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The Effects of Encoding and Retrieval Strategies on Retention of Words in Subjects with Multiple Sclerosis

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THE EFFECTS OF ENCODING AND RETRIEVAL STRATEGIES ON RETENTION OF WORDS IN SUBJECTS WITH MULTIPLE SCLEROSIS

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CHAPTER I

INTRODUCTION

Multiple Sclerosis (MS) is one of the most common disorders of the central nervous system (CNS). It is so common in fact that it has been called "the great crippler of young adults" (Scheinberg, 1987, p. 2). MS is associated most often with symptoms of motor and sensory dysfunction which cause disturbances in ambulation, urination, vision, and the sense of touch. The disease varies considerably in course and severity, leaving its victims with little ability to foresee its long-term effects. The outcome of MS can be mild and include essentially no lifestyle changes. On the other hand, the outcome can include loss of employment, loss of the ability to care for oneself, or in some cases, death. Since the disease often strikes during the productive years of young or middle aged adults, its impact often extends beyond the victim to include her or his family (Matthews, Compston, Allen, & Martyn, 1991; Scheinberg, 1987).

For years the crippling nature of the physical disabilities identified with MS has overshadowed the alterations in mentation that often accompany it. This is somewhat ironic given that, in 1877, Charcot, in one of the first papers on MS, noted "marked enfeeblement of memory; conceptions are formed slowly; the intellectual and emotional faculties are blunted in their totality" (cited in Mahler & Benson, 1990, p. 88). Yet the notion that MS was a disease that predominantly affected motor and sensory functions persisted for nearly a century (Peyser & Poser, 1986). More recently, a growing body of evidence has accumulated that suggests that cognitive deficits are quite common in MS patients (Peyser & Poser, 1986; Rao, 1986). Evidence from neuropsychological studies have found deficits in memory, attention and concentration, information processing speed, conceptual reasoning skills, and visual-spatial skills. Similar to the problems associated with the physical deficits described above, these cognitive deficits are reported to have a profound impact on the victims' lives.

Of the cognitive deficits noted above, memory dysfunction is the most common among MS patients (Grafman, Rao, & Litvan, 1990). Researchers have found 40-60% of MS patients perform below normals on measures of memory (Beatty, Goodkin, Monson, Beatty, & Hertsgaard, 1988; Fischer, 1988; Rao, Hammeke, McQuillen, Khatri, & Lloyd, 1984). Rather than showing a global decline in memory functions, MS patients show deficits in some aspects of memory, whereas other aspects are spared. This irregular pattern of deficits provides some support for the notion that specific components in the memory system of MS patients may be deficient.

In order to understand more fully the point of breakdown in the memory system among MS patients, some researchers have attempted to relate various memory models taken from the cognitive science literature to patients with MS. Using frameworks such as semantic memory (Beatty & Monson, 1990; Beatty, Monson, Goodkin, & Kaplan, 1989; Rao et al., 1992), implicit memory (Rao et al., 1992) and working memory (Litvan, Grafman, Vendrell, Martinez, et al., 1988; Rao et al., 1992), particular patterns of deficit in memory have been found among MS patients. These patterns have added to our understanding of memory in MS. Another model which may shed light on the memory system in MS is the transfer-appropriate processing framework (Morris, Bransford, & Franks, 1977). Briefly, the transfer-appropriate framework suggests that how information is introduced or encoded into the memory system is related to its retrieval. Thus, the transfer from encoding to retrieval is best if the tasks for each is similar in nature. For example, if the information that enters the system is primarily semantic in nature, retention is best if the retrieval task is semantic in nature. Similarly, if phonemic (phonetic) information enters the system, retention is best if the retrieval task is phonemic. This phenomenon has been supported in the literature with a normal subject groups on the semantic-phonemic dimension as well as other dimensions (Blaxton, 1989; Fisher & Craik, 1977; Glover, Rankin, Langner, Todero,

& Dinnel, 1985; Graf & Ryan, 1990; Moeser, 1983; Morris et al., 1977). To date, no study with MS patients has systematically varied encoding strategy by retrieval strategy to test the TAP model. Such data could help elucidate further the memory system of MS patients.

The study described below was designed to address the following research questions:

1. How does semantic encoding compare to phonemic encoding on a word retention task in MS patients?

2. How does semantically-cued retrieval compare to phonemically-cued retrieval on a word retention task in MS patients? How do these two retrieval strategies compare to passive free recall?

3. Is there an interaction effect between encoding and retrieval strategy in MS patients, indicating transfer-appropriate processing?

4. How does the pattern of word retention across various encoding and retrieval strategies for MS patients compare to that for normal controls?

CHAPTER II

LITERATURE REVIEW

The review of the literature is organized into sections on MS, memory, and memory deficits in MS. Some background related to MS is given first, followed by a discussion of its neuropathology. Then, the neuropsychological findings related to MS are summarized. The aspects of memory relevant to this study are then summarized. Overall, memory is conceptualized from an information processing perspective. Finally, the literature on memory deficits among MS patients is examined. A general discussion of the types of deficits observed is followed by specific theoretical models which have been applied to patients with MS.

