of the diffuse plaques into the neuritic plaques commonly associated with AD. In addition, some of the affected neurons produce neurofibrillary tangles. At the same time, a loss of synapses and a resultant decrease in cortical levels of acetylcholine occurs. In time, the individual slowly acquires the cognitive decline that is the hallmark of AD.

Clearly among the most striking cognitive deficits seen in AD is the severe impairment in memory functioning (Coblentz, Mattis, & Zingesser, 1973). Unlike other cognitive deficits (e.g., language, abstract thought, constructional ability) which may not be present in every stage in all patients presenting with AD, memory deficits are always evident (Thal, 1988).

Most research has focused on declarative memory in AD. When compared to healthy controls, AD patients are impaired on such explicit memory tasks as verbal free recall

(Kaszniak, Wilson, & Fox, 1981), verbal recognition memory (Miller, 1975, 1977; Wilson, Bacon, Kramer, Fox, & Kaszniak, 1983), and non-verbal recognition memory (Wilson, Kaszniak, Bacon, Fox, & Kelly, 1982). Impaired performance is also seen in tasks involving verbal paired-associate learning (Corkin, 1982; Rosen & Mohs, 1982), non-verbal paired-associate learning (Corkin, 1982), remote memory (Wilson, Kaszniak, & Fox, 1981), and immediate and delayed memory for short stories and figure drawings (Brinkman, Largen, Gerganoff, & Pomera, 1983).

It is clear that when assessed by explicit memory procedures, patients with AD are impaired in virtually all aspects of memory functioning (Morris & Kopelman, 1986). The degree of memory impairment associated with AD when patients are assessed with implicit memory procedures is less clear, however. As stated earlier, the focus of previous research on dissociations between declarative and procedural memory has been primarily directed to non-demented amnesic populations. With the existence of such a dissociation well-established in amnesic patients, the present study will question whether a similar dissociation may be found in AD patients.

The possibility that parallel memory dissociations will be found in the two groups (Corkin, 1982; Miller, 1975) is strengthened by the fact that certain amnesic disorders (e.g., Korsakoff's syndrome) and certain dementing disorders (e.g., AD) share in part anatomical and neurochemical etiology. Anatomically, damage to and isolation of the hippocampal complex has been linked to patients with certain forms of both dementia (Hyman, Van Hoesen, Damasio, & Barnes, 1984; Tomlinson, 1977) and amnesia (Butters & Cermak, 1975). A significant reduction in the quantity of neurons in the basal forebrain structures (i.e., nucleus basalis of Meynert, medial septal nuclei, diagonal band of Broca) has been found in both AD and Korsakoff patients (Arendt, Bigl, Arendt, & Tennstedt, 1983). Basal forebrain structures are responsible for the cholinergic input to the hippocampus and to the association cortex. A deficiency in the number of neurons in such structures might mediate a reduction in the cholinergic system in both Korsakoff and AD patients, thus connecting the disorders neurochemically as well.

There is also evidence that dementia and amnesia share common symptoms. Huppert and Piercy (1976), for example, examined the effect of word frequency on verbal recognition memory in patients with Korsakoff's amnesia. Patients were presented with a list consisting of both high and low frequency words and were subsequently administered a recognition test. Data were examined for both hit rate (proportion of target stimuli correctly identified) and false alarm rate (proportion of distractor stimuli incorrectly identified as previously viewed). In healthy controls, hit rates are generally found to be higher for low frequency words while false alarms are higher for high frequency words. In contrast, Huppert and Piercy found that Korsakoff patients evidence both a higher hit rate and a higher proportion of false alarms for high frequency words.

In a similar study, Wilson, Bacon, Kramer, Fox, and Kaszniak (1983) examined the effect of word frequency on verbal recognition memory in patients presenting with AD. Subjects were also administered a recognition task following the presentation of a list of both high and low frequency words. In this study, AD patients evidenced a higher proportion of false alarms and a higher hit rate for high frequency words. When compared with the results of Huppert and Piercy (1976), these studies indicate that AD patients perform equivalently to Korsakoff patients. In contrast to healthy controls, both patient groups show a higher hit rate for high rather than low frequency words. All three groups (AD, Korsakoff, control) evidence a greater tendency to produce false alarms to high frequency words.

A direct comparison between Korsakoff and AD patients was made by Kopelman (1985) who compared both groups to healthy controls on a test of visual recognition memory. Borrowing a technique developed by Huppert and Piercy (1978; 1979), Kopelman presented subjects with a series of photographs of objects and administered an immediate test of recognition. The initial exposure duration of each photograph was varied for each subject, however, so that all subjects met a specified criterion for initial recognition performance (70-80% correct). In doing so, all subjects were equated for initial performance. Subjects were then administered repeated recognition tasks at delays of 24 hours and 1 week. Data indicate that both AD and Korsakoff patients showed equal rates of forgetting, neither of which differed from the forgetting rates of the controls. This result implies that both patient groups exhibited an encoding or acquisition deficit rather than an impairment due to an abnormal accelerated rate of forgetting.

Additional similarities in symptomatology were found in a study comparing AD and Korsakoff patients on tests of episodic and semantic memory (Butters, Granholm, Salmon, Grant, & Wolfe, 1987). Three additional subject groups, Huntington's patients, elderly controls, and young controls, were also assessed. All subjects were administered a memory for passages test (episodic memory) and two verbal-fluency tasks (semantic memory). Results indicate that the AD and the Korsakoff patients' performances were identical to each other and distinguishable from the other subject groups by the appearance of significant perseverative and intrusion errors.

Although, as previously stated, most research has focused on declarative memory functioning, a number of studies have addressed procedural memory ability in AD. The results of studies completed to date, however, are somewhat inconsistent, ambiguous and contradictory (Nebes, 1989).

In an early study, Miller (1975) presented a list of words three times to 16 patients with presenile dementia and to age-matched controls. Subjects were instructed to try to remember the words. Following a distractor task, subjects were then presented with the following four memory tasks in counterbalanced order: free recall, recognition in which each study word was paired with a new word, recognition in which the studied words were mixed with new words, and partial information in which the initial letter of each studied word was shown (cued recall).

Results indicate that on recall and both recognition tasks, the performance of the control group was superior to the performance of the patient group. No performance difference was apparent, however, on the partial information task. Furthermore, performance of the patients on partial information was significantly better than their performance on free recall. This was not true in the control group.

It is important to note, however, that all four tasks presented to the subjects in this experiment are explicit in nature. Subjects were instructed to attempt to remember the words upon presentation and, in all cases, were aware that their memory was being assessed during each task. Even the partial information measure, on which the patients evidenced unimpaired performance, was not implicit in nature.

Morris, Wheatley, and Britton (1983) extended Miller's (1975) paradigm to include a group of senile dementia patients. The investigators presented a list of words to ten patients with mild to moderate senile dementia and to ten healthy controls. The subjects were subsequently administered a yes/no recognition task for half of the target words and a partial information, cued recall task for the remaining target words. The results were comparable to Miller's. While the patients were impaired on the recognition task, no differences were found between patients and controls on cued recall. Again it should be noted that both tasks used were explicit in nature, as subjects were aware that their memory was being assessed.

While no direct conclusions can be drawn with respect to memory dissociations from these two early studies, they do suggest that there are certain measures which reveal intact memory functioning in both presenile and senile dementia patients. Despite this finding, further research in memory on AD was generally limited to uncovering those memory functions which were impaired in the disorder.

The first group of studies specifically assessing memory dissociations in non-amnesic, memory disordered populations tended to utilize groups of subjects presenting with differing etiologies. For example, Moscovitch (1982b) conducted two experiments exploring performance differences on implicit and explicit memory tasks. In Experiment 1 recognition and reading speed were assessed in four groups: college students, noninstitutionalized older college alumni, institutionalized elderly subjects, and four memory disordered patients. Only three of the memory disordered patients, however, presented with early AD. One subject's disorder was attributed to anoxia. Results indicate that while the recognition performance of the memory disordered group was impaired (i.e., at chance) relative to, for example, the noninstitutionalized elderly, no differences in reading speed performance was found between the same two groups.

In Experiment 2 Moscovitch (1982b) administered a lexical decision task and a recognition test to the same subject groups. Results mirrored those of Experiment 1. The memory disordered subjects (three out of four with AD) were greatly impaired on recognition but were unimpaired on the lexical decision task, thus evidencing intact direct priming.

Further support for a memory dissociation in non-amnesic, memory disordered subjects was found by Moscovitch, Winocur, and McLachlan (1986) who administered a series of implicit and explicit memory tasks to a variety of subject groups. In Experiment 1 young adults, home-dwelling elderly adults, institutionalized elderly adults, and memory-disordered adults participated. Three of the eight memory-impaired patients presented with mild AD. The remaining five subjects in the group presented with memory disorders of varying etiologies.

Subjects were presented with normal and with geometrically transformed sentences to read. Their reading speed was assessed at three points: immediately, two hours later, and between 4 and 14 days later. Recognition was assessed at both delay periods. Recognition was found to be accurate in both young and home-dwelling elderly subjects at all assessment points. Recognition performance in the institutionalized elderly was accurate at immediate and two-hour delayed assessment. Memory-disordered subjects showed impaired recognition performance at all points. On the other hand, all four groups read the sentences at a faster rate across the three assessment points. Thus, in the memory-impaired group (which included AD patients), implicit memory performance was intact while recognition was not.

In Experiment 2 subjects consisted of 12 young adults, 12 elderly home-dwelling adults, and 8 memory impaired adults, 6 with AD. Subjects were presented with sentences and weakly associated word pairs. Immediately following this, both reading speed and recognition of original, new, and recombined stimuli were assessed. Results of this experiment mirror the results of Experiment 1. The young and the healthy elderly subjects evidenced intact recognition. The memory-impaired subjects, in contrast, were unable to distinguish old from new and recombined items on the recognition task. All three groups, however, read old items faster than new or recombined items, an indication of intact procedural memory.

Diamond and Rozin (1984) administered a series of paired-associate tasks to both memory disordered (four demented, two Korsakoff) and non-memory disordered (six hospitalized non-amnesic) subjects. In one task, subjects were presented with a list of disyllabic familiar words (e.g., per-son). They were subsequently administered both free recall and cued recall tasks. On free recall, the performance of the memory-disordered subjects was impaired relative to the control group. However, the memory-impaired group gave many more correct responses in the cued recall task.

Results of these studies (Diamond & Rozin, 1984; Moscovitch, 1982b; Moscovitch, Winocur, & McLachlan, 1986) suggest that patients presenting with AD exhibit a dissociation in performance between implicit and explicit memory tasks. However, conclusions based on these studies can only be tentative as the memory disordered groups were not completely composed of AD patients.

Although not intending to directly address the issue of dissociations between procedural and declarative memory, Nebes, Martin, and Horn (1984) were among the first group of investigators to clearly reveal a dissociation among memory systems in AD. They compared the performance of 20 AD patients and 20 elderly subjects on both episodic and semantic memory tasks. According to Tulving (1972), episodic and semantic memory can be viewed as two distinct but parallel forms of memory. Episodic memory is a record of contextually-bound, personally-experienced events. The temporal and spatial aspects of the event are themselves a part of the remembered information (e.g., when did event "a" occur, what happened prior to and subsequent to event "a", etc.). In general, information stored in episodic memory takes the form of: I did such and such, at such and such a time, in such and such a place. A more specific example would be seeing the word "dog" on a list of twenty words and remembering its presence there.

Semantic memory, in contrast, is a representation of more abstract concepts. It is a context-free record of facts, symbols, knowledge, procedures, and rules. None of the information encoded in semantic memory is connected to a particular event or time but instead represents general cognitive referents. An example of the type of information stored within semantic memory would be the fact that a dog is a four-legged, furry animal.

Nebes, Martin, and Horn (1984) note that most previous research has utilized episodic memory tasks which require effortful processing, or the dependence upon attentional capacity to use semantic information. They hypothesized that by using tasks requiring only automatic processing, which does not require conscious awareness, a purer assessment of semantic memory ability would be obtained.

Subjects were administered a perceptual threshold measurement task to assess semantic memory and both recognition and free recall tasks to measure episodic memory. The explicit memory tasks (recall and recognition) used to assess episodic memory in this study are also measures of declarative memory. The automatic processing task (paired perceptual threshold) used to evaluate semantic memory is an implicit priming task that can also be used to assess procedural memory.

Eighty words were presented to subjects using a tachistoscope. Although presented serially, the words were actually composed of one word of a pair followed by the other. Half of the pairs were semantically related (e.g., doctor-nurse) and half were unrelated (e.g., pepper-goat). Subjects were required to identify each word after presentation. The time required to identify the second word of each pair was compared for words which followed either a semantically related or a semantically unrelated stimulus. Intact priming would be reflected in a decrease in the time required to identify words which followed semantically related stimuli. Following the priming task, subjects were tested with free recall and recognition for all words.

A significant facilitative effect of priming was evidenced by 85% (17/20) of the AD patients and 90% (18/20) of the controls. In other words, these subjects more quickly identified words which followed semantically associated stimuli than words which followed unrelated items. In contrast, normal elderly subjects performed significantly better than the AD patients on both free recall and recognition. Therefore, while AD patients were impaired in episodic memory tasks as expected, when assessed with this particular implicit measure of semantic memory, subjects with AD showed relatively intact memory ability.

This study clearly indicates that at least certain implicit tasks of memory can be successfully performed by AD patients. These findings show a dissociation between episodic and semantic memory in AD patients but further suggest a dissociation between procedural and declarative memory as well.

In a later study, Nebes, Boller, and Holland (1986) administered two types of priming tasks to 18 AD patients, 18 young controls and 18 elderly controls. In the first task, subjects were read a semantic category (e.g., bird). Following this, a word was presented visually via a tachistoscope. The subject was required to respond "yes" if the stimulus was a member of the previously stated category or "no" if the stimulus did not belong to the semantic category. On 20 trials, the word was a high-dominance example (mean frequency of occurrence per one million words was 98.2), on 20 trials the word was a low-dominance example (mean frequency of occurrence per one million words was 75.6), and on 30 trials the word did not belong to the semantic category.

Response times were found to be equally affected by dominance in both control and AD subjects. All groups responded more rapidly to high-dominance than to low-dominance stimuli. The AD patients, unlike the normal controls however, responded significantly faster when the target word was initially preceded by a related category. This can be taken as evidence for intact priming ability.

In the second task, subjects heard a series of audio-taped sentences in each of which the final word was deleted. Subjects were tachistoscopically presented with a word at the point in the tape where the final word was missing and asked to identify it as quickly as possible. Of 75 sentences, 25 were combined with a congruous word, 25 with a non-congruous word and 25 with a neutral word. In all three subject groups, words were identified significantly faster when preceded by a congruous prime than when preceded by either neutral or non-congruous primes. As in the first task, these findings are indicative of intact priming in AD patients.

In a series of experiments, Hartman (1987; 1989) administered a number of semantic memory tasks to patients presenting with AD and to age- and education-matched healthy controls. Subjects received a semantic verification task, a semantic priming task, and/or a test of recognition memory. On the semantic priming task, naming latency was measured for target stimuli which followed related, unrelated, and neutral primes. AD patients evidenced intact priming on the naming task (i.e., they had a shorter reaction time for words preceded by a related prime) and intact performance on the test of semantic verification. In contrast, the patients evidenced impaired performance on the recognition memory task.

Knopman and Nissen (1987) administered a novel implicit memory task to AD patients and to elderly control subjects as a means of studying procedural learning in these two groups. The procedure involved a visual reaction time task which required subjects to press the appropriate button when an asterisk appeared in one of four possible positions on a computer screen. Five blocks of stimuli were presented. On the first four blocks, the same 10-trial sequence was repeated ten times per block. On the fifth and final block, 100 random stimuli were presented. If procedural memory was intact, a decrease in response time from block one to block four would be expected. Concurrently, an increase in response time from block four to block five would also be predicted.

Overall, control subjects were found to respond more rapidly than AD patients to the stimuli. However, both subject groups showed a decreased reaction time from block one to block four. In addition, an increase in reaction time was evident from block four to block five in both groups. Thus, implicit memory performance was intact in both control subjects and AD patients. As an informal measure of explicit memory performance, the investigators asked the subjects if they had been aware of the repeating sequence embedded in the stimuli. Although the majority of the control subjects recognized the pattern, only one AD subject was aware of the sequence. Knopman and Nissen (1987) interpret these findings as an indication of a memory dissociation in AD; intact procedural memory (measured by the implicit memory task) with impaired declarative memory (informally assessed via post-experiment discussion).

Chertkow, Bub, and Seidenberg (1989) administered a series of measures related to semantic memory to six patients with probable AD and to ten age-matched controls. A lexical decision task was included among the tests. Target words in the procedure were preceded by an associatively related word (e.g., hammer-nail), a semantically related word (e.g., hammer-wrench), or an unassociated word (e.g., hammer-horse). All subjects exhibited intact priming. Interestingly, the AD patients actually exhibited a greater facilitative effect of priming than the age-matched controls. This effect was also found by Nebes, Brady, and Huff (1989) in another study of lexical decision performance in AD.

Partridge, Knight, and Feehan (1990) presented AD patients and healthy elderly controls with a list of words and required subjects to generate a definition for each word. Following this study phase, subjects were administered a cued recall, free recall, or word-stem completion task. Results indicate that on both cued and free recall, AD patients were significantly impaired compared to control subjects. In contrast, no differences were found between the two groups on the implicit, word-stem completion task.

Similar results were found by Grosse, Wilson, and Fox (1990) who also assessed the performance of both AD patients and control subjects on word-stem completion. In addition, subjects were administered a test of recognition memory to assess explicit task functioning. During the study phase, subjects were administered a novel orienting task. A series of incomplete sentences (e.g., "he hit the nail with a ______") were presented and subjects were required to complete each sentence with a best fit word. These words then served as target stimuli for the test phase.

The data indicate that while AD patients exhibited impaired recognition performance when compared to the controls, no differences were found between the two groups on word-stem completion: all subjects completed significantly more word-stems which had been generated in the study session than new, not studied word-stems.

