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IMPLICIT AND EXPLICIT RECOGNITION MEMORY FUNCTION:
A DEVELOPMENTAL STUDY OF NORMAL, READING DISABLED AND ADHD
CHILDREN AND ADULTS

by
KATHLEEN E. MCKAY

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

1995

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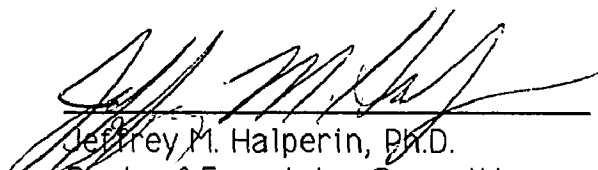
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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

IMPLICIT AND EXPLICIT RECOGNITION MEMORY FUNCTION IN NORMAL,
READING DISABLED, AND ADHD CHILDREN AND ADULTS

by

Kathleen E. McKay

Adviser: Professor Jeffrey M. Halperin

The current dissertation is comprised of two studies. The first Experiment was intended to investigate developmental differences in implicit and explicit memory function across a major portion of the life-span. A total of 108 subjects ranging in age from 7 to 45 years were evaluated using standard measures of cognitive and academic functioning, as well as laboratory measures of implicit and explicit memory function. Implicit memory performance was assessed using two tasks: one perceptually-driven (cued word-stem completion) and one conceptually-driven (category fluency). Explicit memory performance was assessed using a conceptually-driven recognition test. It was predicted that performance on the conceptually-driven tasks would be vulnerable to age and levels-of-processing effects whereas performance on the perceptually-driven measure would not. Consistent with this prediction performance on both conceptually-driven measures (implicit and explicit) was found to be affected similarly by manipulations in levels of processing, whereas performance on the perceptually-driven measure was not. While significant age effects

were obtained on both conceptually-driven measures, on the implicit measure, this effect was random. These results suggest that the vulnerability of performance on conceptually-driven implicit measures to differences in age may result from something other than developmental differences. The results are discussed within the context of processing theories of memory function.

Experiment 2 was designed to investigate potential group differences in implicit and explicit memory function in a sample of reading disabled individuals, normal controls as well as individuals with attention-deficit hyperactivity disorder. Results revealed that groups did not differ in their performance on the explicit measure. However, significant group differences were obtained in performance on the perceptually-driven implicit measure. These results are discussed in terms of their relevance to processing theories of implicit memory function.

Acknowledgments

There are many people (family, friends and teachers) who I would like to thank for helping me through this long process. Your continued support and understanding have been invaluable, and without you, this would have never happened.

I would like to thank Jeffrey Halperin for his patience in working with something with which he was not very familiar. You have my respect, admiration and gratitude. To Doreen Berman and Wilma Winnick, thank you for your diligence and insight. To Jane Healy and John DeLuca, thank you for your time and patience.

I'd like to thank Gudrun, Heinrich, Karen and Jenny, and their families, for their support and understanding, but mostly for their tolerance. I have grown in knowing you. To Susan Schwartz, thank you for picking me up when I fell and for helping me keep my sanity. I value you both as a professional and a friend. To Aileen, thank you for your insight and sensitivity; you are truly a wise and intelligent woman and I'd go to Jersey to pick you up!

Most of all, I would like to thank my parents, Edith and Jim. After 23 years of school, I realize that it is you who have been my best teachers all along. This work is dedicated posthumously to my father and, in full life, to my mother.

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Introduction

Within the discipline of psychology, research on memory has traditionally been limited primarily to studies investigating explicit recollection. While the idea that behavior and cognition can reflect prior experience without conscious awareness of that experience is rooted in ancient philosophy, it was not until the early 1970's that contemporary psychology was equipped with the methodological techniques to study the phenomenon. Since that time, researchers from a variety of disciplines have allocated much attention to the study of implicit in addition to explicit memory function. As a result of their efforts, a tremendous literature has developed which details the characteristics of these memory forms, as well as the purported neural mechanisms which underlie them.

This dissertation is comprised of two experiments. Motivation for the first experiment derived from the fact that, while a handful of studies have compared implicit and explicit memory in subjects of various ages, age comparisons have been restricted to those between young and old adults or between children of various ages. Only two studies have attempted to compare the performance of children and adults. As will be seen, the results of one of these studies are tenuous due to methodological problems in that different tasks were used for different groups. The second study, although methodologically sound in comparing implicit and explicit memory performance of three groups of children to that of young adults, excluded individuals between the ages of 12 and 18 years. Thus, the primary purpose of Experiment 1 was to investigate the development

of implicit and explicit memory, across a major portion of the life-span (i.e., middle childhood to mid-adulthood).

A second motivation for Experiment 1 relates to the recent suggestion that the demonstration of age effects on memory tests depends upon the task demands of the tests employed (i.e., conceptually vs. perceptually-driven) rather than the form of memory targeted (i.e., implicit vs. explicit). Specifically, it has been suggested that conceptually-driven tasks (be they implicit or explicit) are vulnerable to age effects, whereas perceptually-driven tasks are not.

The memory tasks employed in Experiment 1 differed in the extent to which they engage conceptually-driven processing. Implicit memory performance was assessed using two tasks: one perceptually-driven (cued word-stem completion) and one conceptually-driven (category fluency). Explicit memory performance was assessed using a conceptually-driven recognition test. It was predicted that performance on the conceptually-driven tasks would be vulnerable to age effects whereas performance on the perceptually-driven measure would not.

Experiment 2 was intended to investigate hypothesized differences in implicit and explicit memory function in a sample of reading disabled (RD) children relative to non-RD children. The manner in which this group would differ, however, was uncertain. One possibility is that RD children would be impaired relative to non-RD children on tests of implicit memory. The primary impetus for this prediction relates to the belief that performance on implicit tasks reflects the domain-specific properties of the

cognitive system engaged by that task. In keeping with this logic, it would follow that implicit memory for lexical information would be critically dependent on the integrity of intact language mechanisms. Consequently, children with a lexically-based disability would be expected to demonstrate impairment on such a task. Alternatively, it was hypothesized that RD children would demonstrate increased priming relative to non-RD children on the implicit measures. This prediction was based on reports of increased priming in individuals with processing deficits (e.g., Scarborough, Cortese & Scarborough, 1977). The fact that RD children exhibit semantic processing deficits, therefore, argues for enhanced priming relative to non-impaired peers.

The hypothesized difference between RD and non-RD children on the explicit memory test was based on findings which indicate that RD children demonstrate impairment in semantic encoding and processing, as well as in the explicit retrieval of information. The memory performance of RD children in Experiment 2 was also compared to that of a sample of children with Attention-deficit Hyperactivity Disorder (ADHD). The reason for including this sample was to provide a patient control group in order to demonstrate that performance differences in the RD group were not due to non-specific impairment.

Implicit And Explicit Memory Defined

Historically, studies of memory have relied on tests which require subjects to consciously recollect target information by making explicit reference to a specific learning episode. In these studies, performance on tests of free recall, cued recall and recognition have served as the indices of memory. Over the past decade, however, a number of researchers have focused on those situations in which information that has been encoded at some point in time is expressed under conditions which do not require conscious or deliberate recollection of the encoding episode. In these situations, memory is revealed when a change (typically a facilitation) in task performance results from previous exposure to a given stimulus without the conscious evocation of the circumstances under which the exposure took place (e.g., the spatiotemporal context) or awareness that one is engaging in recollection.

The fact that these two types of memory have been found to be dissociable (i.e., independent of one another under certain conditions) has led numerous investigators to conceptualize the memory types, as well as the tasks used to assess them, using various dichotomies. For example, in the mid 1980's, Graf and Schacter (1985) introduced the *explicit vs. implicit* dichotomy as descriptive concepts which relate to a person's psychological experience at the time of retrieval. In describing the methods used to evaluate the two forms of memory, Johnson and Hasher (1987) and Jacoby (1984) introduced the terms *direct vs. indirect* and *intentional vs. incidental*, respectively.

According to Graf and Schacter's (1985) conceptualization, explicit memory refers to the conscious recollection of recently presented information as expressed on standard measures of free recall, cued recall and recognition. Thus, consistent with Jacoby's (1984) and Johnson and Hasher's (1987) understanding of the measures used to evaluate this type of memory, explicit memory instructions require the evocation of a previous incident with the concomitant awareness of recollection. In contrast, implicit memory, as measured by incidental or indirect measures, is revealed when a previous experience facilitates performance on a task in the absence of instructions that require conscious or intentional recollection of that experience. The terms *implicit/explicit* will be adopted throughout this dissertation to refer to two types of memory task.

It should be noted that the implicit/explicit dichotomy proposed by Graf and Schacter (1985) was intended neither to refer to, nor imply the existence of, two separate or independent neural systems. As stated previously, the terms were offered as descriptive concepts which relate to a person's psychological experience at the time of retrieval. The question of whether or not these memory types depend on a single underlying neural mechanism continues to be an issue of great debate. The implications that observed experimental dissociations between implicit and explicit memory have for the postulation of multiple memory systems will be addressed later.

Our present understanding of implicit memory derives from a confluence of ideas and observations from various independent

fields of study, including philosophy, physiology, psychology, neurology and biology. Despite this, many of our current ideas regarding implicit memory are no different from those offered centuries ago. Insights regarding the existence of multiple forms of memory obtained within the last decade are attributable, primarily, to methodological improvements.

The idea of multiple memory forms is not new. In fact, the idea can be found reflected, in subtle form, in the writings of the ancient Greek philosophers in their writings on sensation and perception. The specific concept of "implicit memory" developed somewhat later and stemmed from the more general belief that prior experience is capable of influencing behavior in the absence of conscious awareness for that experience. In the centuries to follow, this idea inspired speculation regarding the nature of the unconscious, and provided the impetus for systematic investigation of the mechanisms which underlie this phenomenon.

As described in Schacter's (1987) historical survey of implicit memory, the idea that previous experience can influence behavior without awareness of that experience was first espoused clearly during the middle of the seventeenth century in the writings of the French philosopher, Rene Descartes. In citing a section from Descartes' (1649) *Passions of the Soul*, Schacter points out that this philosopher was among the first to note that traumatic childhood events "remain imprinted on his [the child's] brain to the end of his life" without "any memory remaining of it" (Haldane & Ross, 1967, p. 391, cited in Schacter, 1987). It was not until the early eighteenth century, however, that philosophers began to realize that prior

experience not only impacts on behavior in the absence of conscious awareness, but that cognition is influenced as well. This latter idea was made explicit by the German philosopher, Gottfried Leibniz, who suggested that, "... often we have an extraordinary facility for conceiving certain things, because we formerly conceived them, without remembering them" (Leibniz, 1916, p. 106 cited in Schacter, 1987). Only a handful of followers embraced Leibniz' idea. Most philosophers at this time, heavily influenced by the British Associationists, focused their attention on aspects of explicit memory.

The idea of implicit memory did not resurface until the early nineteenth century. This time, a French philosopher, Maine de Biran, in his 1804 treatise titled *The Influence of Habit on the Faculty of Thinking* (cited in Schacter, 1987) introduced the idea that behaviors, which have become automatic through practice, often occur without awareness of the discrete actions which characterize them or of the context in which the behaviors were acquired. Maine de Birans' ideas served as the origin for much of our current thinking about implicit memory. For example, his analyses of habit and automatic behavior anticipated later thinking about procedural memory. Similarly, in hypothesizing the existence of three types of memory, he introduced what may be considered the first theory of multiple memory systems. Mechanical memory, referring to unconscious memory for repeated movements, predates Mishkin's theory of habit memory (Mishkin & Petri, 1984). Sensitive memory, referring to the affective component of behavior, which also occurs without conscious recollection, may be seen as being akin to

affective memory. Lastly, representative memory, involved in the conscious recollections of ideas and events, is similar to what Tulving (1972) called "episodic" memory and what Cohen and Squire (1980) labeled "declarative" memory.

By the middle of the nineteenth century, researchers and practitioners from a number of disciplines had become interested in the concept of the unconscious. Some began to focus on the relationship of unconscious processing to memory function and terms such as *unconscious cerebration* (Carpenter, 1874 as cited in Schacter, 1987) and *unconscious memory* (Hering, 1920, as cited in Schacter, 1987) were introduced to describe how prior experience could effect behavior in the absence of conscious recollection for the content or context of those experiences. Evidence in support of these terms, and the theory behind them, derived from clinical and anecdotal observations within the fields of physiology, psychiatry and neurology. In the mid to late nineteenth, and early twentieth centuries, cases were documented in which individuals demonstrated the acquisition of certain skills and/or information in the absence of awareness for the conditions under which the information was acquired.

Numerous examples of this phenomenon were described by neurologists working with amnesic patients. Schacter (1987) credits Sergei Korsakoff, however, with being the first to consider the theoretical implications of this phenomenon for a theory of memory. At the end of the nineteenth century, based on his vast experience with amnesics, Korsakoff described a syndrome which would later bear his name. Individuals diagnosed with Korsakoff's

amnesic syndrome demonstrated temporally-graded retrograde and profound anterograde amnesia within the context of preserved skills and habits. Korsakoff attributed the observed implicit memory phenomena which characterized his syndrome to the existence of memory traces which, while having the capacity to effect behavior, were too weak to reach conscious awareness.

Interest in implicit memory, or "unconscious" memory as it was referred to at that time, persisted throughout the early twentieth century and psychiatrists and neurologists continued to provide case examples. Among the most noteworthy of these cases was that described by the neurologist Claparede (1912, cited in Schacter, 1987) who, after having pricked an amnesic woman with a pin, noted her reluctance to shake his hand despite her inability to recall the reason for her hesitance. Claparede explained this, and similar events, in terms of a dissociation between the memory trace and the ego. He did not, however, consider the implications of his experience for a more general theory of memory.

Other neurologists such as Sigmund Freud and Pierre Janet documented similar case findings with hysterics. While their observations resembled those of Korsakoff, Freud and Janet concerned themselves with how their observations related to psychopathology. Like Claparede, these men did not focus on how their observations related to normal cognitive function.

Ebbinghaus was among the first psychologists to distinguish between implicit and explicit forms of memory and his method of savings provided the means with which to investigate implicit memory. Despite his acknowledgment that use of this method could

provide evidence for what he termed "involuntary" memory (1885, cited in Lockhart and Blackburn, 1993), Ebbinghaus chose not to pursue this line of investigation. It was not until the mid-twentieth century that experimental psychologists began to utilize Ebbinghaus' paradigm as a vehicle for the systematic investigation of implicit memory. Since that time, methodological improvements have resulted in the development of a number of procedures used to assess implicit memory.

Methods Used To Assess Implicit And Explicit Memory

Traditionally, researchers have relied on tests of free recall, cued recall and recognition to assess memory function. In all of these methods, referred to as *direct* tests of memory, the instructions make reference to a previous episode and require the individual to actively recollect information acquired at that time. Success on these tasks, therefore, depends on one's awareness that an event occurred in which the individual acquired information within a particular spatiotemporal context. With the advent of the implicit/explicit distinction, however, it became apparent that an individual could demonstrate the acquisition of information in a manner which did not necessitate conscious awareness of a prior learning episode. Under these circumstances, a change in performance was seen to result from prior experience in the absence of direct reference to that experience. These latter measures, referred to as indirect tests of memory, have increased in number and complexity over the past decade and have been used by researchers studying implicit memory. This rapid increase in the

number of available tests has resulted in a parallel expansion of task-comparison methods intended to quantify and qualify these measures. Based on observed dissociations (and parallel effects) between performance on direct and indirect tasks, researchers have speculated with regard to the nature of the underlying cognitive processes and/or mental states. Theories which derive from task-comparison studies fall under the general heading of "processing theories". These theories can be further categorized based on the type of paradigm and/or cognitive sub-area (e.g., conceptual, lexical or perceptual) with which each is associated.

Direct Memory Tests. Broadly defined, direct tests are those in which, in the instructions, reference is made to a previous event or episode in the personal history of the subject and the subject is asked to produce information which was presented during that episode. Free recall, cued recall and recognition tests are classified as direct memory tests and are used to assess explicit memory. At study, subjects are presented with target information (e.g., a list of words, pictures) and are required to process this information in some way. Frequently, subjects are asked to encode this information according to some predetermined criteria (e.g., respond to a question about the words). At a later time, the examiner refers the subject back to the specific episode in which the individual encoded the information and asks the individual to produce that target information. A necessary requirement for successful completion of these tasks is that the individual consciously attempts to retrieve the requested information with full awareness of the spatiotemporal context within which that information was

acquired. On tests of free-recall, the subject is asked to recall the target information without any assistance from the examiner. For example, when recalling a list of words, a subject may be asked merely to recite the list of words in any order. A similar demand is made on tests of cued recall with the exception that cues are provided to assist retrieval. For example, a subject may be asked to produce the list of words having been provided with the initial letters of the words.

In contrast, recognition tests typically take one of two forms: "yes/no" or "multiple choice". On a yes/no recognition test, an individual is asked to indicate whether a stimulus item was present or absent during a specified learning episode. On a multiple choice test, an individual is presented with a number of choice items and is asked to select the one that was presented during the learning episode. The fact that an individual is required to make explicit reference to a prior learning episode when performing a recognition task is crucial in the classification of this task as a direct measure of memory.

While there is little debate that tests of free and cued recall are truly direct measures of explicit memory, there has been some question regarding the status of recognition tests. Based on findings from studies investigating the effects of aging on implicit memory, a number of researchers have demonstrated that performance on recognition tests can, at times, be supported by implicit mechanisms (e.g., Johnston, Hawley & Elliot, 1991). For the purposes of the current paper, however, recognition will be classified as a direct measure in that the individual is instructed to

make conscious reference to a prior learning episode and recall information acquired during that episode.

Indirect Memory Tests: There are a wide variety of tasks and procedures used to evaluate implicit memory. Despite their heterogeneity, for all indirect measures, memory is inferred from the demonstration that information has been acquired in the absence of a conscious intention to recall the content or the context in which the information was acquired. Thus, on all of these measures, prior experience enhances performance (relative to performance without prior experience) despite the fact that the instructions make reference only to the task at hand and do not require the individual to intentionally evoke a prior learning episode. The tasks are considered to be *indirect* for two reasons. First, they do not explicitly direct the individual to the prior learning experience. Second, evaluation of implicit memory is "inferred" from the difference between performance on a task following exposure to an event relative to performance on the same task in the absence of such prior experience.

Much of the current research on implicit memory focuses on the phenomenon of *direct* or *repetition priming*. Both terms refer to a facilitation in the processing of a stimulus (typically an increase in accuracy and/or decrease in latency of response) resultant to a previous encounter with the same stimulus without explicit reference to the prior study episode. The majority of tasks classified as priming measures are perceptually or lexically based. This is not surprising when one considers that much of our current interest in repetition priming derives from research on word

recognition and lexical organization where researchers use the patterns of priming effects in order to make inferences regarding the nature of lexical access and representation (Schacter, 1987).

In their review of memory measures, Richardson-Klavehn and Bjork (1988) provide a summary of indirect memory tests. They introduce a useful classification scheme which divides indirect tests into four broad categories: (1) tests of factual, conceptual, lexical and perceptual knowledge; (2) tests of procedural knowledge (i.e., skilled performance and problem solving); (3) measures of evaluative response and (4) neurophysiologic responses and conditioning measures. This classification will be used in the present dissertation.

Virtually all exemplars from the first grouping fall under the category of priming measures. While the majority of tasks belonging to this group would be classified as measures of direct or repetition priming, several would be considered tests of indirect priming. The distinction between direct and indirect priming measures will be addressed later. For now, it is important to note that all tasks belonging to this first category are used to investigate structures and processes involved in the retrieval of permanent knowledge.

Included among the measures intended to assess factual and conceptual knowledge are tests which, following exposure to a given stimulus event (e.g., presentation of a word-list), require an individual to retrieve items of general knowledge (e.g., Roediger & Blaxton, 1987), generate members of a given semantic category

(Graf, Shimamura & Squire, 1985) or classify or categorize given stimuli (e.g., Durso & Johnson, 1979).

A variety of tasks fall within the lexical priming domain. Most popular examples of these tasks are: lexical decision tasks (i.e., deciding whether a particular letter string constitutes a legal word; e.g., Scarborough, Cortese & Scarborough, 1977); word-stem completion (i.e., producing a word which completes a given three-letter stem; e.g., Graf, Mandler & Haden, 1982); word-fragment completion (i.e., supplying deleted letters to complete a word fragment such as ss ss ; e.g., Roediger & Blaxton, 1987) and spelling orally presented homophones (e.g., Howard, 1988).

Measures falling under the rubric of perceptual priming tasks include tests of picture naming (e.g., Durso & Johnson, 1979), as well as those requiring an individual to identify tachistoscopically presented whole words (e.g., Jacoby & Dallas, 1981), fragmented words and degraded pictures (e.g., Srinivas, 1991, as cited in Roediger & Srinivas, 1993).

Studies utilizing these tasks typically expose subjects to a study episode during which they are presented with target stimuli of interest. For example, an individual might be asked to answer questions about a list of words or indicate preference for pictured objects. Subsequent to that study episode, the individual is presented with the test. On tasks evaluating factual, conceptual and lexical knowledge, the frequency with which an individual responds with a previously-studied target item serves as the index of implicit recall. On the more perceptually-based tasks, increased

accuracy of identification and/or decreased latency to respond provide a measure of priming.

As mentioned previously, a distinction should be made between *direct* and *indirect priming* tasks. On tests of *direct priming*, an enhancement in the processing of a stimulus occurs after prior experience with that same stimulus. It has been found, however, that priming effects are not limited to these conditions. Exposure to a given stimulus can also facilitate the processing of stimuli which are either associatively or semantically related to that stimulus. For example, Murrell and Morton (1974) found enhanced performance on a word identification task for words that were morphologically similar to words presented at study (e.g., exposure to the word *seen* facilitated identification of the word *sees*) but not for words that are visually similar (e.g., *seen* did not facilitate identification of the word *seed*). The fact that prior experience with a stimulus enhances the processing of material which is related or similar to that stimulus serves as the defining feature of *indirect priming*. Thus, as Klavehn-Richardson and Bjork (1988) point out, *indirect priming* occurs when a change in performance results from the presentation of information that is related in some way (e.g., associatively, semantically, graphemically, phonemically or morphologically) to test stimuli.

Subsumed under the category of procedural tests are those which evaluate an individual's performance as a function of practice, i.e., those which evaluate the acquisition of skills. Skill acquisition paradigms differ from repetition priming paradigms in two respects. First, ongoing feedback is provided throughout the

entire performance of the task. Second, procedural tests typically involve tasks which are novel to the individual and therefore do not qualify as a representation of permanent knowledge (Kirsner, Speelman & Shofield, 1993). Tests which assess one's ability to acquire a perceptual-motor skill such as pursuit rotor and mirror drawing (e.g., Squire & Cohen, 1984) serve as examples. Tests which evaluate the development of certain cognitive skills (e.g., proofreading) and problem-solving abilities (e.g., completing the Tower of Hanoi puzzle) are also classified as procedural tests used to evaluate implicit memory.

Tasks studying the effect of prior experience on an individual's evaluative responses and cognitive judgments comprise the third group of indirect memory tests. On these tasks, experience with target stimuli has been found to influence one's affective preference, as well as various types of cognitive judgments for those stimuli (e.g., Zajonc 1980).

Among the final grouping of tasks considered to be indirect measures of memory are those which measure changes in physiologic responses such as the galvanic skin response and event-related potentials, as well as conditioned responses (e.g., conditioned eyeblink). As these behaviors typically occur without conscious awareness or intention, changes in their magnitude or strength are viewed as an indication for the acquisition of a behavioral response to a previously neutral stimulus. Consistent with this idea, is that of researchers (e.g., Schacter & Moscovitch, 1984) who view an infant's tendency to habituate in response to a familiar stimulus as a facilitation in the processing

of that stimulus. In this regard, habituation may also be considered an example of an indirect measure of memory. As will be seen, such a consideration has implications for the ontogenetic development of the systems which underlie implicit and explicit memory.

Experimental Dissociations Between Implicit And Explicit Memory

A great deal of research over the past decade has indicated that, under certain circumstances, performance on tests of implicit memory is dissociable from, and independent of, performance on tests of explicit memory. The cumulative findings of research in this area provide significant evidence of the functional and statistical independence of these memory types.

Dissociations Suggesting Functional Independence. Two tasks are said to be functionally independent when manipulation of an independent variable effects performance on one but not the other task, or effects performance on both tasks, but in opposite directions (Tulving, 1985). The performance of normal subjects on tests of explicit (i.e., recall and recognition) and implicit (e.g., priming measures) memory has revealed four important characteristics which have served as evidence for the functional independence of these types of memory.

First, changing the modality of stimulus presentation between study and test has been found to have little or no effect on explicit memory performance (e.g., free recall or recognition). In contrast, it has been demonstrated that implicit memory depends greatly on the surface characteristics of the stimuli presented. For instance, Jacoby and Dallas (1981) demonstrated that changing the modality

of presentation from study (i.e., auditory) to test (i.e., visual) greatly reduced the effect of priming on a perceptual identification task, but had no effect on yes/no recognition performance. Similarly, priming effects on lexical decision, word-stem and word-fragment completion tasks have been found to be effected by study-test modality changes, whereas performance on recall and recognition tests have been less sensitive to these changes (e.g., Graf, Shimamura & Squire, 1985; Roediger & Blaxton, 1987 and Roediger & Weldon, 1987, in Berry & Dienes, 1993). This modality-specific characteristic of implicit memory performance has been termed *transfer-appropriate processing* and suggests that the amount of priming is greatest when processing operations at test are most similar to those engaged during the learning phase. The principle is akin to that expressed in the concepts of primary and secondary stimulus generalization in studies of conditioning, as well as in Tulving's (1983) encoding specificity principle. The implication of transfer appropriate processing for a generalized theory of implicit memory will be addressed later in this paper.