Multiple Sclerosis

Background and neurology of MS. MS is a progressive disease of the CNS, with a prevalence of approximately 50-60 persons per 100,000 (Adams & Victor, 1989; Baum & Rothschild, 1981). The onset of MS is typically between the ages of 15 and 50, with the average age being 29-30. The disease affects women more often than men by a ratio of 1:1.5 to 1:2 (Sibley, Bramford, & Clark, 1984). Typically, the initial symptoms include a tingling sensation or numbness in the hands, feet, or face, weakness in the legs, diplopia, loss of vision, and vertigo (Ebers, 1986; Matthews et al., 1991). The course of the disease varies greatly among individuals. Approximately 80% of patients with MS experience periods of attack and improvement, in which an exacerbation of the symptoms occurs followed by a period of remission. In this relapse-remitting course, symptoms generally do not fully remit, but rather worsen with each successive attack. About 10% of patients experience a chronic progressive course in which the symptoms progress slowly without remission. The remaining 10% of patients experience a remission of the disease but have very few or no subsequent exacerbations and appear to sustain no lasting impairments (Silberberg, 1977).

Neurologically, MS is a disease that primarily affects the white matter in the CNS (Matthews et al., 1991). White matter in the CNS of normal adults consists of neurons covered by a fatty substance known as myelin. Sheaths of myelin are produced by oligodendrocytes that produce processes that wrap around axons in order to increase the speed of electrical transmission across the axon. The myelin of MS patients becomes inflamed and destroyed, leaving the neuron spared but functionally ineffective. As foci of demyelination accumulate, they form plaques that range from 1.0 mm to several centimeters in length (Raine, 1990). These lesions are asymmetrical and can affect myelinated axons anywhere in the CNS, regardless of functional or anatomical boundaries, but typically they are found in the paraventricular white matter of the brain, as well as the optic nerve, optic tract, and spinal cord (Adams & Victor, 1989; Ebers, 1986; Matthews et al., 1991).

MS lesions have been classified as chronic or acute (Raine, 1990). Chronic lesions are sharply demarcated in appearance from the surrounding unaffected white matter. Chronic lesions may be inactive or active. Chronic inactive lesions, sometimes known as silent, are grey and glassy in appearance and have little inflammatory activity. Active chronic lesions are often pink and soft, and have less distinct margins than inactive lesions. Acute lesions, on the other hand, are more rare and usually associated with chronic progressive MS. They are pink in color, have indistinct margins, and are associated with severe inflammatory activity. While the cause of these lesions is unknown, it is thought that an interaction between a childhood viral infection and a host immune response is responsible (Matthews et al., 1991).

There is no specific diagnostic test for MS (Sibley, 1990). The diagnosis is usually achieved through the exclusion of other possible diseases. A combination of clinical, laboratory, and radiologic findings are used to provide evidence for a diagnosis. History of the disease course for the individual, along with a neurological exam are obtained. Additional diagnostic information can be obtained through analysis of cerebrospinal fluid (Haughton, Ho, Williams, & Eldevik, 1979).

A variety of brain imaging techniques have been used to visualize pathological changes of the brains of MS patients. Among these techniques, computerized tomography (CT) and magnetic resonance imaging (MRI) have been used most extensively with MS patients (Haughton et al., 1979; Matthews et al., 1991). Unenhanced CT scans have been used to identify low density lesions and ventricular dilation (Willoughby & Paty, 1990). However, they are generally insensitive to small lesions and often underestimate their number. Willoughby and Paty (1990) have estimated that lesions smaller than 0.7 cm are not detected by unenhanced CT. CT enhanced with IV iodine for contrast increases the sensitivity to low density lesions. With this technique 50-80% of patients with clinically active disease were positively identified. CT has been most useful in identifying structural changes in the brain due to the cumulative effects of MS lesions. With the advent of MRI, greater resolution is available for the identification of MS lesions. When CT and MRI scans are compared, MRI identifies virtually all lesions seen on CT, plus additional smaller lesions not found on CT (Willoughby & Paty, 1990). Studies have shown MRI to identify lesions of MS patients 3 to 5 times more than CT. However, CT has been more useful in distinguishing new inflammatory lesions from established lesions. MRI with contrast enhancements identifies even a greater number of lesions than MRI without contrast, with the added benefit of being able to distinguish old and new lesions (Willoughby & Paty, 1990).

Thus, much has been discovered about the neurology of MS since the disease was identified. However, much less has been determined about the effects of the disease on various cognitive functions. Findings from neuropsychological studies, along with correlates with neuroimaging, are reviewed in the next section.

Neuropsychology of MS. When MS was first described in 1877 by Charcot, he reported a number of cognitive deficits in addition to the motor and sensory deficits. However, relatively little attention has been paid to alterations in mentation until the latter part of this century (Peyser & Poser, 1986; Rao, 1986). Recently, researchers have examined various cognitive skills in patients with MS including: intellectual functions, attention and concentration, information processing speed, conceptual reasoning skills, visual-spatial skills, and language functions (Rao, 1986). Each of these cognitive skills will be reviewed briefly.