Taken together, these studies suggest that, similar to amnesic patients and healthy controls, patients presenting with AD show evidence of a dissociation between memory systems. When assessed with certain implicit tasks, AD patients show relatively intact memory. When memory is assessed using explicit tasks, as has been consistently found in the past, performance of patients with AD is significantly impaired. These data are therefore consistent with the existence of a memory dissociation between procedural and declarative memory in Alzheimer's patients.

However, not all investigations support these conclusions. Other studies indicate that procedural memory can be impaired in AD patients (e.g., Shimamura, Salmon, Squire, & Butters, 1987) and that performance may be dependent upon the specific implicit task chosen (Nebes, 1989; Ober & Shenaut, 1988).

Shimamura, Salmon, Squire, and Butters (1987) administered a series of memory tasks to patients with AD of mild to moderate severity, Huntington's disease, and Korsakoff's disease. Three control groups matched for age to each patient group were also studied. The groups ranged in size from six to nine subjects.

Subjects rated a list of ten words on a scale of liking and then were administered a word-stem completion task. Subjects were also administered the 15-item Rey Auditory Verbal Learning Test which includes measures of both recall and recognition. All three patient groups were impaired on both recall and recognition relative to their respective control groups. However, of all the memory impaired populations, only the AD patients evidenced impairment on the word-stem completion task. In a similar study (Butters, 1987), the performance of AD patients was found to be impaired on verbal word-stem completion but intact on the pursuit rotor task, an alternative procedural task.

Salmon, Shimamura, Butters, and Smith (1988) attempted to replicate and advance the findings of Shimamura, Salmon, Squire, and Butters (1987) in a larger sample of subjects. They administered both implicit and explicit memory measures to patients presenting with Alzheimer's, Huntington's, or Korsakoff's disease as well as to controls. Subjects were initially presented with a list of words to rate and subsequently tested with two explicit memory tasks (recall and recognition) and two implicit memory tasks (word-stem completion in Experiment 1 and category/functional cuing in Experiment 2).

Results of Experiment 1 indicate that while all groups, including the AD patients, evidenced priming scores greater than baseline guessing rates, the AD and the Huntington's subjects evidenced impairment in word-stem completion when compared to their respective control groups. The Korsakoff's patients' performance on word-stem completion was equivalent to their controls. All three patient groups evidenced impaired recall and recognition relative to the control groups. These data replicate the findings of Shimamura, Salmon, Squire, and Butters (1987). In Experiment 2 of the study, both Huntington's and Korsakoff's disease subjects evidenced intact performance relative to the control group on the category/functional cuing task. Only the AD subjects revealed impaired performance on this implicit test of memory. As in Experiment 1, all three patient groups evidenced impaired explicit memory performance.

Ober and Shenaut (1988) presented AD patients and healthy adults with a lexical decision task. Subjects were required to determine if a string of letters was or was not a word. All target stimuli were preceded by either semantically related, phonetically (rhyming) related, or unrelated primes. In addition, target items were repeated once throughout the study. Thus, measures of both direct and indirect priming were obtained.

Data indicate that AD patients did not benefit from indirect semantic priming. Healthy adults, on the other hand, did show the expected reduction in response time in the indirect semantic priming condition. In contrast, both AD patients and healthy adults showed intact direct priming. Response time decreased in both groups upon the second presentation of the target items.

In a related study, Albert and Milberg (1989) also presented AD and control subjects with a lexical decision task. In this case, however, only indirect priming was measured. As was found by Ober and Shenaut (1988), control subjects evidenced intact indirect priming; that is, reaction time required to identify real words was shorter when those words were preceded by a related word. As a group, AD patients showed no facilitation when the target stimulus was preceded by a related word. It should be noted, however, that an interesting picture emerged when Albert and Milberg looked more closely at the performance of the AD patients. Six of the ten AD patients actually evidenced a significant facilitative priming effect, and this was even greater than the effect seen in the controls. This effect was neutralized, however, by the remaining four AD subjects who actually evidenced negative priming; their performance was better when the target stimulus followed an unrelated word than when it followed a related word. Thus, although as a group AD patients did not evidence intact indirect priming, sixty percent of the subjects did show a robust priming effect.

In an attempt to study dissociations in non-verbal memory, Heindel, Salmon, and Butters (1990) presented AD, Huntington's, and control subjects with a series of line drawings of common objects and asked subjects to name them. Subsequent to this study phase, subjects were administered a picture-fragment identification test followed by a cued recall test. The instructions of these two tasks varied but the tasks were equivalent. Subjects were presented with a series of incomplete, fragmented stimuli. In the fragment identification task, subjects were instructed to state the first thing that came to their mind upon presentation. In the cued recall task, subjects were asked to identify each object after being informed that they had seen the same drawings before, but as intact figures in the study phase. Subjects were shown a series of increasingly complete drawings until all the stimuli were correctly identified. When compared to control subjects, both AD and Huntington's patients were found to be significantly impaired on cued recall. In contrast, only the AD subjects evidenced impaired performance on the implicit, fragment identification task. Huntington's patients performed as well as the healthy controls.

The studies reviewed above do not lead to a firm conclusion with respect to implicit memory performance in AD. While in all cases AD patients are impaired on explicit memory tasks, there is evidence for both intact and impaired performance on implicit memory tasks. Of the 14 studies reviewed which limited their amnesic population to AD and strictly differentiated between implicit and explicit measures, AD patients showed intact performance on ten and impaired performance on seven tests of implicit memory measured in the studies. This is detailed in Table 1.

Table 1

Performance of AD Patients on Tasks of Implicit and Implicit Memory

	TASK	EXPLICIT	IMPLICIT
Nebes et al. (1984)	**Paired Perceptual Priming**		=
	Free Recall	-	
	Recognition	-	
Nebes et al. (1986)	**Sentence Priming**		=
	Story Recall	-	
	Paired Associates	-	
Butters (1987)	**Pursuit Rotor**		=
	Word-Stem Completion		-
Knopman et al. (1987)	**Embedded RT Test**		=
Shimamura et al. (1987)	**Word-Stem Completion**		-
	Recall	-	
	Recognition	-	
Ober et al. (1988)	**Direct Lexical Decision**		=
	Indirect Lexical Decision		-
Salmon et al. (1988)	**Word-Stem Completion**		-
	Category Cueing		-
	Recall	-	
	Recognition	-	
Albert et al. (1989)	**Indirect Lexical Decision**		-
Chertkow et al. (1989)	**Indirect Lexical Decision**		+
Hartman (1989)	**Naming Latency**		=
	Recognition	-	
Nebes et al. (1989)	**Indirect Lexical Decision**		+
Grosse et al. (1990)	**Word-Stem Completion**		=
	Recognition	-	
Heindel et al. (1990)	**Picture-Fragment Completion**		-
	Cued Recall	-	
Partridge et al. (1990)	**Word-Stem Completion**		=
	Free Recall	-	
	Cued Recall	-	

*Explicit Tasks

- : impaired performance

Implicit Tasks

- : impaired facilitation
= : normal facilitation
+ : increased facilitation

Effortful Versus Automatic Processing

One possible variable which may underlie these inconsistent findings is the degree of processing capacity required by each particular implicit task (Jorm, 1986). All cognitive processes require energy from an individual's attentional capacity, a nonspecific resource for cognitive processing (Hasher & Zacks, 1979). Cognitive operations, however, vary in the amount of cognitive effort necessary for their successful completion (Kahnemann, 1973). Operations which require effortful processing necessitate considerable cognitive capacity and demand. In contrast, operations which involve automatic processing require minimal effort and demand.

Attentional capacity is limited, however, even in healthy individuals. Tasks which require effortful processing drain energy from our limited attentional capacity and, as such, may interfere with other tasks. Automatic processing tasks, on the other hand, require significantly less attentional capacity; they do not drain energy from our attentional capacity and are thus less likely to interfere with other cognitive processes (Hasher & Zacks, 1979; Schneider & Shiffrin, 1977). This enables basic information to be encoded even as more demanding cognitive tasks are occurring.

According to Schneider and Shiffrin (1977) the process of learning may be represented on a continuum from effortful or controlled to automatic. Thus, when an individual is faced with a novel, unfamiliar task, effortful processing is initially required to successfully complete the task. Once a new association is formed and the task becomes familiar to the individual, automatic processing becomes the most effective and preferred mode of processing. For example, as a child learns to write, effortful processes are required. In time, as the child becomes a fluent writer, automatic processes are sufficient to complete the task.

Hasher and Zacks (1979) have outlined five variables essential to the concept of effortful and automatic processing: intentional versus incidental learning, practice and instructions, interference, variations in capacity, and developmental trends. (a) Intentional versus incidental learning. Effortful processing is limited to conditions where learning is voluntary and intentional. An individual is therefore always aware of such processing. Automatic processing, on the other hand, does not require such awareness. It can occur under both intentional and incidental learning conditions. (b) Practice and instructions. Effortful processing benefits from both practice and instruction. Because automatic processing occurs without awareness, neither practice nor instruction will improve processing. (c) Interference. Effortful processing requires substantial attentional capacity and will thus interfere with the effectiveness of other processing tasks. Automatic processing, on the other hand, does not interfere with other cognitive activity. (d) Variation in capacity. The capacity for effortful processing varies both between and within individuals. Variables such as stress, arousal and depression can decrease the effectiveness of effortful processing. Automatic processing, in contrast, remains unchanged across such state changes. (e) Developmental trends. Automatic processes develop and peak in efficiency earlier in development than effortful processes (see Parkin & Streete, 1988). With age, effortful processing declines whereas automatic processing remains essentially intact (Howard, 1988).

The dichotomy between effortful and automatic processing may be applicable to the area of memory dissociations. Discrepancies within this area may in part be attributable to variations in the amount of cognitive effort required by different priming tasks (Nebes, 1989). Memory tasks requiring automatic processing drain minimal energy from an individual's limited cognitive resources and may therefore be a more pure reflection of memory ability than effortful tasks. If a task requires too much effort and places too much demand on a subject's limited attentional capacity, that task may be failed. Therefore, it is plausible that a subject may exhibit impaired performance on a memory task not because of a deficit in memory ability per se, but as a result of the cognitive effort required by the task. This is true in an elderly population (Burke, White, & Diaz, 1987) and especially true in AD patients (see (e), developmental trends, above) whose cognitive impairment is so global as to often interfere with even the simplest task.

Nebes, Martin, and Horn (1984) note that most previous studies of memory have utilized episodic memory tasks which require effortful processing, or the need for attentional capacity to use semantic information. They hypothesized that by using tasks requiring only automatic processing without conscious awareness a purer assessment of semantic memory ability would be obtained. Results of their study, reviewed earlier, support this contention. Their data indicate that when the assessment task does not require a conscious decision or an effortful search, certain aspects of memory are found to be unimpaired in AD patients. The authors suggest that implicit priming tasks are automatic in nature and may thus be the assessment of choice.

It may be the case, however, that not all implicit tasks are in fact automatic but in fact can be ranked with explicit tasks along a continuum of processing demand. For example, although word-fragment completion is implicit in nature, it requires considerable cognitive effort in the form of attention, searching and analyzing, all of which are impaired in AD. Subjects must first be able to understand the demands of a task which they are not regularly confronted with. The subject needs to search for the correct answer, selecting and discarding erroneous solutions along the way. Successful completion requires lexical search and knowledge of rules of spelling and letter combinations (Witherspoon & Moscovitch, 1989). Such a procedure requires significant cognitive effort and demand.

In contrast, the requirements of the perceptual threshold measurement task, for example, are significantly less demanding; subjects must simply read each word aloud as it is flashed in their visual field. This requires less cognitive effort and, in fact, requires almost nothing but reading, an automatic processing task in the adult (Jorm, 1986). It may thus be the case that the performance of AD patients on tasks of implicit memory is to a large degree dependent upon the degree of cognitive difficulty required.

Goals of the Present Study

To summarize, a dissociation between two distinct systems of memory has been found in patients with amnesic disorders (e.g., Korsakoff patients). Declarative memory, the explicit retention of information, facts and events, is found to be impaired in amnesics when measured by explicit tasks, such as recall and recognition. In contrast, procedural memory, the implicit retention of skills, processes and procedures, is found to be spared when assessed by implicit memory tasks, such as skill learning and priming. It could be presumed that each memory system is associated with a distinct brain region with only the structures underlying declarative memory affected in amnesia.

Most research has shown that, as with amnesic patients, severe, unequivocal declarative memory deficits are found in AD patients. In contrast, while many studies have revealed intact procedural memory in amnesic samples, fewer investigations have focused on procedural memory in AD and the results of these studies have been inconclusive. AD patients show clear evidence of intact priming performance in some experiments but impaired performance in still others.

These inconsistencies may be attributable to differences among the specific memory tasks themselves as well as to differences in the designs of previous experiments. The tasks studied vary in the amount of processing capacity they demand. At one extreme are effortful processing tasks which make significant cognitive demands. Automatic processing tasks, at the other extreme, require minimal energy and cognitive capacity. AD patients, who have limited cognitive resources, are likely to fail any task requiring too much cognitive effort. Thus, it may be that a complete assessment of memory functioning in AD patients requires the administration of automatic as well as effortful processing tasks.

Given this background information, the purposes of the present study were threefold: (a) to determine how the performance of AD patients on implicit and explicit memory tasks compares to that of healthy, elderly subjects; (b) to determine if the dissociation between procedural and declarative memory that has already been established in amnesic patients will be evident in patients presenting with AD; and (c) to ascertain if the degree of processing demand (effortful versus automatic) has a significant effect on memory performance in AD and in elderly control subjects. Furthermore, the design, tasks and procedures of the present set of experiments have been specifically chosen to address certain flaws in the design and execution of previous studies, some of which may have contributed to the inconsistent findings to date.

Research Design

The design of the present experiments is a departure from the designs of recent investigations. Most studies within this area have employed a within-subjects design. While generally more powerful than between-subjects designs, such variables as carryover and fatigue effects present in many within-subjects designs often limit the effectiveness of the procedure and the validity of the results. This is particularly true in the case of the repeated administration of implicit and explicit memory tests.

The conventional way to overcome such effects in a within-subjects design is to present the repeated assessments in a counterbalanced format. However, by far the majority of previous investigations into memory dissociations have utilized a single fixed order. This design is demanded by the nature of the variable of interest: namely implicit versus explicit memory task performance. By definition a subject, presented with an implicit task, is unaware that memory is being assessed. Therefore, in studies administering both implicit and explicit memory tasks within subjects, the explicit task must always follow the implicit task. If instead the initial task is explicit, it may become clear to the subject that the words presented in the initial phase of the experiment are part of the content of the subsequent implicit memory task.

For these reasons, as stated above, most investigations have employed a within-subjects, fixed-order design (e.g., Grosse, Wilson, & Fox, 1990; Hartman, 1987; Nebes, Martin, & Horn, 1984; Salmon, Shimamura, Butters, & Smith, 1988; Shimamura & Squire, 1984). There is clearly an additional danger, aside from carryover and fatigue effects, in this type of design however. In the process of being administered each subsequent assessment, the subject either generates or is presented with to-be-recalled items from the original study list. Therefore, it is possible that by the final memory task, the subject will have seen some target items only once during the study phase while having seen (or generated) other items two, three or even four times during previous assessments. As the majority of these experiments are concerned with direct priming, in which a previously seen stimulus facilitates subsequent processing of the same stimulus, it is important that at the time of the memory assessment all to-be-remembered items have been presented an equal number of times to the subject.

Similarly, the very act of remembering a study item during any single memory test may serve to enhance the memory of that item on subsequent tests (Shimamura, 1985). For example, Graf, Shimamura, and Squire (1985) examined memory performance on word-stem completion following free recall. All subjects received these two tests in a fixed-order design. Analysis of the data revealed that the percentage of successful word-stem completions for words recalled on the initial free recall task was twice as large as for words not recalled on the initial task. Graf and Mandler (1984) presented subjects with three memory tasks in the following fixed order: word-fragment completion, free recall, and recognition. Analyses indicate that test items presented on the word-fragment completion test were more often recalled and recognized than test items not presented on the word-fragment completion test. This same effect has been found in at least four additional studies as well (Danion, Zimmerman, Willard-Schroeder, Grange, & Singer, 1989; Mutter, Howard, Howard, & Wiggs, 1990; Shimamura & Squire, 1984; Tulving, Schacter, & Stark, 1982).

Hintzman (1980) describes difficulties which may appear in the statistical analysis of data generated by memory measures, especially when the focus is the relationship between performances on multiple tests of memory retrieval. He refers to what has become known as Simpson's Paradox: when two or more contingency tables are combined and collapsed, the resulting data may show a relationship different from the relationship of each original member. One example he cites is the problem with utilizing both recall and recognition in the same experiment. Clearly this reservation can be extended to studies using both implicit and explicit tasks in the same experiment as well.

Issues such as these clearly point to the problems inherent in a within-subjects, fixed-order design. Despite these problems, however, few investigators have examined or even addressed the issue of experimental design. The present study, as a means of reducing at least some of the confounding present in previous research, has used an independent groups design.

There are other shortcomings in the experimental designs of previous work that may have threatened the validity of studies within the area of memory dissociations in AD and which are addressed in the current set of experiments. These include combining AD subjects with other memory-disordered populations (e.g., Diamond & Rozin, 1984; Moscovitch, 1982b; Moscovitch, Winocur, & McLachlan, 1986), contaminating the "implicit" task by describing it as a memory test within the initial instructions (Burke, White, & Diaz, 1987; Cermak, Blackford, O'Connor, & Bleich, 1988; Miller, 1975; Morris, Wheatley, & Britton, 1983; Perruchet & Baveux, 1989), and utilizing different lists of study words for the implicit and explicit assessments (Shimamura, Salmon, Squire, & Butters, 1987).

As a means of overcoming these potential problems: (a) all memory-disordered patients included in the present study were diagnosed as having AD; (b) the instructions presented with the study list did not include reference to "memorizing" or to a future memory test; and (c) all subjects were administered the same list of target words regardless of the specific memory task to follow.