A second characteristic providing evidence for the functional independence of implicit and explicit memory derives from studies which have demonstrated that implicit memory performance is less effected than performance on measures of explicit recall by manipulations of retention interval. For example, using a word-stem completion task, Tulving, Schacter and Stark (1982) found that priming effects persisted across delays of several days and months despite marked declines in recognition performance. Jacoby and Dallas (1981) obtained similar findings using a word-identification

test. Despite this, Graf and Mandler (1984) found priming effects on a word-stem completion task to be a transient phenomenon relative to performance on explicit measures of recognition.

The third characteristic used as evidence of functional independence is that explicit, but not implicit, memory is effected by variations in the encoding requirements at study. Jacoby and Dallas (1981) found that performance on a yes/no recognition task was effected by variations in the type of encoding required at study, whereas performance on a word-identification task was not. Similar findings were reported by Schacter and McGlynn (1987), who studied implicit memory for common idioms (e.g., sour grapes) using a free-association test (i.e., by having subjects respond with the first word that comes to mind when presented with a prompt; e.g., sour - ?). Here too, performance on the explicit measure was effected by manipulation of the independent variable, whereas performance on the free association test was not.

The fourth piece of evidence in support of a functional dissociation derives from research evaluating the effects of proactive and retroactive interference on each form of memory. While performance on tests of recall and recognition have been found to be vulnerable to manipulations in proactive and retroactive interference, priming effects obtained on tests of word-stem (Graf & Schacter, 1987) and word-fragment completion (Sloman, Hayman, Ohta, Law & Tulving, 1988) were not.

Statistical Independence. Statistical analyses demonstrating the stochastic independence of performance on measures of implicit and explicit memory have frequently been cited as additional

evidence for the independence of these memory forms. Stochastic independence refers to "the relation between two events in which the probability of their joint occurrence is equal to the product of the probabilities of the occurrence of each event alone" (Ostergaard & Jernigan, 1993, p. 328). When considering memory tasks, stochastic independence can be seen using a within-subjects design in which memory for certain target information is evaluated successively using two different tests. The results of the two tests are said to occur independently when performance on the first does not effect performance on the second. For example, that certain target items are produced during an implicit test should not effect the likelihood that these items will be correctly identified on a subsequent explicit test.

Within the implicit memory literature, stochastic independence has been found to exist in performance on indirect and direct measures under a variety of conditions (e.g., Tulving, Schacter & Stark, 1982, as well as Hayman & Tulving, 1989, using tests of word-fragment completion and recognition; Schacter, Cooper, Tharan & Rubens, 1991, using a test of object perception). This finding has been interpreted, by many researchers, as evidence for the hypothesis that performance on these tasks is mediated by different memory systems. That stochastic independence has also been found to exist between various implicit measures (e.g., Witherspoon & Moscovitch, 1989), however, serves to weaken the argument for multiple memory systems. Recently, the finding that performance on implicit measures is influenced by numerous factors other than the previous study episode (e.g., perceptual processes and

familiarity with target information) has led researchers to question how much of the variance in these tasks is attributable to memory per se. Given this, the issue regarding the significance of a finding for stochastic independence between measures continues to warrant further investigation.

Dissociations Between Implicit/Explicit Memory in Memory-Disordered Patients. Dissociations between implicit and explicit memory have been reported by researchers using a variety of indirect tasks in a number of memory-disordered patient populations. Intact performance on indirect measures, in the presence of poor performance on direct measures, has been found in individuals with amnesia, early stage Alzheimer's disease (e.g., Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991, using word-identification and completion priming tasks), herpes simplex encephalitis (e.g., Kapur, 1988, using pursuit-rotor), Multiple Sclerosis (e.g., Rao, Grafman, DiGiulio, Mittenberg, Bernardin, Leo, Luchetta & Unverzagt, 1993, using identification of degraded words and mirror reading, and, Beatty & Monson, 1990, using word-stem completion), as well as in Huntington's and Parkinson's Diseases (Heindel, Salmon, Shults, Walicke & Butters, 1989, using motor-skill learning and word-stem completion).

Dissociations in Other Syndromes. Implicit/explicit dissociations have also been observed in other neuropsychological syndromes, although the evidence is somewhat fragmented. For example, dissociations have been reported in individuals with alexia without agraphia (e.g., Coslett & Saffran, 1989), prosopagnosia (e.g., Tranel & Damasio, 1988), Broca's aphasia (e.g., Andrews & Seron,

1975), Wernicke's aphasia (e.g., Milberg & Blumstein, 1981) and visual object agnosia (e.g., Margolin, Friedrich & Carbon, 1983). As examination of these dissociations is beyond the scope of this paper, the reader is referred to Berry and Dienes (1993) for a review.

Dissociations Observed in Amnesic Patients. The most striking dissociations between implicit and explicit memory performance have resulted from studies investigating these processes in amnesics. The finding that severely amnesic patients have been found to perform well, and at times equal to controls, on numerous measures of implicit memory, has served as impetus for continued research in the area of learning and memory. Evidence for preserved implicit memory in the presence of deficient explicit memory first emerged in the late 1960's in studies of skill learning. In 1968, Corkin reported retention of perceptual-motor skills in amnesics as demonstrated on tests of mirror-tracing. Brooks and Baddeley (1976) later reported similar findings on a test of pursuit-rotor ability. In the decades to follow, preserved memory function in amnesics was reported in studies of classical conditioning (e.g., acquisition of eye-blink; Weiskrantz & Warrington, 1979), reading of mirror-reversed words (e.g., Cohen & Squire, 1980) and, more recently, on tests of direct and indirect priming (e.g., Graf, Squire & Mandler, 1984; Shimamura & Squire, 1984; Smith & Oscar-Berman, 1990), as well as, exclusion tests (e.g., Cermak, Verfaellie, Sweeney, & Jacoby, 1992). In all of these paradigms, preserved performance on indirect measures was observed only in the absence of conscious awareness that memory was being tested.

The dramatic dissociations between implicit and explicit memory observed in amnesic patients have inspired a tremendous amount of theorizing intended to elucidate the neural mechanisms and cognitive processes which underlie these dissociations.

Explaining Dissociations Between Memory Types

Numerous theories have been offered to explain observed dissociations between implicit and explicit memory. The majority of these theories derive from attempts to account for the dissociations observed in amnesic patients. During the 1970's the memory deficits characterizing amnesia were interpreted in terms of consolidation theory. Activation theories were proposed as a result of the inability of consolidation theory to account adequately for findings which suggested that implicit memory was preserved in this population. More recently, observed dissociations have been explained either in terms of various processing abilities which underlie performance on direct and indirect measures, or as providing evidence for the existence of multiple memory systems. The relative advantage of one view over the other continues to be an issue of great debate among learning and memory theorists.

Activation Views. In the 1970's, the explicit memory deficits observed in amnesic patients were explained in terms of difficulties in consolidation. According to consolidation theorists, poor performance on tests of recall and recognition reflected a deficiency in the transfer of information from a primary (short-term) memory system to a secondary (i.e., long-term) memory

system. The failure of consolidation theory to account adequately for the observed dissociations between implicit and explicit memory function in amnesics, however, gave rise to what are now called "activation theories".

The major principle common to all activation theories is that implicit memory phenomena (verbal and nonverbal) result from the temporary activation of pre-existing representations rather than reflecting the establishment of new memory traces. Diamond and Rozin (1984) proposed, in explanation of repetition priming, that exposure to a word results in the automatic activation of a preexisting representation for that word. Thus, exposure to a word during the encoding phase of a memory test serves to activate, or prime, semantic memory where the representation exists in a non-contextual form. Once activated, the preexisting representation remains available for a period somewhat beyond the span of short-term memory and is more accessible than non-activated representations. This availability increases the probability that the representation (e.g., the word) will be produced when the subject is exposed to conditions which are similar to those experienced at encoding.

The strength of activation theories lies in their ability to account for a number of implicit memory phenomena. For example, activation theories could easily accommodate the finding that performance on indirect measures was resistant to levels of processing while that on direct measures was not. The viability of these theories has relied on research which has indicated that amnesics do not demonstrate priming effects for novel information

such as pseudowords (e.g., Cermak, Talbot, Chandler & Wolbarst, 1985; Diamond & Rozin, 1984).

More recently, however, findings (e.g., Gordon, 1988; and Smith & Oscar-Berman, 1990; Bowers, 1994) that amnesics, and normal subjects, do exhibit priming effects for information which has no preexisting representation (e.g., pseudowords and novel associations) have posed problems for activation theorists resulting in their gradual withdrawal from the forefront of memory research.

Processing Views. Processing views were offered as an alternative to activation theories. Broadly defined, processing views are those which attribute implicit/explicit dissociations to differences in processing operations within a single memory system (e.g., Blaxton, 1989, and Roediger, 1990). The principle of *transfer-appropriate processing* is integral to the theories which fall into this category. According to this principle, implicit memory tests will yield priming when the processing operations at test resemble, or mimic, those engaged during prior learning (Roediger, 1990b). The theory successfully characterizes the transfer of learning which takes place in priming and accounts nicely for findings which have demonstrated that, with changes in study/test modality, the amount of priming observed on indirect tests declines.

The principle of transfer-appropriate processing has inspired theorists to explain experimental dissociations between implicit and explicit memory in terms of how the cognitive operations engaged at study compare to those required at test. The results of several studies have been interpreted to suggest that the amount of

priming obtained on a given task depends on the extent to which the encoding operations overlap with the retrieval processes. The earliest evidence of this derives from the research of Winnick and Daniel (1970), who documented a dissociation between performance on word identification and free recall as a result of variations in study condition. Subjects in this study were required to read familiar words, generate a word from a picture, or generate a word from a definition. It was found that priming effects obtained on a word-identification task were greater for words that were read in isolation than for those presented in either of the two generation conditions. In contrast, free recall was better for words which were generated than for words read in isolation. Jacoby (1983) obtained similar results in a study on word repetition when he varied the context in which target words were initially encountered. In this latter experiment, subjects were required to process words in one of three contexts: (a) to read words presented in isolation, (b) to read words presented in the context of a semantic associate (e.g., north-south), or (c) to generate a word from a semantic associate (e.g., north - _____). Jacoby's suggestion that the contexts differed in the extent to which they provided conceptual support to the word recognition process led to his distinction between tests which require *data-driven* and *conceptually-driven processes*.

Conceptually-driven processes are characterized by activities such as elaborating, rehearsing, imaging, reflecting, organizing and reconstructing. These processes are subject-initiated and require conscious intention. In contrast, data-driven processes are guided

by the information that is presented at study or test. They are believed to occur automatically as soon as a stimulus is presented and include perceptual, phonemic and auditory processes.

Insofar as Jacoby's (1983) distinction can be used to describe the operations engaged during encoding, so too can they describe the retrieval processes required at test. Explicit memory tests (i.e., direct measures) are typically conceptually-driven whereas implicit memory tests are mostly data-driven. Despite this, both types of processing can be engaged on either type of task. It is possible, therefore, to have a direct measure with a data-driven component and an indirect measure which requires conceptually-driven processes. Given this, it would follow that information acquired when conceptual encoding is required should transfer best to conceptually-driven tests, be they direct or indirect. Similarly, information that is acquired under conditions which evoke perceptual processing should transfer best to data-driven tests, be they direct or indirect. The findings obtained by MacLeod (1989) when studying fragment-completion performance provide support for this argument. MacLeod presented subjects with words in isolation (i.e., under conditions that were primarily data-driven) or within the context of a paragraph (i.e., under conditions which engaged conceptual processes). Priming effects obtained on a data-driven indirect test (i.e., fragment completion task) were greater for words presented in isolation (i.e., under conditions which evoked similar processes to those required at test) than for words presented under conditions which evoked conceptual processing.

A major criticism (see e.g., Roediger, 1990b) of the research in this area relates to the tendency for researchers to focus only on performance differences between direct and indirect measures without consideration for the fact that both tasks may require the same type of processing. Only recently has attention been directed to exploring comparisons between performance on either implicit or explicit tests which vary in processing requirements (i.e., data-driven implicit tests vs. conceptually-driven implicit tests). Researchers who have investigated this issue have reported dissociations between measures of implicit memory which are conceptually-driven and those that are data-driven (e.g., Blaxton, 1989; Smith & Branscombe, 1988 and Srinivas & Roediger, 1990). The results of these studies provide evidence in support of processing views. However, further study is critical in order for a determination to be made regarding their advantage relative to other views in accounting for dissociations between implicit and explicit memory.

Multiple-Systems Views. Proponents of multiple-systems views contend that human memory is composed of functionally different systems. Historically, researchers have tended to explain implicit/explicit dissociations in terms of separate underlying memory systems: one system subserving implicit memory function and another underlying explicit memory function. Demonstration of innumerable dissociations, however, has resulted in the postulation of numerous dichotomies. Of these, only several key dichotomies will be reviewed here.

Dichotomy approaches. Amnesic subjects are able to learn to perform a task without recollection of either the learning episode, or the fact that they have ever performed the task at all. This finding led Tulving (1972) to distinguish between *episodic* and *semantic* memory. As summarized by Cermak (1984), *episodic* memory includes memory for specific, personally-experienced events whereas *semantic* memory is characterized by memory for linguistic knowledge, general principles, associations and rules. According to Tulving's theory, recollection of a specific episode depends on an individual's ability to recall the context within which the episode occurred. In contrast, while the contents of semantic memory are assumed to have been acquired within a specific context, recollection of that context is not necessary when recalling a general or semantic fact.

In 1985, Tulving modified his theory to include a third type of memory: *Procedural Memory*. Procedural memory is defined as knowledge which is inaccessible to consciousness. As such, procedural memory can be expressed only indirectly through some form of action and, perhaps, conditioned responses or other behaviors that permit the inference that the performer possesses certain types of knowledge. It is procedural memory that is demonstrated in the performance of motor skills which, on becoming automatic, are difficult to describe consciously. The use of grammatical knowledge in the production and comprehension of language would also be considered an example of procedural knowledge.

The second dichotomy, based on the results of research with amnesics, was proposed by Cohen and Squire (1980). These researchers introduced the *procedural-declarative* distinction. The *procedural* system, as explained above, enables retention of how to perform a task without conscious awareness. In contrast, the *declarative* system, comprised of semantic and episodic memory, contains information which is accessible to consciousness. That is, it permits conscious awareness of the learning episode, as well as awareness that one has performed the task in the past (i.e., declarative knowledge of the act).

Based on elaborations of this theory, Cohen (1984) and Squire (1987) included repetition priming as a form of procedural memory and classified indirect measures such as word-fragment completion and word-identification tasks as being data-driven. The realization that many indirect tests require processes other than those of a purely perceptual nature, however, has led theorists to substitute the more general term *nondeclarative* for the term *procedural*. The overly-inclusive nature of this latter term, however, has led to difficulties with using this dichotomy.

Independent neural mechanisms. In their most extreme form, multiple-systems views argue for the existence of two completely independent neural mechanisms as the basis for implicit and explicit memory function. The ultimate goal then for researchers who investigate memory within a multiple-systems framework, is to localize the structures responsible for implicit and explicit memory function. Evidence in support of a view proposing independent neural mechanisms is based on extensive research with

amnesic individuals with known brain pathology (e.g., H. M., Scoville & Milner, 1957; Milner, Corsi & Teuber, 1968). The results of these studies, in addition to those obtained from the study of animal and biochemical models of amnesia, have provided significant evidence that damage to structures on the medial surface of the temporal lobe (i.e., hippocampus and amygdala) and the projection sites of these structures within the diencephalon (i.e., anterior and dorsolateral thalamus, and hypothalamus) causes amnesia. The projection sites of the diencephalon within the prefrontal cortex (i.e., ventromedial prefrontal cortex), as well as disruption of the cholinergic neurons in the basal forebrain, have also been implicated in amnesia. For a review of the literature outlining the neural mechanisms of explicit memory, the reader is referred to Mayes (1988).

Interpreting implicit/explicit dissociations within the context of what is known about the neuropathology underlying memory disorders has enabled theorists to speculate about what neural systems might underlie implicit memory function. Early attempts at localizing the mechanisms which underlie implicit memory were inspired by findings of spared implicit memory function in amnesic patients. The impetus for early localization hypotheses stems from the belief that structures which underlie implicit memory function must be other than those which are damaged in amnesia (i.e., hippocampus, amygdala, diencephalon).

Recently however, evidence has been reported suggesting that the neural mechanisms responsible for explicit memory function also contribute to performance on implicit memory tasks (see e.g.,

Jernigan & Ostergaard, 1993). Such findings have motivated some researchers to abandon the belief that the neural mechanisms which underlie these forms of memory are completely independent.

Repetition Priming And Multiple-Systems Views

Repetition priming has typically been regarded as a form of procedural memory; however, its relationship to multiple-system views continues to be debated. When considering the phenomenon within the context of the proposed dichotomies, it becomes clear that repetition priming does not quite fit either the procedural or the semantic category. As Sherry and Schacter (1987) point out, priming is not a form of procedural memory as its demonstration occurs following one trial and does not develop gradually as does the acquisition of habits or skills. Neither can repetition priming be considered an example of semantic memory as it occurs in the absence of conscious recollection.

In an attempt to reconcile this difficulty, Tulving and Schacter (1990) (see also Schacter, 1990) proposed a multiple-system theory which has several advantages relative to the previously mentioned dichotomy views. First, it accommodates a number of observed implicit/explicit dissociations. Second, it is compatible with processing interpretations of these dissociations, and third, it has implications for a developmental theory of memory. The theory differs from those previously presented in that it is monohierarchical rather than dichotomous. The theory proposes that data-driven priming depends on the existence of what Tulving and Schacter term a *perceptual representation system* (PRS). The PRS

is viewed as a subsystem of procedural memory and should be considered as distinct from other memory types (e.g., semantic and episodic). Ontogenetically, the PRS, and consequently the procedural system, are believed to develop first. Some forms of implicit memory (e.g., classically conditioned responses) are seen in infancy, suggesting that this system is in place from birth, if not earlier. In the true spirit of Hughlings Jackson's assertion (1880, as cited in Parkin, 1993) that the vulnerability of brain systems is inversely related to their evolutionary status, it is believed that the implicit system is resistant to the effects of aging, as well as trauma and disease. In contrast, episodic memory, the most specialized system, is the last to develop ontogenetically and maturationally. As such, it is the most vulnerable to aging and trauma. Tulving (1991) viewed the neural mechanisms which subserved episodic memory as unnecessary for priming.

Based on this theory, the PRS is divided into several subsystems, each of which subserves different types of priming. For example, data-driven lexical priming (observed on tasks such as stem and fragment completion) is dependent upon a *word-form system*. In contrast, priming observed on object-perception tasks (e.g., degraded-object identification tasks) is dependent upon a *structural-description system*. Based on this hierarchy, semantic memory is also seen as a subsystem of the PRS and is believed to underlie priming on conceptually-driven tasks.

Evidence for the PRS derives, in part, from studies of persons with known brain pathology who, despite severely impaired access to semantic knowledge, demonstrate relatively intact access to

perceptual-structural knowledge of words and objects (e.g., Warrington, 1982; Warrington & Weiskrantz, 1982). Such findings argue for a perceptual component to the performance on verbal as well as nonverbal tasks.

Additional evidence for the PRS stems from studies which have used positron emission tomography (PET) to explore various aspects of lexical processing (e.g., Peterson, Fox, Posner, Mintun & Raichle, 1988). These studies have indicated that one brain region underlies processing of semantic information whereas another is responsible for word-form information. Results of PET studies have been interpreted to indicate that, while these systems are at times interactive, they are also capable of acting independently.

Tulving and Schacter's theory would typically be classified as a "multiple-systems" view. Alternatively, however, it may be viewed as the first attempt to reconcile systems with processing views. Systems and processing views are not mutually exclusive. In fact, there is a growing tendency to treat them as complimentary.

Reconciliation of Multiple-Systems and Processing Views

Proponents of multiple-systems views have historically interpreted single dissociations between implicit and explicit memory as evidence for the existence of two independent and nonoverlapping memory systems. Recently however, researchers (e.g., Shimamura, 1993) have become critical of this interpretation arguing that, while single dissociations provide good evidence for a qualitative distinction between tasks, they should not be interpreted to reflect the existence of independent memory systems.

Single dissociations between performance on two measures indicate that at least one component or process is not shared by the two measures; they do not imply the existence of nonoverlapping memory systems.

To infer the existence of independent systems, a double dissociation between performance on implicit and explicit memory tasks must be demonstrated for groups with different pathology. That is, a patient group would have to exhibit severely impaired implicit memory in the presence of intact explicit recall for the same material for which amnesic patients demonstrate impaired explicit, but intact implicit, recall. A double dissociation of this type would suggest strongly that the tasks are subserved by independent neural mechanisms.

While double dissociations between different types of implicit memory have been observed, there have been no reports of reliable double dissociations between implicit and explicit memory. The absence of such evidence significantly weakens the multiple-systems argument suggesting the possibility that implicit and explicit memory share common neural mechanisms. Several researchers (e.g., Jernigan & Ostergaard, 1993; Randolph, 1991) have reported recent evidence in support of this possibility.

Double dissociations between performance on different implicit memory tasks in different patient groups serve as evidence that implicit memory is not a unitary phenomenon. Rather, it is believed that implicit memory is subserved by multiple neural substrates and that different brain structures underlie different types of implicit memory. For example, the neural mechanisms

thought to underlie classically conditioned responses and motor skill learning (i.e., cerebellum and basal ganglia) are different from those implicated in lexical priming (i.e., posterior temporo-parietal cortex) (Ostergaard & Jernigan, 1993).

The finding of a double dissociation between lexical priming and skill learning in individuals with Alzheimer's Disease (AD) and Huntington's Chorea (HC) provides evidence for the idea that different types of implicit memory are subserved by different brain structures. Several research groups (Heindel, Salmon, Schults, Walicke, & Butters, 1989, Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991) have reported that patients with early-stage AD, a cortical degenerative disease, exhibit impaired performance on tests of word-stem completion and free-association priming in the presence of preserved skill learning on pursuit-rotor and perceptual identification tasks. In contrast, patients with HC, a subcortical disease that causes cell loss in the neostriatum, have demonstrated the opposite pattern. These patients were found to exhibit intact performance on word-stem completion and free-association tasks in the presence of impaired ability on the pursuit-rotor task.

Consistent with Tulving and Schacter's (1990) theory of a PRS, the above results have been interpreted to suggest the existence of two separate systems to account for the two priming types: a structural-perceptual system which purportedly underlies motor-skill learning; and a lexical-semantic system which underlies lexical or word-based priming. Based on the nature of the dissociation demonstrated by patients with HC, motor-skill learning is presumed to be subserved by neostriatal areas, such as the basal

ganglia, which are disrupted in this disorder. In contrast, lexical priming, impaired in AD patients, is hypothesized to depend on the integrity of cortical structures that are disrupted in AD (i.e., association areas in the occipito-temporo-parietal cortex).

Ostergaard and Jernigan (1993) have proposed an alternative explanation of this research. They argued that the observed dissociation between the performance of AD and HC may reflect a dissociation between language and motor function rather than different memory processes. Specifically, the impaired performance of AD patients may be attributable to the fact that they had more severe linguistic deficits. In contrast, the impairment of HD patients on the motor-skill task may have resulted from impaired motor functions.

For most proponents of multiple-systems views, the mechanisms which underlie explicit memory function are thought to be unnecessary for implicit memory function. The results of two recent studies (Jernigan & Ostergaard, 1993; Randolph, 1991), however, have suggested otherwise. These studies will be reviewed in depth as the anatomical findings of both have implications for systems, as well as processing views.

Jernigan and Ostergaard (1993) conducted a study with the intention of linking priming and explicit memory function to the amount of damage to certain structures found in individuals with AD, HC, amnesia due to anoxic episodes, alcoholic Korsakoff (AK) patients and normal age-matched subjects. Volume estimates of the caudate nuclei, mesial temporal lobes and posterior temporo-parieto-occipital cortex for all subjects were determined using

magnetic resonance imaging (MRI). The subjects were treated as a single group and memory impairment and anatomical abnormalities were viewed along a continuum of severity. It was reasoned that, should the extent of damage to a particular structure correlate with impairment of a given function, the same relationship should be seen regardless of etiology.

During the study phase of their experiment, Jernigan and Ostergaard (1993) required subjects to read aloud a list of words that were presented on a computer screen. Following a delay, subjects were then asked to identify a series of tachistoscopically-presented words. The series was comprised of words that were presented during the study phase, as well as new words. Following the presentation of a word, subjects were asked to indicate whether the word was presented during the study phase. The number of correct classifications (i.e., hits plus correct rejections) provided during this recognition test served as the measure of explicit recall. The difference between mean latencies to identify old and new words was used as an index of implicit memory. A third dependent measure was provided in the use of mean latency to identify new words as an index of lexical processing efficiency.