Proposal and Hypotheses

In the present set of experiments, a series of memory tasks was administered to two subject groups: AD patients and age- and education-matched healthy adults. The memory tasks varied on two dimensions: memory type (explicit and implicit) and cognitive load (effortful and automatic). Two tests of implicit memory (word-fragment completion and perceptual threshold measurement) and two tests of explicit memory (free recall and recognition) were administered.

The particular implicit tasks studied were selected for the quite different levels of cognitive effort required. As described above, the word-fragment completion task demands considerable cognitive effort while the perceptual threshold measurement task requires much less. The explicit memory tasks were selected to "match" the extent of cognitive demand required by the two implicit tasks: the free recall task was matched to the more effortful word-fragment completion task in Experiment 1, while the recognition task was matched to the less demanding, automatic perceptual threshold measurement task in Experiment 2.

While free recall and recognition are both explicit tasks requiring considerable cognitive processing, there are differences between the tasks with respect to processing requirements and strength of effort required (see Hashtroudi, Ferguson, Rappold, & Chrosniak, 1988; Johnson & Hasher, 1984; Williamsen, Johnson, & Eriksen, 1965). Recognition is a less demanding task than free recall. By definition, the recognition task includes a direct presentation of the target stimulus to the subject, allowing for a familiarity response. In contrast, there are no cues present to orient the subject in the free recall task, thus necessitating more active retrieval processes.

Furthermore, both free recall and word-fragment completion are tasks involving two separate stages of processing. In the initial stage for both, the subject must generate possible candidate stimuli. In the second stage, the subject must determine either if the generated stimulus had been seen (free recall) or completes the fragment (word-fragment completion). In contrast, the recognition and perceptual threshold measurement tasks require only the second stage: no internal generation is necessary. This lends further validity to the description of free recall and word-fragment completion as effortful and recognition and perceptual threshold measurement as automatic.

The following hypotheses were based on a review of previous research findings. If in fact the degree of processing demand required by each memory task is an important variable, AD patients would be expected to exhibit a dissociation between memory systems similar but not identical to the dissociation seen in amnesic groups. More specifically, it was hypothesized that the AD patients would perform more poorly than the controls on tests of recall and recognition, both explicit tasks of memory. In contrast, it was expected that priming performance on the implicit tasks in AD patients would be mediated by the degree of cognitive demand required by each task. Compared to the matched control subjects, the AD patients were expected to exhibit impaired priming ability on word-fragment completion (Experiment 1), an implicit task requiring significant cognitive effort, but intact priming ability on perceptual threshold measurement (Experiment 2), an implicit task requiring minimal cognitive resources.

Experiment 1

In Experiment 1, the initial study phase presented a list of words without reference to the study component of the experiment. Half of the subjects were subsequently administered a word-fragment completion test, an effortful processing, implicit memory task. The remaining subjects received a free recall task, an explicit memory measure matched to word-fragment completion in terms of relative cognitive processing effort. The performance of the AD patients was compared to that of the controls on both memory measures.

Method

Subjects. A total of 50 subjects participated in Experiment 1. There were 25 patients with a clinical diagnosis of Alzheimer's disease and 25 healthy adults.

Patients. Twenty-five patients (13 men and 12 women) with a clinical diagnosis of Alzheimer's disease were studied. Subjects in this experimental group ranged from 55 to 85 years of age (M=71.96; SD=8.14) and had attended 6 to 20 years of school (M=13.17; SD=3.65). Mean and standard deviation values according to experimental task are presented in Table 2. Patients were recruited from the Alzheimer's Disease Research Center (ADRC) located within the Department of Psychiatry at the Mount Sinai School of Medicine.

All selected patients had previously been diagnosed at

Table 2

Values of Demographic Variables for AD patients and Elderly Controls in Experiment 1

	Free Recall N=24		Fragment Completion N=26	
	AD N=12	EC N=12	AD N=13	EC N=13
Age				
Mean	73.00	68.88	70.92	73.61
SD	9.04	6.12	7.24	7.31
Education				
Mean	13.33	15.83	13.00	13.77
SD	2.99	3.01	4.30	3.00

the ADRC according to the following rigorous criteria. All patients met the Diagnostic and Statistical Manual of Mental Disorders III-Revised (DSM III-R; American Psychiatric Association, 1987) criteria for primary degenerative dementia of the Alzheimer type. The National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) (McKhann, Drachman, Folstein, Katzman, Price, & Stadlan, 1984) criteria for probable AD was also used. To participate in the present study patients must have met both the DSM-III-R and the NINCDS criteria, further increasing the validity of the diagnosis.

Diagnosis of AD was made based on a thorough medical, psychiatric, and neurological assessment. Procedures included a complete history, a physical examination, mental status testing, electroencephalogram (EEG), chest x-ray, CAT Scan (CT), complete blood count (CBC), serum chemistries (CHEM), urinalysis, and thyroid function tests. Patients presenting with or evidencing a history of hypertension, diabetes, epilepsy, head injury, cardiovascular disease, major psychiatric disorder, or substance abuse were excluded. All patients evidenced significant deterioration of functioning consistent with AD for a minimum of one year's time.

Severity of AD was measured with the Mini-Mental State (MMS) Examination (Folstein, Folstein, & McHugh, 1975), a brief screening test which evaluates cognitive functioning.

Based on criteria used at the ADRC, scores of 26 or below out of a possible 30 points are indicative of cognitive decline consistent with dementia. MMS scores for patients participating in Experiment 1 ranged from 9 to 26 (M=18.02; SD=5.44).

Since the MMS is an instrument containing items that assess memory, the variable of interest, use of the scale to determine the subject sample may be considered a confound. However, in the present study the scale was used only for the assessment of disease severity, with the diagnosis already previously established. Further, the MMS only uses questions relating to declarative memory and not procedural memory. Since it is already clear that declarative memory is impaired in AD and since the primary question in the present study involves procedural memory, any possible confounding is at a minimum.

In addition, the MMS is one of the few cognitive functioning assessment scales to maintain a relatively even balance of items requiring effortful processing and those requiring automatic processing (Jorm, 1986). Nineteen out of the 30 items on the scale require effortful processing.

Control Subjects. Twenty-five healthy adults (14 men and 11 women), judged not to be suffering from any form of dementia, formed the control group. The control subjects were selected to be matched to the patients in terms of age and education. Controls ranged in age from 62 to 90 years

(M=71.25; SD=6.71) and had attended from 8 to 20 years of school (M=14.80; SD=3.01). This matched group did not differ significantly from the AD patients in terms of age or years of education whether comparing each subject group in its entirety (AD versus control) or comparing subjects separately based on the experimental task received (free recall versus word-fragment completion). Mean and standard deviation values according to specific experimental task are presented in Table 2.

Older adults were recruited from a pool of control subjects participating in studies being conducted by the Department of Psychiatry at the Mount Sinai School of Medicine. This pool had been generated primarily through community advertisements. Although control subjects had participated previously in other research studies conducted at Mount Sinai, their participation was limited and thus this sample is not composed of a group of "professional normals." The older adults were matched to the AD subjects in terms of education and age. All older adults were screened for medical, psychiatric, and neurological disorders. Screening procedures included a complete history, a physical examination, mental status testing, CBC, CHEM, urinalysis and, when available, CT and EEG. Prospective subjects presenting with or evidencing a history of diabetes, epilepsy, hypertension, head injury, cardiovascular disease, major psychiatric disorder, or substance abuse were not included. Older adults obtained scores of between 27 and 30 (M=28.91; SD=1.26) on the MMS.

All subjects provided voluntary written informed consent. In the case of the AD patients, written consent from their caregivers was obtained. All subjects were tested individually. Subsequent to participation, all subjects were informed of the purpose of the study.

Study Materials and Memory Tests. The stimulus set for the experiment was composed of 29 words selected according to the following criteria. All words represented concrete objects (e.g., ARROW). All words were between four and eight letters in length. All words had a word frequency level of between 25 and 300 per million words (Carroll, Davies, & Richman, 1971). Each word was centered on a three inch by five inch white index card, used in the study phase, in one inch black capital letters.

Two lists of 12 words each were selected from the set of 29 words so that the mean word frequency in List 1 (M=83 per million) and List 2 (M=80 per million) did not differ. Half of the words in each list represented objects that could be picked up and half did not (see below). Half of each subject group was presented with one of the two lists during the initial study phase of the experiment. The remaining subjects were presented with the alternate list. The five words remaining from the original set of 29 were used as buffers (two words at the beginning and three words at the end of the study list) in order to counteract any primacy or recency effects in performance. Thus a total of 17 words were presented to each subject.

For the free recall test, a response sheet was developed and consisted of a single lined sheet preceded by the following printed instructions: "Earlier you were shown a list of words and asked if you could pick up the objects represented by the words. I would now like you to try to recall as many of those words as possible. Please write all the words you can remember on this page. When you are through, please turn this paper over."

For the word-fragment completion test, between one and four letters in each word were removed. No more than two consecutive letters were removed from any single word (e.g., N E _ D _ _, NEEDLE). When properly completed, all fragments could be made into only one particular concrete word. A test sheet was developed and consisted of a single page containing two columns of word-fragments. One half of the items on the word-fragment test sheet were from List 1 and the remaining items were from List 2 to provide old (primed) and new (non-primed) words for each group. The first three items on the list always consisted of previously unseen words to help ensure that the subjects did not realize that some of the stimuli were previously presented. The remainder of each list consisted of both old and new words in a randomized order. The fragments were preceded by the following printed directions: "The following is a list of words which are missing letters. Please fill in the missing letters so that you make a complete word. All words are either a place or a thing. Work as quickly as possible. You may complete the items in any order you like. If you have trouble with an item, you can go to the next word and come back to that item later. If you need to, you can use an extra sheet of paper to write on. When you are through please turn your paper over."

The entire set of 24 target words and their word fragments are presented in Appendix A.

Procedure. At the onset of the experiment, subjects were given instructions relating the upcoming experiments to learning in general. No specific reference was made to the memory component of the tasks.

Each of the 17 words (5 buffer, 12 study) was then presented by hand individually to the subject. The specific study list and the order of the words within each of the two lists were randomized for each subject. Each target word was presented once for a duration of 5s, with a 2s inter-word interval.

Subjects were told to read each word aloud and to determine if the word presented could be picked up by the subject (e.g., flower-yes, river-no). No other information was given. This general type of task was chosen so that subjects would not be expecting a memory task to follow.

The specific task was chosen as it is a deep-processing task, requiring subjects to identify the word, examine its meaning, process the weight and size of the object and, finally, encode the results of that procedure. It has been suggested that in order to reflect accurate performance in a demented population, the study phase of a memory task must ensure that the patients successfully attended to, understood, and encoded the stimuli (Grosse, Wilson, & Fox, 1990; Partridge, Knight, & Feehan, 1990). If instead, patients had been presented with a shallow processing task at encoding, the to-be-tested material may not have been encoded and poor results may not have reflected impaired memory retrieval ability per se. Thus the task used in the present study helped to ensure that memory functioning was in fact being examined during the test phase of the experiment.

Immediately following the presentation of the study list, subjects were randomly assigned to and administered one of two possible memory tasks: free recall or word-fragment completion.

For free recall, all subjects received the test sheet described earlier and were read the instructions as printed on the form. No additional instructions or information were given.

For word-fragment completion, the general task was initially explained. Subjects were then presented with three practice fragments. After it was clear that the subject understood the task, the word-fragment completion test sheet described earlier was presented and the printed instructions were read aloud. No other instructions or information was given. Half of the list consisted of items initially presented in the study phase while the remaining items were not presented as part of the study list. They were, however, used to determine a level of baseline completion performance (i.e., what percentage of the total number of fragments will the subject complete given that the word had not been previously presented).

For each subject, the entire procedure was completed in a single session and lasted approximately 30 minutes or less.

Results

The measure of interest in the free recall task was the total number of items correctly recalled from the initial study list of 12 words. Possible scores ranged from 0 to 12. In the word-fragment completion task, the measure of interest was the difference in the number of fragments completed for previously presented and for new words. Possible difference scores (total number of primed fragments completed minus total number of non-primed fragments completed) ranged from -12 to 12. Thus the variable of interest in the free recall task is a measure of words recalled while the variable of interest in the word-fragment completion task is a measure of performance difference.

Because of the considerable scaling differences in the measurement scales of the two tasks, the data from the two tasks were analyzed in separate procedures. Separate analyses have been carried out in the majority of previous studies comparing explicit memory tasks and completion tasks (Brown, Brown, & Bowes, 1989; Cermak, Blackford, O'Connor, & Bleich, 1988; Danion, Zimmerman, Willard-Schroeder, Grange, & Singer, 1989; Graf, Shimamura, & Squire, 1985; Graf, Squire, & Mandler, 1984; Grosse, Wilson, & Fox, 1990; Komatsu & Ohta, 1984; Light & Singh, 1987; Light, Singh, & Capps, 1986; McClelland & Pring, 1991; Nissen, Knopman, & Schacter, 1987; Partridge, Knight, & Feehan, 1990; Shimamura, Salmon, Squire, & Butters, 1987).

Free Recall. The test protocols were scored to obtain a measure of performance on the tests of free recall. The mean number of words correctly identified from the target words on the study list was computed for each subject group.

Data were analyzed initially to determine the effects of subject gender and list type. No significant differences emerged as a function of either variable. As a result of this finding, the data were collapsed by subject gender and list type in all subsequent analyses. A significant effect of subject group emerged, $t(23)=9.86$, $p<.001$. AD patients recalled significantly fewer target words ($M=0.3$) than did elderly controls ($M=6.5$).

When both AD patients and elderly controls were considered together as a group, there was a significant correlation between MMS score, reflecting general cognitive capacity, and recall performance, $\underline{r}(22)=.78$, $\underline{p}<.001$. This relationship was reduced to a large degree and was nonsignificant when AD patients ($\underline{r}=.48$) and control subjects ($\underline{r}=.06$) were analyzed separately. The significant correlation found when combining the subject groups appears to result from the high recall and MMS scores of the controls analyzed with the low recall and MMS scores of the patients. The restriction of range occurring in analysis of individual subject groups clearly reduced the value and significance of the correlation. Correlation coefficients can be found in Table 3.

Word-fragment Completion. The test protocols were tabulated to obtain a measure of performance on the word-fragment completion test. A relatively stringent criterion considered a completion to be correct only if it exactly matched its respective target word.

The mean number of fragments correctly completed by each subject group was calculated. Separate totals were tabulated for primed fragments formed from target stimuli presented in the study phase and non-primed fragments formed from words not previously presented. Inclusion of the new baseline fragments provided a measure of the percentage of fragments subjects successfully completed without prior

Table 3

Correlations Between Task Performance and Level of Cognitive Capacity as Assessed by the MMS in Experiment 1

Group	N	RECALL	N	FRAGMENT COMPLETION Primed	FRAGMENT COMPLETION Non-primed
AD	12	.48	13	.41	.29
EC	12	.06	13	.12	.17
TOTAL	24	.78*	26	.72*	.61*

*p=.001

exposure. The difference in completion rates between the primed and the non-primed fragments represents the priming effect. Performance for each subject group is illustrated in Figure 1.

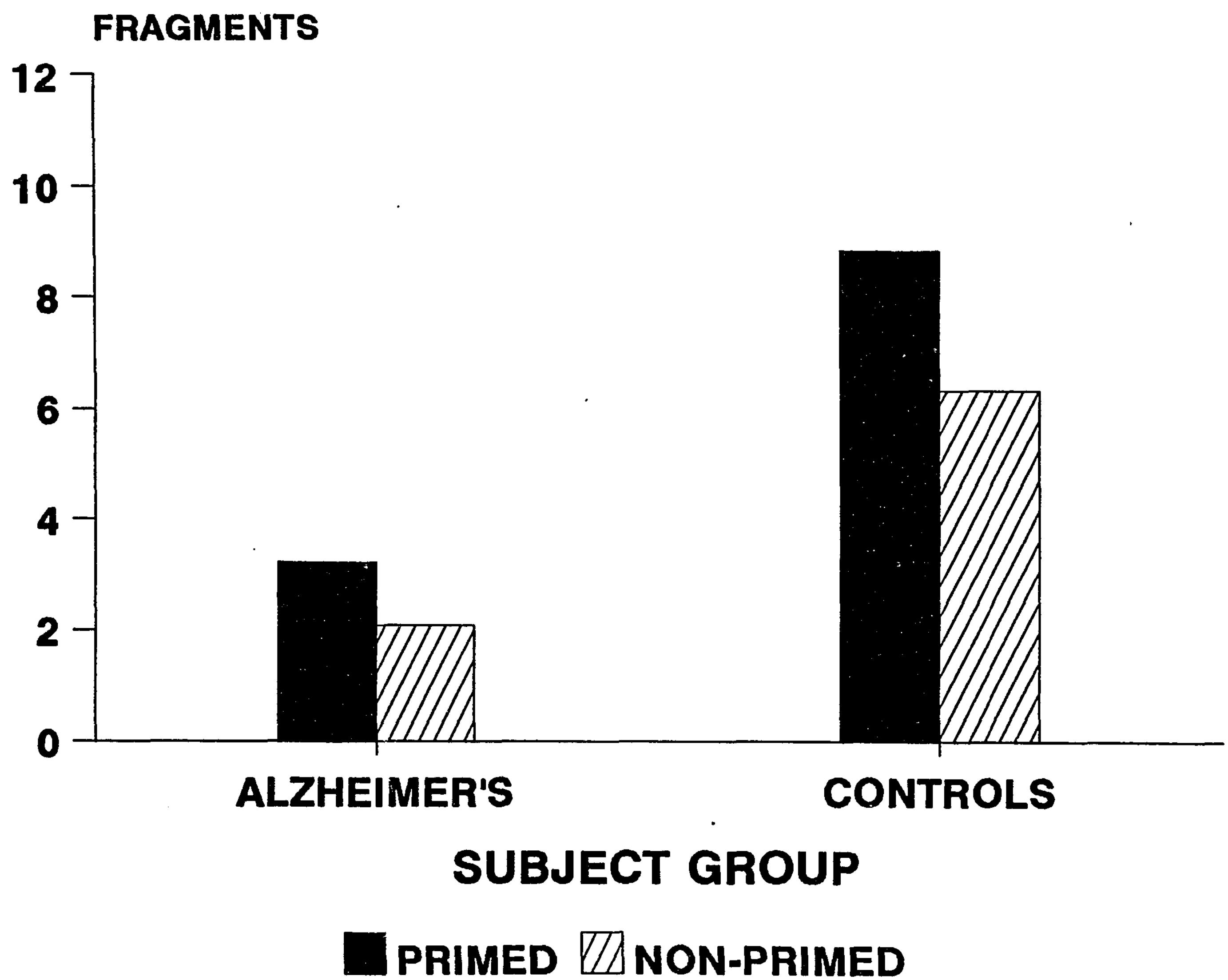
Data were analyzed initially to determine the effects of subject gender and list type. No significant differences emerged as a function of gender. As a result, the data were collapsed by subject gender in all subsequent analyses. In contrast, a significant effect of list type emerged. As such, this variable was included in all further analyses.

Data were subjected to a mixed analysis of variance with subject group (AD patients, elderly controls) and list type (List 1, List 2) serving as the between subjects variables and fragment condition (primed, non-primed) serving as the repeated measure.

A significant main effect of subject group emerged, $\underline{F}(1,25)=26.43$, $\underline{p}<.001$. AD patients completed a significantly lower number of fragments ($\underline{M}=2.65$) than elderly controls ($\underline{M}=7.58$). A significant main effect of fragment condition was also found $\underline{F}(1,25)=27.60$, $\underline{p}<.001$. As a group then, AD and control subjects completed a significantly greater number of previously seen fragments ($\underline{M}=6.04$) than new fragments ($\underline{M}=4.19$). A significant interaction between fragment condition and list was found, $\underline{F}(1,25)=33.77$, $\underline{p}<.001$. A greater priming effect was seen overall with List 1 (primed $\underline{M}=7.67$, non-primed $\underline{M}=3.42$) than

Figure 1

Fragment completion performance as a function of fragment condition and subject group in Experiment 1.



ALZHEIMER'S N=13 CONTROLS N=13

with List 2 (primed M=4.64, non-primed M=4.86. A significant interaction between subject group and list was also found, F(1,25)=4.73, p<.001. In AD patients, a greater number of fragments were completed from List 1 (M=4.17) than List 2 (M=2.14). In the controls, in contrast, more List 2 (M=8.14) than List 1 (M=6.92) fragments were completed. No other main effects or interactions were found to be significant. Analysis of variance tables are presented in Appendix B.

Perhaps the most noteworthy finding for fragment completion was the absence of a significant fragment condition by subject group interaction, although the effect did approach significance, F(1,25)=3.18, p=.089. The direction of the performance of both subject groups on word fragment completion was equivalent since both the AD and the control subjects completed more primed fragments than non-primed fragments.

Priming Effect. While both groups show some effect of priming (i.e., more fragment completions for target than for new fragments), the degree of priming, represented by the percent primed/non-primed difference in completion rates, was less than half the size in the AD (9.6%) as in the control subjects (21%). In other words, when control subjects had previously viewed a fragment as a completed word, they were 21% more likely to complete the fragment than when they had not been previously exposed to the item.

In contrast, previous exposure to the target word increased performance in AD patients by less than 10% as compared to performance on new, baseline items.

In order to examine the priming effect within each subject group, the data were examined using t-tests. As expected, the difference between the number of primed fragments ($\underline{M}$=8.85; $\underline{SD}$=1.99) and non-primed fragments ($\underline{M}$=6.31; $\underline{SD}$=2.93) completed by the control subjects was significant, $\underline{t}(12)=3.56$, $\underline{p}=.004$. In contrast, while AD patients also completed more primed fragments ($\underline{M}$=3.23; $\underline{SD}$=3.63) than non-primed fragments ($\underline{M}$=2.08; $\underline{SD}$=2.66), the difference in performance was not statistically significant, $\underline{t}(12)=1.25$, $\underline{p}=.236$.

Overall, while only 6 of the 13 AD subjects (43%) evidenced intact priming, 10 of the 13 control subjects (77%) exhibited the priming effect. Interestingly, in the 10 cases where priming was not exhibited, subjects had all seen List 2 in the study phase.

An individual item analysis was conducted on the fragments in order to determine possible explanations for the unexpected interactions between subject group and list type and fragment condition and list type. The total percentage of correct completions per word (i.e., of the 26 subjects who saw each word, what percentage actually correctly completed each fragment?) was tabulated for both AD (see Table 4) and control (see Table 5) subjects. Data

Table 4

Fragment Completion Performance in AD Patients as a Function of Priming Condition: Item Analysis

Percentage of subjects correctly completing each stimulus

Word	List #	Primed Condition	Non-Primed Condition	Priming Effect	Total Correct
Cattle	1	17%	0%	yes	8%
Street	1	67%	43%	yes	54%
Chair	1	33%	29%	yes	31%
Garden	1	100%	29%	yes	62%
Stove	1	67%	43%	yes	54%
Child	1	50%	29%	yes	38%
Snake	1	50%	14%	yes	31%
Arrow	1	67%	43%	yes	54%
Stick	1	50%	14%	yes	31%
Railroad	1	67%	29%	yes	46%
Ranch	1	50%	14%	yes	31%
Shirt	1	0%	14%	no	8%
Total	1	51%	25%	-	37%
Mountain	2	14%	50%	no	31%
Stream	2	0%	0%	no	0%
Plant	2	14%	17%	no	15%
Flower	2	0%	0%	no	0%
Trunk	2	0%	17%	no	8%
Field	2	14%	17%	no	15%
Stone	2	14%	17%	no	15%
Beach	2	29%	33%	no	31%
Forest	2	14%	33%	no	23%
Harbor	2	0%	0%	no	0%
Trail	2	14%	17%	no	15%
Needle	2	14%	17%	no	15%
Total	2	11%	18%	-	14%
Total	1 & 2	29%	22%	-	26%

Table 5

Fragment Completion Performance in Elderly Controls as a Function of Priming Condition: Item Analysis

Percentage of subjects correctly completing each stimulus

Word	List #	Primed Condition	Non-Primed Condition	Priming Effect	Total Correct
Cattle	1	10%	14%	no	8%
Street	1	100%	100%	no	100%
Chair	1	83%	71%	yes	77%
Garden	1	100%	100%	no	100%
Stove	1	100%	100%	no	100%
Child	1	83%	57%	yes	69%
Snake	1	83%	71%	yes	77%
Arrow	1	100%	86%	yes	92%
Stick	1	100%	71%	yes	85%
Railroad	1	100%	86%	yes	92%
Ranch	1	50%	43%	yes	46%
Shirt	1	33%	0%	yes	15%
Total	1	78%	67%	-	72%
Mountain	2	86%	67%	yes	77%
Stream	2	29%	17%	yes	23%
Plant	2	86%	33%	yes	62%
Flower	2	29%	17%	yes	23%
Trunk	2	86%	83%	yes	85%
Field	2	57%	17%	yes	38%
Stone	2	57%	17%	yes	38%
Beach	2	71%	33%	yes	54%
Forest	2	86%	50%	yes	69%
Harbor	2	57%	0%	yes	31%
Trail	2	100%	83%	yes	92%
Needle	2	100%	33%	yes	69%
Total	2	70%	37%	-	55%
Total	1 & 2	74%	53%	-	63%

are presented in the form of percentages since unequal numbers of subjects were tested on List 1 (*n*=12) and List 2 (*n*=14). In the control group, each fragment was completed by at least one subject. Three of the fragments (all from List 1) were completed by all 12 control subjects while one of the fragments (also from List 1) was completed by only one control subject. In the AD group, in contrast, there were three fragments (all from List 2) which were not completed by even a single subject and seven additional fragments (five from List 2 and two from List 1) completed by either only one or two AD subjects. At the other extreme, four fragments (all from List 1) were completed by either seven or eight AD subjects.

When individual fragments were analyzed with respect to priming, the list effect became even more apparent. For each fragment, the total number of subjects who completed that item was tabulated based on whether the subject had or had not been previously presented with its target word. An item was considered to be primed if its fragment was completed by more subjects who had seen the target word than subjects who had not. In the control subjects, 8 of the 12 words from List 1 were primed by the previous presentation of List 1 while 12 out of 12 words from List 2 were primed by the prior presentation of List 2. In other words, a greater number of control subjects completed individual target fragments associated with their respective study phase list for 20 out of 24 total possible items. This pattern was equivalent for both lists. The AD subjects showed a different effect however. Similar to the controls, AD patients evidenced a priming effect in the majority of individual items from List 1; 11 out of 12 possible words were primed. In stark contrast, however, was the lack of a priming effect in List 2. None of the 12 words from List 2 revealed a priming effect in the AD subjects. In other words, AD subjects who had not previously seen an item were equally or more likely to complete the fragment as AD subjects who had actually been previously presented with the item.

Discussion

The primary purpose of Experiment 1 was to compare the performance of AD patients and control subjects on two tests of memory, distinguished primarily by the fact that one test (free recall) was explicit in nature while the other test (word-fragment completion) was implicit. Furthermore, successful performance on both tasks required a significant degree of effortful processing. It was predicted that, when compared to matched healthy control subjects, AD patients would exhibit impaired recall performance on free recall and impaired priming performance on word-fragment completion. Results from Experiment 1 support this hypothesis.

As expected, the performance of AD patients on the test of free recall was significantly and unequivocally impaired.

In fact, 10 of the 12 AD subjects were unable to recall a single item from the study list. This finding is consistent with the literature which clearly demonstrates a severe impairment in memory functioning in AD patients when assessed with free recall (e.g., Kaszniak, Wilson, & Fox, 1981).

However, the fact that only 2 of the 12 subjects were able to recall any items from the list suggests that there was a floor effect in the recall task. As AD patients have been shown to be consistently impaired on free recall of words regardless of the number of target items, this floor effect appears to have limited impact on the conclusions of this experiment.

The results of the word-fragment completion test were not as easily interpretable however. As expected, AD patients completed far fewer fragments overall than did the control subjects. In this respect, the performance of the patient group was unquestionably impaired. The majority of AD patients were able to comprehend and execute the task, however, as all but three AD subjects completed at least one fragment.

The degree of priming exhibited by the control subjects (21%) exceeded the degree of priming exhibited by the AD patients (9.6%) by more than double, also suggesting that performance on the fragment completion test was impaired in AD patients when compared to controls. Unexpectedly, however, both AD and control subjects exhibited some degree of facilitation due to priming. This finding is reflected in the non-significant fragment condition by subject group interaction. However, although more primed fragments than non-primed fragments were completed by both the AD and the control groups, this difference reached significance only in the controls.

The results obtained on the word-fragment completion task in Experiment 1 must be viewed within the context of the significant interactions between fragment condition and list and subject group and list. While the control subjects evidenced a facilitative effect of priming on both List 1 and List 2, the AD patients showed this effect only with List 1. In fact, not a single AD patient presented with List 2 exhibited a facilitative effect of priming. There are two plausible explanations which may account for this. Either the List 2 fragment formations or the List 2 items themselves were somehow different.

Careful consideration suggests that the fragment formations were more likely responsible for the list effect. Both List 1 and List 2 were initially matched by a variety of rigid criteria, including word frequency, concreteness and number of letters. This matching process established a priori the similarity of Lists 1 and 2. Furthermore, the fact that such an effect was obtained only in the word-fragment completion task and not in the free recall task suggests that the effect was probably due to the fragment formations themselves and not to the particular words selected. If in fact the specific words on List 1 and List 2 were in some way distinct and responsible for these findings, the fragment condition by list interaction would have also been obtained within the context of the free recall task. As this was not the case, it is highly unlikely that the list effect was due to the specific words themselves.

It seems more reasonable to conclude that the effect was a result of differences in the fragment formations between List 1 and List 2. The fragments from List 2 were apparently more difficult for the AD patients then the fragments from List 1. The controls, in contrast, were equally able to complete the fragments from both lists. The only criterion set for the development of the fragments was that no more than two consecutive letters could be removed from each word. The interactions with list type appear to have resulted from the fact that not enough a priori criteria were developed to ensure that the fragments from List 1 and List 2 were in fact comparable. In any case, given that the results of the experiment indicated that AD patients were impaired, as expected, on the word-fragment completion task, the salience of the list effect is minimized.

The finding of impaired priming in AD patients on the word-fragment completion test is consistent with the proposed effect of the processing component of the task. As stated above, the task requirements of word-fragment completion are complex. A successful performance involves intact problem-solving skills and knowledge of rules of spelling and letter combinations. However, unlike free recall, the task provides subjects with cues in the form of a very structured and limited response set. Thus, while selection of a response in a free recall task does not provide the subject with a method for determining the success of the response, in word-fragment completion the subject is able to determine immediately if the selected response is accurate (i.e., do the letters I place within the fragment serve to form a real word?). Therefore, while the cognitive demand required by the task leads to a reduced facilitation from priming in AD patients compared to control subjects, the structure provided by the task itself perhaps enabled the AD patients to exhibit some, albeit highly reduced, degree of intact facilitation by priming.

While the deficit in the implicit memory task performance seen in Experiment 1 is consistent with the proposed effect of the processing demand of the task, such a finding is not sufficient to conclude that this variable is definitely having an impact. If in fact the high degree of processing demand required by the memory tasks in Experiment 1 did play a role in the impaired performance of AD patients, it would be expected that implicit memory tasks which required minimal cognitive effort would reveal unimpaired priming performance. Such an outcome would support the importance of the cognitive processing dimension. Experiment 2 was undertaken to examine this possibility directly.

Experiment 2

The main goal of Experiment 2 was to compare performance of AD patients and control subjects on memory tasks requiring a smaller degree of cognitive processing effort than those measures used in Experiment 1. In Experiment 2, subjects were administered the identical word list presented in Experiment 1, again without reference to the memory assessment to follow. Subsequent to the study phase, half of the subjects received a perceptual threshold measurement task, an automatic processing, implicit procedure. The other half were administered a recognition task, a test of explicit memory matched to perceptual threshold measurement in terms of cognitive processing requirements. If in fact the data indicate that AD patients evidence unimpaired facilitation from priming on the perceptual threshold measurement task, the existence of a memory dissociation as well as the importance of the processing dimension in AD will be supported.

Method

Subjects. A total of 41 subjects, 19 AD patients and 22 healthy controls, participated in Experiment 2. No subject participated in both Experiments. Eleven men and eight women with a clinical diagnosis of AD were studied. Patients were recruited from the ADRC located within the Department of Psychiatry at the Mount Sinai School of Medicine. All selected patients met the same inclusion and exclusion criteria for patients outlined in Experiment 1. Subjects in the AD group ranged from 55 to 87 years of age (M=69.53; SD=8.35) and had attended between 8 and 20 years of school (M=13.95; SD=3.31). No significant differences in demographic variables were found between patients in Experiments 1 and 2. Mean and standard deviation values for each task are presented in Table 6. MMS scores for patients participating in Experiment 2 ranged from 13 to 26 (M=20.47; SD=4.54).

Twelve older adult men and ten older adult women, judged not to be suffering from any form of dementia, formed the control group. Older adults were recruited from a pool of control subjects participating in studies being conducted by the Department of Psychiatry at the Mount Sinai School of Medicine. All older adults met the same entry criteria outlined for control subjects in Experiment 1. They were selected to be matched to the AD subjects in terms of education and age. Control subjects ranged in age from 58 to 83 years (M=69.14; SD=6.39) and in education from 12 to 20 years (M=15.64; SD=3.01). This matched group did not differ significantly from the AD patients in terms of age or years of education whether comparing each subject group from Experiment 2 in its entirety (AD versus control) or comparing subjects separately based on the experimental task received (recognition versus perceptual threshold measurement). No significant differences in demographic

Table 6

Values of Demographic Variables for AD patients and Elderly Controls in Experiment 2

	Recognition N=22		Perceptual Threshold N=19	
	AD N=10	EC N=12	AD N=9	EC N=10
Age				
Mean	72.60	67.17	66.11	71.50
SD	8.07	5.54	7.66	6.80
Education				
Mean	14.30	16.17	13.56	15.00
SD	3.83	2.72	2.79	3.33

criteria were found between controls in Experiments 1 and 2. Mean and standard deviation values according to each task are presented in Table 6. MMS scores for control subjects participating in Experiment 2 ranged from 27 to 30 (M=28.64; SD=1.26).

All subjects provided voluntary written informed consent. In the case of AD patients written consent from their caregivers was obtained. Subjects were tested individually. Subsequent to completion of the experiment, all subjects were informed of the purpose of the study.

Study Materials and Memory Tests. The present experiment utilized the identical study lists administered in Experiment 1. Both lists consisted of 12 target words preceded by two and followed by three buffer items to counteract both primacy and recency effects, respectively.

For the recognition test, three alternative choices for each target word were selected based on the following criteria. All alternate words were concrete in nature. One alternative was semantically related to the target word (e.g., stone, rock). The second alternative was graphemically related to the target word (e.g., stone, phone). The third and final alternative was unrelated to the target word (e.g., stone, grape) but met two criteria: it had to have the same number of letters as the study word and begin with a different letter. These three distinct categories of foils (semantically related, graphemically related, and unrelated) were selected to determine if either subject group consistently chose a specific type of alternate response when incorrect.

It was reasoned that a pattern of errors consisting primarily of semantic alternates would reflect some degree of intact "memory." Consistently selecting the alternate item which represents the same semantic concept as the target item indicates that subjects have encoded at study and are correctly identifying at test at least one important component of that target. Similarly, a pattern of errors consisting primarily of phonetic alternates also implies some degree of intact memory. In contrast, an error pattern consisting of either primarily unrelated or a combination of all three alternates would indicate little memory savings.