As predicted for explicit memory, only the amount of volume loss to temporo-limbic structures correlated with poor recognition memory. No correlations were obtained between anatomical measures and priming performance. Multiple regression analysis, however, revealed that caudate volume loss and temporo-limbic loss both contributed to priming performance. The nature of this contribution was such that caudate damage was associated with

increased priming, whereas damage to temporo-limbic structures was associated with decreased priming. In addition, while amount of volume loss to all areas was found to correlate with decreased processing efficiency, regression analysis indicated that caudate loss was most strongly related to inefficient lexical processing.

Jernigan and Ostergaard (1993) interpreted the findings regarding the caudate in terms of previous studies (e.g., Scarborough et al., 1977) that have shown increased priming under experimental conditions which disrupt one's ability to process a stimulus (e.g., degrading stimuli). In light of these results, Jernigan and Ostergaard reasoned that impairment in lexical/perceptual processing (i.e., slower word-identification), associated with caudate damage, acted in a way similar to experimental manipulations which disrupt processing, and effected greater priming. They predicted that, should processing deficits be the result of damage to this structure, then caudate damage alone should be predictive of increased priming.

The results of a study conducted by Randolph (1991) were seen as providing evidence for this prediction. Randolph investigated priming on a word-stem completion task and cued recall performance in normal individuals as well as those with AD and HC. Like Jernigan and Ostergaard, Randolph initially compared the absolute priming scores (i.e., without accounting for baseline performance) of all groups and found that, relative to normals, AD patients were impaired, whereas HC patients performed comparably. Randolph also found, however, that priming in all three groups correlated with performance on cued recall (explicit memory). When

an analysis of covariance was performed to remove the cued-recall variance from the priming scores, results revealed that the priming performance of AD patients was comparable to that of normals (suggesting that the initial impairment was attributable to a defect of memory-related priming), whereas that of HC patients was greater relative to normals. According to Ostergaard and Jernigan (1993), the results obtained by Randolph (1991) are consistent with those obtained on their anatomical study. Randolph's (1991) results can be viewed as indicating that damage to temporo-limbic structures is associated with reduced priming. Additionally, the hyperpriming observed in the HC patients can be seen as reflecting impairment in lexical/perceptual processing.

In their anatomical study, Jernigan and Ostergaard (1993) also evaluated the relationship between priming, processing efficiency and recognition memory. While recognition memory did not correlate with priming, multiple regression analysis revealed that recognition and processing efficiency both contributed significantly to the prediction of priming performance. The nature of this contribution was such that good recognition and decreased processing efficiency were both associated with increased priming.

PET Studies

The more recent use of neuroimaging techniques to study memory has provided insight into the mechanisms which underlie implicit and explicit memory. For example, a study conducted by Petersen, Fox, Posner, Mintun and Raichle (1988) using normal subjects implicated a region of the left extrastriate occipital

cortex where activity is attributable to the coding of the visual form of words. Additional evidence in support of the belief that lexical priming depends on the integrity of cortical mechanisms derives from a study using PET in normal subjects which demonstrated activity in the posterior cortex during completion of word-stem completion tasks (Squire, Ojemann, Miezin, Petersen, Videen & Raichle, 1992). It should be noted, however, that in this latter study, increased blood flow in the right hippocampus was significantly higher, relative to baseline, when subjects were performing a cued recall task, as well as when they were engaging in word-stem completion. Due to the fact that the blood flow during the cued recall task was significantly higher relative to the word-stem completion task, the authors interpreted their results as indicating that the hippocampus was involved in cued recall, neglecting the significant involvement in word-stem completion. Consistent with Ostergaard and Jernigan's (1993) interpretation, these results can be seen as suggesting that the hippocampus was involved in both tasks, albeit to different degrees. The extent of hippocampal involvement might have differed due to the different processing requirements of the tasks.

The significance of the findings from the above-mentioned studies (i.e., Jernigan & Ostergaard, 1993; Randolph, 1991, and Squire et al., 1992) lies in the common finding that, contrary to previous belief, implicit and explicit memory share common neural mechanisms. Further, it was found that, while priming effects are attributable, in part, to a memory-related component, they are also attributable to an independent perceptual/lexical processing

component. Given this, any theory which attempts to explicate memory function must, of necessity, integrate processing theory with structural evidence.

Implicit and Explicit Memory function in Adults

A substantial amount of research has demonstrated that performance on direct tests of recall and recognition in normal adults declines with age (e.g., Salthouse, 1988; Parkin, 1992). In contrast, studies investigating the performance of this population on indirect measures have yielded conflicting results.

Most research on implicit memory function in adults has found age invariance. For example, comparable priming effects for young and older adults have been found on tests of fragment completion (e.g., Light, Singh & Capps, 1986) word-stem completion (e.g., Park & Shaw, 1992; Light & Singh, 1987), identification of degraded or briefly presented words (e.g., Light & Singh, 1987), lexical decision (Moscovitch, 1982 as cited in Light & La Voie, 1993) and spelling of homophones in accordance with a previously biased meaning (e.g., Howard, 1988). Nonetheless, several studies have demonstrated reliable age effects on indirect measures. For example, age differences have been found on tasks of word-stem completion (e.g., Chiarello & Hoyer, 1988; Hultsch, Masson & Small, 1991), word identification (e.g., Abbenhuis, Raaijmakers, Raaijmakers & van Woerden, 1990) and homophone spelling bias (Davis, Cohen, Gandy, Colombo, Van Dusseldorp, Simolke & Romano, 1990). In an attempt to resolve the inconsistencies in these findings, Light and LaVoie (1993) performed a meta-analysis of studies which examined

implicit memory in young and older adults. Based on their analyses they concluded that, while age-related differences on indirect priming measures do exist, these differences are much smaller than those seen when using direct measures.

The issue of whether age differences in performance reflect true age-related differences in the underlying processes involved in implicit memory, however, remains unresolved. In response to a growing body of evidence, some researchers (e.g., Graf, 1990, Russo & Parkin, in press, as cited in Parkin, 1993) have argued that observed age differences on implicit memory tasks are secondary to differences in the extent to which young and older adults use explicit memory to facilitate performance on these tasks. It is hypothesized that, as adults age, there is a decrease in the self-initiation of strategic retrieval processes. Recently, researchers have begun to view this decline in the ability to initiate strategies as a consequence of deteriorating memory function associated with the frontal lobes (Parkin & Walter, 1991). Should this be the case, this theory would hold important implications for our understanding of the development of these processes in children. Given that development of the frontal lobes has been found to extend into adolescence, one might postulate that implicit memory function should improve throughout childhood. This possibility, however, has not yet been explored.

Of particular relevance to the current study is research investigating age differences in the acquisition and recall of novel or associative information. A large literature exists which indicates that older, relative to younger, adults are impaired on

direct memory tests which evaluate the formation of new associations. These findings have been interpreted in two ways. One explanation suggests that older adults have difficulty in acquiring new associations, whereas the other proposes that the demonstrated impairment is due to problems with retrieval. As Light and LaVoie (1993) suggest, a finding of age invariance on indirect measures evaluating the formation of new associations would argue strongly for the existence of retrieval difficulties in the elderly. Unfortunately, studies which have evaluated priming for new associations have also resulted in a great deal of ambiguity. While age-related differences have been reported in some studies (e.g., Howard, 1988; Howard, Heisey & Shaw, 1986), a number of researchers have reported the absence of such differences (e.g., Howard, Fry & Brune, 1991; Nilsson, Backman & Karlsson, 1989). Furthermore, methodological differences across studies have made it difficult to draw conclusions regarding the reasons for discrepant findings.

One theory proposed to explain the discrepant findings of studies evaluating the acquisition of new associations relates to the question of whether it is necessary for an individual to encode new associations under elaborative conditions in order to demonstrate priming for those associations (Howard et al., 1991). While Howard et al. (1991) have demonstrated that older, relative to younger, adults show less priming due to decreased ability to engage in elaborative encoding, the question of whether the development of the ability to benefit from elaborative conditions impacts on the priming performance of children has yet to be explored.

Implicit and Explicit Memory function in Children

Most research on implicit memory function has been restricted to comparisons between young and older adults with relatively little attention afforded to the nature of these processes in children.

Despite this, the idea that multiple forms of memory exist has been addressed. For example, based on observations of infants and young children, Piaget (1952, cited in Naito, 1993) distinguished between memory in the *broad* sense and memory in the *strict* sense. When adapted to the present schema of memory types, the former, i.e., adaptive responses based on sensorimotor procedures, is akin to implicit memory. In contrast, the latter, characterized by the ability to consciously recollect information acquired within a particular spatiotemporal context, is similar to explicit memory.

In the early 1980's, several similar dichotomies were introduced to accommodate the emerging evidence for two memory forms in infants. For example, Schacter and Moscovitch (1984), in referring to the ontogeny of the memory types, described *early* and *late* systems. In comparing their findings in infants to those derived from research on amnesics, Schacter and Moscovitch argued that the early system (the contents of which is not accessible to consciousness) is fully functional at birth and is spared in amnesia. The late system, which enables conscious access to information, begins to emerge at around eight months of age, and is impaired in amnesics.

In like manner, Mandler (1988), also working with infants, introduced the term *sensorimotor procedures* in reference to an

infant's ability to recognize a previously encountered stimulus (e.g., habituation to a familiar stimulus). She distinguished this primitive form of recognition from the ability to recall. Whereas the sensorimotor procedures are not accessible to consciousness, with development of the ability to recall, information stored in a conceptual form can be consciously accessed. Although not explicitly stated as such, Mandler's theory reiterates that proposed by Piaget (1952) in that the ability to recall emerges at a time coincident with the onset of object permanence.

Despite the attention afforded to these functions in the infant memory literature, only four studies have compared implicit and explicit memory function in children. These studies vary widely in methodology as well as in age-range targeted. Two studies (i.e., Parkin & Streete, 1988, and Greenbaum & Graf, 1989) targeted children as young as three years of age. As the age-range targeted in this dissertation includes children only as young as seven years, these two studies are the least relevant of the four when considering the current experiment. Given this, their results will be reviewed only briefly.

Greenbaum and Graf (1989) explored implicit memory in three, four and five-year-olds using a modified word-production task. Subjects were asked to name and memorize line drawings of familiar objects that are typically seen in one of several predetermined settings (e.g., zoo, restaurant). Subjects were then told a brief story about going to one of these settings and were asked to name items that they might find there. The frequency with which the children provided a previously-presented object as a

category exemplar served as the index of implicit memory. Performance on a test of free recall was used as the measure of explicit memory.

Results indicated age-invariance on the priming measure with clear differences between age groups on the recall measure. While these findings were interpreted as evidence for the proficiency of implicit memory in early childhood (despite difficulties with explicit recall), the absence of older child and adult samples precludes conclusions regarding the development of this ability across the lifespan.

Parkin and Streete (1988) evaluated implicit and explicit memory function in children aged three-, five- and seven-years-old, as well as a group of adults over 20 years of age. Implicit memory was assessed using a fragmented-picture-identification paradigm (i.e., savings scores), while a yes/no recognition test served as the measure of explicit memory.

Although overall performance on the implicit measure improved with age, priming effects were found to be comparable for all ages when subjects were equated on baseline performance. Parkin and Streete interpreted the age effects as reflecting an age-related improvement in "perceptual learning" rather than in implicit memory per se. The reason for this cautious interpretation related to the results of post hoc analyses which suggested that the age-effect was due to an increase in the influence of explicit memory with age. Parkin and Streete concluded that, in order to demonstrate age-invariance in implicit memory, it is necessary to

conduct an experiment in which implicit memory is assessed without the contaminating influence of explicit memory.

Of the remaining two developmental studies, both focused on implicit memory in early childhood. The first, conducted by Carroll, Byrne and Kirsner (1985), compared implicit and explicit memory in children aged five, seven and ten years. As a separate experiment, Carroll et al. also investigated these functions in adults. In both experiments, pictures were presented under one of two encoding conditions: deep and shallow. In the deep encoding condition, subjects were required to judge the weight of a pictured object whereas, in the shallow condition, subjects were required to search for a cross marked on the picture. Explicit memory was assessed using recognition of tachistoscopically-presented pictures. Differences in latency to name previously presented pictures, relative to new pictures, served as the index of implicit memory.

Recognition of pictures improved with age for the child sample. In addition, performance on the recognition test was differentially effected by encoding, such that deeply-encoded pictures were better recognized than those encoded under shallow conditions.

Results of the priming test (i.e., naming latencies) did not reveal variations in performance with age. However, a significant age by encoding interaction was reported indicating an effect of encoding on the children's priming performance (i.e., priming was greater for deeply encoded pictures), but not on that of the adults. In order to clarify this inconsistency, Carroll et al. (1985) conducted a third experiment with 7-year-old children using picture

identification accuracy (as opposed to latency) as the index of implicit memory. The findings of this final experiment did not suggest an effect of encoding on priming for the seven-year-old children. However, the fact that the two experiments differed in methodology prevented resolution of the incongruity obtained in the previous experiments.

While the Carroll et al. study suggested age invariance in implicit memory function in middle childhood, caution must be exercised when attempting to extend these findings into adulthood. Differences in the methodology used in the child and adult experiments make it difficult to interpret these findings within a developmental framework.

The second study comparing implicit and explicit memory function in a middle childhood sample was performed by Naito (1990), who conducted a series of three experiments evaluating implicit and explicit memory performance as a function of encoding condition and retention interval. In her first experiment, first-, third- and sixth- grade Japanese children, as well as a sample of Japanese university students (mean age 22.1 years) served as subjects. Explicit memory was evaluated using either a recall or recognition paradigm, while performance on a word-fragment completion test served as the index of implicit memory.

During the encoding procedure, subjects were exposed to a list of Japanese words and were asked to respond to one of two question types: a "physical letter" question in which subjects judged whether the target word contained a given letter from the Hiragana alphabet,

or an elaborative "category" question which required subjects to provide the category to which the target word belonged.

In the first experiment, subjects were given a word-fragment completion task following the encoding condition. While results of this experiment revealed an increase in the number of word-fragments completed with age; priming effects did not differ with age. In addition, priming rates for physically-encoded words were no different than those obtained for categorically-encoded words. In contrast to the findings of Carroll et al. (1985), encoding effect did not vary with age.

In Naito's (1990) second experiment, subjects were exposed to the same encoding condition, however, a free recall test was given in lieu of the implicit measure. Results revealed an interaction between age and encoding condition such that recall of categorically-encoded words increased linearly with age. For physically-encoded words, adults recalled significantly more than first-graders, however, no differences were found among the child sample.

In the third experiment of this series, Naito examined the effect of retention interval on explicit and implicit memory. First- and sixth-graders, and university students, were instructed to study and memorize a list of 32 words. Following seven-minute and six-day intervals, subjects completed a word-fragment completion test or a yes/no recognition test. For all ages, performance on the recognition test declined with time. Further, while analysis of recognition performance revealed improvement with age in the short delay condition; children performed better than adults following the

long delay. This latter result was interpreted as reflecting familiarity effects (i.e., that adults have difficulty with recognition when target words are familiar) akin to those reported by Jacoby and Dallas (1981).

Similar to the results obtained in Experiment 1, overall performance on the word-fragment completion test improved with age. The same amount of priming, however, was obtained for all ages. Naito (1990) interpreted this finding as evidence that repetition priming is developmentally stable from middle childhood to adulthood. A main effect of retention interval was also obtained such that more items were completed following the long delay than the short delay. This latter finding, attributable to an increase in overall performance, was interpreted to reflect increased fluency on the word-fragment-completion test following the long delay.

In summary, the results of studies which have compared implicit and explicit memory in children have suggested the existence of a developmental dissociation between the two forms of memory. Based on findings from studies on infant memory, it is believed that implicit memory develops earlier than explicit memory, and is functional in neonates. Evidence from studies comparing these functions in older children suggests that, while explicit memory improves with age, implicit memory remains stable throughout childhood. The findings regarding implicit memory in children are tenuous, however, in that they are based on the results of studies which vary widely in subjects and experimental procedures.

Implicit and Explicit Memory Function in Reading Disabled Children

Studies investigating memory function of learning disabled children have focused primarily on explicit memory. In general, these studies have indicated that learning disabled (LD) children have significant difficulty on direct measures that require conscious recollection of prior learning episodes. For example, it has been reported that LD children, relative to non-disabled peers, recall less information (e.g., Lorschach, 1980), are less accurate in their recognition of prior events (e.g., Lorschach & Gray, 1985), engage in less semantic processing (e.g., Ceci, 1983 and 1984), and fail to apply self-initiated memory strategies such as rehearsal and organization (Bauer, 1982). These deficits have been hypothesized by some (e.g., Ceci, 1983), however, to exist only in circumstances which require the use of "purposive" (i.e., effortful) processing. While these studies have made clear that LD children have significant difficulty on direct measures of explicit memory, very little is known about implicit memory function in this population.

Only one study (Lorschach & Worman, 1989) has explored implicit and explicit memory function in learning disabled (LD) children. In this study, a sample of third- and sixth-grade LD and non-LD children were exposed to a series of 33 pictures and were asked to name them. Subjects were told to expect a memory test at a later time. Twenty-eight of the stimulus pictures were exemplars from one of four categories (i.e., vehicles, tools, animals and clothing). The remaining five pictures were unrelated to the categories and to one another. Explicit memory was assessed using a free recall, followed by a cued (i.e., category cue) recall test.

Performance of the four groups (i.e., LD and nonLD from both grades), on both measures, revealed significant age effects (older recalling more than younger) and group effects (non-LD recalling more than LD). Performance on a test of fragmented-picture identification serving as the index of implicit memory, revealed no effect of age or group.

The results of Lorschach and Worman's (1989) study might be taken to reflect the integrity of the structural-description subsystem of the PRS in LD children. In accordance with this theory, the object-perceptual-identification task used in Lorschach and Worman's study would be seen as a data-or perceptually-driven indirect measure of nonverbal priming. That the performance of LD children on this task does not differ from non-LD peers suggests that the subsystem believed to subserve this function is also intact. The results of the study have no relevance when considering the functioning of the word-form subsystem, or of the semantic subsystem, as no measure of linguistic priming was employed.

Memory Function in ADHD Children

Research on memory function in ADHD children has consistently failed to demonstrate significant memory impairment on explicit tasks. For example, ADHD children were found to perform comparably to normal control peers on three serial recall tasks (Benezra & Douglas, 1988). These results indicated that ADHD children demonstrate comparable encoding speeds and similar patterns of spontaneous decay of verbal traces. In addition, ADHD

children were not found to be more susceptible than controls to interference.

Despite the lack of evidence for impairment of ADHD children on explicit memory tasks, a number of researchers (e.g., Douglas & Benezra, 1990) have reported findings suggesting that ADHD children have difficulty spontaneously employing mnemonic strategies for retrieval purposes. Douglas (1988) has argued that this difficulty stems from defective self-regulatory or "executive" processes which underlie the organization and monitoring of information processing, the sustaining of attention throughout processing and the inhibition of inappropriate responding. It has been suggested that, while ADHD children are as capable of utilizing these strategies (e.g., August, 1987), it is their failure to maintain the use of the strategy in situations which require effortful and self-regulated performance over time that distinguishes them from normal children.

Experiment 1

A Developmental Study of Implicit and Explicit Memory

Rationale for Experiment 1

A large body of evidence exists in support of the idea that explicit recall improves throughout childhood and then declines in late adulthood. This effect has been demonstrated on tests of free recall, cued recall and recognition (c.f., Richardson-Klavehn & Bjork, 1988). In contrast, while the studies of implicit memory in adults have resulted in inconsistent findings, the few studies evaluating the effects of age on this function in children have reported age invariance. Despite this, it has been argued (e.g., Light & La Voie, 1993) based on metaanalysis, that implicit memory performance does vary with age, however, to a much lesser extent than explicit memory.

The disparity in these views relates, in part, to differences between the measures used in studies investigating developmental differences in implicit and explicit memory. It has been suggested that the vulnerability of performance on memory tests to age effects depends on the task demands of those tests (e.g., conceptually-driven vs. perceptually-driven) rather than the type of memory being assessed (e.g., implicit vs. explicit). Consistent with this, performance on conceptually-driven tests (be they direct or indirect) would be vulnerable to age differences whereas that on perceptually-driven tests would not be.

A second reason for the discrepant views relates to the tendency of researchers to restrict their investigation to age-

ranges at either end of the spectrum without consideration for how these memory forms develop across the life-span. That is, most studies investigating the development of implicit and explicit memory, have restricted age comparisons to those between young and old adults or between children of various ages. The results of studies evaluating implicit memory function in adults raise important, and as yet unanswered, questions regarding the nature of these processes in children. Similarly, studies evaluating these memory types in children have yielded interesting findings which are not generalizable to adults. Only two studies have attempted to compare the performance of children with that of adults. The results of one of these studies (i.e., Carroll et al, 1985) were tenuous due to an inconsistency in the method used to investigate these processes in the age groups targeted. The second study (Naito, 1990), while methodologically sound in comparing implicit and explicit memory performance of three groups of children to that of young adults, excluded individuals between the ages of 12 and 18 years. The present study was designed to address these deficiencies.

The first experiment of this dissertation was intended to investigate the development of implicit and explicit memory in subjects ranging in age from middle childhood to mid-adulthood (i.e., 7-50 years). Implicit memory was assessed using two indirect lexical measures which differed in the degree to which they engage conceptual and perceptual cognitive processes. The first measure, a cued word-stem completion test, is characterized as primarily a perceptually-driven implicit measure. In contrast, the second

implicit measure, a category fluency test, is characterized as a conceptually-driven indirect test. Explicit memory will be assessed using a conceptually-driven direct measure: a four-choice recognition test.

Hypotheses

1. Predicted Effects Age on Memory Test Performance: It was predicted that age effects would vary as a function of task requirements and not of the form of memory targeted. Specifically, it was hypothesized that performance on the conceptually-driven implicit and explicit measures would vary in an age-dependent manner (i.e., with performance improving with age). Conversely, age invariance would be demonstrated on the perceptually-driven implicit measure.
2. Predicted Effects of Encoding on Memory Test Performance: Encoding requirements at the time of study also served as an independent variable in the current experiment. It has been suggested (e.g., Roediger & Srinivas, 1993) that performance on measures of implicit and explicit memory may be effected differentially by manipulations in encoding. The nature of this effect for recognition memory is such that information which has been encoded semantically (i.e., under conditions which require processing the meaning of the to-be-remembered material) is better recalled than material which is not encoded semantically (e.g., on tasks which require the

subject to indicate whether a word contains a given consonant). In contrast, the results of studies which have evaluated the effect of encoding on implicit memory performance are inconsistent. Most studies have reported that implicit memory performance is resistant to encoding manipulations (e.g., Naito, 1990). There is some evidence to suggest, however, that the effect of encoding on memory is task dependent (e.g., Light & La Voie, 1993). That is, conceptually-driven measures (be they direct or indirect) are vulnerable to encoding effects, whereas perceptually-driven measures are not. More recently, Brown and Mitchell (1994) conducted a metaanalysis of 131 studies and reported levels of processing effects in 79% of those studies. Priming was found to be greater following semantic than nonsemantic encoding on both perceptual and conceptual implicit memory tests as well as in within- and between-subjects designs.

Consistent with the principle of transfer-appropriate processing, it was predicted that manipulation of the encoding requirement at time of study would effect performance on the conceptually-driven tasks (i.e., category fluency and recognition) but not on the perceptually-driven stem-completion task. It was hypothesized that a greater proportion of semantically-encoded target items would be produced on the fluency and recognition tests relative to non-semantically-encoded

items. In contrast, it was predicted that there would be no effect of encoding on the cued word-stem completion test.

3. Predicted Age X Encoding Interaction on Memory Test

Performance: It was believed that age and encoding condition would interact in such a way as to effect task performance differentially. It was predicted that performance on the conceptually-driven tasks (i.e. fluency and recognition) would reflect an interaction between these variables, whereas performance on the perceptually-driven task (i.e. stem completion) would not. The reason for this prediction related to findings which indicate age-related changes in the ability to initiate mnemonic strategies spontaneously. Age-related changes on tests of explicit recall are often attributed to an improvement (i.e., when explaining improvement in explicit memory throughout childhood) or a decline (i.e., when explaining declines in memory function in late adulthood) in the ability to apply mnemonic strategies spontaneously. Despite developmental differences in this ability, it has been found that children benefit equally relative to adults when mnemonic strategies are provided. Thus, the memory performance of young relative to old subjects should not differ for target items which were presented under circumstances which promoted semantic encoding.

In contrast, developmental differences should be reflected in memory performance for target information which was presented under conditions which did not inspire semantic encoding. Consistent with the afore-mentioned predictions, it was hypothesized that this interaction would be found on the conceptually-driven tasks and not for the perceptually-driven task.

4. Foil-Choice Hypothesis: The reason for employing a four-choice recognition test in this experiment related to studies which report developmental differences in the pattern of recognition errors. For example, it has been found that younger, relative to older, children tend to commit more false recognition errors on the basis of structural and acoustic features. In contrast, the errors of older children are based on semantic attributes (Lorsbach & Gray, 1985). This age-related increase in the amount of attention given to semantic features, with the concomitant decline in processing of structural features, reflects a development in effortful semantic processing ability. It was predicted that the pattern of recognition errors demonstrated by subjects in the current experiment would vary with age. It was hypothesized that the error pattern of younger, relative to older, subjects would reflect a tendency to focus on the structural or acoustic features of the stimuli. In contrast, the error pattern

demonstrated by older subjects on the recognition test was predicted to reflect the tendency of these subjects to focus on the semantic characteristics of the target stimuli.