The test sheets for the recognition test consisted of each target word and its three related foils. The words were printed two inches apart in one column and centered on the page. The locations of each set of four words were randomized on each sheet so that the target and foil words were not in the same position on each test form. A total of 12 sheets were printed, one for each target word. Instructions, printed on a cover sheet, read as follows: "Earlier you were shown a list of words and asked if you could pick up the objects represented by the words. I am now going to show you a series of sheets with four words printed on each paper. One of the four words was presented to you before on the list. Please choose the word which you remember as being on that list. If you are unsure, please guess the word which you believe you had seen."

For the perceptual threshold measurement task, a Gebrands 3-Field tachistoscope was used. Thirty-four words (10 filler, 24 target) were printed on 4 inch by 6 inch white cards in 1/8 inch black Letraset capital letters. The cards were inserted into the tachistoscope for presentation during the test phase.

<u>Procedure</u>. The study phase presented in Experiment 2 was equivalent to the study phase in Experiment 1. Subjects were initially given instructions relating the upcoming experiment to learning in general. No specific reference was made to tasks involving memory. Subjects were told that they would be presented with a series of words and were required to read each word aloud and to determine if the word presented could be picked up by the subject (e.g., flower-yes, river-no). No additional information was given. Each of the 17 words (5 buffer, 12 study) was then presented individually to the subject. The specific study list and the order of the words within each of the two lists were randomized for each subject. Each word was presented by hand once for a duration of 5s, with a 2s inter-word interval.

Immediately following the presentation of the study list, subjects were randomly assigned to and administered one of two possible memory tasks: recognition or perceptual threshold measurement. For recognition, subjects received the 12 test sheets, described above, each of which contained a single study item and its three alternatives. Subjects were read the instructions printed on the test form. No other instructions or additional information were given.

For the perceptual threshold measurement task, subjects were comfortably seated at the tachistoscope and were instructed to look into the eyepiece of the machine. They were then read the following instructions: "You will see a series of words, presented one at a time, flashed very rapidly on the screen. Try to determine what word is being presented and tell your guess to the experimenter out loud. If you are unsure of the exact word, you should guess. Before each word appears on the screen, a bracket will appear in your field of vision. Please focus on this bracket as that is the position where the word will soon appear. Are you ready?"

A total of 34 words were presented to each subject. The first ten words were fillers that were used to acclimate the subject to the machine and to ensure that the subject understood the instructions. These words were discarded during the data analysis. The remaining 24 words consisted of a randomly presented combination of the 12 target words seen in the study phase (List 1 or List 2) and 12 baseline words (the alternate list) used to determine a baseline level of threshold duration.

The first five stimuli, one half of the filler words, were each initially presented for a duration of 2s. This relatively long duration enabled the subject to easily identify the target, get acclimated to the apparatus and learn where each target word would appear. The second five filler stimuli were presented via an ascending method of limits. Each word was initially presented for an exposure duration of .04s with subsequent increases of .005s until each word was correctly identified by the subject. The purpose of this presentation was to ensure that the subject understood the instructions and that the specific task could be completed correctly. If a subject was unable to identify any of the filler stimuli, the experiment was stopped and the data discarded.

Following the 10 filler stimuli, the 24 target words were then presented in the same manner as the last five of the filler words, via the ascending method of limits. Words were again presented at an initial duration of .04s and subsequently increased by .005s increments until the word was correctly identified.

For each subject in Experiment 2, the procedure was completed in one session and lasted 30 min or less.

<u>Results</u>

The measure of interest in the recognition task was the total number of items correctly recognized from the initial study list of 12 words. In the perceptual threshold measurement task, the measure of interest was the difference in perceptual threshold durations for previously presented words and new words, as measured in milliseconds. Because of the considerable differences in the measurement scales of the two tasks, the data analyses were carried out separately for each task (see Cermak, Talbot, Chandler, & Wolbarst, 1985; Jacoby & Dallas, 1981; Winnick & Daniel, 1970).

Recognition. The test protocols were scored to obtain a measure of performance on the recognition test. The mean number of words correctly identified from the target words was calculated for each subject group. Data were analyzed initially to determine the effects of subject gender and list type. No significant differences emerged as a function of either variable. As a result of this finding, the data were collapsed by subject gender and list type in all subsequent analyses.

A significant difference was found in the number of words correctly recognized by the two groups, $t(21)=5.57$, $p<.001$. AD patients recognized significantly fewer target words (M=6.80) than did the control subjects (M=11.58).

When AD patients and elderly controls were combined as one group, there was a significant correlation between MMS score, a reflection of general cognitive ability, and recognition performance, $r(20)=.79$, $p=.001$. This relationship was not significant when AD patients (r=.46) and elderly controls (r=.17) were analyzed separately. The lack of significance is related to the restriction of range of values obtained in each individual subject group. Correlation coefficients can be seen in Table 7.

Recognition Errors. The types of recognition errors, semantic, phonetic, or unrelated, committed by both AD and control subjects were tabulated and the data are presented in Figure 2. Mean number of recognition errors was significantly greater in the AD patients (M=5.20) than in the controls (M=.42), $t(21)$=5.57, p<.001. The total number of errors committed by the AD patients ranged from a minimum of one to a maximum of ten whereas no control made more than two total errors.

When the data were analyzed based on error type, an interesting picture emerged. In all cases, the limited number of errors committed by the control subjects were semantic in nature. There was not a single phonetic or unrelated error made by the control group. The pattern of errors committed by the AD subjects was somewhat more variable. AD patients were equally likely to commit all three types of errors. Although semantic errors (42%) slightly outnumbered phonetic (27%) and unrelated (31%) errors, there were no significant differences among the error types. When the error patterns of individual AD subjects were reviewed, it was revealed that seven of the ten subjects made errors in all three categories.

Table 7

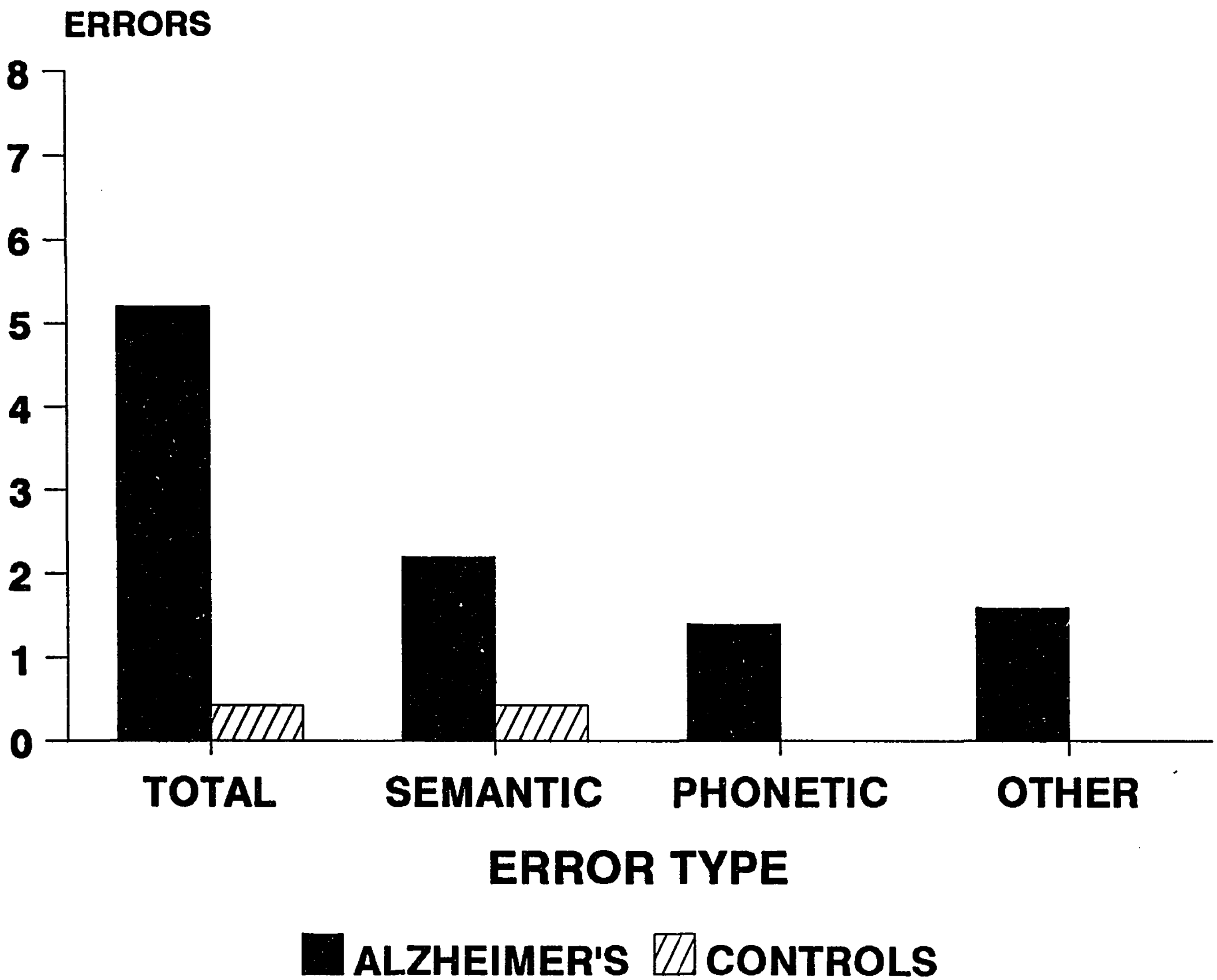
Correlations Between Task Performance and Level of Cognitive Capacity as Assessed by the MMS in Experiment 2

	N	RECOGNITION	N	PERCEPTUAL THRESHOLD PRIMED	PERCEPTUAL THRESHOLD NON-PRIMED
AD	10	.46	9	-.58*	-.61*
EC	12	.17	10	-.60*	-.64*
TOTAL	22	.79**	19	-.65**	-.68**

*p=.05
**p=.001

Figure 2

Recognition errors as a function of error type in AD patients and healthy controls.



ALZHEIMER'S N=10 CONTROLS N=12

Perceptual Thresholds. In addition to the nine subjects included in the analysis, four other AD patients had been entered into the study. These subjects, however, were unable to perform the perceptual threshold measurement task. In all cases, the four subjects stated that they could not read any of the initial filler items. As a result, the four subjects were dropped from subsequent data analysis. Possible explanations for their difficulties are discussed below.

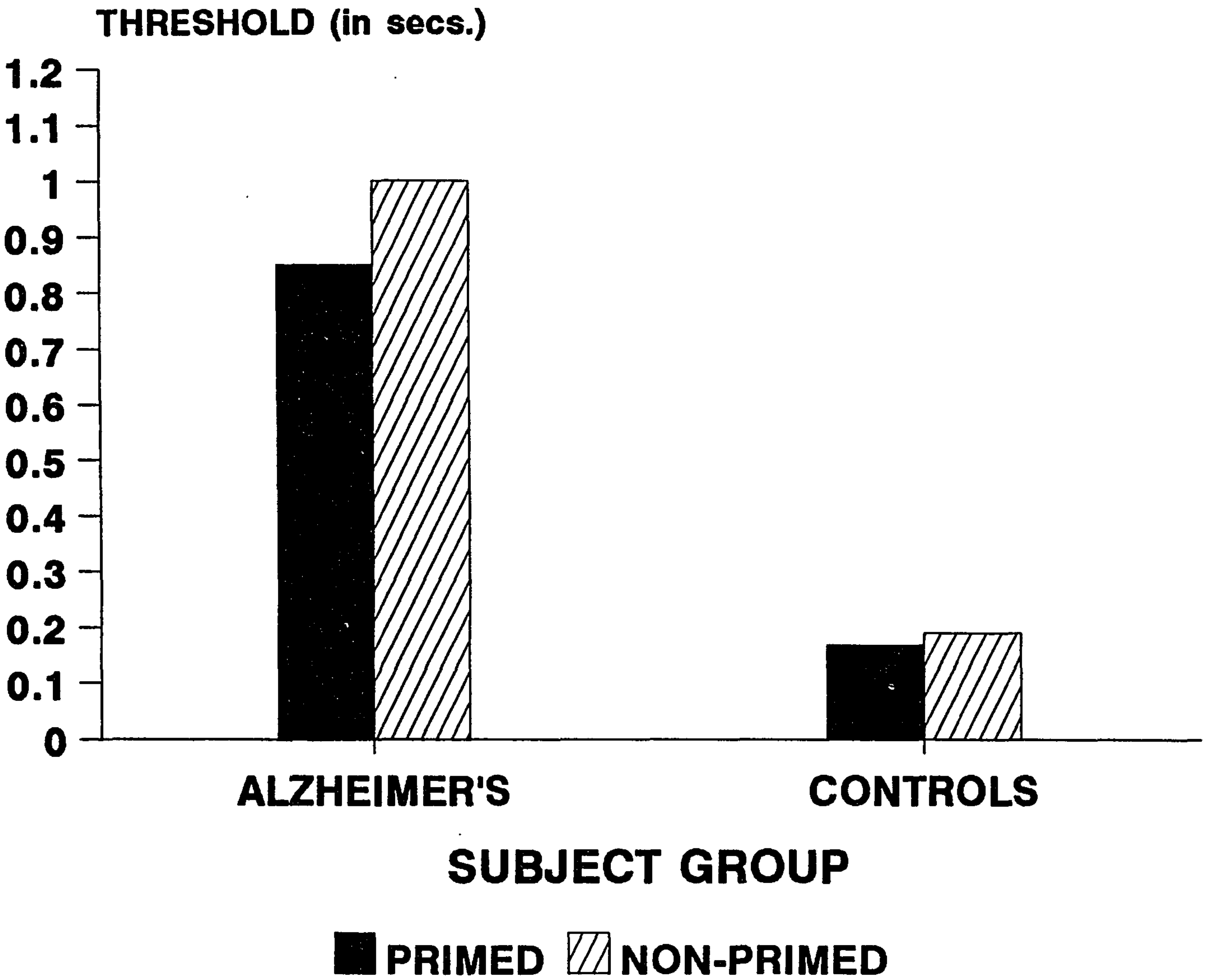
The test protocols of the remaining nine AD subjects and the ten elderly control subjects were scored to obtain a measure of performance on the perceptual threshold measurement test. Mean threshold durations were calculated for both primed and non-primed items for each subject group and are illustrated in Figure 3.

Data were analyzed initially to determine the effects of subject gender and list type. No significant differences emerged as a function of either variable. As a result of this finding, the data were collapsed by subject gender and list type in all subsequent analyses.

A mixed analysis of variance (see Appendix B) was carried out with subject group (AD patients, elderly controls) serving as the between subjects variable and threshold condition (primed, non-primed) serving as the repeated measure. Because of the skewed distribution seen in the perceptual threshold measurement scores, the data

Figure 3

Perceptual threshold measurement performance as a function of threshold condition and subject group in Experiment 2.



ALZHEIMER'S N=9 CONTROLS N=10

were transformed to a logarithmic scale to adjust for the skewness and stabilize the variances. Such a distribution is not wholly unexpected given the wide discrepancy in mean and variance of the threshold durations of the AD patients and the controls.

A significant main effect of subject group emerged, $F(1,17)=8.103$, $p=.011$. Words were identified at longer durations in AD patients ($M=.93s$) than in elderly controls ($M=.18s$). No other effects were significant.

Priming Effect. In order to examine the priming effect within each subject group, the data were analyzed within groups using related t-tests. In AD patients, a significant difference was found between the threshold durations of primed and non-primed stimuli, $t(8)=3.44$, $p=.009$. Primed items were identified faster ($M=.85s$; $SD=1.13$) than non-primed items ($M=1.00s$; $SD=1.25$) in the AD patients. The mean percentage difference between primed and non-primed items was 15% in the patient group. The decreased mean threshold for previously presented words (i.e., the priming effect) was evident in all nine of the AD patients.

The control subjects, in contrast, did not evidence a significant difference in threshold durations between primed and non-primed stimuli, although the difference approached significance, $t(9)=2.151$, $p=.060$. There was no difference between identification durations of primed items ($M=.17s$; $SD=.16$) and non-primed items ($M=.19s$; $SD=.18$). In the controls, the mean percentage difference between primed and non-primed items was 11%. Although not significant, nine of the ten control subjects evidenced a shorter mean threshold for previously presented words.

Performance on the perceptual threshold measurement task was significantly correlated with cognitive functioning (See Table 7) in both AD patients and healthy controls. The greater the degree of cognitive impairment, reflected in lower MMS scores, the longer the threshold duration. This was true for performance on both primed (AD $r=-.58$, $p=.05$; controls $r=-.60$, $p=.05$) and non-primed stimuli (AD $r=-.61$, $p=.05$; controls $r=-.64$, $p=.05$). The significant correlation in the control subjects in spite of the restricted range of possible scores (27 to 30) appears to be a function of a single outlier. This subject obtained the lowest possible MMS score (27) and also had the longest threshold duration of all controls, which was in fact nearly three times as long as the subject with the next longest duration. There was also a significant correlation between MMS scores and difference scores (primed durations minus non-primed durations) in the entire subject sample ($r=.66$, $p=.01$) but not within the individual subject groups.

Discussion

Experiment 2 compared the performance of AD patients and healthy controls on two measures of memory: recognition and perceptual threshold measurement. While both tasks require minimal cognitive effort, the recognition task is explicit in nature and perceptual threshold measurement is implicit. It had been hypothesized that AD patients would evidence impaired performance on the test of recognition memory but intact priming performance on perceptual threshold measurement. The outcome of Experiment 2 supports this hypothesis.

As expected based on previous research, AD patients performed significantly worse than healthy age- and education-matched controls on recognition. While every control recognized ten or more of the 12 original items, only two AD patients equalled that level of performance. Most patients were able to perform the basic task however, as all but one subject recognized more items than would be expected by chance. A comparable level of performance was exhibited by AD patients in a number of earlier studies (e.g., Miller, 1975, 1977; Wilson, Bacon, Kramer, Fox, & Kaszniak, 1983).

Analysis of the number and pattern of recognition errors committed by the subjects revealed further differences between the AD patients and the elderly controls. With respect to total number of errors, significantly fewer errors were made by the controls. In fact, errors were committed by only four of the 12 control subjects and no control made more than a total of two errors. This outcome was fully expected based on previous research on explicit recognition memory in demented and control subjects. More interesting was the analysis of the pattern of errors committed by the groups.

This issue has been previously investigated in both control subjects and in AD patients. Albert, Heller, and Milberg (1988) found that as healthy subjects age, naming errors are predominantly semantic in nature. They conclude that the semantic nature of the errors indicates that, although incorrect, the subject actually knew a great deal about the target word.

In AD, a number of investigators (Bayles & Tomoeda, 1988; Martin & Fedio, 1983; Wilson, Kaszniak, Fox, Garron, & Ratusnik, 1981) have found that the majority of errors made on tasks of confrontation naming are also semantic in nature. This was confirmed by Nebes (1989) who, after reviewing the literature, reported that errors in naming made by patients with dementia are usually semantic and are rarely visual in nature.

In the present experiment, the recognition task administered to the subjects consisted of the target word and three alternate choices: a semantically related, a phonetically related and an unrelated item. Although the control subjects committed a total of only five errors, a very consistent pattern emerged. In every case the alternative item selected was semantically related to the target word. This suggests that even though the subjects were unable to recognize the correct answer, they were always able to remember the meaning of the word.

The error pattern of the AD patients was quite different. Of 52 total errors committed by the patients, 22 were semantic, 14 were phonetic, and 16 were unrelated. Thus, although semantic errors (42%) slightly outnumbered phonetic (27%) and unrelated (31%) errors, the difference between these percentages was nonsignificant. This inconsistent pattern suggests that many of the responses made by the patient group reflected guesses rather than true memory savings.

Because of the limited number of studies focused on implicit memory in AD, fewer confident predictions based on previous research could be made with regard to the perceptual threshold measurement task. It was hypothesized however, based on the limited attentional capacity required by the task, that AD patients would exhibit a facilitation from priming on the perceptual threshold measurement task. Results of the present experiment support this hypothesis.

One hundred percent of the AD patients who completed the task (9 out of 9) evidenced a facilitative effect of priming. In the AD group, subjects exhibited a significantly lower perceptual threshold for items which they had previously seen as compared to newly administered items. In the patients, primed targets were identified 15% faster overall than non-primed words.

In contrast, while 92% of the control subjects (11 out of 12) had decreased threshold durations for items which they had previously seen as compared to newly administered items, the difference between primed and non-primed stimuli (11%) did not reach significance. These results indicate that the degree of priming exhibited in the perceptual threshold measurement task was actually greater in AD patients than in elderly controls.

The absence of a significant facilitative effect of priming in the control subjects may be a function of the extremely short threshold durations exhibited by that group. These low perceptual thresholds were evident for both primed (.17s) and non-primed (.19) stimuli. It may be the case that such extreme speed of identification considerably reduced the possibility of revealing differences between the two conditions. In fact, there is evidence that a greater facilitative effect of priming is found as the duration of a stimulus presentation increases (Nebes, Brady, & Huff, 1989; Stanovich & West, 1983), supporting the possibility that the lack of significance in the controls may have been in part a function of their brief threshold durations.

It should also be noted that the effect is in the expected direction in 11 of the 12 control subjects as well as in the group as a whole. While not significant, the effect is close to significance (p=.06). Perhaps a larger number of subjects would have decreased the relatively high variance and led to significant findings.

While the AD subjects showed an advantage over the controls with respect to degree of priming facilitation, the patients were still significantly impaired relative to the controls in terms of overall threshold durations: AD patients exhibited significantly higher thresholds than the elderly adults. Thus, even given the significant priming effect, it cannot be said that the performance of the AD patients on this automatic implicit memory task was completely spared.

Several findings suggest that priming performance on the perceptual threshold measurement task was closely linked to degree of cognitive impairment in the AD subjects. First, significant negative correlations were found between threshold performance on both primed and non-primed items and MMS scores (see Table 6). For example, the two AD subjects with the highest thresholds (M=2.78s) also had lower MMS scores (M=18.00) than the remaining AD subjects (M=22.70). Thus increased cognitive dysfunction, reflected in lower MMS scores, appears to be associated with higher perceptual threshold durations. Correlations were significant in the AD patients, as well as in the control subjects and the two subject groups combined.

Second, while MMS scores ranged from 14 to 26 (M=21.67) in the nine patients who were able to perform the test, scores ranged from 9 to 16 (M=11.00) in the 4 patients unable to complete the task. This suggests that with further declining cognitive abilities, the test can no longer even be performed. As stated above, unsuccessful protocols had been aborted in all cases because the subject claimed to be unable to read the word due to its size. Because no vision tests were performed, it is not clear that poor vision is definitely the only or necessarily even the primary cause of failure. It is equally likely that overall level of cognitive functioning had a direct effect.

Therefore, it appears that as cognitive ability declines, the cognitive demands of even an automatic processing task greatly increase. In the case of moderately demented AD patients, they may no longer retain the necessary skills to complete a task such as perceptual threshold measurement.

General Discussion

The general aim of the current set of experiments was to evaluate the role of cognitive processing demand on implicit and explicit memory performance in both healthy, elderly and AD subjects. More specifically, the goals of the present study were: (a) to compare the performance of AD patients and matched healthy control subjects on implicit and explicit memory tasks; (b) to determine if in AD, a dissociation exists between implicit and explicit memory tasks (and thus procedural and declarative memory systems) as it does in amnesic patients; and (c) to examine the possible effects of cognitive processing demand (effortful versus automatic) on such a dissociation.

In brief, the results of the experiments reported here indicate that (a) relative to healthy controls, AD patients are significantly impaired on tasks of explicit memory but unimpaired on the priming component of certain tests of implicit memory; (b) while AD patients do appear to exhibit a dissociation among systems of memory, this dissociation is different from the one seen in amnesic patients; and (c) the degree of cognitive demand required by an implicit memory task mediates priming performance in AD and thus plays a critical role in dissociations among systems of memory in AD.

EXPLICIT MEMORY MEASURES

Two tasks of explicit memory were administered to AD subjects and their matched controls: free recall in Experiment 1 and recognition in Experiment 2. Both tasks are presumed to reflect the operation of the declarative memory system. Performance of AD patients on both tasks was unequivocally impaired when compared to the performance of control subjects. AD patients both recalled and recognized significantly fewer target items than did the healthy, elderly subjects. These results confirm the findings of previous research which has demonstrated a clear and severe impairment on tests of explicit memory and declarative memory functioning in AD (e.g., Kaszniak, Wilson, & Fox, 1981; Miller, 1975, 1977; Wilson, Bacon, Kramer, Fox, & Kaszniak, 1983; Wilson, Kaszniak, Bacon, Fox, & Kelly).

IMPLICIT MEMORY MEASURES

Two tests of implicit memory were presented to the subjects: word-fragment completion in Experiment 1 and perceptual threshold measurement in Experiment 2. While performance on both tasks is thought to reflect the operation of the procedural memory system, they differ with respect to the degree of processing required of the subject. Word-fragment completion is a complex, effortful task while perceptual threshold measurement is a relatively straightforward, automatic task.

The results of Experiment 1 indicate that when assessed by word-fragment completion, the performance of AD patients is totally impaired. However, the results of Experiment 2 indicate that when assessed with perceptual threshold measurement, aspects of the performance of AD patients are unimpaired. In Experiment 2, although AD patients evidenced a higher threshold overall than control subjects, the AD patient group exhibited unimpaired priming performance as evidenced by an intact facilitative effect of priming. In fact, the degree of facilitation from priming on the perceptual threshold measurement task was significantly greater for AD patients than for the controls, who did not evidence a significant facilitative effect of priming.

Although it may at first appear unusual that AD patients would evidence a greater advantage from priming, a similar finding of greater facilitation in AD patients than in controls was also found by Chertkow, Bub, and Seidenberg (1989) and Nebes, Brady, and Huff (1989). In both cases, the investigators had employed a lexical decision task paradigm.

One possible reason for the increased facilitative effect of priming in the patient group may relate to the performance of the control group. As described earlier, the threshold durations for both primed and non-primed targets in the controls were very low (.17s and .19s, respectively). This may have considerably reduced the possibility of finding effects due to the priming condition. In contrast, the threshold durations for the AD subjects were relatively long, perhaps enabling the priming effect to be more apparent. Had the perceptual threshold measurement task been more difficult (with degraded or smaller stimuli for example), a facilitative effect of priming equal to or greater than that seen in the AD patients may have been evidenced in the control subjects. However, increasing task difficulty would have made the procedure too difficult for the patient group, rendering the data meaningless.

PROCESSING CAPACITY

Taken together, Experiments 1 and 2 indicate that under certain conditions, AD patients do in fact exhibit a facilitative effect of priming. The present study further suggests that the degree of cognitive demand required by a memory task has a considerable influence on priming performance in patients with AD. These patients exhibit limits in attentional capacity as a result of both aging and, to a greater degree, the degeneration associated with their disorder. As such, when a task requires a large degree of effortful processing (e.g., word-fragment completion), that task will be failed. In contrast, when a task is automatic in nature (e.g., perceptual threshold measurement), priming performance in AD patients can be evident, at least in the early stages of the disease.

This relationship between priming performance on an automatic test of memory functioning and degree of cognitive impairment was clearly evident in the current study. Performance on the MMS, a test of general cognitive functioning, was used to categorize subjects according to level of cognitive functioning. Analysis of the data shows that a significant correlation emerged between priming performance and cognitive ability in both AD and control subjects. At some point the cognitive changes associated with AD become so severe, however, that even automatic tasks will be failed. A review of the data from the current study supports this contention: the patients unable to complete the perceptual threshold measurement task obtained lower, and thus worse, scores overall on the MMS than did the successful subjects.

These results support the findings of Jorm (1986) who proposed that in AD, effortful processing is impaired early in the course of the disorder, while automatic processing remains intact until the later stages of the disease. He reasoned that if this proposal were correct, it would be expected that performance on tasks requiring effortful processing would be impaired in all AD patients regardless of severity while performance on tasks necessitating only automatic processing would remain intact until at least the later stages of AD. As a means of verifying this hypothesis, Jorm reviewed studies in which AD patients were grouped by severity of illness. Jorm's evaluation covered a wide range of processes and procedures including vocabulary, reading, naming, retrieval, storage, and learning. Jorm concluded that in all these areas, performance on automatic processing tasks remained intact until later in the disorder while performance on effortful processing tasks revealed early decline.

The results obtained in the current study suggest a reevaluation of earlier investigations. Based on these findings, it might be expected that previous studies which found impaired priming performance in AD either (a) utilized implicit memory tasks which required significant effortful processing or (b) utilized a group of subjects who either completely or in part consisted of AD patients with a relatively severe impairment. A review of these studies suggests that at least some of the negative results might be accounted for by these explanations.

Of the six studies finding impaired performance on implicit memory tasks, four different memory tests were involved: word-stem completion (Butters, 1987; Salmon, Shimamura, Butters, & Smith, 1988; Shimamura, Salmon, Squire, & Butters, 1987), picture-fragment identification (Heindel, Salmon, & Butters, 1990), lexical decision assessing indirect priming (Albert & Milberg, 1989; Ober & Shenaut, 1988), and category cuing (Salmon, Shimamura, Butters, & Smith, 1988).

In the case of studies which utilized the word-stem completion or the picture-fragment identification paradigms, impaired priming in AD patients may have been the result of the significant effortful processing required by these tests. The task requirements of word-stem completion are very similar to those required by word-fragment completion, a task previously described as effortful (Witherspoon & Moscovitch, 1989). Furthermore, the picture-fragment identification task, used by Heindel, Salmon, and Butters (1990), was defined by these investigators as simply being a pictorial analogue to the word completion tests. A case can therefore be made that failure on these tests by AD patients may at least in part be a result of the relatively high degree of processing effort required.

The lexical decision task theoretically falls somewhere in the middle of the continuum between effortful and automatic processing tasks. As such, the processing requirement of such a test may not in itself be an adequate explanation for the poor priming performance sometimes seen in AD patients. However, a review of the studies which found impaired indirect priming performance on lexical decision tests in AD (Albert & Milberg, 1989; Ober & Shenaut, 1988) suggests that the degree of dementia exhibited by the subjects may have had a strong impact on patient performance and hence on study conclusions.

Albert and Milberg (1989), for example, administered a lexical decision task to ten AD patients and to ten healthy controls. As a group, AD patients evidenced impaired facilitation relative to the controls. However, a closer analysis of the data revealed that six of the ten AD patients actually evidenced a strong facilitative effect of priming, even greater than that seen in the controls. The remaining four patients showed a negative priming effect, with reduced response times to unrelated primes. When the AD patients were divided into separate groups of "primers' and "negative-primers", it was discovered that the negative-primers were significantly impaired on a test of general cognitive functioning relative to the primers. Thus it appears that priming facilitation on this automatic implicit memory task is strongly related to degree of cognitive impairment. This finding mirrors the results of the current study, as well as those of Jorm (1986) which suggest that (a) automatic tasks, in contrast to effortful tasks which are impaired at every stage of AD, are less impaired or even unimpaired in early AD but (b) with increasing cognitive impairment, even generally automatic tasks will be failed.

Ober and Shenaut (1988) also found a reduced facilitative effect of priming in AD patients on the lexical decision task. No information was published, however, on the relationship between priming performance and level of dementia. Interestingly, they did note that of twelve patients initially tested, three subjects were unable to perform the task and were dropped from the analysis. As in the current study, it was the unsuccessful subjects who scored lowest on a test of general cognitive functioning.

Information as to the degree of cognitive impairment exhibited by subjects was also unavailable in a study completed by Salmon, Shimamura, Butters, and Smith (1988). While they claim that their tasks, word-stem completion and category cuing, are "automatic" in nature, they define "automatic" as equivalent to implicit. The current investigation as well as previous studies reviewed earlier clearly suggest, however, that a task is not necessarily automatic by virtue of being implicit.

Inherent in this issue is the fact that no general set of rules currently exists which clearly delineates how to rate a task along the automatic-effortful processing continuum. While Hasher and Zacks (1979) have outlined five variables which are relevant to the concept of effortful and automatic processing, their categorization is primarily descriptive. It was not their intention to develop guidelines by which tasks can be rated as effortful, automatic, or somewhere in between.

To date, investigators who have categorized tasks as primarily effortful or primarily automatic have utilized different methods to determine the degree of cognitive demand. Because no one definitive set of guidelines presently exists, the current study had adopted criteria developed by several investigators (e.g., Hasher & Zacks, 1979; Jorm, 1986; Schneider & Shiffrin, 1977; Witherspoon & Moscovitch, 1989) to categorize the memory deficits as automatic or effortful. Clearly, one useful goal of future research would be to develop a single system by which tasks may be categorized according to an independent criteria on automatic-effortful processing dimension.

DISSOCIATIONS IN AD VERSUS AMNESIC DISORDERS

One notable finding to result from the current study is that the memory dissociation seen in AD patients is different from that found in amnesic patients. Unlike amnesic patients, who evidence normal priming performance on both effortful and automatic implicit memory tasks, AD patients appear to exhibit impaired priming performance on effortful tasks but spared priming performance on at least one automatic task. One plausible explanation which may account for this difference lies in the underlying neuroanatomy of these disorders.

Although AD and amnesia do share common components, as outlined earlier, they are primarily different disorders with different etiology and sequelae. AD is primarily a cortical dementia whereas amnesia largely effects subcortical regions. Since it has been suggested that procedural memory may in fact be cortically-mediated (Zola-Morgan & Squire, 1990), it is not surprising that processes which may rely on cortical integrity (e.g., implicit memory tasks) can be impaired in AD but spared in amnesia. This may be especially true in the case of tasks relying on effortful processing. Similarly, it is also not surprising that as AD progresses, further compromising the cells of the cortex, even overlearned, automatic processing tasks will become impaired.

MULTIPLE MEMORY SYSTEMS

The experiments reported here lend additional support to the concept of multiple systems of memory. As stated previously, the existence of dissociations among distinct tasks of memory within any single population is a strong indication that there are multiple, dissociable memory systems. Such a finding has been previously seen in a number of populations including elderly healthy subjects and patients presenting with a variety of amnesic disorders. In AD, however, no clear consensus on this subject has emerged. It should be noted that earlier investigations which found impaired performance in AD on tasks of implicit memory are not necessarily inconsistent with the multiple memory systems hypothesis. Finding deficits in both implicit and explicit memory tasks can equally likely indicate impairment in two distinct memory systems as it can impairment in one single system underlying both types of memory tasks. In contrast, functional dissociations in performance between memory tasks argues for a dual memory system model. The current study adds support to the previous investigations which found evidence for a dissociation among memory systems in AD.

FUTURE DIRECTIONS

The present experiments have highlighted the importance of assessing the degree of effortful processing required by measures of cognitive functioning in general and memory ability in particular. Future studies should take into account the level of cognitive processing demanded by experimental tasks. A wide variety of memory tasks, rated a priori on the processing continuum, should be administered to AD and other subject groups as a means of replicating and advancing the current findings. The current study also points to a need to examine variables in addition to processing capacity which may indirectly effect the performance of subjects on tasks of memory functioning. For example, the roles played by such factors as stress, attention, mood state and anxiety in memory functioning should be examined further.

Furthermore, the current study emphasizes the need for experimental rigor in the design and execution of future experiments. Flaws in the methodology of previous research which were addressed in the present study were related to selection of subjects, instructions, and research design. These and other methodological issues need to be a central focus of further work.

The results of the present set of experiments is encouraging in that they indicate that not all aspects of memory functions are impaired in AD. Most research has focused primarily on deficits in memory and cognitive functioning associated with AD. The current study, along with the results of other recent studies examining procedural memory, suggests that further research should be directed at determining the abilities that remain relatively unimpaired or less impaired in AD and other related disorders. When and if a pocket of intact cognitive functioning is uncovered, these skills can then serve as a focus for developing aids to daily living and even programs aimed at cognitive remediation.