Method

Subjects

A total of 108 subjects (61 males and 47 females) ranging in age from 7 years, 0 months to 47 years, 5 months participated in Experiment 1. Seventy-nine percent of the sample were Caucasian, 11% were Hispanic, 5% were Black and 5% were of some other descent (e.g., Asian).

The child sample (i.e., subjects < 19 years-old) was recruited primarily from two parochial schools in an outlying suburb of New York City. Most subjects were from families of middle socioeconomic status. Remaining child subjects were recruited from families living in the same outlying suburb. Adult subjects were recruited from the subject pool of the Psychology Department at Queens College of the City University of New York.

Subjects were divided into five age groups: 7 years, 0 months through 8 years, 11 months; 9 years, 0 months through 10 years, 11 months; 11 years, 0 months through 13 years, 11 months; 14 years, 0 months through 19 years, 11 months; and 20 years, 0 months and older. Table 1 shows the characteristics of the subjects based on these age divisions. The groups did not differ significantly on measures of intelligence, (KBIT Composite: $F(4,103)=.859, p=.491$; KBIT Vocabulary: $F(4,103)=.116, p=.977$; KBIT Matrices: $F(4,103)=2.26, p=.067$). Subjects from all age-groups were also comparable on the Arithmetic ($F(4,103)=.351, p=.843$), and Spelling ($F(4,103)=.846, p=.499$) subtests of the WRAT-R. While one-way ANOVA revealed a significant difference between age-groups on the Reading subtest of the WRAT-R ($F(4,103)=2.47, p=.049$), post-hoc

analyses using Tukey-Highly Significant Difference (HSD) Multiple Range Test failed to reveal significant individual group differences.

Consent

For child subjects, consent was obtained from their parent or legal guardian. A consent form explaining the nature of the study and procedure was given to the parent or guardian (see Appendix A). This consent form was reviewed and approved by the Institutional Review Board of Queens College of the City University of New York. The child's assent was obtained following a verbal explanation of the general purpose of the study and the procedure. The experiment was not conducted unless such assent had been obtained. Subjects who wished to terminate testing at any point during the session were permitted to do so without consequence.

Adult subjects were asked to sign a consent form which informed them fully of the nature and procedure of the study (see Appendix A). The experiment was not conducted unless this consent was obtained.

Test Battery

All subjects were administered a battery of tests consisting of measures of intelligence and academic achievement in addition to three experimental memory tests. Subjects were equated on measures of intelligence and academic ability. The Kaufman Brief Intelligence Test (KBIT) was used to provide an index of overall intelligence and the Wide Range Achievement Test-Revised (WRAT-R) provided an index of academic achievement in the areas of word-

recognition, written spelling and written arithmetic. A complete description of these tests can be found in Appendix B.

Administration of the entire battery of tests took approximately one hour and the order of test administration was held constant for all subjects. The order of administration was:

1. KBIT Expressive Vocabulary
2. KBIT Definitions
3. Encoding Condition of Memory Tests
4. KBIT Matrices
5. WRAT-R Arithmetic
6. Category Fluency Test
7. Cued Word-Stem Completion
8. Four-Choice Recognition
9. WRAT-R Word Recognition
10. WRAT-R Spelling

Diagnostic Interview

Memory performance may vary with the presence or absence of various psychiatric disorders. In order to avoid the possible confounding effect of psychological disturbance on memory, all subjects were screened for the presence of several disorders from the Diagnostic and Statistical Manual-III-Revised (DSM-III-R) using a structured diagnostic interview. For each child subject, the consenting parent was interviewed using the Diagnostic Interview Schedule for Children-Version 2.1. Adult subjects were interviewed

with regard to the presence or absence of the symptoms which characterize the specified DSM-III-R disorders.

Exclusionary Criteria

In order to assure homogeneity of the developmental sample in the areas of intelligence, academic ability and absence of psychological disturbance, subjects were evaluated for the presence of specific exclusionary criteria. With regard to intelligence, subjects who obtained a KBIT Composite standard score of less than 85, or a standard score of less than 80 on any subtest of the WRAT-R were excluded. In addition, subjects who, at the time of the study, met DSM-III-R criteria for a diagnosis of ADHD, a mood disorder or an anxiety disorder were excluded. Individuals who were suspected of psychosis, dementia or substance abuse on the basis of informal questioning were also excluded.

Experimental Memory Tests

Stimulus presentation, as well as the subsequent implicit and explicit tests, were programmed to run on a Toshiba T1200 laptop computer, using Quick Basic.

Target Stimulus Selection. Thirty-two stimulus words were selected from a first-grade reading primer (Durr & Pike, 1986). The sole criterion for selection was that each word belong to one of six pre-specified categories: (1) animals, (2) parts of a house, (3) parts of nature, (4) things you ride on or ride in, (5) things to wear and (6) things to eat. A list of the stimulus words, sorted by category, can be seen in Appendix C. The 32 stimulus words were randomly

assigned to form 16 word-pairs such that no single word-pair was comprised of words belonging to the same category. The purpose of instituting this criterion for pairing was to form relatively novel associations and avoid the possible confound of presenting pairs which might be readily associable in a manner other than that encouraged by the encoding question.

Stimulus Presentation. The 16 stimulus word-pairs were then randomly assigned to one of two encoding conditions: a semantic encoding condition or a non-semantic encoding condition. The presentation of these stimuli within each encoding condition was then counterbalanced such that, for one design (i.e., ABBA), four word-pairs to be semantically encoded were presented first followed by eight pairs in the non-semantic condition, followed by the remaining four pairs belonging to the semantic condition. In the alternative, BAAB, design, four pairs from the non-semantic condition preceded presentation of eight pairs from the semantic condition, followed by the remaining four from the non-semantic condition.

The 16 word-pairs were then re-assigned to an encoding condition such that those originally belonging to the semantic condition were now assigned to the non-semantic condition and visa versa. The order of presentation of stimuli was again counterbalanced according to an ABBA/BAAB design resulting in two additional designs. Administration of the four designs was randomized across subjects.

Recognition Test Foil Selection

During the recognition test, subjects were asked to select, from four possible choices, the correct target stimulus which completed each word-pair presented during the encoding condition. Among the four choice words were: (a) the correctly-paired choice, (b) a semantic foil, (c) a phonemic foil and (d) an other-paired foil.

Semantic Foils: Category membership served as the determinant for semantic foil selection. Specifically, a word which belonged to the same category as the correctly-paired choice was randomly selected as the semantic foil. For example, for the word-pair *PLANE-DUCK*, the word *PIG* was presented as the semantic foil as it shared category membership (i.e., animals) with the correctly-paired word *DUCK*.

Phonemic Foils: Words which were similar to the correct choice in initial or end consonant sound were selected as phonemic foils. Thus for the word-pair *PLANE-DUCK*, the word *DUMP* served as the phonemic foil as it shared the initial consonant sound *Du*

Other-Paired Foils: Other-paired foils were randomly selected from the list of target word-pairs. These words were selected from the list of 16 words which served as the "second word" in each of the target word-pairs. For example, in the case of *PLANE-DUCK*, the word *ROOF*, originally appearing as the second word in the word-pair *FLOWER-ROOF*, served as the other-paired foil.

A list of the four choices for each target word-pair is listed in Appendix D.

Procedure

Stimulus Presentation and Encoding Condition.

All subjects were oriented to the computer and keyboard and were given the following instructions:

A series of word-pairs will be presented in the top half of the screen, one word-pair at a time. Below each word-pair will be a question about the words. You are to answer the question. For some word-pairs the answer to the question will be 0, 1 or 2 (experimenter points to keys labeled 0, 1 or 2). For others, the answer will be "yes" or "no" (experimenter points to keys labeled Y and N). You will be told when to respond using the keys labeled 0, 1, 2 or Y, N. I would like you to try to remember each word-pair because you will be asked about them later.

An example of the screen configuration can be found in Appendix E.

Semantic-Encoding Condition: In the semantic-encoding condition, subjects were asked to respond to a question which required processing the meaning of the word-pair. For example, given the word-pair *SNAKE-HAM*, subjects were asked, "How many of these words bite?" Subjects were then instructed to indicate their response by pressing one of three keys marked "0", "1" or "2". Each word-pair was accompanied by a different question.

Non-Semantic Encoding Condition: In the non-semantic encoding condition, subjects were asked to compare the number of letters in each word and, therefore, to attend to a non-semantic feature of the words. For all words assigned to this latter condition, subjects were presented with the question, "Do these words have the same number of letters?" Subjects were instructed to respond to these questions by pressing one of two keys labeled "Y"

(for yes) or "N" (for no). The questions which accompanied word-pairs and the correct responses are shown in Appendix F divided according to encoding condition.

For all subjects, a message appeared on the screen informing them when to switch from using one set of response keys to the other. The examiner provided an additional verbal prompt to insure that subjects knew when to switch keys. Subjects were instructed to read each stimulus word-pair and question aloud. If the subject read any of the words or questions incorrectly, the examiner corrected them and the subject was then required to repeat the pair or question properly. A short tune followed each correct response and was accompanied by a message on the screen which read, "YOU ARE RIGHT." In contrast, a deep tone followed each incorrect response, accompanied by the presentation of the instruction, "PLEASE TRY AGAIN." The total number of errors for each condition was recorded. It was necessary that subjects provide a correct response before advancing to the next stimulus pair.

A 30-minute interval followed the encoding condition and preceded administration of both implicit measures and the recognition test. During this time period, subjects were given two nonverbal tasks: the arithmetic subtest of the WRAT-R and the Matrices subtest of the K-BIT.

Implicit Recall Measures

Implicit recall was assessed using two separate measures: (1) Category Fluency and (2) Cued Word-Stem Completion.

Category Fluency: The category fluency test provided an index of semantic/conceptual priming. As mentioned previously, each of the 32 stimulus words belonged to one of six semantic categories: (1) animals, (2) parts of a house, (3) parts of nature, (4) things to ride on or ride in, (5) things to wear and (6) things to eat. Subjects were informed that they were going to play a word game. No reference was made to the prior encoding episode. Subjects were told that they were going to be given a category name and that they were to provide, verbally, as many exemplars as they were able to think of. An example was provided using the category "colors". Subjects were allotted 45 seconds per category to generate verbally as many items belonging to each semantic category as possible. The total number of responses was recorded, as was the frequency with which subjects produced the previously-exposed stimulus words. When a word which was not an appropriate exemplar was provided, the examiner informed the subject in such a way that did not interfere with the continuity of the test (e.g., by shaking her head).

The total number of words generated for all categories provided an index of total fluency. The number of stimulus words produced during the fluency test, divided by the total fluency score for each subject served as the measure of fluency priming. The proportion of semantically and non-semantically-encoded target words produced during fluency was determined in like fashion (i.e., by dividing the total number of stimulus words from each condition by the total number of words provided on the test).

Cued Word-Stem Completion: A cued word-stem completion task similar to that described by Graf, Mandler and Haden (1982)

was used as the second measure of implicit recall. On this task, the instruction: "RESPOND WITH THE FIRST WORD THAT COMES TO MIND" was presented centered in the upper half of the computer screen. Centered in the lower half of the screen, a stimulus or novel word (e.g., *RING* in the case of a stimulus word and *BLACK* as a novel word) and a two-letter word-stem (e.g., *ST___*) was presented side by side separated by a hyphen. An example configuration can be seen in Appendix E.

Subjects were then asked to provide, verbally, the first word that comes to mind that begins with each given word-stem. The task was presented as a "word-game" and subjects were informed that, sometimes, the first word might help them to think of a word that begins with the provided stem and, sometimes, it might not. A sample using the pair *DOG-MO___* was provided to insure that subjects understood the task. Subjects were encouraged to respond as quickly as they could regardless of whether or not their generated word was related to the first word. Responses which occurred within an allotted 20-second time period were typed in by the examiner. If a subject was unable to provide a response within the allotted twenty seconds, the next item was presented. Those items which did not elicit a response within the allotted time period were dropped from final analyses. It was necessary to drop those items which were not responded to, and calculate a proportional score, in order to control for the tendency of younger subjects relative to older subjects to complete fewer items.

A total of 40 items (16 original stimuli and stems + 24 novel stimuli followed by stems) were presented in random order on the

cued word-stem completion test. The order of presentation was the same for all subjects. The first word of each of the original 16 stimulus pairs was presented along with the stem of the second word of that pair. For example, for the pair *"PLANE-DUCK"*, the word *"PLANE"* was presented with the stem *"DU___"* during the stem-completion test. In addition to the 16 stimulus items presented during the cued stem-completion task, 24 novel words were presented with fragments which began the second word of each original stimulus pair. For example, the fragment *"DU___"*; from the original stimulus pair *"PLANE-DUCK,"* was presented in the context of a novel word: *"FORK-DU___"*. The assignment of stems to novel words was randomized. A list of the stem-completion stimuli is shown in Appendix G.

The number of times a subject provided a target word to complete the word-stem was recorded. For each subject, this number was divided by the total number of items completed. It is this proportion that served as the total measure of stem-completion priming. The proportions of semantically- and non-semantically-encoded stimuli produced was calculated separately and were used to determine the relative effect of encoding on this task.

Explicit Memory Test

Explicit memory was assessed using a forced, four-choice recognition paradigm. Immediately following completion of the cued stem-completion task, subjects were referred to the initial encoding event, i.e., when they were asked to answer questions about word-pairs and responded using the 0, 1, 2 or the Y, N keys on the

keyboard. When each subject's ability to recall this event was confirmed, the initial word of each stimulus word-pair was presented centered in the upper half of the computer screen along with the question, "What word went with:". Below this configuration, centered in the lower portion of the screen, were four words from which the subject was asked to select the correct choice. Among the four choice words were: (a) the correctly-paired word, (b) a semantic foil, (c) a phonemic foil and (d) an other-paired foil. An example of this configuration can be seen in Appendix E.

For each of the 16 recognition items, the four choice possibilities were presented randomly to avoid response bias. If a subject was uncertain of the correct choice, he or she was encouraged to guess. Therefore, subjects were required to respond to all recognition questions. When the subject indicated his or her response, it was selected, and highlighted on the screen, by the examiner using the cursor keys.

The total number of correct choices provided an index of overall recognition memory. The effect of encoding on recognition was assessed by comparing the proportion of correctly recognized semantically-encoded word-pairs to that of correctly recognized non-semantically-encoded pairs.

Validation of Memory Measures

In order to demonstrate that the implicit memory measures (i.e., the cued word-stem completion test and the category fluency priming test) were valid measures of priming, it was necessary to show that individuals who were exposed to the encoding condition

produced significantly more target items, on both tasks, relative to subjects who were not exposed to the encoding condition. To demonstrate this effect, the performance of a group of subjects ($N = 9$) who were exposed to the encoding condition (i.e., experimental group) was compared to that of a group of subjects ($N = 9$) who were not exposed to the encoding condition (i.e., baseline-only group). The validity of the implicit memory measures would be confirmed if the experimental group produced significantly more target items on the cue word-stem completion test and the category fluency test relative to the baseline-only group.

Sample Characteristics: A group of nine subjects were randomly selected to serve as baseline-only subjects. These subjects were exposed to all aspects of the procedure as described above with the exception that they were not exposed to the encoding condition. A group of subjects (i.e., experimental subjects) who were exposed to the encoding condition and who matched the baseline-only group in age and IQ served as the comparison group. The characteristics of the two groups were compared using independent sample t -tests. Analyses revealed that the two groups did not differ in age ($t(16) = -.01, p = .992$), on measures of intelligence (K-BIT Composite: $t(16) = .58, p = .567$; K-BIT Vocabulary: $t(16) = .55, p = .588$; K-BIT Matrices: $t(16) = .49, p = .632$) or on measures of academic achievement (WRAT-R Reading: $t(16) = .00, p = 1.00$; WRAT-R Spelling: $t(16) = -1.57, p = .137$; WRAT-R Arithmetic: $t(16) = 1.98, p = .065$). The means and standard deviations on these descriptive measures for both groups are shown in Table 2.

Cued Word-Stem Completion Test: As shown in Figure 1, comparison of the mean target production for each group on the stem-completion task revealed that the experimental group produced significantly more targets relative to the baseline-only group ($t(9.79) = 4.84$; $p = .001$). This finding served to establish the cued word-stem completion test as a valid priming measure.

Category Fluency Priming Test: To obtain an overall index of target production on the fluency test, for each subject, the total number of targets produced on this task were divided by the total number of responses produced. Once again, as can be seen in Figure 1, subjects exposed to the encoding condition produced proportionally more targets relative to the baseline-only subjects, ($t(16) = 2.46$, $p = .026$). This finding served to establish the category fluency test as a valid priming measure.

Recognition Performance. Groups were also compared on total recognition performance. Results of independent samples t-tests revealed that the experimental group correctly identified significantly more pairs (Mean = 8.59, $sd = 2.6$) relative to the baseline-only group (Mean = 3.00, $sd = .93$) ($t(17.2) = 13.57$, $p < .001$). The performance of the experimental group was well above chance level whereas that of the baseline-only group was not.

Results

Design Analyses

To determine the equality of the four designs that resulted from the counterbalancing procedures, overall priming rates, and

total correct on recognition, obtained on each design were compared using a one-way ANOVA. Priming rates did not differ as a function of design (cued stem-completion priming: $F(3,104)=.83$, $p=.48$; category fluency priming: $F(3,104)=.25$, $p=.86$); and the mean total correct on recognition did not differ as a function of design ($F(3,104)=.75$, $p=.52$). Given this, the performances of all subjects on all memory tests were collapsed across counterbalancing design procedures.

Implicit Memory Performance

Cued word-stem completion priming: Comparison of priming rates demonstrated by different Age-groups was conducted using a two-way mixed ANOVA with Age-group as the between-subjects variable and Encoding Condition (semantic vs. non-semantic) as the within-subjects variable. Mean priming rates are shown in Figure 2 as a function of Age-group and Encoding Condition. Analysis revealed no effect of age on overall priming ($F(4,103) = .62$, $p = .63$). As can be seen in Figure 3a, there was no effect of encoding on the overall number of primes produced on the stem-completion task ($F(1,103) = .10$, $p = .75$). The Age-group X Encoding Condition interaction was not significant ($F(4,103) = .8$, $p = .53$). These results are consistent with the hypotheses of age invariance and null effect of encoding condition on this task.

Category Fluency Priming: Analysis of fluency priming rates was conducted using a two-way mixed ANOVA with Age-group serving as the between-subjects variable and Encoding Condition as the within-subjects variable. These data are depicted in Figure 4.

Analysis revealed a main effect of Age-group ($F(4,103) = 3.63, p < .01$). As can be seen in Figure 5, post-hoc analysis using the Tukey-HSD procedure revealed the nature of this effect to be such that subjects aged 9-10 differed significantly from subjects aged 14-19 on this task. An additional ANOVA, controlling for intelligence and academic measures revealed that this effect was not accounted for by age-differences in a general cognitive factor. Analysis revealed a significant main effect of age-group (A main effect of Encoding Condition ($F(1,103) = 14.36, p < .001$) on overall fluency priming was obtained. As shown in Figure 3b the nature of this effect was such that significantly more semantically encoded target items were produced relative to items from the non-semantic encoding condition. The Age-group X Encoding Condition interaction was not significant ($F(4,103) = 1.45, p = .22$).

Explicit Memory Performance

Percent Correct on Recognition: Comparison of age differences on percent correct on recognition was conducted using a two-way mixed ANOVA with Age-group as the between subjects variable and Encoding Condition as the within-subjects variable. Analysis revealed that age-groups did not differ in the percentage of word-pairings correctly identified on the recognition test ($F(4, 103) = 1.34; p = .26$). However, one-way ANOVA revealed a significant linear trend such that total correct increased with age ($F(1,103) = 4.87, p = .029$). A main effect of encoding condition on percent correct was obtained ($F(1, 103) = 156.38, p < .001$) indicating that, for all age-groups, semantically-encoded word-pairs were better

recognized (Mean = .66, sd = .19) than non-semantically encoded pairs (Mean = .41, sd = .21). The relative effect of Encoding Condition on all memory measures is shown in Figure 3c.

A significant age-group X encoding condition interaction was also demonstrated ($F(4, 103) = 6.78, p < .001$) and is shown in Figure 6. To explore the nature of this interaction, a difference score was computed by subtracting the number of non-semantically encoded pairs correctly recognized from the number of semantically encoded pairs correctly recognized. Post-hoc analysis of this difference score was conducted as a function of age-group using a one-way ANOVA. Analysis revealed that the relative effect of encoding on recognition performance varied with age ($F(4, 103) = 6.78, p < .001$). Post hoc analysis using the Tukey-HSD procedure revealed that 9-10 year-olds demonstrated the greatest difference and differed significantly from subjects aged 7-8, 11-13 and 20 years or older. As predicted, the smallest difference between percent recalled in each condition was exhibited by the oldest subjects. These results are depicted graphically in figure 7.

Foil-type Analysis. A mixed three-way ANOVA was used to investigate potential differences in foil-type selection on the recognition task. Age-group served as the between-subjects variable with Foil-type (phonemic vs. semantic vs. other-paired) and Encoding Condition (semantic vs. non-semantic) serving as within-subjects variables. Analysis revealed no significant Age-group differences ($F(4, 103) = 1.31; p = .27$). However, significant main effects of Encoding Condition ($F(1, 103) = 167.14; p < .001$) and Foil-type ($F(2, 206) = 54.82; p < .001$) were obtained. In order to explore

the main effect of Encoding condition, paired-samples t-tests were used to compare the percentage of each foil-type as a function of encoding condition. Analyses revealed that, for each foil-type (i.e., phonemic, semantic and other-paired), the number of foils selected for semantically-encoded pairs was significantly less than those for non-semantically encoded pairs. For example, of the word-pairs which were semantically-encoded, the percentage of phonemic foils which were selected was significantly less than the percentage of phonemic foils selected for non-semantically encoded pairs ($t(107) = 2.31$; $p = .02$). The same effect was obtained for semantic foils ($t(107) = 4.87$; $p < .001$) and other-paired foils ($t(107) = 8.17$; $p < .001$). Independent paired-samples t-tests were also used to explore the nature of the main effect of Foil-type. These data are shown in Figure 8. Analyses revealed that, for all subjects, significantly more other-paired foils were selected relative to phonemic and semantic foils respectively (other-paired vs. phonemic: $t(107) = 8.95$; $p < .001$; other-paired vs. semantic: $t(107) = 9.01$; $p < .001$). There was no difference between the number of semantic and phonemic foils chosen ($t(107) = .05$; $p = .96$).

The Age-group X Encoding Condition interaction was significant ($F(4, 103) = 6.81$; $p < .001$). The interactive effect of these variables on foil selection mirrors the Age-group X Encoding interaction found for total correct on recognition and indicates that the relative difference between total number of semantic and non-semantic foils chosen was greatest for the 9-10 year-olds.

The Encoding Condition X Foil-type interaction was also significant ($F(2, 206) = 9.26$; $p < .001$). To explore this interaction

it was necessary to explore the relative effect of encoding on each foil-type. In order to do this, a difference score was computed for each foil-type by subtracting the total number of foils selected for semantically encoded items from the total number selected for non-semantically encoded items. The difference scores for all foil-types were compared using paired samples t-tests. As can be seen in Figure 9, analysis revealed that the effect of encoding was greatest for other-paired foils (Mean = .14, sd = .18). Furthermore, the effect of encoding for this foil-type was significantly greater relative to that obtained for semantic foils (Mean = .07, sd = .16; $t(107) = 4.25, p < .001$) and phonemic foils (Mean = .03, sd = .16; $t(107) = 2.47, p = .02$). Comparison of the relative effect of encoding on semantic and phonemic foils approached significance ($t(107) = 1.90, p = .06$).

The Age-group X Foil-type interaction was not significant ($F(8, 206) = .55; p = .82$) and the three-way Age-group X Encoding Condition X Foil-type interaction was not significant ($F(8, 206) = 1.24; p = .28$).

Other Non-Hypothesis Testing Analyses

Encoding Task Performance. The total number of errors committed by each age group during the encoding procedure was compared using a two-way mixed ANOVA (age-group as between-subjects variable, encoding condition as within-subjects variable). Analysis yielded a significant main effect of Age ($F(4, 103) = 3.4, p = .012$). Post-hoc analysis using the Tukey-HSD procedure indicated the nature of this effect to be such that children aged 7 to 8 years

committed significantly more errors than subjects belonging to the three oldest age-groups.

A main-effect of encoding condition on total errors was also obtained ($F(1,103)=39.4, p=.000$) indicating that, for all age-groups, significantly more errors were committed on items which were semantically encoded relative to those in the non-semantic condition.

The Age-group X Encoding Condition interaction approached significance ($F(4,103)=2.44, p=.051$) suggesting that the relative effect of encoding condition on error production varied as a function of age. As can be seen in Figure 10, it appears that the performance of the 7-8 year-olds was most effected by encoding condition.

Additional analysis using a one-way ANOVA revealed that, while groups did not differ in the total number of errors on the non-semantically encoded items ($F(4,103)=.694, p=.598$), a significant difference between age-groups was obtained when comparing the number of errors exhibited on semantically-encoded items ($F(4,103)=3.30, p=.014$). As can be seen in Figure 10, post-hoc analysis using the Tukey Procedure revealed that children aged 7-8 made significantly more errors in the semantic encoding condition relative to children in the three oldest age-groups.