Appendix A

Recognition stimuli: targets, fragments, foils and list #

1.	SHIRT	SHEET	BLOUSE	TABLE	1
2.	CATTLE	RATTLE	STEER	MIRROR	1
3.	STOVE	CLOVE	OVEN	KNIFE	1
4.	ARROW	BARREL	SPEAR	STORK	1
5.	RAILROAD	RAINBOW	TRAIN	HOSPITAL	1
6.	CHAIR	CHAIN	STOOL	DONUT	1
7.	STREET	BEET	ROAD	POSTER	1
8.	RANCH	WRENCH	FARM	DONUT	1
9.	SNAKE	STEAK	SERPENT	TRUCK	1
10.	STICK	STACK	TWIG	PIANO	1
11.	GARDEN	GARNISH	ORCHARD	CRAYON	1
12.	CHILD	CHIME	BABY	PLANK	1
13.	STONE	PHONE	ROCK	GRAPE	2
14.	NEEDLE	NOODLE	SYRINGE	CANDLE	2
15.	FIELD	SHIELD	PASTURE	RIFLE	2
16.	TRUNK	TANK	SUITCASE	PHOTO	2
17.	FLOWER	TOWER	ROSE	PICKLE	2
18.	STREAM	STRING	RIVER	WINDOW	2
19.	FOREST	FROST	WOODS	CARTON	2
20.	MOUNTAIN	FOUNTAIN	HILL	PAINTING	2
21.	TRAIL	TAIL	PATH	BRICK	2
22.	HARBOR	HARNESS	PORT	PASTRY	2
23.	PLANT	PLANE	SHRUB	CHART	2
24.	BEACH	LEECH	SHORE	APPLE	2

Appendix B

Analysis of variance tables for Experiments 1 and 2.

Experiment 1: Word-Fragment Completion

Between Subjects

Source	Sum-of-Squares	DF	Mean-Square	F-Ratio	p
SUBJ	293.773	1	293.773	26.432	.000
LIST	8.099	1	8.099	0.729	.402
SUBJ x LIST	52.620	1	52.620	4.734	.041
ERROR	244.512	22	11.114		

Within Subjects

Source	Sum-of-Squares	DF	Mean-Square	F-Ratio	p
a	52.620	1	52.620	27.602	.000
a x SUBJ	6.055	1	6.055	3.176	.089
a x LIST	64.389	1	64.389	33.775	.000
a x SUBJ x LIST	.132	1	.132	.069	.795
ERROR	41.940	22	1.906		

Experiment 2: Perceptual Threshold Measurement

Between Subjects

Source	Sum-of-Squares	DF	Mean-Square	F-Ratio	p
SUBJ	15.454	1	15.454	8.103	.011
ERROR	32.421	17	1.907		

Within Subjects

Source	Sum-of-Squares	DF	Mean-Square	F-Ratio	p
a	.014	1	.014	.960	.341
a x SUBJ	.001	1	.001	.040	.843
ERROR	.255	17	.015		

References

Albert, M. S., Heller, H. S., & Milberg, W. (1988). Changes in naming ability with age. Psychology and Aging, 3, 173-178.

Albert, M. S., & Milberg, W. (1989). Semantic processing in patients with Alzheimer's disease. Brain and Language, 37, 163-171.

American Psychiatric Association (1987). Diagnostic and statistical manual of mental disorders. (3rd ed. revised). Washington, DC.: Author.

Arendt, T., Bigl, V., Arendt, A., & Tennstedt, A. (1983). Loss of neurons in the Nucleus Basalis of Meynert in Alzheimer's disease, paralysis agitans and Korsakoff's disease. Acta Neuropathologica, 61, 101-108.

Bayles, K. A., & Tomoeda, C. K. (1983). Confrontation naming impairment in dementia. Brain and Language, 19, 98-114.

Blessed, G. Tomlinson, B. E., & Roth, M. (1968). The association between quantitative measures of dementia and of senile changes in the grey matter of elderly subjects. British Journal of Psychiatry, 114, 797-811.

Botwinick, J., & Birren, J. E. (1951). The measurement of intellectual decline in the senile psychoses. Journal of Consulting Psychology, 15, 145-150.

Brinkman, S. D., Largen, J. W., Gerganoff, S., & Pomera, N. (1983). Russell's revised Memory Scale in the evaluation of dementia. Journal of Clinical Psychology, 39, 989-993.

Brooks, D. N., & Baddeley, A. D. (1976). What can amnesic patients learn? Neuropsychologia, 14, 111-122.

Brown, M. W., Brown, J., & Bowes, J. B. (1989). Absence of priming coupled with substantially preserved recognition memory in lorazepam-induced amnesia. The Quarterly Journal of Experimental Psychology, 41A, 599-617.

Burke, D. M., White, H., & Diaz, D. L. (1987). Semantic priming in young and older adults: Evidence for age constancy in automatic and attentional processes. Journal of Experimental Psychology: Human Perception and Performance, 13, 79-88.

Burke, D. M., & Yee, P. L. (1984). Semantic priming during sentence processing by young and older adults. Developmental Psychology, 20, 903-910.

Burns, A., Jacoby, R., & Levy, R. (1990a). Psychiatric phenomena in Alzheimer's disease. IV: Disorders of behaviour. British Journal of Psychiatry, 157, 86-94.

Burns, A., Jacoby, R., & Levy, R. (1990b). Psychiatric phenomena in Alzheimer's disease. III: Disorders of mood. British Journal of Psychiatry, 157, 81-86.

Burns, A., Jacoby, R., & Levy, R. (1990c). Psychiatric phenomena in Alzheimer's disease. II: Disorders of perception. British Journal of Psychiatry, 157, 76-81.

Burns, A., Jacoby, R., & Levy, R. (1990d). Psychiatric phenomena in Alzheimer's disease. I: Disorders of thought content. British Journal of Psychiatry, 157, 72-76.

Butters, N. (1987). Procedural learning in dementia: A double dissociation between Alzheimer and Huntington's disease patients on verbal priming and motor skill learning. Journal of Clinical and Experimental Neuropsychology, 9, 37.

Butters, N., & Cermak, L. S. (1975). Some analysis of amnesic syndromes in brain-damaged patients. In R. L. Isaacson & K. Pribram (Eds.), The Hippocampus: Volume 2 (pp. 377-409), NY: Plenum Press.

Butters, N., Granholm, E., Salmon, D. P., Grant, I, & Wolfe, J. (1987). Episodic and semantic memory: A comparison of amnesic and demented patients. Journal of Clinical and Experimental Neuropsychology, 9, 479-497.

Carroll, J. B., Davies, P., & Richman, B. (1971). The American Heritage Word Frequency Book. Boston: Houghton Mifflin Company.

Carroll, M., Byrne, B., & Kirsner, K. (1985). Autobiographical memory and perceptual learning: A developmental study using picture recognition, naming latency, and perceptual identification. Memory & Cognition, 13, 173-179.

Carroll, M., & Kirsner, K. (1982). Context and repetition effects in lexical1033Xdecisand recognition memory. Journal of Verbal Learning and Verbal Behavior, 21, 55-69.

Cerella, J., & Forzard, J. L. (1984). Lexical access and age. Developmental Psychology, 20, 235-243.

Cermak, L. S., Blackford, S. P., O'Connor, M., & Bleich, R. P. (1988). The implicit memory ability of a patient with amnesia due to encephalitis. Brain and Cognition, 7, 145-156.

Cermak, L. S., Talbot, N., Chandler, K., & Wolbarst, L. R. (1985). The perceptual priming phenomenon in amnesiacs. Neuropsychologia, 23, 615-622.

Chertkow, H., Bub, D., & Seidenberg, M. (1989). Priming and semantic memory loss in Alzheimer's disease. Brain and Language, 36, 420-446.

Chiarello, C., & Hoyer, W. J. (1988). Adult age differences in implicit and explicit memory: Time course and encoding effects. Psychology and Aging, 3, 358-256.

Clifton, C. (1966). Some determinants of the effectiveness of priming word associates. Journal of Verbal Learning and Verbal Behavior, 5, 167-171.

Coblentz, J. M., Mattis, S., Zingesser, L. H., Kasoff, S. S., Wisniewski, H. M., & Katzman, R. (1973). Presenile dementia: Clinical aspects and evaluation of cerebrospinal fluid dynamics. Archives of Neurology, 29, 299-308.

Cofer, C. N. (1967). Conditions for the use of verbal associations. Psychological Bulletin, 74, 1-12.

Cohen, N. J. (1984). Preserved learning capacity in amnesia: Evidence for multiple memory systems. In L. Squire & N. Butters (Eds.) The neuropsychology of memory (pp. 83-103). New York: Guilford Press.

Cohen, N., & Corkin, S. (1981). The amnesic patient. H. M.: Learning and retention of cognitive skill. Society for Neuroscience Abstracts, 7, 235.

Cohen, N., Eichenbaum, H., Deacedo, B. S., & Corkin, S. (1985). Different memory systems underlying acquisition of procedural and declarative knowledge. Annals of the NY Academy of Sciences, 444, 54-71.

Cohen, N., & Squire, L. R. (1980). Preserved learning and retention of pattern-analyzing skill in amnesia: Dissociation of "knowing how" and "knowing that". Science, 210, 207-209.

Collins, A. M., & Quillian, M. R. (1970). Facilitating retrieval from semantic memory: The effect of repeating part of an inference. Acta Psychologia, 33, 304-314.

Corkin, S. (1982). Some relationships between global amnesias and the memory impairments in Alzheimer's disease. In S. Corkin, K. L. Davis, J. H. Growdon, E. Usdin, & R. L. Wurtmen (Eds.), Aging: Vol. 19. Alzheimer's disease: A report of progress (pp. 149-164). New York: Raven.

Corsellis, J. A. N. (1970). The limbic areas in Alzheimer's disease and in other conditions associated with dementia. In G. E. W. Wolsternholme & M. O'Conner (Eds.), Alzheimer's disease and related conditions (pp. 37-45). London: Churchill.

Craik, F. I. M. (1977). Age differences in human memory. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (pp. 384-420). New York: Van Nostrand Reinhold.

Cutting, J. (1978). A cognitive approach to Korsakoff's syndrome. Cortex, 14, 485-495.

Danion, J. M., Zimmerman, M. A., Willard-Schroeder, D., Grange, D., & Singer, L. (1989). Diazepam induces a dissociation between explicit and implicit memory. Psychopharmacology, 99, 238-243.

Davies, P. (1985). A critical review of the role of the cholinergic system in human memory and cognition. Annals of the NY Academy of Sciences, 444, 212-217.

Davies, P., & Maloney, A. J. R. (1976). Selective loss of central cholinergic neurons in Alzheimer's disease. Lancet, 2, 1403.

Davis, K. L., Mohs, R. C., Rosen, W. G., Greenwald, B. S., Levy, M. I., & Horvath, T. B. (1983). Memory enhancement with oral physostigmine in Alzheimer's Disease. New England Journal of Medicine, 308, 721.

Diamond, R., & Rozin, P. (1984). Activation of existing memories in the amnesic syndrome. Journal of Abnormal Psychology, 93, 98-105.

Drachman, D. A., & Leavitt, J. (1974). Human memory and the cholinergic system. Archives of Neurology, 30, 113-121.

Eich, E. (1984). Memory for unattended events: Remembering with and without awareness. Memory and Cognition, 12, 105-111.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-mental state: A practical method for grading the cognitive state of patients for the clinician. Journal of Psychiatric Research, 12, 189-198.

Forbach, G. B., Stanners, R. F., & Hochhaus, L. (1974). Repetition and practice effects in a lexical decision task. Memory & Cognition, 2, 337-339.

Forster, K. I., & Davis, C. (1984). Repetition, priming and frequency attenuation in lexical access. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10, 680-698.

Fuld, P. A., Katzman, R., Davies, P., & Terry, R. D. (1982). Intrusions as a sign of Alzheimer dementia. Chemical and pathological verification. Annals of Neurology, 11, 155-159.

Glass, A. L., & Butters, N. (1985). The effect of associations and expectations on lexical decision making in normals, alcoholics, and alcoholic Korsakoff patients. Brain and Cognition, 4, 465-476.

Goate, A., Chartier-Harlin, M., Mullan, M., Brown, J., Crawford, F., Fidani, L., Giuffra, L., Haynes, A., Irving, N., James, L., Mant, R., Newton, P., Rooke, K., Roques, P., Talbot, C. Pericak-Vance, M., Roses, A., Williamson, R., Rossor, M., Owen, M., & Hardy, J. (1991). Segregation of a missense mutation in the amyloid precursor protein of familial Alzheimer's disease. Nature, 349, 704-706.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. Journal of Verbal Learning and Verbal Behavior, 23, 553-568.

Graf, P., Mandler, G., & Haden, P. E. (1982). Simulating amnesic symptoms in normals. Science, 218, 1243-1244.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. Journal of Experimental Psychology: Learning, Memory, and Cognition, 11, 501-518.

Graf, P., & Schacter, D. L. (1987). Selective effects of interference on implicit and explicit memory for new associations. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 45-53.

Graf, P., Shimamura, A. P., & Squire, L. R. (1985). Priming across modalities and priming across levels: Extending the domain of preserved function in amnesia. Journal of Experimental Psychology: Learning, Memory, and Cognition, 11, 386-396.

Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10, 164-178.

Grosse, D. A., Wilson, R. S., & Fox, J. H. (1990). Preserved word-stem completion priming of semantically encoded information in AD. Psychology and Aging, 5, 304-306.

Hartman, M. D. (1987). A cognitive-neuropsychological study of semantic representation in dementia of the Alzheimer type. (Doctoral Dissertation, U. of Minn.). Dissertation Abstracts International, 48, 2781B.

Hartman, M. (1991). The use of semantic knowledge in Alzheimer's disease: Evidence for impairments of attention. Neuropsychologia, 29, 213-228.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. Journal of Experimental Psychology: General, 108, 356-388.

Hashtroudi, S., Ferguson, S. A., Rappold, V. A., & Chrosniak, L. D. (1988). Data-driven and conceptually driven processes in partial-word identification and recognition. Journal of Experimental Psychology: Learning, Memory, and Cognition, 14, 749-757.

Hashtroudi, S., Parker, E. S., DeLisi, L. E., Wyatt, R. J., & Mutter, S. A. (1984). Intact retention in acute alcohol amnesia. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10, 156-163.

Heindel, W. C., Salmon, D. P., & Butters, N. (1990). Pictorial priming and cued recall in Alzheimer's and Huntington's disease. Brain and Cognition, 13, 282-295.

Hintzman, D. L. (1980). Simpson's paradox and the analysis of memory retrieval. Psychological review, 87, 398-410.

Howard, D. V. (1983). The effects of aging and degree of association on the semantic priming of lexical decisions. Experimental Aging Research, 9, 145-157.

Howard, D. V. (1988). Implicit and explicit assessment of cognitive aging. In M. L. Howe & C. J. Brainerd (Eds.), Cognitive development in adulthood: Progress in cognitive development research (pp. 3-37). NY: Springer-Verlag.

Howard, D. V., Heisey, J. G., & Shaw. R. J. (1986). Aging and the priming of newly learned associations. Developmental Psychology, 22, 78-85.

Howard, D. V., McAndrews, M. P., & Lasaga, M. I. (1981). Semantic priming of lexical decisions in young and old adults. Journal of Gerontology, 36, 707-714.

Huppert, F. A., & Piercy, M. (1976). Recognition memory in amnesic patients: Effect of temporal context and familiarity of material. Cortex, 12, 3-20.

Huppert, F. A., & Piercy, M. (1978). Dissociation between learning and remembering in organic amnesia. Nature, 275, 317-318.

Huppert, F. A., & Piercy, M. (1979). Normal and abnormal forgetting in organic amnesia: Effect of locus of lesion. Cortex, 15, 385-390.

Hyman, B. T., Van Hoesen, G. W., Damasio, A. R., & Barnes, C. L. (1984). Alzheimer's disease: Cell-specificity pathology isolates the hippocampal formation. Science, 225, 1168-1170.

Jacoby, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. Journal of Verbal Learning and Verbal Behavior, 22, 485-508.

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

Jacoby, L. L., & Witherspoon, D. (1982). Remembering with and without awareness. Canadian Journal of Psychology, 32, 300-324.

Johnson, M. K., & Hasher, L. (1987). Human learning and memory. Annual Review of Psychology, 38, 631-668.

Jorm, A. F. (1986). Controlled and automatic information processing in senile dementia: A review. Psychological Medicine, 16, 77-88.

Kahnemann, D. (1973). Attention and effort. Englewood Cliffs, N.J.: Prentice Hall.

Kang, J., Lemaise, H., Unterbeck, A., Salbaum, J. M., Masters, C. L., Grzeschik, K., Multhaup, G., Beyreuther, K., & Muller-Hill, B. (1987). The precursor of Alzheimer's disease amyloid A4 protein resembles cell surface receptor. Nature, 325, 733-736.

Kaszniak, A. W., Wilson, R. S., & Fox, J. H. (1981). Effects of imagery and meaningfulness on free recall and recognition in presenile and senile dementia. International Journal of Neuroscience, 12, 264.

Kaszniak, A. W., Wilson, R., Lazarus, L., Lessor, J., & Fox, J. H. (1981). Memory and depression in dementia. Paper presented at the Ninth Annual Meeting of the International Neuropsychological Society, Atlanta, GA.

Kihlstrom, J. F. (1980). Posthypnotic amnesia for recently learned material: Interactions with "episodic" and "semantic" memory. Cognitive Psychology, 12, 227-251.

Kinsbourne, M., & Wood, F. (1975). Short term memory and the amnesic syndrome. In D.D. Deutsch & J.A. Deutsch (Eds.), Short-term memory (pp. 258-291). NY: Academic Press.

Kirsner, K., Milech, D., & Standen, P. (1983). Common and modality-specific processes in the mental lexicon. Memory & Cognition, 11, 621-630.

Kirsner, K., & Smith, M. C. (1974). Modality effects in word identification. Memory & Cognition, 2, 637-640.

Knopman, D. S., & Nissen, M. J. (1987). Implicit learning in patients with probable Alzheimer's disease. Neurology, 37, 784-788.

Knopman, D. S., & Nissen, M. J. (1991). Procedural learning is impaired in Huntington's disease: Evidence from the serial reaction time task. Neuropsychologia, 29, 245-254.

Kolers, P. (1976). Reading a year later. Journal of Experimental Psychology: Human Learning and Memory, 2, 554-565.

Komatsu, S., & Ohta, N. (1984). Priming effects in word-fragment completion for short- and long-term retention intervals. Japanese Psychological Research, 26, 194-200.

Kopelman, M. D. (1985). Rates of forgetting in Alzheimer-type dementia and Korsakoff syndrome. Neuropsychologia, 23, 623-638.

Kopelman, M. D., & Corn, T. H. (1988), Cholinergic 'blockade' as a model of cholinergic depletion: A comparison of the memory deficits with those of Alzheimer-type dementia and the alcoholic Korsakoff syndrome. Brain, 111, 1079-1110.

Light, L. L., & Albertson, S. A. (1989). Direct and indirect tests of memory for category exemplars in young and older adults. Psychology and Aging, 4, 487-492.

Light, L. L., & Singh, A. (1987). Implicit and explicit memory in young and older adults. Journal of Experimental Psychology: Learning, Memory and Cognition, 13, 531-541.

Light, L. L., Singh, A., & Capps, J. L. (1986). Dissociation of memory and awareness in young and older adults. Journal of Clinical and Experimental Neuropsychology, 8, 62-74.

Lipowski, Z. J. (1978). Organic Brain syndrome: A reformulation. Comprehensive Psychiatry, 19, 309-322.

Loftus, E. F. (1973). Activation of semantic memory. American Journal of Psychology, 86, 331-337.

Martin, A., & Fedio, P. (1983). Word production and comprehension in Alzheimer's disease: The breakdown of semantic knowledge. Brain and Language, 19, 124-141.

Martone, M., Butters, N., Payne, M., Becker, J. T., & Sax, D. S. (1984). Dissociations between skill learning and verbal recognition in amnesia and dementia. Archives of Neurology, 41, 965-970.

Masson, M. E. J. (1984). Memory for the surface structure of sentences. Remembering with and without awareness. Journal of Verbal Learning and Verbal Behavior, 23, 579-592.

McAndrews, M. P., Glisky, E. L., & Schacter, D. L. (1987). When priming persists: Long-lasting implicit memory for a single episode in amnesic patients. Neuropsychologia, 25, 497-506.

McClelland, A. G. R., & Pring, L. (1991). An investigation of cross-modality effects in implicit and explicit memory. The Quarterly Journal of Experimental Psychology, 43A, 19-33.

McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price, D., & Stadlan, E. M. (1984). Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease. Neurology, 34, 939-944.

McKoon, G., & Ratcliff, R. (1979). Priming in episodic and semantic memory. Journal of Verbal Learning and Verbal Behavior, 18, 463-480.

Meyer, D. E., & Schvaneveldt, R. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. Journal of Experimental Psychology, 90, 227-234.

Meyer, D. E., & Schvaneveldt, R. (1976). Meaning, memory and mental processes. Science, 192, 27-33.

Miller, E. (1975). Impaired recall and the memory disturbance in presenile dementia. British Journal of Social and Clinical Psychology, 14, 73-79.

Miller, E. (1977). Abnormal aging: The psychology of senile and presenile dementia. New York: Wiley.

Milner, B., Corkin, S., & Teuber, H. L. (1968). Further analysis of the hippocampal amnesic syndrome: 14 year follow-up study of H.M. Neuropsychologia, 6, 215-234.

Mishkin, M., Malamut, B., & Bachevalier, J. (1984). Memories and habits: Two neural systems. In G. Lynch, J. L. McGough, & N. M. Weinberger (eds.), The neurobiology of learning and memory (pp. 65-77). NY: Guilford Press.

Mitchell, D. B. (1989). How many memory systems? Evidence from aging. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 31-49.

Mitchell, D. B., & Brown, A. S. (1988). Persistent repetition priming in picture naming and its dissociation from recognition memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 14, 213-222.

Mitchell, D. B., Brown, A. S., & Murphy, D. R. (1990). Dissociations between procedural and episodic memory: Effects of time and aging. Psychology and Aging, 5, 264-276.

Morris, R. G., & Kopelman, M. D. (1986). The memory deficits in Alzheimer-type dementia: A review. The Quarterly Journal of Experimental Psychology, 38A, 575-602.

Morris, R. G., Wheatley, J., & Britton, P. (1983). Retrieval from long-term memory in senile dementia: Cued recall revisited. British Journal of Clinical Psychology, 22, 141-142.

Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen models. In P. A. Kolers, M. E. Wrolstad, & H. Bouma (Eds.), Processing of visible language: Vol 1. (pp. 259-268). New York: Plenum Press.

Moscovitch, M. (1982a). Multiple dissociations of function in amnesia. In L. S. Cermak (Ed.), Human memory and amnesia (pp. 337-370). Hillside, New Jersey: L. Erlbaum Associates.

Moscovitch, M. (1982b). A neuropsychological approach to perception and memory in normal and pathological aging. In F. I. M. Craik & S. Trehub (Eds.), Aging and cognitive processes (pp. 55-79). New York: Plenum Press.

Moscovitch, M., Winocur, G., & McLachlan, D. (1986). Memory as assessed by recognition and reading time in normal and memory-impaired people with Alzheimer's disease and other neurological disorders. Journal of Experimental Psychology: General, 115, 331-347.

Murrell, G. A., & Morton, J. (1974). Word recognition and morphemic structure. Journal of Experimental Psychology, 102, 963-968.

Murrell, J., Farlow, M., Ghetti, B., & Benson, M. D. (1991). A mutation in the amyloid precursor protein associated with hereditary Alzheimer's disease. Science, 254, 97-99.

Musen, G., & Treisman, A. (1990). Implicit and explicit memory for visual patterns. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 127-137.

Mutter, S. A., Howard, D. V., Howard, H., & Wiggs, C. L. (1990). Direct and indirect tests of memory after closed head injury. Cognitive Neuropsychology, 7, 329-346.

Nebes, R. D. (1989). Semantic memory in Alzheimer's disease. Psychological Bulletin, 106, 377-394.

Nebes, R. D., Boller, F., & Holland, A. (1986). Use of semantic context by patients with Alzheimer's disease. Psychology and Aging, 1, 261-269.

Nebes, R. D., Brady, C. B., & Huff, F. J. (1989). Automatic and attentional mechanisms of semantic priming in Alzheimer's Disease. Journal of Clinical and Experimental Neuropsychology, 11, 219-230.

Nebes, R. D., Martin, D. C., & Horn, L. C. (1984). Sparing of semantic memory in Alzheimer's disease. Journal of Abnormal Psychology, 93, 321-330.

Neely, J. H. (1976). Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. Memory & Cognition, 4, 648-654.

Neisser, U. (1954). An experimental distinction between perceptual process and verbal response. Journal of Experimental Psychology, 47, 399-402.

Nilsson, L. G., Backman, L., & Karlsson, T. (1989). Priming and cued recall in elderly, alcohol intoxicated and sleep deprived subjects: A case of functionally similar memory deficits. Psychological Medicine, 19, 423-433.

Nissen, M. J., Cohen, N. J., & Corkin, S. (1981). The amnesic patient H. M.: Learning and retention of perceptual skills. Society for Neuroscience Abstracts, 7, 235.

Nissen, M. J., Knopman, D. S., & Schacter, D. L. (1987). Neurochemical dissociation of memory systems. Neurology, 37, 789-794.

Nissen, M. J., Ross, J. L., Willingham, D. B., Mackenzie, T. B., & Schacter, D. L. (1988). Memory and awareness in a patient with multiple personality disorder. Brain and Cognition, 8, 117-134.

Ober, B. A., & Shenaut, G. K. (1988). Lexical decision and priming in Alzheimer's disease. Neuropsychologia, 26, 273-286.

Parkin, A. J., & Streete, S. (1988). Implicit and explicit memory in young children and adults. British Journal of Psychiatry, 79, 361-369.

Partridge, F. M., Knight, R. G., & Feehan, M. (1990). Direct and indirect memory performance in patients with senile dementia. Psychological Medicine, 20, 111-118.

Perruchet, P., & Baveux, P. (1989). Correlational analysis of explicit and implicit memory performance. Memory & Cognition, 17, 77-86.

Perry, E. K., Tomlinson, B. E., Blessed, G., Bergmann, K., Gibson, P. H., & Perry, R. H. (1978). Correlation of cholinergic abnormalities with senile plaques and mental test scores in senile dementia. British Medical Journal, 2, 1457-1459.

Peters, B., & Levin, H. S. (1979). Effects of physostigmine and lecithin on memory in Alzheimer's Disease. Annals of Neurology, 6, 219-221.

Richardson-Klavehn, H. L. III, & Bjork, R. A. (1988). Measures of memory. Annual Review of Psychology, 39, 475-543.

Roediger, H. L. III, & Blaxton, T. A. (1987). Retrieval modes produce dissociations in memory for surface information. In D. S. Gorfein & R. R. Hoffman (Eds.), Memory and cognitive processes: The Ebbinghaus Centennial Conference (pp. 349-379). Hillsdale, New Jersey: Erlbaum Press.

Roediger, H. L. III, & Weldon, M. S. (1987). Reversing the picture superiority effect. In M. A. McDaniel, & M. Pressley (Eds.), Imagery and related mnemonic processes: Theories, individual differences, and application (pp. 151-174). New York: Springer-Verlag.

Rose, T. L., Yesavage, J. A., Hill, R. D., & Bower, G. H. (1986). Priming effects and recognition memory in young and elderly adults. Experimental Aging Research, 12, 31-37.

Rosen, W. G., & Mohs, R. C. (1982). Evolution of cognitive decline in dementia. In S. Corkin, K. L. Davis, J. H. Growdon, E. Usdin, & R. L. Wurtman (Eds.), Aging, Volume 19, Alzheimer's disease: A report of progress (pp. 183-188). New York: Raven.

Rosen, J., & Zubenko, G. S. (1991). Emergence of psychosis and depression in the longitudinal evaluation of Alzheimer's disease. Biological Psychiatry, 29, 224-232.

Rouse, R. O., & Verinis, J. S. (1962). The effect of associative connections on the recognition of flashed words. Journal of Verbal Learning and Verbal Behavior, 1, 300-303.

Salmon, D. P., Shimamura, A. P., Butters, N., & Smith, S. (1988). Lexical and semantic priming deficits in patients with Alzheimer's disease. Journal of Clinical and Experimental Neuropsychology, 10, 477-494.

Scarborough, D. L., Cortese, C., & Scarborough, H. (1977). Frequency and repetition effects in lexical memory. Journal of Experimental Psychology: Human Perception and Performance, 3, 1-17.

Scarborough, D. L., Gerard, L., & Cortese, C. (1979). Accessing lexical memory: The transfer of word repetition effects across task and modality. Memory & Cognition, 7, 3-12.

Schacter, D. L. (1985a). Multiple forms of memory in humans and animals. In N. Weinberger, J. McGough, & G. Lynch (Eds.), Memory systems of the brain: Animal and human cognitive processes (pp. 351-379). New York: Guilford Press.

Schacter, D. L. (1985b). Priming of old and new knowledge in amnesic patients and normal subjects. Annals of the NY Academy of Sciences, 444, 41-53.

Schacter, D. L. (1987). Implicit memory: History and current status. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 501-518.

Schacter, D. L., Cooper, L. A., & Delaney, S. M. (1990). Implicit memory for unfamiliar objects depends on access to structural descriptions. Journal of Experimental Psychology: General, 119, 5-24.

Schacter, D. L., & Graf, P. (1986). Preserved learning in amnesic patients: Perspectives from research on direct priming. Journal of Clinical and Experimental Neuropsychology, 8, 727-743.

Schacter, D. L., & Graf, P. (1989). Modality specificity of implicit memory for new associations. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 3-12.

Schacter, D. L., Harbluck, J. L., & McLachlan, D. R. (1984). Retrieval without recollection: An experimental analysis of source amnesia. Journal of Verbal Learning and Verbal Behavior, 23, 593-611.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: 1. Detection, search, and attention. Psychological Review, 84, 1-66.

Selkoe, D. J. (1991). Amyloid protein and Alzheimer's disease. Scientific American,, 265, 68-78.

Sherry, D. F., & Schacter, D. L. (1987). The evolution of multiple memory systems. Psychological Review, 94, 439-454.

Shimamura, A. P. (1985). Problems with the finding of stochastic independence as evidence for multiple memory systems. Bulletin of the Psychonomic Society, 23, 506-508.

Shimamura, A. P. (1986). Priming effects in amnesia: Evidence for a dissociable memory function. The Quarterly Journal of Experimental Psychology, 38, 619-644.

Shimamura, A. P., Salmon, D. P., Squire, L. R., & Butters, N. (1987). Memory dysfunction and word priming in dementia and amnesia. Behavioral Neuroscience, 101, 347-351.

Shimamura, A. P., & Squire, L. R. (1984). Paired-associate learning and priming effects in amnesia: A neuropsychological study. Journal of Experimental Psychology: General, 113, 556-570.

Squire, L. R. (1982). The neuropsychology of human memory. Annual Review of Neuroscience, 5, 241-273.

Squire, L. R., & Cohen, N. J. (1984). Human memory and amnesia. In G. Lynch, J. L. McGough, & N. M. Weinberger (Eds.), Neurobiology of learning and memory (pp. 3-64). New York: Guilford Press.

Squire, L. R., Shimamura, A. P., & Graf, P. (1985). Independence of recognition memory and priming effects: A neuropsychological analysis. Journal of Experimental Psychology: Learning, Memory, and Cognition, 11, 37-44.

Stanovich, K. E., & West, R. F. (1983). On priming by a sentence context. Journal of Experimental Psychology: General, 112, 1-36.

Starr, A., & Phillips, L. (1970). Verbal and motor memory in the amnesic syndrome. Neuropsychologia, 8, 75-88.

Swinney, D. A., Onifer, W., Prather, P. & Hirshkowitz, M. (1979). Semantic facilitation across sensory modalities in the processing of individual words and sentences. Memory & Cognition, 7, 159-165.

Terry, R. D., & Katzman, R. (1983). Senile dementia of the Alzheimer type. Annals of Neurology, 14, 497-506.

Thal, L. J. (1988). Dementia update: Diagnosis and neuropsychiatric aspects. Journal of Clinical Psychiatry (supplement), 49, 5-7.

Thal, L. J., Fuld, P. A., Masur, D. M., & Sharpless, N. D. (1983). Oral physostigmine and lecithin improve memory in Alzheimer's Disease. Annals of Neurology, 13, 491-494.

Tomlinson, B. E. (1977). The pathology of dementia. In C. E. Wells (Ed.), Dementia (pp. 113-153). Philadelphia: F. A. Davis.

Tomlinson, B. E., Blessed, G., & Roth, M. (1970). Observations on the brains of demented old people. Journal of Neurological Science, 11, 205-242.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), Organization of Memory (pp 381-403). New York: Academic Press.

Tulving, E. (1985). How many memory systems are there? American Psychologist, 40, 385-398.

Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. Science, 247, 301-306.

Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 8, 336-342.

Verfaellie, M., Cermak, L. S., Blackford, S. P., & Weiss, S. (1990). Strategic and automatic priming of semantic memory in alcoholic Korsakoff patients. Brain and Cognition, 13, 178-192.

Warrington, E. K., & Weiskrantz, L. (1968). A new method for testing long-term retention with specific reference to amnesic patients. Nature, 217, 972-974.

Warrington, E. K., & Weiskrantz, L. (1970). The amnesic syndrome: Consolidation or retrieval? Nature, 228, 628-630.

Warrington, E. K., & Weiskrantz, L. (1978). Further analysis of the prior learning effect in amnesic patients. Neuropsychologia, 16, 169-177.

Warrington, E. K., & Weiskrantz, L. (1982). Amnesia: A disconnection syndrome? Neuropsychologia, 20, 233-248.

Weiskrantz, L. (1987). Neuroanatomy of memory and amnesia: A case for multiple memory systems. Human Neurobiology, 6, 93-105.

Wickelgren, W. A. (1979). Chunking and consolidation: A theoretical synthesis of semantic networks, configuring in conditioning, S-R versus cognitive learning, normal forgetting, the amnesic syndrome, and the hippocampal arousal system. Psychological Review, 86, 44-60.

Williamsen, J. A., Johnson, H. J., & Eriksen, C. W. (1965). Some characteristics of posthypnotic amnesia. Journal of Abnormal Psychology, 70, 123-131.

Wilson, R. S., Bacon, L. S., Kramer, R. L., Fox, J. H., & Kaszniak, A. W. (1983). Word frequency effect and recognition memory in dementia of the Alzheimer's type. Journal of Clinical Neuropsychology, 5, 97-104.

Wilson, R. S., Kaszniak, A. W., Bacon, L. D., Fox, J. H., and Kelly, M. P. (1982). Facial recognition memory in dementia. Cortex, 18, 329-336.

Wilson, R. S., Kaszniak, A. W., & Fox, J. H. (1981). Remote memory in senile dementia. International Journal of Neuroscience, 12, 264-265.

Wilson, R. S., Kaszniak, A. W., Fox, J. H., Garron, D. C., & Ratusnik, D. L. (1981). Language deterioration in dementia. Paper presented at the Ninth Annual Meeting of the International Neuropsychological Society, Atlanta, GA.

Wilson, W. R. (1979). Feeling more than we can know: Exposure effects without learning. Journal of Personality and Social Psychology, 37, 811-821.

Winnick, W. A., & Daniel, S. (1970). Two kinds of response priming in tachistoscopic recognition. Journal of Experimental Psychology, 84, 74-81.

Winocur, G., & Weiskrantz, L. (1976). An investigation of paired-associate learning in amnesic patients. Neuropsychologia, 14, 97-110.

Witherspoon, D., & Moscovitch, M. (1989). Stochastic independence between two implicit memory tasks. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 22-30.

Zola-Morgan, S., & Squire, L. R. (1990). The neuropsychology of memory: Parallel findings in humans and non-human primates. Annals of the NY Academy of Sciences, 608, 434-456.