Total Fluency: Analysis of total fluency responses was conducted using a one-way ANOVA to explore developmental differences in this variable. Analyses revealed a significant effect of age-group on overall fluency ($F(4,103) = 14.04, p < .001$). As shown in Figure 11, the data are best described as a linear trend ($F(1, 103) = 55.79, p < .001$) with fluency increasing with age. Post-

hoc analysis using the Tukey-HSD procedure revealed that, while the two youngest groups did not differ on this measure, each of these groups differed significantly from all other groups.

Gender Differences: Analyses of potential gender differences in performance on the encoding task and all memory tests were conducted using t-tests for independent samples. With one exception (i.e., Total Fluency: $t(106) = 2.69, p < .01$), analyses revealed no gender difference on any task: Encoding Errors: $t(106) = .36, p = .72$; Stem-completion Priming: $t(106) = 1.31, p = .19$; Fluency Priming: $t(106) = .20, p = .84$; Total Correct on Recognition: $t(106) = 1.67, p = .10$. The nature of the gender difference on total fluency responses was such that females (Mean = 94.43, $sd = 21.18$) were more fluent on this task relative to males (Mean = 84.08, $sd = 18.71$).

It should be noted that, with the exception of the oldest age-group, the male to female ratio for each age-group was similar. Relative to the number of females in all other age-groups, an unrepresentatively greater number of females served as subjects in the oldest age-group (i.e., > 20 years). In the absence of any significant effects of gender, the effect of this disproportionately greater number of females in the oldest age-group was not viewed as effecting group performance on any measure.

Discussion

Experiment 1 was designed to investigate the development of implicit and explicit memory across a major portion of the life-span (mid-childhood through mid-adulthood). Research exploring age differences on tests of implicit memory have yielded inconsistent results in adults, whereas the few studies evaluating age differences on tests of implicit memory in children have demonstrated age invariance. Despite the inconsistent findings, the results of a metaanalysis of studies in this area (Light & La Voie, 1993) suggest that performance on implicit measures does vary with age, however, to a much lesser extent than that on explicit measures. In explanation of the inconsistent findings, it has been suggested that the vulnerability of performance on implicit measures to age effects depends on the task demands (e.g., conceptually-driven vs. perceptually-driven) rather than the type of memory being assessed (e.g., implicit vs. explicit). The nature of this effect is such that age differences would be found on conceptually-driven tasks (be they direct or indirect) but not on perceptually-driven tasks. This reasoning served as the basis for the first hypothesis in this experiment and it was predicted that performance on the conceptually-driven fluency priming measure and recognition tests would vary in an age-dependent manner with performance improving with age. In contrast, it was predicted that performance on the perceptually-driven measure (word-stem completion test) would not vary with age.

Effects of Age on Memory Test Performance. As predicted, overall priming on the perceptually-driven stem-completion task

was resistant to age effects. Marginally consistent with prediction was the finding of an effect of age on the conceptually-driven category fluency priming measure. The nature of this effect, however, was not consistent with the predicted increase in fluency priming with age and does not suggest a developmental trend. Rather, age-groups differed in a somewhat arbitrary way with subjects aged 9-10 producing significantly more primes on this task relative to 14-19 year olds. This finding does not easily lend itself to interpretation. One possibility is that group differences on this conceptually driven task may have resulted from differences in overall cognitive ability. The absence of evidence suggesting that 9-10 year-old subjects performed differently on these measures relative to other groups, makes this possibility unlikely. Alternatively, group differences may reflect age-related differences in the way information is processed. As there is no evidence in this experiment to suggest the existence of such differences, however, this possibility is also unlikely.

Consistent with a large body of evidence indicating that performance on explicit memory tests (i.e., free and cued-recall and recognition) improves with age, it was hypothesized that performance on the explicit memory test (i.e., four-choice recognition) would improve with age. Despite the finding that overall recognition performance did not differ significantly between age-groups, the significant linear trend on this dependent variable (i.e., that recognition performance improved with age) is viewed as evidence that recognition memory does improve with age. The absence of a main effect of Age on overall recognition performance

may be attributable to the fact that the recognition paradigm utilized in Experiment 1 (i.e., four-choice) is one which provides a relatively greater amount of environmental support (i.e., cueing information) relative to other explicit tests employed in the literature (e.g., free-recall). It is believed that the degree to which age differences on explicit tests emerge may vary as a function of the degree of environmental support provided. Given this, it would be expected that age differences would be most profound on tests which provide minimal assistance at the time of recall (e.g., free-recall measures) and less profound when cues or choices are provided.

In summary, these data provide partial support for the processing view in its prediction for manipulations in independent variables to effect performance on conceptually-driven measures but not performance on perceptually driven measures, regardless of the type of memory being assessed (i.e., implicit vs. explicit). The finding that performance on the conceptually driven measure was effected by age in an indiscriminant way, however, suggest that age-related differences in performance on conceptually-driven implicit measures may be attributable to something other than developmental differences.

Effects of Encoding on Memory Test Performance. Consistent with hypothesized age effects, it was predicted that performance on the two conceptually-driven tests would also be vulnerable to manipulations in "levels-of-processing", or differences in encoding requirements, whereas performance on the perceptually-driven test would not.

This prediction was fully confirmed. A main effect of encoding was obtained such that performance on both conceptually-driven measures was effected by the encoding manipulation in the predicted direction. Specifically, on the explicit recognition test, significantly more semantically-encoded word-pairs were recognized correctly relative to pairs belonging to the non-semantic condition. This finding is consistent with a large body of literature demonstrating "levels-of-processing" effects on measures of explicit memory.

Similarly, more semantically-encoded items were produced on the conceptually-driven implicit task (category fluency priming) relative to those in the non-semantic condition. Taken together, these data support the hypothesis that performance on conceptually-driven measures (be they implicit or explicit) is vulnerable to experimental manipulations while performance on perceptually-driven measures is not. While this finding provides some support for the processing view, the absence of a perceptually-driven explicit measure detracts from the strength of these results.

Interactive Effect of Age and Encoding on Memory Test Performance. It was also hypothesized that the relative effect of encoding on recognition performance would vary as a function of age. This hypothesis was based on findings which suggest an improvement in the ability to apply mnemonic strategies spontaneously with increased age. The nature of this effect was predicted to be such that, on conceptually-driven measures, the relative advantage of semantic over non-semantic encoding would be greatest for younger when compared to older subjects.

A significant interaction between age and encoding condition was obtained for only the conceptually-driven recognition test. In order to examine this effect on performance, a difference score was calculated by subtracting the number of non-semantically encoded word-pairs recognized from the number of semantically encoded pairs recognized correctly. As shown in Figure 7, analysis of this difference score revealed that the relative effect of encoding was greatest for 9-10 year-olds and that this difference was significantly greater relative to that of subjects aged 7-8, 11-13 and 20 years and older. While the difference score computed for subjects 14-19 year-olds was less relative to 9-10 year-olds, the difference was not significant. Thus, this finding, in part, supports the original hypothesis that encoding would have a differential effect for younger relative to older children in that the greatest difference was obtained for subjects aged 9-10 years, while the smallest difference was exhibited by subjects 20 years or older. The finding that the difference score computed for 7-8 year-olds was also significantly less relative to that of the 9-10 year-olds is not consistent with the original hypothesis. It is not clear why the this group demonstrated a smaller difference relative to the 9-10 year-old children. However, the effect may, in part, be attributable to the fact that, relative to all other age-groups, the percentage of semantically-encoded pairs recognized correctly was greatest for 9-10 year-olds (Mean = .738, sd = .15) and least for 7-8 year-olds (Mean = .599, sd = .15).

Foil-Selection. With regard to foil-selection, developmental differences in the pattern of recognition errors were predicted.

This prediction was based on findings which demonstrated that younger, relative to older, children tend to commit more false recognition errors on the basis of structural and acoustic features. In contrast, the errors of older children are based on semantic attributes (Lorsbach & Gray, 1985). This age-related increase in the amount of attention given to semantic features, with the concomitant decline in processing of structural features, is viewed as reflecting a development in effortful semantic processing ability. Consistent with this view, it was predicted that the pattern of recognition errors demonstrated by subjects in the current experiment would vary with age such that the error pattern of younger, relative to older, subjects would reflect a tendency to focus on the structural or acoustic features of the stimuli. In contrast, the error pattern demonstrated by older subjects on the recognition test was predicted to reflect the tendency of these subjects to focus on the semantic characteristics of the target stimuli. Thus, an Age-group X Foil-Type interaction was predicted. It was hypothesized that this interaction would be characterized by a decrease in the number of phonemic errors committed with age with a concomitant increase in the number of semantic errors. The absence of the predicted developmental trend may reflect the finding that significantly more other-paired foils were selected by all subjects regardless of encoding condition. While, in retrospect, this effect seems logical (i.e., that a word serving previously as a target stimulus may be selected as a false recognition error more frequently than one which was not a target-stimulus), this effect was not anticipated. It is believed that, had the other-paired foil-

type been replaced with an "unrelated foil-type" developmental differences between semantic and phonemic foil-selection may have been found.

Experiment 2

Implicit and Explicit Memory in ADHD and RD Children

Rationale for Experiment 2

Experiment 2 was designed to investigate predicted differences in explicit and implicit memory in a sample of reading disabled (RD) and ADHD children. It has been widely documented that children with language-based learning disabilities demonstrate impairment in several areas of explicit memory function. Many of the memory deficits observed in this population, however, are believed to stem either from difficulties with encoding and semantic processing or from the tendency of RD children to demonstrate impairment in the ability to apply mnemonic strategies spontaneously. Given this, it is uncertain whether the memory deficits exhibited by RD children result from a processing disability or from a more fundamental impairment in memory function. The reason for including the ADHD sample was to provide a patient control group in order to demonstrate that performance differences in the RD group were not due to non-specific impairment.

Hypotheses

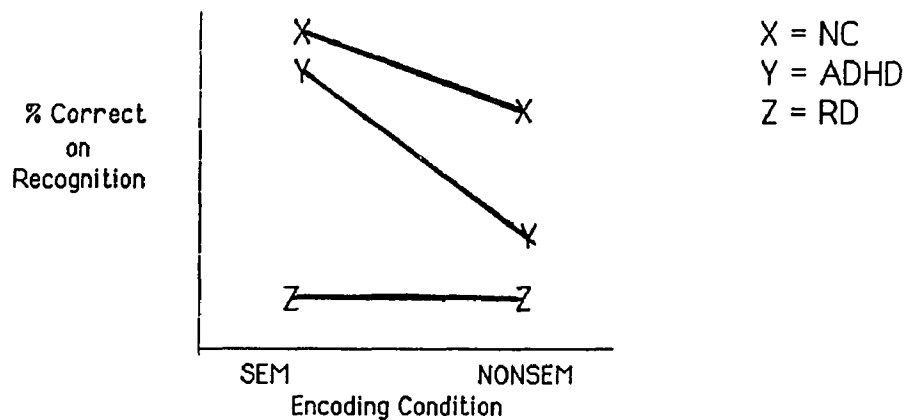
1. Explicit Memory Test Performance: One purpose of Experiment 2 was to test the hypothesis that the explicit memory deficits displayed by RD children result from semantic processing deficits rather than an impairment in memory function. In order to explore this hypothesis, the ability of a group of RD children to recall semantically and

non-semantically encoded information on an explicit memory test (i.e., four-choice recognition) was compared to that of a group of age and intelligence matched non-RD controls, as well as a sample of ADHD children.

While ADHD children have been found to perform comparably to non-ADHD children (and better than RD children) on tests of explicit memory, these children exhibit difficulty with the spontaneous application of mnemonic strategies. Despite this, and unlike RD children, ADHD children have been found to benefit from the provision of semantic encoding strategies in a similar way to normal controls. Thus, it was predicted that the effect of encoding on explicit memory would differ across groups.

Consistent with the findings of previous research, it was predicted that the RD sample would demonstrate impaired overall recognition performance relative to the non-RD and ADHD children. It was believed, however, that this effect would relate to differences in the relative ability of each group to benefit from the provision of semantic encoding strategies rather than from a deficit in memory per se. Thus, it was predicted that RD children would differ from both the NC and ADHD children in their ability to benefit from the provision of this strategy.

Additionally, it was predicted that both the RD and ADHD groups would differ from the NC group in their ability to recall information which was not encoded semantically at study. The predicted performance for all groups is depicted below.



2. Implicit Memory Test Performance: The predicted performance of RD relative to non-RD children on the implicit memory tests in this experiment was uncertain. The reason for this uncertainty related to the conflict between structural and processing theorists when explaining priming. Consistent with Tulving's postulation of a PRS, one might predict that RD children would demonstrate significantly less priming relative to the non-RD group due to a deficiency in the word-form system. Results of studies which have explored the effect of processing on implicit memory performance, however, contradict the conclusion derived from this line of reasoning. Several researchers (e.g., Scarborough et al.,

1977) have reported findings of increased priming under experimental conditions which interfere with one's ability to process a stimulus (e.g., degrading a stimulus). Additional evidence that processing difficulties influence priming in this manner derives from a study reporting increased priming in a sample of patients who demonstrated impairment in processing efficiency (Jernigan and Ostergaard, 1993). Thus, when viewed within a processing framework, it was expected that individuals with semantic processing difficulties (i.e., RD children) would demonstrate increased priming on lexical tasks.

3. Foil-Choice Hypothesis: Group differences were also predicted in the pattern of errors demonstrated on the recognition test. This prediction was based on findings which suggest a delay in the development of effortful semantic processing ability in RD children. It has been demonstrated that, on multiple choice recognition tests, younger relative to older children tend to commit more errors on the basis of structural and acoustic features. In contrast, the false recognition errors of older children are based on semantic attributes. While this trend has been observed in non-disabled children, it has not been demonstrated by learning-disabled children. Rather, it has been found that the encoding preferences of learning disabled children remain fixed with age such that

structural features serve as the dominant encoding preference. These children afford little attention to semantic characteristics of the to-be-remembered material. Given this, it was predicted that the error pattern exhibited on the recognition test would differ on the basis of group. Reading disabled children were predicted to make more phonemically related errors relative to normal and ADHD children. In contrast, normal children were predicted to make more semantically related errors.

Method

Subjects

A total of 48 individuals (31 males and 17 females) between 7 and 45 years of age served as subjects in Experiment 2. Subjects were recruited and consent was obtained in the same manner as that described in Experiment 1. A copy of the consent forms for children and adults can be found in Appendix A. Subjects were assigned to one of three groups on the basis of criteria specified below:

Reading Disabled Subjects: A total of 16 subjects (9 male and 7 female) ranging in age from 7 years, 2 months to 23 years, 6 months qualified for assignment to the reading disabled (RD) group. The diagnosis of reading disability (RD) was made according to the criteria specified by Morrison and Siegel (1991). Individuals who earned a KBIT IQ composite above 85, with WRAT-R reading and/or spelling standard scores below 80, and who did not meet DSM-III-R criteria for ADHD were classified as reading disabled.

Attention-deficit Hyperactivity Disordered Subjects. A total of 16 subjects (11 male and 5 female), ranging in age from 7 years 4 months to 44 years, 1 month, qualified for placement in the ADHD group. Diagnosis of ADHD for child subjects was made on the basis of parent responses to the behavior disorders module of the Diagnostic Interview Schedule for Children, Version 2.1 (DISC-2.1). Diagnosis of ADHD for adult subjects was made on the basis of their endorsement of symptoms which characterize this disorder at the time of interview. In order to be included in this group, adult subjects had to report a persistent history of these symptoms since childhood. The diagnostic criteria for the related disorders,

Oppositional Defiant Disorder and Conduct Disorder, were also reviewed. In order to maintain maximally discriminable groups, subjects who obtained a comorbid diagnosis of RD were excluded from the ADHD group. Additionally, subjects who met criteria for a mood or anxiety disorder on the basis of a parent interview were excluded from the study.

Normal Control Subjects: A group of 16 subjects (11 male and 5 female), ranging in age from 7 years, 5 months to 42 years, 9 months, served as normal control (NC) subjects. These subjects were selected from those subjects who participated in Experiment 1 and were matched with ADHD and RD subjects on the basis of non-verbal intelligence as estimated by the K-BIT Matrices subscale, age and gender, blind to performance on memory measures.

Subject Characteristics. Several one-way analyses of variance were conducted to compare the groups on measures of intelligence and academic achievement. The means and standard deviations of subject characteristics are shown in Table 3 for each group.

Groups were comparable in age ($F(2,45) = .34; p = .71$) and on the measure of non-verbal IQ, KBIT Matrices ($F(2, 45) = 1.40; p = .26$). Significant group differences were obtained on measures of verbal IQ (KBIT Vocabulary: $F(2, 45) = 9.45, p < .001$) and overall IQ (KBIT Composite: $F(2, 45) = 6.86, p = .003$). Post hoc analyses using the Tukey-HSD Multiple Range Test revealed that, on both indexes, the RD group differed significantly from both the ADHD and NC groups (i.e., $ADHD=NC > RD$).

Significant group differences were obtained on all measures of academic ability (WRAT-R Arithmetic: $F(2,45) = 7.39$; $p = .002$; WRAT-R Reading: $F(2,45) = 53.13$; $p < .001$; WRAT-R Spelling: $F(2, 45)$; $p < .001$). Post hoc analyses using the Tukey-HSD procedure revealed that, on the Arithmetic subtest, the RD group scored significantly lower than the NC group. On the Reading subtest, the performance of the RD group was significantly lower relative to both the ADHD and NC (i.e., $RD < ADHD=NC$). On the Spelling subtest, the performance of the RD group was significantly lower than the ADHD and NC groups. Additionally, the performance of the ADHD group on the Spelling subtest was significantly lower than the NC group (i.e., $(NC > ADHD) > RD$).

Procedure

The procedure used in Experiment 2 was identical to that described in Experiment 1. Subjects were individually administered a battery of tests (lasting approximately 45 minutes to an hour in length) which included:

1. Kaufman Brief Intelligence Test (KBIT)
2. Wide Range Achievement Test
3. Implicit Measures
 - a. Category Fluency
 - b. Cued Word-Stem Completion
4. Four-Choice Forced Recognition Test

The reader is referred to Experiment 1 for a detailed explanation of test administration.

Results

Implicit Memory Performance

Cued Word-Stem Completion Priming. Group comparisons were conducted using a two-way mixed ANOVA with Diagnostic Group (RD vs. ADHD vs. NC) serving as the between groups variable and Encoding Condition (semantic vs. non-semantic) serving as the within-group variable. These data are depicted in Figure 12. The main effect for Diagnostic Group on overall stem-completion priming approached significance ($F(2, 45) = 2.79, p = .07$) and there was no main effect of Encoding Condition ($F(1, 45) = 2.24; p = .14$). However, the Diagnostic Group X Encoding Condition interaction was significant ($F(2, 45) = 3.26; p < .05$) indicating that Encoding Condition effected the priming performance of the groups differentially. In order to explore this interaction, additional analyses using a one-way ANOVA were conducted and revealed that, while groups did not differ in the number of non-semantically encoded primes produced on stem-completion ($F(2, 45) = .14, p = .87$), the RD group provided significantly more semantically-encoded primes on this task relative to the NC group ($F(2, 45) = 4.41; p = .02$).

Category Fluency Priming. Comparison of groups on fluency priming rates was conducted using a mixed two-way ANOVA with Diagnostic Group as the between-subjects variable and Encoding Condition as the within-subjects variable. These data are shown in Figure 13. Analysis revealed that groups did not differ on this

measure ($F(2, 45) = .59, p = .56$). There was no effect of Encoding Condition ($F(1, 45) = .29, p = .59$) and there was no Group X Encoding Condition interaction ($F(2, 45) = .48, p = .62$).

Explicit Memory Performance

Percent Correct on Recognition. Group comparisons of percent correct on recognition were conducted using a mixed two-way ANOVA with Diagnostic Group as the between-subjects variable and Encoding Condition as the within-subjects variable. These data are depicted in Figure 14. Analysis revealed that groups did not differ on the total number of word-pairs correctly recognized ($F(2, 45) = .36; p = .70$). A significant main effect of Encoding Condition was obtained ($F(1, 45) = 72.58; p < .001$) such that semantically encoded pairs were better recognized than non-semantically encoded pairs. The Diagnostic Group X Encoding Condition interaction was not significant ($F(2, 45) = .12; p = .89$).

Foil-Type Analysis. A mixed three-way ANOVA was used to investigate potential group differences in foil selection. Diagnostic Group served as the between-subjects variable (ADHD vs. RD vs. NC) and there were two within-subjects variables: Foil-Type (semantic vs. phonemic vs. other-paired) and Encoding Condition (semantic vs. non-semantic). Analysis revealed that there was no main effect of group ($F(2, 45) = .48; p = .62$). A significant main effect of Encoding Condition was demonstrated ($F(1, 45) = 72.64; p < .001$) such that significantly more false recognition errors were made on items which were in the non-semantic condition relative to the semantic condition. Paired-samples t-tests were used to compare the

percentage of each foil-type as a function of encoding condition. Analyses revealed that, for each foil-type (i.e., phonemic, semantic and other-paired), the number of foils selected for semantically-encoded pairs was significantly less than those for non-semantically encoded pairs. For example, of the word-pairs which were semantically-encoded, the percentage of phonemic foils selected (Mean = .09, sd = .09) was significantly less than the percentage of phonemic foils selected for non-semantically encoded pairs (Mean = .13, sd = .11) ($t(47) = 2.19$; $p = .03$). The same effect was obtained for semantic foils ($t(47) = 3.03$; $p < .01$) and other-paired foils ($t(47) = 5.27$; $p < .001$). This effect mirrors the main effect of Encoding Condition obtained on overall recognition correct (i.e., that significantly more semantically-encoded pairs were recognized correctly relative to non-semantically encoded).

A main effect of Foil-Type was found ($F(2, 90) = 37.23$; $p < .001$) as well as a significant Diagnostic Group X Foil-Type interaction ($F(4, 90) = 4.12$; $p = .004$). As can be seen in Figure 15, the nature of the main effect of Foil-Type was such that, for all groups, significantly more other-paired foils were chosen relative to phonemic or semantic foils. The difference between semantic and phonemic foils, for all groups, was not significant.

As shown in Figure 16, the Diagnostic Group X Foil-Type interaction relates to the fact that the discrepancy between other-paired foils and the other two foil-types is greatest for the RD group relative to the ADHD and NC groups. Additional analysis using a one-way ANOVA to compare the mean number of other-paired foils obtained by each Diagnostic Group approached significance ($F(2, 45)$

= 2.90, $p = .065$) suggesting that the RD group tended to make more other-paired false recognition errors relative to the ADHD and NC groups.

The Encoding Condition X Foil-type interaction was also significant ($F(2, 90) = 4.76$; $p = .01$). This interaction is depicted in Figure 17. In order to explore the relative effect of encoding on each foil-type, a difference score was computed for each foil-type by subtracting the total number of foils selected for semantic items from the total number selected for non-semantic items. The difference scores for all foil-types were compared using paired samples t -tests. As can be seen from the data presented in Figure 17, analysis revealed that the effect of encoding was greatest for other-paired foils (Mean = .16, $sd = .21$). The effect of encoding for this foil-type was significantly greater relative to that obtained for semantic foils (Mean = .07, $sd = .16$; $t(47) = 2.03$, $p = .05$) and phonemic foils (Mean = .04, $sd = .14$; $t(47) = 2.91$, $p = .01$). Comparison of the relative effect of encoding on semantic and phonemic foils revealed no significant difference ($t(47) = .82$, $p = .42$).

The three-way Diagnostic Group X Encoding Condition X Foil-type interaction was not significant ($F(4, 90) = .38$; $p = .82$).

Other Non-Hypothesis Testing Analyses

Encoding Task Performance. A mixed two-way ANOVA with Diagnostic Group as the between-subjects variable (RD vs. ADHD vs. NC) and Encoding Condition (semantic vs. non-semantic) as the within-subjects variable) was used to evaluate potential group

differences in encoding errors. As shown in Figure 18, analyses revealed that groups did not differ in total number of errors committed ($F(2, 45) = 2.29; p = .11$). However, a main effect of encoding was obtained ($F(1, 45) = 17.79; p < .001$) such that, for all groups, significantly more errors were committed during the semantic encoding procedure relative to those committed during the non-semantic encoding procedure. The Diagnostic Group X Encoding Condition interaction was not significant ($F(2, 45) = 2.09; p = .14$).

Total Fluency. One-way ANOVA was used to investigate potential group differences in overall fluency. As shown in Figure 19, a significant effect of Diagnostic Group was obtained ($F(2,45) = 4.82; p = .01$). Post-hoc analysis using the Tukey-HSD procedure revealed the nature of this effect to be such that NC subjects (Mean = 90.44, sd = 19.54) differed significantly from both the ADHD (Mean = 72.25, sd = 17.31) and RD (Mean = 75.13, sd = 16.45) groups.

Discussion

Experiment 2 was designed to investigate hypothesized group differences in performance on implicit and explicit memory tests. Consistent with previous findings of impairment on tests of explicit memory, it was predicted that RD, relative to NC and ADHD subjects, would demonstrate impaired recognition memory for information which was semantically encoded. It was hypothesized that this impairment would result from an inability of the RD subjects to benefit from semantic encoding to the same extent that NC and ADHD subjects would, rather than from a memory deficit per se.

The predicted performance of RD children on tests of implicit memory was uncertain. While it was hypothesized that RD subjects would differ from ADHD and NC subjects, it was not clear whether they would demonstrate enhanced or decreased priming on the two implicit measures.

Explicit Memory Performance

Significant group differences were predicted on overall recognition performance. Consistent with demonstrated findings of explicit memory deficits in RD children, and the absence of such deficits in ADHD children, it was predicted that the RD sample would exhibit significantly weaker performance on this task relative to the NC and ADHD groups. This finding was hypothesized to result from the differential effect of encoding on recognition performance for the RD group (i.e., a Group X Encoding Condition interaction) rather than a memory deficit per se. The presence of semantic encoding deficits have been well documented in reading

disabled children. It was predicted that, secondary to semantic encoding deficits, and impairment in the ability to benefit from semantic encoding strategies when provided, the RD group would recognize significantly less semantically-encoded items relative to the other two groups. Furthermore, as ADHD children have been found to benefit equally relative to non-ADHD children from the provision of semantic encoding strategies, it was hypothesized that these groups would not differ in their ability to recognize semantically-encoded pairs.

Based on previous findings of impairment in the ability of both RD and ADHD children to apply mnemonic strategies spontaneously, it was predicted that both groups would correctly recognize significantly fewer word-pairs from the non-semantic condition relative to the NC group. As can be seen in Figure 14, none of these hypotheses was confirmed. Groups did not differ in overall recognition performance. What is more, all groups recognized significantly more semantically-encoded pairs relative to those in the non-semantic condition indicating that all groups benefited equally from this encoding strategy. It is believed that the absence of group differences on overall recognition, as well as the absence of a Group X Encoding Condition interaction, may relate to the fact that adequate encoding was assured on this task. Specifically, during the encoding procedure, it was necessary that each subject provide the correct response in order to proceed to the next item. Additionally, if a subject, on reading the stimulus items, responded incorrectly, the examiner would correct him or her and require that the word be repeated correctly. Thus, when encoding is ensured,

groups do not differ in recognition performance. This would seem to suggest that the explicit memory deficits found amongst reading disabled children may result from encoding differences rather than a memory deficit per se. Additionally, these results suggest that, when encoding is ensured, reading disabled subjects are able to benefit from the provision of semantic encoding strategies.

Implicit Memory Performance

Cued Word-Stem Completion. Consistent with the hypothesis of group differences on implicit measures, diagnostic groups were found to differ in the amount of priming demonstrated on the stem-completion task. The finding that RD children produced significantly more (rather than less) primes on this task is consistent with reports of increased priming in individuals with processing deficits. Additionally, this finding lends support to an explanation of this phenomenon from a processing view in that priming performance relates to relative differences in subjects' ability to process target stimuli.

No prediction was offered with regard to how the manipulation in the Encoding Condition would effect the performance of each group on this measure. However, the absence of a main effect of this variable is consistent with the hypothesis offered in Experiment 1. In Experiment 1, the prediction regarding an effect of Encoding on implicit test performance was dependent upon classification of the implicit measure as being primarily conceptually- or perceptually-driven. Given the classification of the cued-stem-completion task as a perceptually-driven test, it

was predicted that Encoding Condition would not have an effect. Thus, the finding that Encoding Condition differentially effected the performance of RD subjects on this measure, but not that of ADHD or NC subjects, was unexpected.

In an attempt to explain these results from a processing theory viewpoint, it seems logical to look for group differences which may provide information regarding the nature of the processing deficits in the RD group. Clearly, this group differs significantly from the ADHD and NC groups on linguistically-based tests of academic functioning suggesting impairment in semantic knowledge. Additionally, the RD group differs from the NC group on total fluency performance. Thus, on the test-battery administered, the RD group exhibited linguistic processing deficits on several measures. Additionally, the differential effect of encoding for this group is consistent with the idea of transfer-appropriate processing in that the RD group (i.e., a group with semantic processing deficits) demonstrated increased priming for information which was semantically-encoded but not for information in the non-semantic encoding condition.

However, the fact that the ADHD group was also significantly less fluent relative to the NC group raises the possibility that this group is also impaired on some aspect of linguistic processing. The absence of evidence for semantic processing deficits in the ADHD group on measures of academic ability, in combination with previous literature demonstrating impairment in executive functioning, it is likely that performance on this task reflects difficulty with the organization of semantic knowledge rather than an impoverishment

thereof. Regardless of the etiology of this impairment, one might expect that a similar effect of encoding would be found for the ADHD group. However, when the finding of impaired fluency for the ADHD sample is considered within the context of intact performance on language-based measures of academic functioning, it appears that the linguistic processing deficits in the ADHD sample are significantly different, and certainly not as severe, relative to those of the RD sample. Although the number of semantically-encoded primes produced by the ADHD group was not found to differ from that of the RD and NC groups, it can be seen in Figure 13 that the ADHD group fell midway between the other groups and that the slope representing the relative effect of encoding on this measure was similar for the ADHD and RD groups. Thus, the manipulation in encoding effected the performance of these groups in a similar way, and in a way that differed from how it effected the performance of the NC subjects.

Category Fluency Priming. Diagnostic group differences were predicted on the category fluency priming task. The reason for this prediction related to the categorization of the category fluency test as a linguistically based implicit measure without consideration for this task as a conceptually-driven task as opposed to a perceptually driven task. The absence of significant group differences on this task may relate to the difference in task requirements (i.e., conceptually-driven vs. perceptually-driven). Given this, one might have predicted that performance on the category fluency test would be vulnerable to experimental manipulations in a way similar to

other conceptually-driven tests be they implicit or explicit measures.

This reasoning would have argued strongly for an effect of encoding on this measure, at least for the NC group. While a significant effect of encoding was demonstrated on this task for the developmental sample in Experiment 1 (Figure 3b), there was no effect of encoding on the performance of any of the groups from this sample. Given the inconsistency between the results of Experiment 1 and 2, one is left to speculate with regard to the reason.

Foil-Selection

Significant group differences were also predicted in foil-type selection. This prediction was based on findings which suggest a delay in the development of effortful semantic processing ability in RD children. It has been demonstrated that, on multiple choice recognition tests, younger relative to older children tend to commit more errors on the basis of structural and acoustic features. In contrast, the false recognition errors of older children are based on semantic attributes. While this trend has been observed in non-disabled children, it has not been demonstrated by learning-disabled children. In contrast, it has been found that the encoding preferences of learning disabled children remain fixed with age such that structural features serve as the dominant encoding preference. Given this, it was predicted that the RD group would select more phonemically-related errors relative to NC and ADHD subjects. Conversely, NC subjects were predicted to make more semantically-related errors.

The prediction for group differences in foil-selection was not confirmed, however a main effect of Foil-type was demonstrated. The nature of this main effect was similar to that obtained in Experiment 1, namely that all groups selected significantly more other-paired foils relative to semantic or phonemic types. The absence of a significant difference between the number of semantic and phonemic foils selected is interpreted to have resulted from the tendency of all subjects to select other-paired stimuli as a recognition choice. The presence of a significant Diagnostic Group X Foil-Type interaction, however does suggest that the pattern of false recognition errors differed for groups. As can be seen in Figure 14, the RD group selected more other-paired foils relative to both the ADHD and NC groups. The reason for this finding is unclear. One might have predicted such a finding for ADHD children, given the impulsivity which characterizes this disorder. That is, it would seem logical that individuals who are impulsive might select any choice which "looks" familiar. In the absence of an objective measure of impulsivity, however, this reasoning is speculative.

General Discussion

Explicit Test Performance

The primary purpose of Experiment 1 was to investigate the development of implicit and explicit memory across a major portion of the life-span (i.e., middle childhood to mid-adulthood). Based on previous findings that performance on explicit tests (i.e., free recall, cued-recall and recognition) improves with age, it was hypothesized that age differences would be found on recognition performance given its classification as a conceptually-driven measure. While the results of Experiment 1 were consistent with hypothesized age differences in the demonstration of a significant age-related increase in overall recognition, the magnitude of the age-effects was relatively modest as compared to age-effects typically seen on measures of free-recall. Thus, these data, when viewed within the context of other findings (e.g., Naito, 1990) suggest that demonstration of age differences on explicit measures depends greatly on the type of test used. Specifically, age differences may be most profound on measures which do not provide any cueing or "environmental support" (e.g., on tests of free-recall), and relatively less marked on tests which provide cueing (e.g., on forced or multiple choice tests). Taken together, these findings have implications for how memory tests are currently classified. The current results suggest that performance on recognition tests may not be vulnerable to manipulations in independent variables in the same way that performance on tests of free recall. Thus, rather than consider these tests to be similar in that they are both explicit

measures, the tests may be better classified using a continuum which characterizes them in terms of the degree of environmental support provided as well as in terms of the extent to which they engage perceptual and conceptual processing.

The finding that the RD sample in Experiment 2 demonstrated comparable recognition performance, relative to the ADHD and NC groups, has implications for the nature of, and the possible reasons for, findings of impairment on explicit measures in this population. The absence of group differences in recognition performance may be interpreted as suggesting that at least some of the explicit memory deficits demonstrated in previous studies of memory in RD subjects is attributable to encoding and/or lexical processing deficits rather than to a deficit in retrieval. Additionally, the fact that, in this experiment, subjects were informed prior to the encoding procedure that they would be asked to recall the information presented at some later point has implications for the ability of the diagnostic groups to employ and benefit from encoding strategies. Specifically, if one controls for encoding such that adequate processing of lexical information is ensured for RD subjects, their recognition performance is effected similarly to that of non-RD subjects by manipulations in encoding. This finding is interpreted to mean that the RD group was able to benefit as well as the ADHD and NC groups from the provision of meaningful information at the time of encoding. In the absence of a means by which to gauge the extent to which each group utilized this information to assist recognition, however, there can be no conclusion made regarding the relative ability of each group to apply a mnemonic strategy at the

time of recall. It is believed that this latter phenomenon could best be explored using a within-subjects design and by administering two explicit tests: one in which the experimenter does not provide guidance in using a mnemonic strategy and one in which such guidance is provided. The relative improvement in recall for the RD sample obtained across measures might be compared to other non-RD groups.

The current experiment did not employ a free-recall paradigm. Therefore, any conclusion made regarding the explicit test performance of the RD sample in Experiment 2 cannot be generalized to performance on measures other than recognition. Based on previous literature (e.g., Dallago & Moely, 1980), it is likely that the free-recall performance of RD individuals might differ from non-RD even when encoding is ensured. One possible explanation for the absence of significant group differences in recognition ability in Experiment 2 relates to the fact that recognition as well as other cued-recall tests benefit retrieval by narrowing the range of possible responses. In doing this, recognition and cued-recall tests would facilitate memory performance in the RD sample, as well as in younger subjects as in Experiment 1, by providing an external structure or additional environmental support.

The failure to include a free-recall test in the current experiment is viewed as a significant weakness. There were a number of reasons, however, for not including such a measure. One reason related to the age of the sample. It was believed that the youngest subjects would have demonstrated significant difficulty, and may not have been able to freely recall any of the word-pairs on

a test of free-recall. Second, inclusion of an additional explicit measure as a within-subjects factor would have potentially resulted in order effects, therefore confounding results. Thus, one suggestion for further research would be to explore the free-recall ability of RD subjects under conditions which ensure comparable levels of encoding by requiring that subjects achieve a specified level of mastery. This approach is frequently used in animal studies of memory and enables one to delineate differences in encoding and retrieval. Alternatively, one might employ a between-subjects design.

Implicit Test Performance

Category Fluency Priming: The hypothesis for an effect of encoding condition on implicit test performance in both Experiments related to the classification of the implicit measures as being primarily perceptually or conceptually-driven. Consistent with prediction, it was found in Experiment 1 that the performance of the developmental sample on the perceptually-driven test (i.e., cued stem-completion) did not vary as a function of encoding condition whereas performance on the conceptually-driven (i.e., category fluency test) did vary as a function of encoding condition. The relative vulnerability of these tasks to the effects of encoding condition in Experiment 1 is consistent with results of other studies (e.g., Rajaram & Roediger, 1993, Hamann, 1990, and Srinivas & Roediger, 1990) indicating that performance on perceptually-driven tasks (be they implicit or explicit) is not sensitive to levels-of processing manipulations whereas performance on conceptually

driven tasks is effected by variations in this variable. However, these results must be interpreted cautiously as encoding condition did not effect the performance of the NC group on the conceptually-driven measure in Experiment 2. It is unclear why this effect was not obtained for this group, however, it is believed that one possible reason may relate to the difference in sample sizes and the under-representation of older subjects in this sample.

An effect of age was also hypothesized for performance on the conceptually-driven implicit measure but not for performance on the perceptually-driven measure. The basis for this prediction related to the proposed vulnerability of conceptually-driven measures (be they implicit or explicit) to variations in subject variables. While this hypothesis was confirmed by the finding of a main effect of age, the nature of this effect was arbitrary (i.e., 9-10 y.o. subjects producing significantly more primes relative to 14-19 y.o. subjects) and was not consistent with the prediction of an age-related increase in overall priming on this task. It is believed that the age-related difference on this task may relate to something other than maturational differences. In the absence of objective age-related differences in Experiment 1, or significant group differences on this task in Experiment 2, the possible reasons for this effect can be only speculative.

Cued Stem-Completion Priming. Based on the classification of the cued-stem completion task as a perceptually-driven implicit measure, it was predicted that performance on this measure in Experiment 1 would be resistant to age and encoding effects. This

hypothesis was confirmed and is consistent with results of previous studies (e.g., Rajaram & Roediger, 1993; Srinivas & Roediger, 1990).

The finding of increased priming in Experiment 2 for the RD sample is consistent with Jernigan and Ostergaard's (1993) finding of an association between decreased processing efficiency and increased priming. That increased priming was demonstrated on the perceptually-driven implicit measure in Experiment 2 and not on the conceptually-driven measure has significant implications for the nature of the disability in this sample as well as for how these tests are characterized. An ongoing debate in psycholinguistic research exists concerning the representational format of words. On one hand, a number of theorists have adopted a lexical stance which suggests that separate and discrete representations exist for each word in our vocabulary. According to these theorists, the first stage of word recognition is to gain access to the appropriate lexical entry. These lexical entries are thought to specify the meaning, pronunciation and other relevant features of previously-encountered words. One possible explanation of the hyperpriming by the RD sample relates to potential differences in the retrievability or organization of these representations for RD subjects. In explanation of lexical priming, it is possible that by exposing individuals to lexical information (e.g., a word), one "primes" the representations of that information making them more readily available than representations for "non-primed" information. Given this, the primed representations for lexical information in individuals with lexical processing deficits may be viewed as being more readily available and hence more accessible relative to that of

the representations for non-impaired individuals. The possible reasons for this enhanced availability and accessibility are believed to relate to both the nature and severity of the processing deficit of the RD sample.

With regard to the nature of the processing deficit, it has been suggested that RD individuals are deficient in their ability to activate word knowledge (i.e., semantic memory) (see Swanson, 1991, for review). It remains unclear, however whether this deficiency results from an impoverishment in word knowledge per se, or from a deficiency in the organization or "internal coherence" of the information stored in semantic memory. Given the impairment in academic skills and category fluency in the RD sample, it is likely that the finding of enhanced priming, and the differential effect of encoding, on the stem-completion priming performance of this group relates to both. In order to arrive at this conclusion, one must consider the test performance of the RD sample relative to that of the ADHD. In Experiment 2, the RD sample demonstrated significant impairment on tests of single word reading and written spelling relative to the ADHD group. Although these are gross measures, this finding may be seen as reflecting an impoverishment in semantic knowledge. In contrast, both the ADHD and RD groups were impaired, relative to the NC group, on the measure of category fluency, a task which requires organization of semantic information. The absence of impairment on the academic measures for the ADHD group, in combination with findings which suggest that individuals with ADHD exhibit difficulties on measures of executive function, would suggest that impairment on the fluency

test for both groups resulted from impairment in organizational ability. In order to attribute the finding of enhanced priming solely to a deficit in semantic knowledge, one would expect that the performance of the ADHD group would resemble that of the NC group. While these groups did not differ significantly in the overall number of primes produced on the stem-completion test, as can be seen in Figure 12, the slope of the line representing the relative effect of encoding on task performance differs for the NC and ADHD group. Furthermore, the slope representing the effect of encoding for the ADHD group is similar to that obtained for the RD group suggesting that the manipulation in encoding effected the task performance similarly for these two groups. It is believed that the combined impairment in semantic knowledge and organizational ability produced an additive effect resulting in the enhanced priming. This conclusion must be interpreted cautiously, however, given the absence of additional measures of semantic knowledge and organizational ability. It is certain that RD individuals are heterogeneous with regard to the nature of their lexical processing deficits. This heterogeneity has inspired a number of researchers to propose the existence of subtypes to categorize the deficits found amongst RD individuals. Given the demonstration of a differential effect of encoding for the RD sample on the stem-completion task in Experiment 2, it is possible that the finding of enhanced priming for this group may relate to the existence of a specific deficit (e.g., phonological processing). In order to understand the influence of lexical processing on this task more clearly, further research should attempt to delineate the nature of the lexical processing deficits in

this group by devising a more comprehensive battery of tests to evaluate various aspects of linguistic processing.

Future Research

There are a number of recommendations for future research. The first relates to the failure to include a free recall measure and the resultant absence of age-related differences on explicit memory performance in Experiment 1. While a significant age-related linear trend on recognition test performance was demonstrated in Experiment 1, there were no significant differences between age-groups on this task. When taken within the context of findings which demonstrate clear developmental differences on measures of free-recall (c.f., Richardson-Klavehn & Bjork, 1988) this finding raises the possibility that explicit memory tests are not a homogenous group and may differ in the degree to which they engage conceptual and/or perceptual processes. The development of a classification scheme which characterizes explicit measures in terms of the relative degree to which they engage these processes would be one potential direction for future research.

A second weakness in this dissertation was the failure to include what would be characterized as a "perceptually driven" explicit memory measure. While the results of Experiment 1 were interpreted to support the processing view that the vulnerability of memory test performance to manipulations in certain independent and subject variables depends on the processes engaged by those tasks, the absence of a perceptually driven explicit measure detracts from the strength of this support. Future research in this

area should employ tasks from each category (i.e., conceptually-driven implicit vs. conceptually-driven explicit vs. perceptually-driven implicit vs. perceptually-driven explicit). Use of a within-subjects design would better enable demonstration that performance on conceptually-driven measures (be they implicit or explicit) is vulnerable to the effects of manipulations in various independent variables in a way which perceptually-driven measures are not.

The finding that RD subjects performed comparably to the ADHD and NC groups on the recognition test raises the possibility that previous demonstrations of memory impairment in this RD subjects may relate to difficulties with encoding rather than a memory deficit per se. The discrepancy between previous findings of impairment on explicit recall measures in RD children and the current results suggests the need for criterion-controlled studies in which memory is assessed in circumstances in which adequate encoding of the to-be-remembered material is insured. Such a design will better enable one to discern whether the apparent explicit memory deficits seen in RD individuals are attributable to encoding deficits or to problems with retrieval.

While the finding of increased priming in the RD sample in Experiment 2 provides additional support for a processing view of priming, it leaves many questions unanswered. First and foremost is the question of why an impairment in linguistic processing would effect increased linguistic priming for information which was encoded perceptually but not for information which was encoded semantically. In order to explore the possible answers to this

question, one must first discern the effect of various types of processing deficits on the different types of priming measures (i.e., conceptually-driven vs. perceptually-driven). An interesting question is whether the finding of increased priming relates to the type of processing deficit or the severity of the processing deficit in the RD group. For example, one might ask, "would individuals with impaired perceptual processing perform similarly relative to individuals with linguistic processing deficits on implicit measures?". While the current results suggest a relationship between the type and/or severity of a processing deficit and priming, the nature of this deficit has yet to be determined.

In summary, the results of this dissertation raise interesting questions with regard to how memory tests are classified. Processing theorists contend that the vulnerability of memory test performance to variations in certain independent and subject variables depends on the cognitive process engaged by those tasks rather than the type of memory being assessed. While experiments 1 and 2 provide support for this view, the obtained results suggest there to be some fundamental differences between conceptually-driven implicit measures and conceptually-driven explicit measures such that performance on them is not vulnerable to manipulations in certain independent variables in the same way. Thus, the picture becomes less clear. Further research will be necessary to determine the relationship between information processing and implicit memory test performance. In addition, it is hopeful that with the advent of more sophisticated neuroimaging techniques, the neural mechanisms which underlie performance on both implicit and

explicit measures will be determined.

Table 1
Experiment 1
Subject Characteristics

	7-8 years	9-10 years	11-13 years	14-19 years	20 > years
N	19	20	23	20	26
Age	8.21 (.52)	10.17 (.45)	12.38 (.94)	16.58 (1.84)	31.13 (8.21)
M/F	13 / 6	13 / 7	15 / 8	11 / 9	9 / 17
KBIT Comp	111.63 (7.59)	115.55 (11.02)	114.78 (8.87)	113.05 (9.30)	111.38 (9.59)
KBIT Matrices	110.58 (8.73)	118.55 (13.68)	117.17 (9.49)	115.10 (11.58)	111.12 (10.86)
KBIT Vocab	110.37 (9.19)	109.15 (8.88)	109.35 (9.57)	108.45 (7.77)	109.27 (8.87)
WRAT-R Reading	107.84 (7.41)	108.10 (8.03)	113.00 (10.21)	113.25 (11.68)	106.23 (10.14)
WRAT-R Spelling	104.32 (8.18)	105.20 (8.82)	109.39 (12.33)	108.90 (11.44)	105.38 (14.85)
WRAT-R Math	109.00 (15.18)	106.80 (11.01)	110.65 (15.04)	106.20 (15.07)	107.62 (13.59)

Table 2
Subject Characteristics
Baseline-Only vs. Experimental Subjects
Mean (SD)

	Baseline Only	Experimental
N	9	9
M/F	2 / 7	3 / 6
Age in Years	18.19 (9.66)	18.24 (9.54)
KBIT Composite	117.67 (8.28)	115.44 (7.84)
KBIT Vocabulary	113.89 (10.25)	111.44 (8.40)
KBIT Matrices	117.78 (8.30)	115.89 (8.12)
WRAT-R Read	109.33 (11.45)	109.33 (7.81)
WRAT-R Spell	106.22 (11.93)	114.44 (10.27)
WRAT-R Math	114.33 (12.24)	104.22 (9.19)

Figure 1
Mean Overall Priming Scores
Baseline-Only vs. Experimental
Subjects

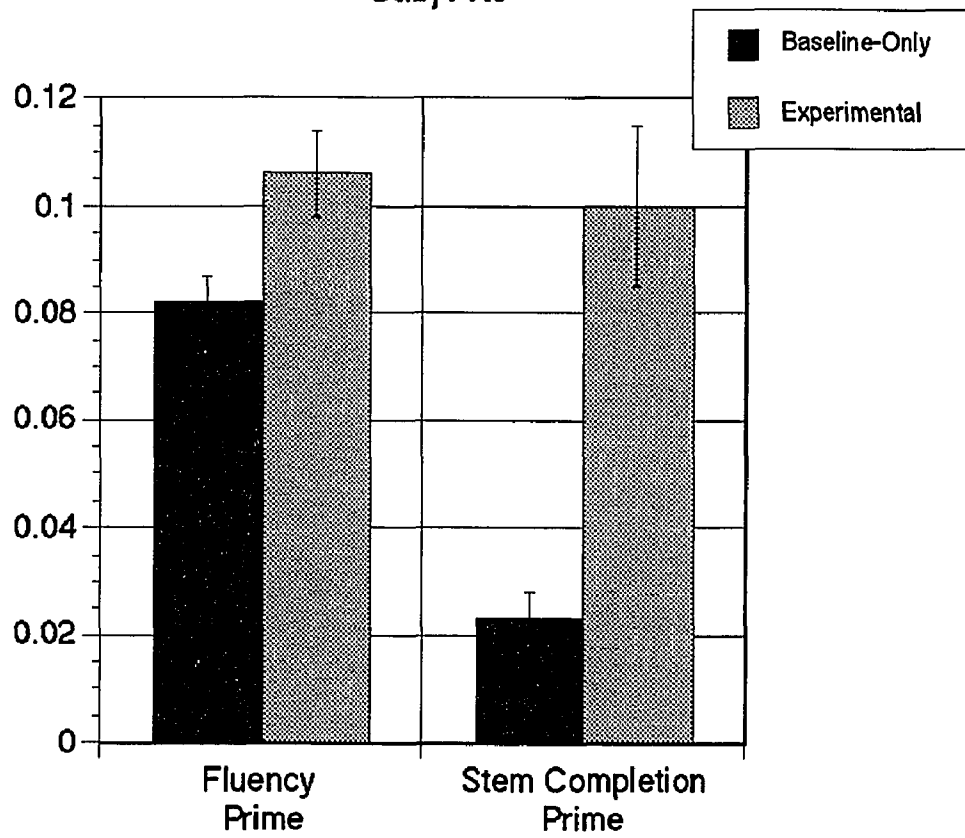


Figure 2
Mean Priming on Word-Stem
Completion as a Function of
Age and Encoding Condition

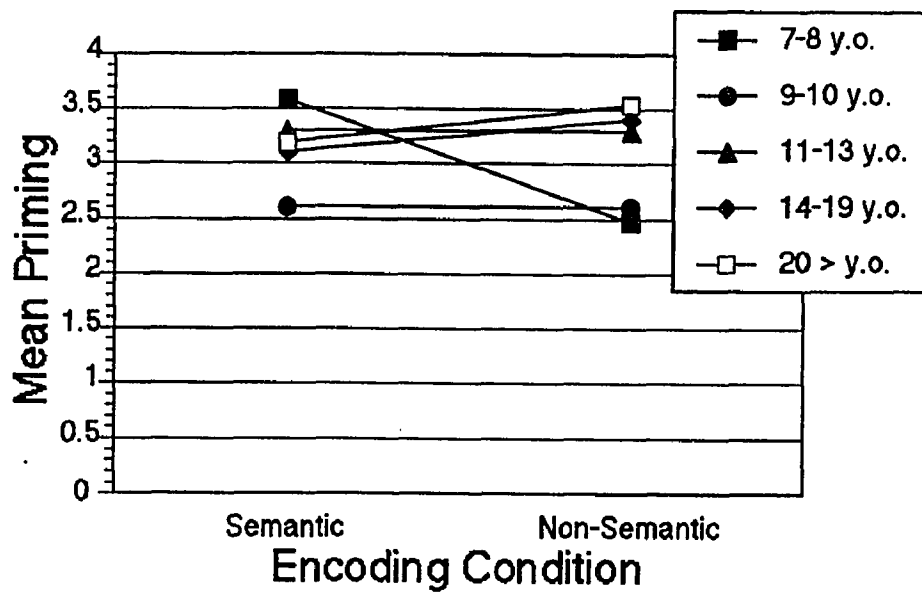


Figure 3
Effect of Encoding on Memory Tests
for Developmental Subjects (N=108)

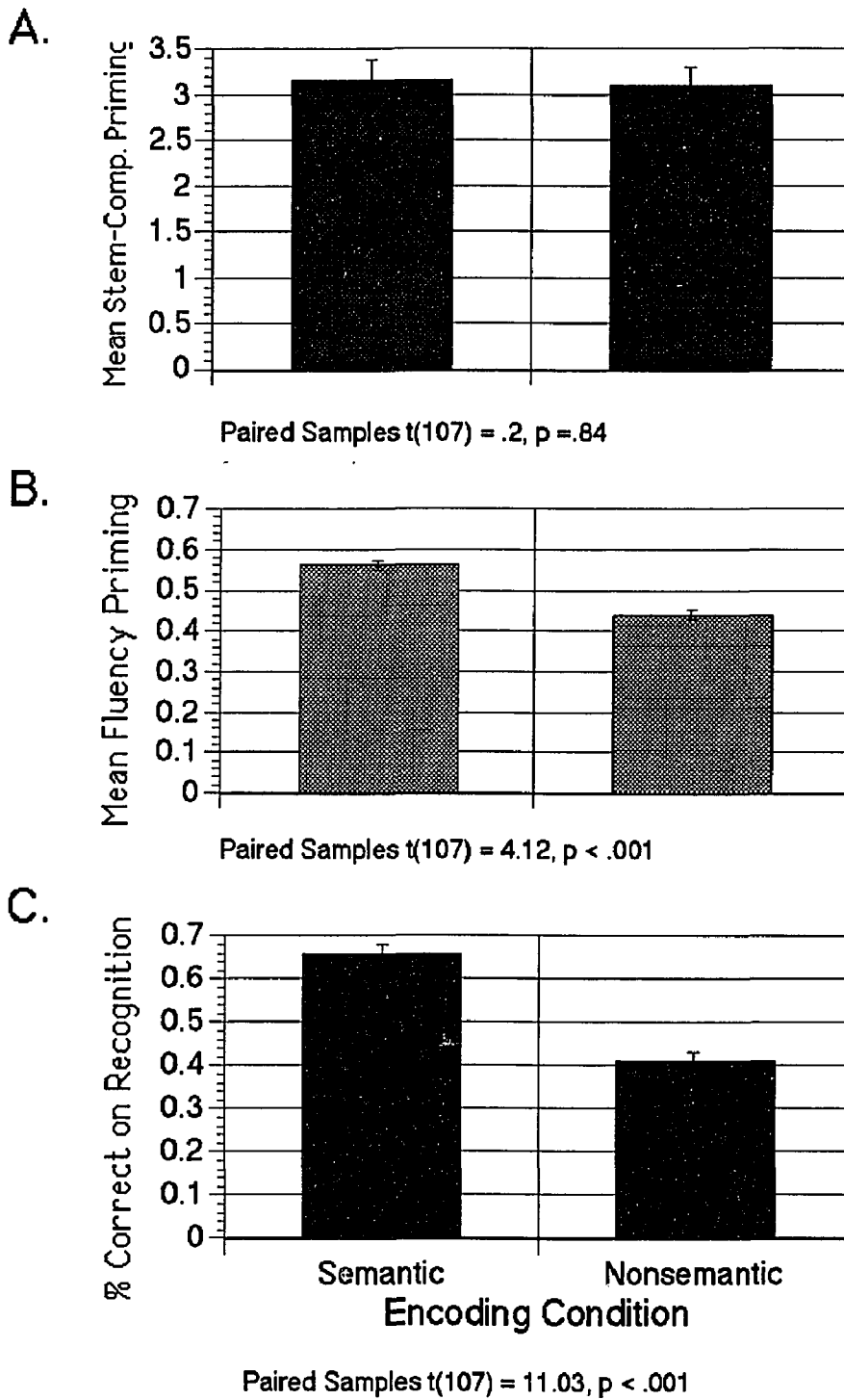


Figure 4
Mean Fluency Priming as a
Function of Age and
Encoding Condition

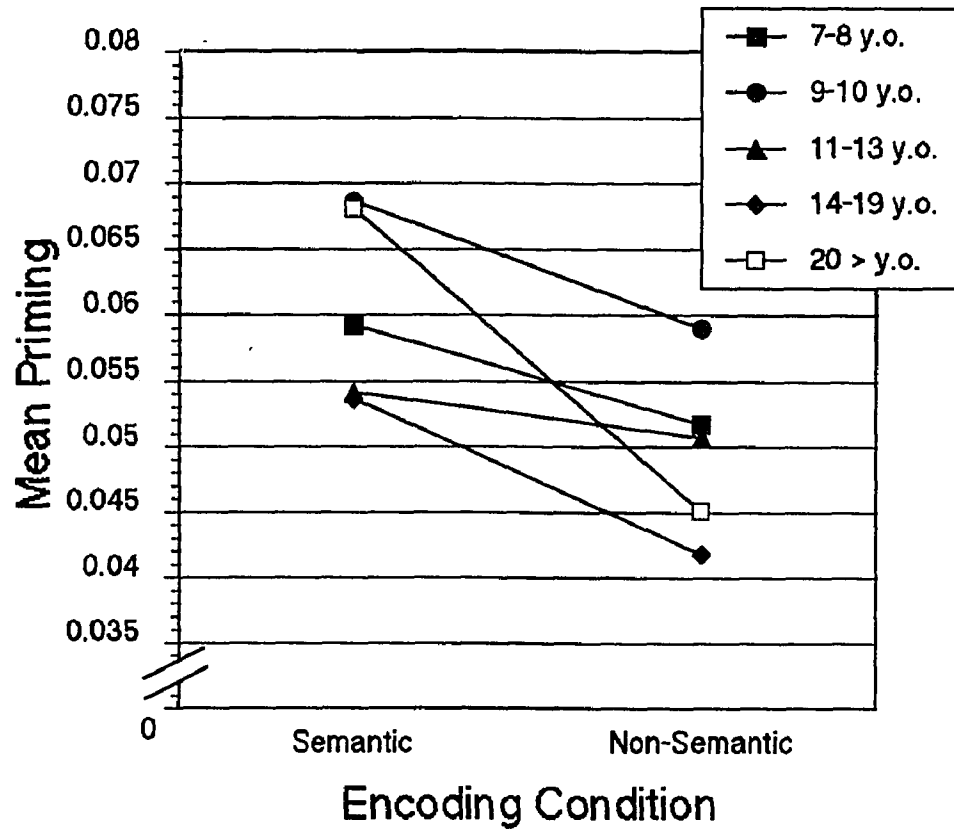
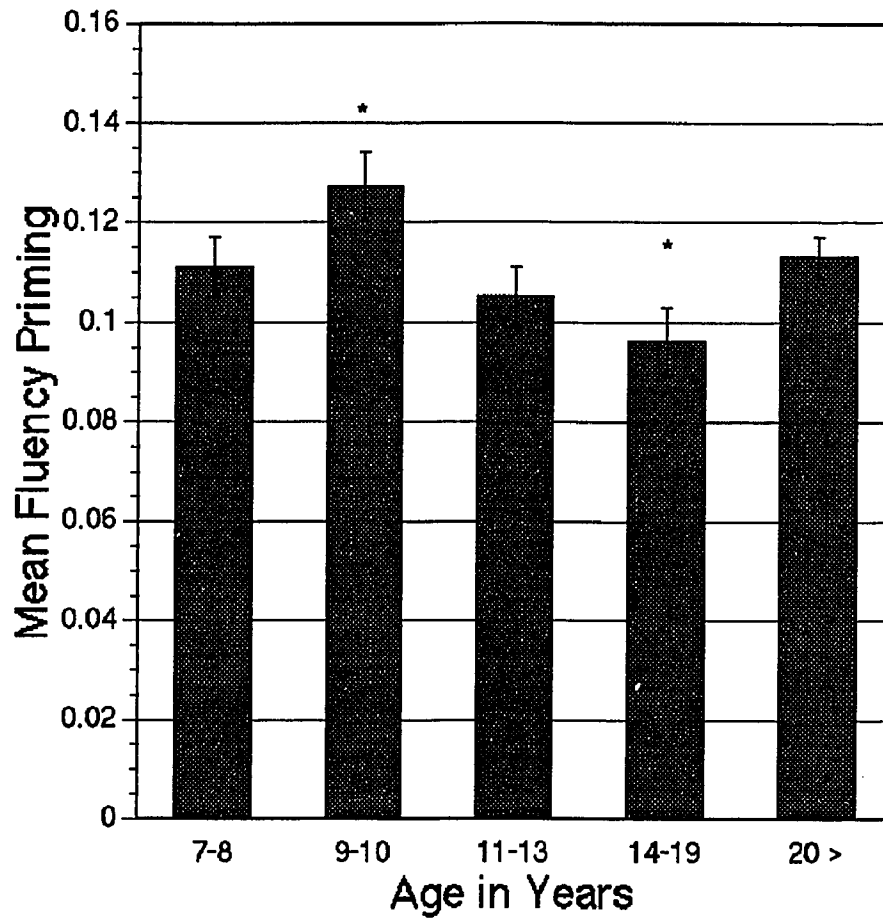


Figure 5
Mean Fluency Priming as a
Function of Age



* Groups differ $F(4, 103) = 3.45, p = .01$

Figure 6
Mean Percent Correct on
Recognition as a Function of
Age and Encoding Condition

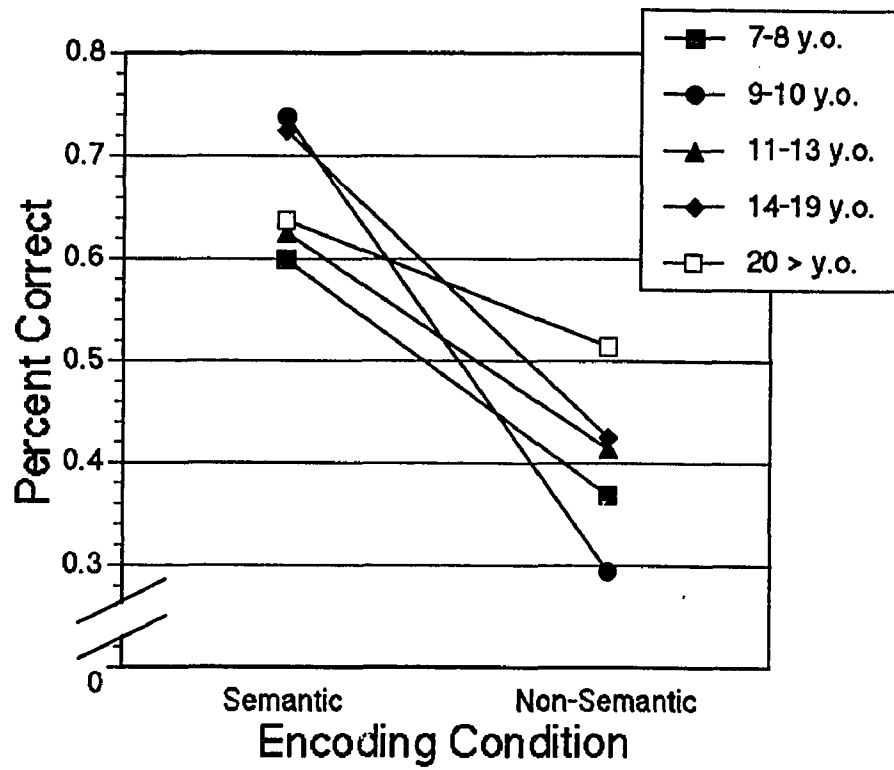
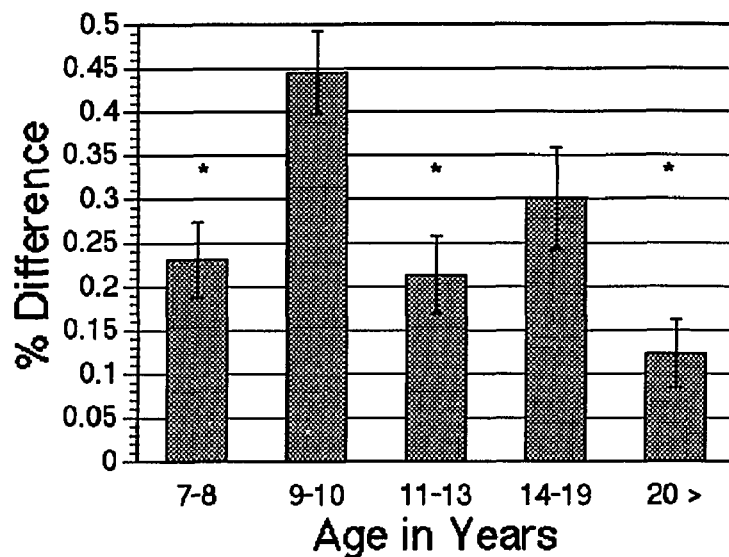


Figure 7
Encoding Difference on Total
Recognition Correct as a
Function of Age-Group



* Groups differ from 9-10 y.o.

Figure 8
Mean Number of Foils for
Developmental Sample
(N=108) as a Function of Foil-
Type

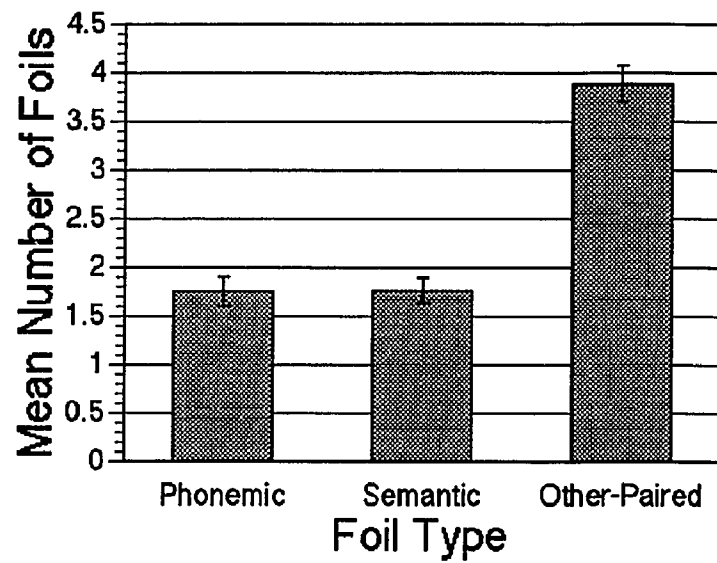


Figure 9
Mean Percentage of Foils for
Developmental Sample (N=108)
as a Function of Encoding
Condition

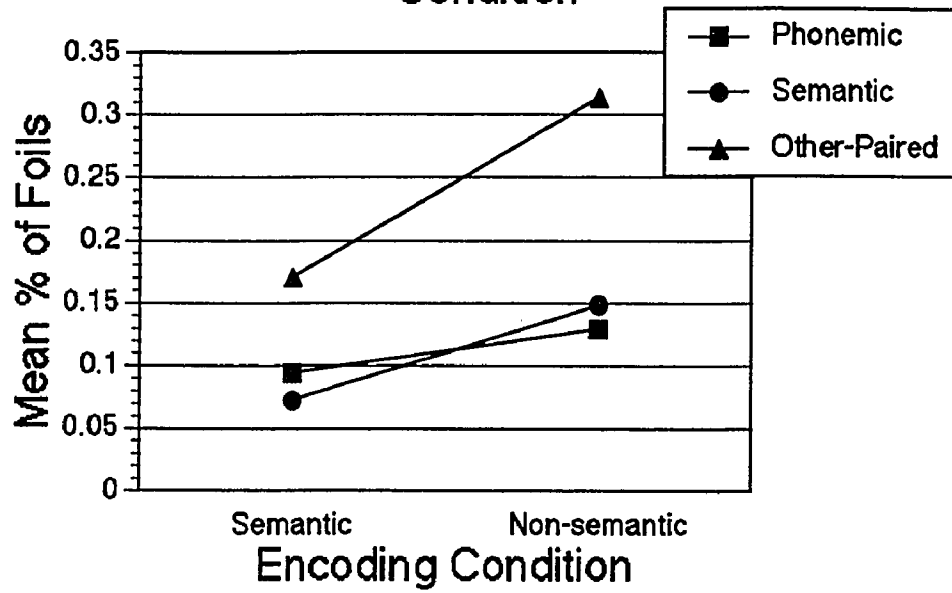


Figure 10
Mean Encoding Errors as a
Function of Age-Group and
Encoding Condition

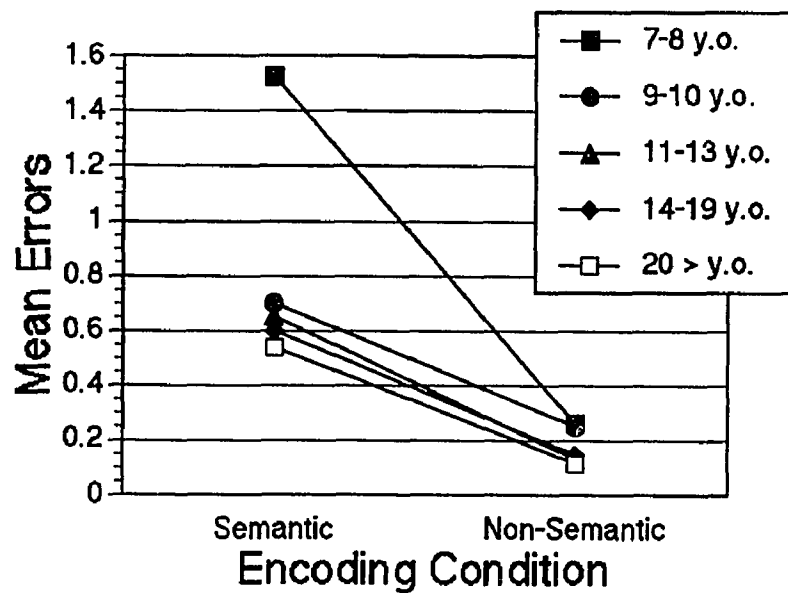


Figure 11
Total Fluency as a Function
of Age

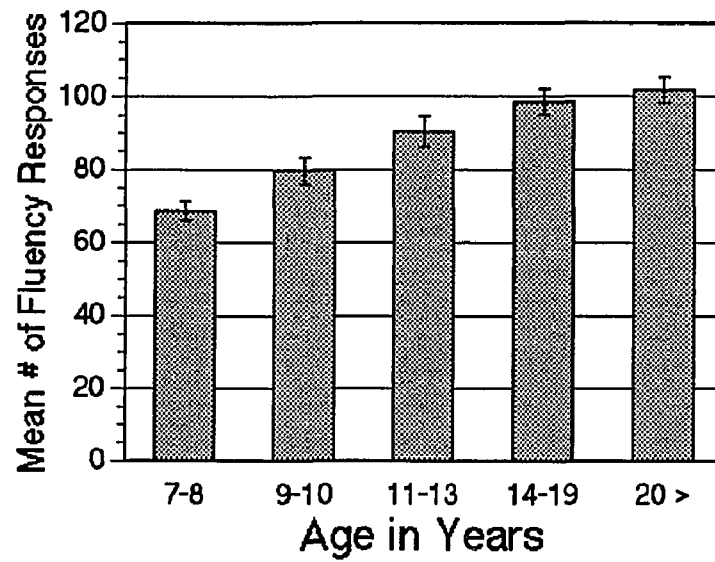


Table 3
Subject Characteristics
Experiment 2

	ADHD	RD	Normal controls
N	16	16	16
Age	14.12 (10.32)	12.19 (4.55)	14.53 (9.69)
M/F	11 / 5	9 / 7	11 / 5
KBIT Matrices	116.5 (13.91)	109.87 (10.53)	113.88 (8.72)
KBIT ¹ Vocabulary	110.38 (10.60)	97.00 (9.91)	109.00 (8.02)
KBIT ¹ Composite	115.31 (11.52)	103.69 (7.73)	112.75 (8.30)
WRAT-R ² Math	104.13 (12.35)	92.63 (12.48)	111.19 (16.18)
WRAT-R ¹ Reading	111.25 (8.26)	82.31 (10.86)	111.63 (8.33)
WRAT-R ³ Spelling	102.75 (7.71)	78.00 (6.36)	109.00 (7.51)

¹ RD group differs from ADHD and NC groups; $p < .05$

² RD group differs from NC group, $p < .05$

³ All groups differ from each other, $p < .05$

Figure 12
Mean Stem-Completion
Priming as a Function of
Diagnostic Group and
Encoding Condition

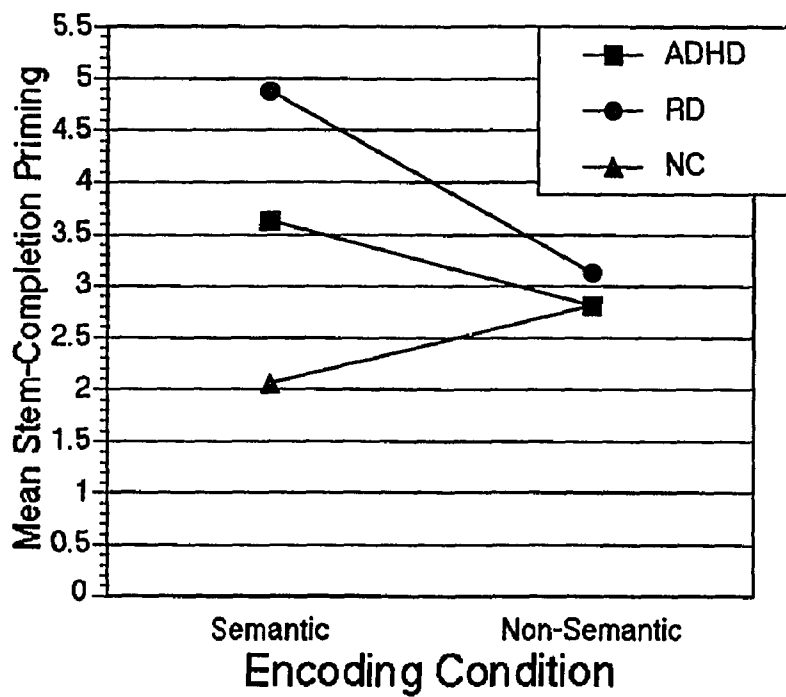


Figure 13
Mean Fluency Priming as a
Function of Diagnostic Group
and Encoding Condition

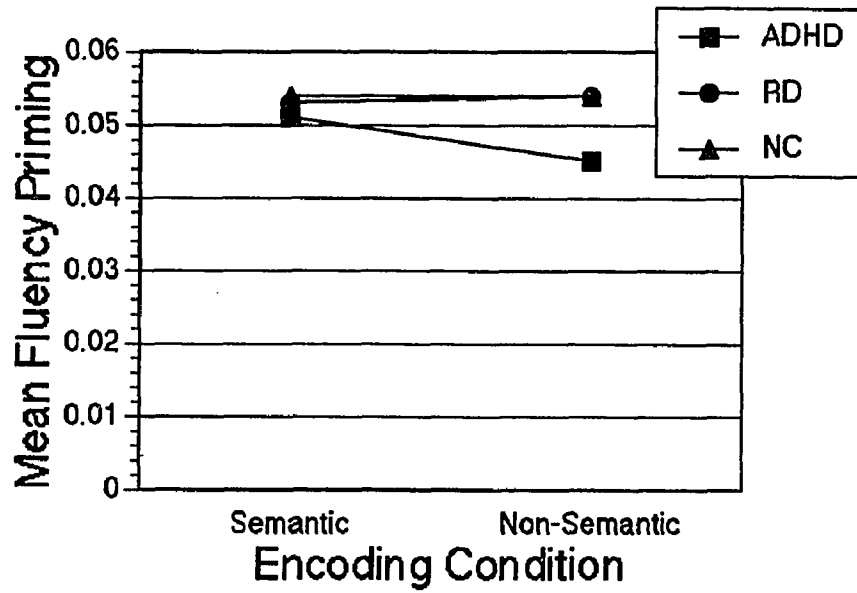


Figure 14
Mean Percent Correct on
Recognition as a Function of
Diagnostic Group and
Encoding Condition

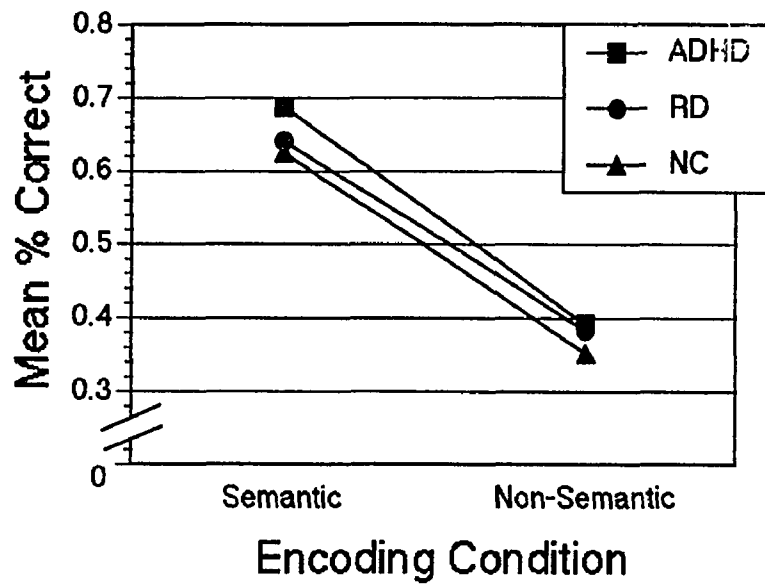


Figure 15
Mean Number of Foils as a
Function of Diagnostic Group
and Foil Type

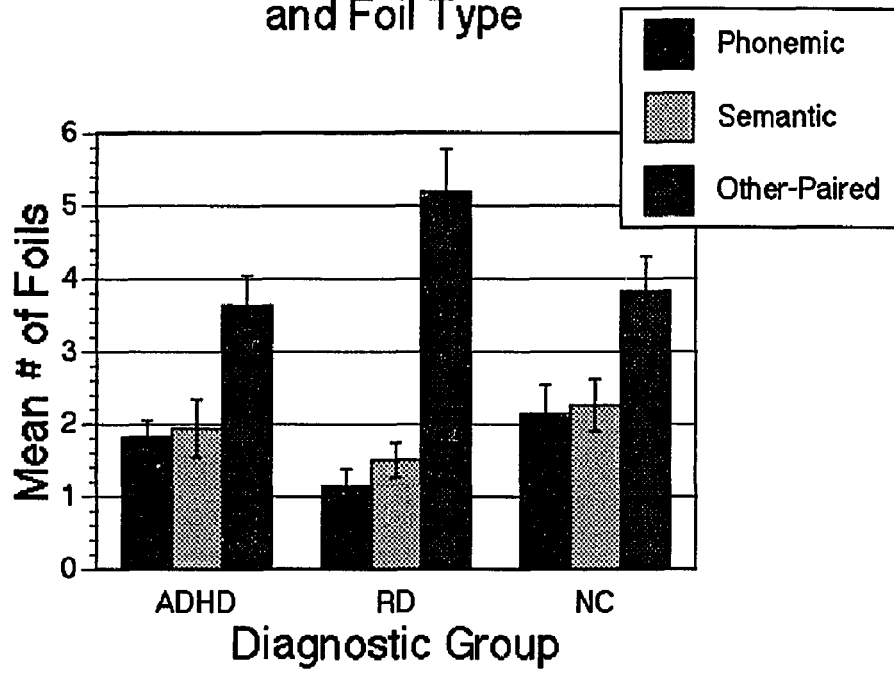


Figure 16
Mean Number of Foils as a
Function of Diagnostic Group
and Foil Type

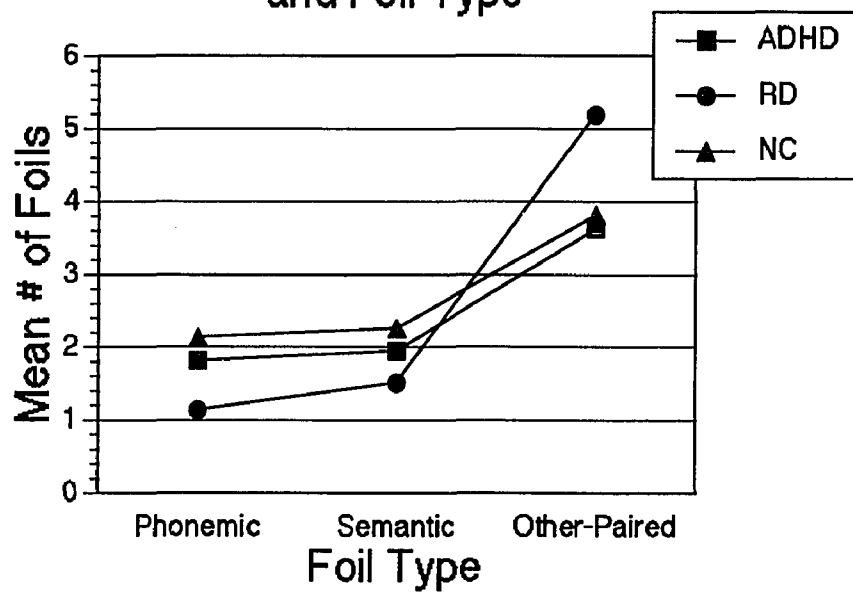


Figure 17
Mean Percentage of Foils For
Diagnostic Groups (N=48) as
a Function of Foil-Type and
Encoding Condition

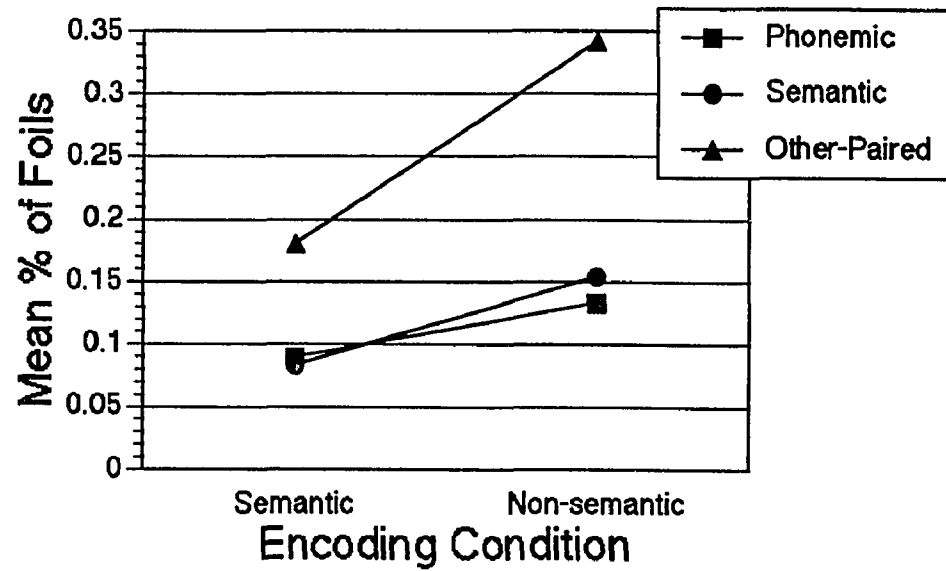


Figure 18
Mean Encoding Errors as a
Function of Diagnostic Group
and Encoding Condition

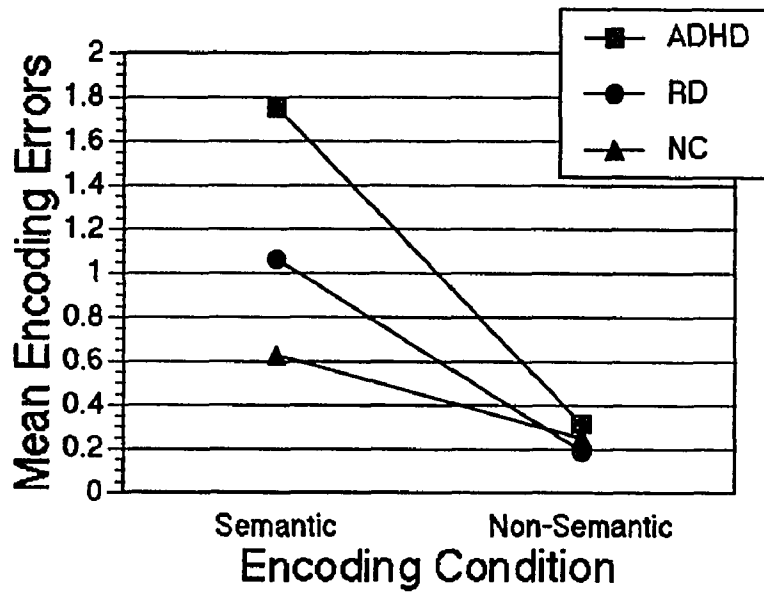
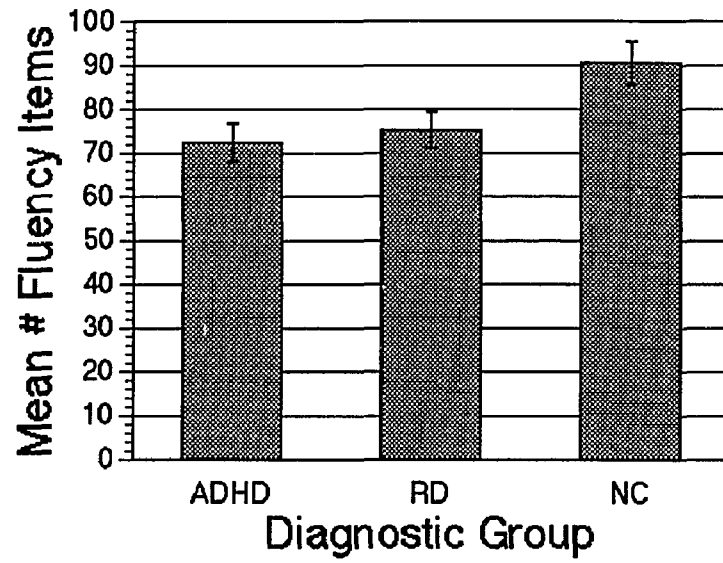


Figure 19
Mean Number of Items
Produced on Fluency Test as
a Function of Diagnostic
Group



Appendix A

Consent Forms1. Consent for Child Subjects:

You and your child are invited to participate in a research study. This study is being conducted by a graduate student from Queens College of the City University of New York to fulfill the dissertation requirement for a doctoral degree in Psychology. The purpose of this study is to determine whether children with reading disabilities and/or Attention-deficit Hyperactivity Disorder (ADHD) have memory difficulty due to an inability to encode information adequately. We will also be looking at these functions in children without reading disabilities or ADHD to see how these groups compare. We are looking for children, aged 7 years or older, who are normal, who have a learning disability or who have ADHD.

Participation in the study entails completion of a battery of psychological tests which will last approximately 45 minutes. Among the tests administered will be an intelligence test; a test of academic functioning which assesses single word recognition, written spelling and arithmetic; and a computerized memory test. Most children report that the tests are fun and are somewhat like games. Testing can be conducted at a mutually convenient time. If, once the session has begun, the child wishes to terminate testing at any time, or for any reason, he or she may do so without consequence.

In addition to the testing, we ask that the parent/guardian, as well as the child's teacher, complete a short questionnaire which evaluates behavior. Lastly, a brief telephone interview will be conducted with the parent or guardian to help determine group placement and to obtain any additional information that might be needed. Group assignment will be made on the basis of the child's performance and responses to the interview. The results of this evaluation will be kept strictly confidential and will only be provided to the parent if requested.

The results of this study will provide insight into the cognitive deficits which characterize children with reading disabilities and which frequently accompany children with ADHD. In addition, these results will have implications for the development of techniques used to remediate cognitive deficits in these children.

If interested, please complete and detach the bottom portion along with the completed questionnaire to the front office of your school with "Attention Kathy McKay" on the front. If you have any questions about the nature of the study, please do not hesitate to call me at (XXX)XXX-XXXX. Thank you.

++++
I grant permission for _____ to participate in the research study on memory. I have been informed and understand that participation entails a 45 to 60 minute testing session. I am fully aware that completion of this testing is contingent upon my child's assent and that he or she may withdraw from the study at any time without consequence. I am also aware that I will be interviewed on the phone, at a mutually convenient time, about my child's behavior. I have completed the enclosed questionnaire and am aware that my child's teacher will be completing one that is similar.

signature of parent

name of parent

2. Consent for Adult Subjects:

You are invited to participate in a research study. This study is being conducted by a graduate student from Queens College of the City University of New York to fulfill the dissertation requirement for a doctoral degree in Psychology. The purpose of this study is to determine whether individuals with reading disabilities and/or Attention-deficit Hyperactivity Disorder (ADHD) have memory difficulty due to an inability to encode information adequately. We will also be looking at these functions in individuals without reading disabilities or ADHD to see how these groups compare.

Participation in the study entails completion of a battery of psychological tests which will last approximately 45 minutes. Among the tests administered will be an intelligence test; a test of academic functioning which assesses single word recognition, written spelling and arithmetic; and a computerized memory test. Most people report that the tests are fun and are somewhat like games. Testing can be conducted at a mutually convenient time. If, once the session has begun, you wish to terminate testing at any time, or for any reason, you may do so without consequence.

In addition to the testing, the examiner will interview you regarding the presence or absence of certain behaviors.

The results of this study will provide insight into the cognitive deficits which characterize persons with reading disabilities and which frequently accompany ADHD. In addition, these results will have implications for the development of techniques used to remediate cognitive deficits in individuals who have these disorders.

++++
I agree to participate in the memory experiment described above. I have been informed and understand that participation entails a 45 to 60 minute testing session. I am fully aware that completion of this testing is contingent upon my willingness to do so and that I may withdraw from the study at any time without consequence. I am also aware that I will be interviewed following completion of the testing session about behaviors which I may or may not exhibit.

Signature of subject

Name of subject

Witness

____/____/____
Today's Date

Appendix B

Intelligence and Academic Measures.

Kaufman Brief Intelligence Test. Intelligence was assessed using the Kaufman Brief Intelligence Test (K-BIT) (Kaufman and Kaufman, 1990). This test provides a measure of verbal and nonverbal intelligence for individuals aged 4 to 90 years. The test is composed of two scales. The first, Vocabulary, assesses verbal, school-related skills by evaluating a person's word knowledge and verbal concept formation. The Vocabulary scale is comprised of two parts: Expressive Vocabulary (45 items) and Definitions (37 items). Expressive vocabulary is a test of object naming and subjects are presented with pictures of common objects which they are asked to name. Part B, Definitions (37 items), is administered to subjects 8 years and older. On this test, subjects are asked to provide the word that best fits two given clues. The first clue is a phrase which defines the word. The second clue provided is a partial spelling of the word. A sample item can be seen below with instructions for the examiner:

a dark color

B R _ W _

EXAMINER: points to the verbal phrase and says, "A DARK COLOR, that's one clue about the word you're looking for. Here's another clue"
 (examiner points to the word with missing letters)
 "what is the word?"
 (Answer: BROWN)

The Vocabulary scale provides an estimate of an individual's language development and his or her level of verbal

conceptualization. The creators of the test suggest that the Vocabulary standard score is a measure of what Horn and Cattell (1966) call "crystallized intelligence", i.e., the kind of learning and problem solving that depends heavily on formal schooling and cultural experiences.

The second subtest, Matrices (48 items), measures nonverbal skills by evaluating an individual's ability to complete analogies which involve meaningful pictures or abstract designs. The subtest provides a measure of Horn and Cattell's (1966) "fluid intelligence," or the ability to adapt and be flexible when encountering novel problem-solving situations. All items require the subject to discern, by reasoning, a relationship among pictured items and to select, from a multiple choice array, which item best completes each of several analogy types. For subjects participating in the present study, the easiest items were characterized by meaningful stimuli and subjects were asked to select which of six pictures best completed a 2 X 2 visual analogy. For example, a hat goes with a head just as a shoe goes with a *foot*. As the subtest progresses, abstract stimuli replace meaningful stimuli and subjects are required to solve 2 X 2 or 3 X 3 matrices or to select which of the choices completes a pattern of dots. It is these later items which require nonverbal reasoning and flexible problem-solving. Administration time for the entire test ranges between 15 and 30 minutes.

The test provides separate age-based standard scores with a mean of 100 and a standard deviation of 15 for each of Vocabulary and Matrices. In addition, an overall standard score, called the

"K-BIT IQ Composite", is considered an estimate of overall intelligence. The IQ Composite obtained using the K-BIT bears a conceptual relationship to the global scores provided by other major intelligence tests for children and adults. The Vocabulary/Matrices dichotomy of the K-BIT closely resembles the Verbal/Performance dichotomy which characterizes the Wechsler Series. Individuals who score at an extreme level on the K-BIT would be expected to perform in like manner on the Wechsler tests. Similarly, those who show significant differences between the Verbal and Matrices subtests would be expected to exhibit similar discrepancies on the more comprehensive measures of intelligence.

Wide Range Achievement Test-Revised. Academic achievement was assessed using the Wide Range Achievement Test-Revised (Jastak and Wilkinson, 1984). This test provides a measure of achievement in three areas of basic academic skill: reading (single word recognition and pronunciation), written spelling to dictation and written arithmetic computation. There are two levels of the test available and level selection is dependent on age. Level one is for children aged 5 through 11 years and level two, for individuals 12 years or older. The test provides age-based standard scores with a mean of 100 and a standard deviation of 15, grade norms and percentiles.

Reading. The Reading test of the WRAT-R is comprised of two sections: a pre-reading and formal reading section. The pre-reading section is for children aged 7 years and younger and assesses a child's ability to name 13 single letters, to recognize 10 single letters by matching, and to identify two letters in their name. As

the minimum age of subjects in the current study was 7 years, the pre-reading portion of the test was administered only when a subject failed to achieve a basal of six consecutive correct responses. On the formal reading portion of the test, subjects were required to read single words aloud with a time limit of ten seconds per word. When a subject came to a word which he or she perceived as difficult, they were encouraged to make their best attempt at reading the word. As this subtest is not a measure of speech or dictation, unusual pronunciations due to colloquialisms, foreign accents, and defective articulation were credited as long as the peculiarity was consistent throughout. The test was discontinued when the subject made ten consecutive errors or when they read all 75 words.

Spelling. The spelling test of the WRAT-R is comprised of two sections: a symbol copying pre-test and a formal spelling test. Again, the pretest was administered only to those subjects who did not obtain a basal of six consecutive correct responses on the formal spelling test. On the spelling test, subjects were instructed that the examiner would first read a target word, then a sentence with the target word in it, and then the target word again. Subjects were directed to write their response on the line corresponding to the numbered item. The test was discontinued when a subject made 10 consecutive errors or completed all items.

Arithmetic: On the arithmetic portion of the WRAT-R, subjects were allotted 10 minutes to complete a written math test. For subjects younger than 8 years of age, a pretest was

administered if three consecutive correct responses were not obtained on the formal written test.

Appendix C

Stimulus words by category membership.

<u>CATEGORY</u>	<u>TARGET EXEMPLARS</u>
ANIMALS	GIRAFFE, SNAKE, DUCK, HAWK, DEER, SEAL
PARTS OF A HOUSE	CHIMNEY, STAIRS, ROOF, WALL, FLOOR
PARTS OF NATURE	FLOWER, TREE, STAR, BUSH, MOUNTAIN
THINGS TO RIDE ON/IN	SLED, PLANE, WAGON, SHIP, BIKE
THINGS TO WEAR	RING, SCARF VEST, BELT, MITTEN, SLIPPERS
THINGS TO EAT	HAM, CORN, LOLLIPOP, BREAD, PEACH

Appendix D

Multiple-Choice Stimuli

<u>Stimulus</u>	<u>Correctly-paired Choice</u>	<u>Semantic Foil</u>	<u>Phonemic Foil</u>	<u>Other-paired Foil</u>
BREAD	WAGON	CART	WORD	SLIPPERS
PLANE	DUCK	PIG	DUMP	ROOF
CORN	HAWK	EAGLE	WALK	CHIMNEY
LOLLIPOP	STAIRS	WINDOW	HAIR	DUCK
SLED	GIRAFFE	HORSE	LAUGH	STAIRS
SNAKE	HAM	PIZZA	CAN	DEER
RING	CHIMNEY	TABLE	CHAMP	HAWK
FLOWER	ROOF	DOOR	ROOT	BELT
SEAL	MITTEN	SHIRT	MILL	TREE
WALL	TREE	PLANT	TRAIN	PEACH
VEST	BIKE	TRUCK	PIKE	MITTEN
BUSH	SLIPPERS	SHOES	SCISSORS	STAR
FLOOR	PEACH	PEAR	PEEL	HAM
MOUNTAIN	BELT	SOCKS	BELL	BIKE
SHIP	STAR	BEACH	STORM	GIRAFFE
SCARF	DEER	DOG	FEAR	WAGON

Appendix E

1. Example of encoding trial configuration

<p style="text-align: center;">SNAKE-HAM</p> <p style="text-align: center;">How many of these words can bite?</p>

2. Example of cued word-stem completion trial configuration

<p style="text-align: center;">RESPOND WITH THE FIRST WORD THAT COMES TO MIND</p> <p style="text-align: center;">BLACK - ST_____</p>
--

3. Example of recognition trial configuration

<p style="text-align: center;">What word went with: PLANE</p> <p style="text-align: center;">CORRECT CHOICE SEMANTIC FOIL PHONEMIC FOIL OTHER-PAIR FOIL</p>

Appendix F

List of word-pairs with questions and correct response
by encoding condition

SEMANTIC ENCODING CONDITION

<u>WORD PAIR</u>	<u>QUESTION</u>	<u>CORRECT RESPONSE</u>
RING-CHIMNEY	How many of these words have wheels?	0
SLED-GIRAFFE	How many of these words can travel on land?	2
SNAKE-HAM	How many of these words can bite?	1
CORN-HAWK	How many of these words can fly?	1
LOLLIPOP-STAIRS	How many of these words can be colored yellow?	2
BREAD-WAGON	How many of these words are usually colored red?	1
FLOWER-ROOF	How many of these words rhyme with the word "TIME"?	0
PLANE-DUCK	How many of these words have wings?	2
WALL-TREE	How many of these words can fly?	0
SHIP-STAR	How many of these words can be found in the sky?	1
SCARF-DEER	How many of these words eat grass?	1
VEST-BIKE	How many of these words can be colored blue?	2
MOUNTAIN-BELT	How many of these words can be used for carrying water?	0
SEAL-MITTEN	How many of these words live in water?	1
BUSH-SLIPPERS	How many of these words need water to survive?	1
FLOOR-PEACH	How many of these words rhyme with the word "PIG" ?	0

NON-SEMANTIC ENCODING CONDITION

<u>WORD PAIR</u>	<u>QUESTION</u>	<u>CORRECT RESPONSE</u>
RING-CHIMNEY	Do these words have the same number of letters?	N
SLED-GIRAFFE	Do these words have the same number of letters?	N
SNAKE-HAM	Do these words have the same number of letters?	N
CORN-HAWK	Do these words have the same number of letters?	Y
LOLLIPOP-STAIRS	Do these words have the same number of letters?	N
BREAD-WAGON	Do these words have the same number of letters?	Y
FLOWER-ROOF	Do these words have the same number of letters?	N
PLANE-DUCK	Do these words have the same number of letters?	N
WALL-TREE	Do these words have the same number of letters?	Y
SHIP-STAR	Do these words have the same number of letters?	Y
SCARF-DEER	Do these words have the same number of letters?	N
VEST-BIKE	Do these words have the same number of letters?	Y
MOUNTAIN-BELT	Do these words have the same number of letters?	N
SEAL-MITTEN	Do these words have the same number of letters?	N
BUSH-SLIPPERS	Do these words have the same number of letters?	N
FLOOR-PEACH	Do these words have the same number of letters?	Y

Appendix G

Cued stem-completion stimuli: stimulus and novel words with
accompanying fragments

STIMULUS WORDS AND STEMS

SEAL - MI _____
 BREAD - WA _____
 SCARF - DE _____
 WALL - TR _____
 CORN - HA _____
 VEST - BI _____
 BUSH - SL _____
 LOLLIPOP - ST _____
 SLED - GI _____
 SNAKE - HA _____
 RING - CH _____
 FLOOR - PE _____
 FLOWER - RO _____
 MOUNTAIN - BE _____
 SHIP - ST _____
 PLANE - DU _____

NOVEL WORDS AND STEMS

PAPER - PE _____
 BLACK - ST _____
 HAIR - BI _____
 FILM - GI _____
 BASEBALL - MI _____
 BLUE - SL _____
 KITE - ST _____
 PICTURE - RO _____
 TELEVISION - DE _____
 NICKEL - BE _____
 NOSE - CH _____
 PENCIL - HA _____
 FORK - DU _____
 LAWNMOWER - TR _____
 COMB - HA _____
 LEASH - WA _____
 CLOCK - SL _____
 CAR - TR _____
 GUN - BE _____
 DOOR - HA _____
 BENCH - WA _____
 MOON - RO _____
 TEETH - CH _____
 CIRCLE - PE _____

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