Both longitudinal and cross-sectional studies have been used to evaluate intellectual skills in MS (Rao, 1986). Intellectual skills are commonly measured using the Wechsler Adult Intelligence Scale-Revised (WAIS-R) that yield a Verbal Intelligence Quotient (VIQ) and a Performance Intelligence

Quotient (PIQ). Some longitudinal studies have found significant decreases in verbal and performance intelligence scores in MS patients when compared to normal controls (Canter, 1951) and brain damaged patients (Ivnik, 1978a). In another longitudinal study, Fink and Houser (1966) found no significant decrease in VIQ scores in a group of recent onset MS patients over a one year interval. However, this group of MS patients may not have been representative since the mean age of onset of the disease was 40 years. Cross-sectional studies have been used to compare intellectual scores of groups of MS patients who differ in duration of illness or degree of disability (Ivnik, 1978b; Marsh, 1980; Rao et al., 1985), though generally no significant differences were found. Studies that have made comparisons among subtest scores generally have found PIQ scores to be significantly lower than VIQ scores (Heaton, Nelson, Thompson, Burks, & Franklin, 1985; Ivnik, 1978a; Ivnik, 1978b; Marsh, 1980), suggesting possible deficits in visuospatial information processing. However, since the PIQ subtests rely heavily on motor and sensory functions, it is unclear whether lower scores on these scales indicate poor visuospatial functioning or poor motor and sensory functioning (Rao, 1986). One subtest, Digit Span, has been found to be consistently lower, indicating decreased attention and concentration. Thus, some degree of intellectual decline does appear to be related to MS.

Several studies have been designed to investigate the conceptual reasoning abilities of MS patients. In general, MS patients exhibited diminished skills in conceptual reasoning relative to normal controls or non-brain-damaged patients (Heaton et al., 1985; Peyser, Edwards, Poser, & Filskov, 1980; Rao et al., 1984). In addition, no differences were identified in conceptual reasoning between MS and mixed brain damaged patients (Goldstein & Shelly, 1974; Ivnik, 1978a; Matthews, Cleeland, & Hopper, 1970). Thus, MS patients appear to be more similar to brain damaged patients than normal controls in conceptual reasoning abilities. Although most studies have reported only summary scores, one study (Rao & Hammeke, 1984) analyzed patterns of errors to determine the underlying nature of disturbance in conceptual reasoning. These authors found MS patients to make errors in concept formation and ability to shift sets. These errors appear to be unrelated to deficits in memory or attention (Rao, 1986).

Language disorders are less frequently reported in the literature (Fennell & Smith, 1990; Rao, 1986). Some studies have found deficiencies in confrontation naming (Beatty et al., 1988; Beatty, Goodkin, Monson, & Beatty, 1989; Jambor, 1969) in MS patients, whereas other studies have shown deficits on measures of verbal fluency (Beatty et al., 1988; Beatty, Goodkin, Beatty, & Monson, 1989; Heaton et al., 1985; Rao, Leo, & St. Aubin-Faubert, 1989). However, these skills are thought to have a strong memory component (Butters, Martone, White, Granholm, & Wolfe, 1986), confounding these findings. As part of an extensive neuropsychological battery, Rao, Leo, Bernardin, and Unverzagt (1991) administered measures of naming and oral comprehension to MS and controls; no significant differences were found on either of these measures. Further research would be required before conclusions could be drawn about the presence of language dysfunction in MS.

Disturbances of visuospatial functioning has been reported in the literature (Fennell & Smith, 1990), however, the measures typically used to assess visuospatial functioning (e.g., PIQ from the WAIS-R) also require sensory and motor skills, planning and executive functions, and psychomotor speed. As mentioned earlier, poorer performance of MS patients on these measures may be due to a variety of skill deficits (Fennell & Smith, 1990; Rao, 1986). To provide a less contaminated measure of visuospatial functions, Rao et al. (1991) administered four tests which do not require motoric responses. MS patients showed significant impairment on three of these tests compared to normal controls. Also, there was no correlation between these measures and a measure of visual acuity. These results provide stronger evidence for the presence of visuospatial dysfunction in MS.

A number of recent studies have found disturbances in information processing speed in MS. Beatty and his colleges (Beatty et al., 1988; Beatty, Goodkin, Monson, et al., 1989) compared MS patients to normals on a task in which subjects were presented with a key containing geometric symbols paired with numbers 1 through 9 with several rows of the symbols below. Subjects were asked to substitute as rapidly as possible the symbols with the number with which they were paired. Subjects were asked to make the substitutions orally to reduce the effects of motoric disability in MS patients. These studies found that MS patients made fewer correct responses indicating slower information processing. Several studies (Litvan, Grafman, Vendrell, & Martinez 1988; Rao et al. 1991) have found MS patients to be impaired relative to normals on the Paced Auditory Serial Learning Task (Gronwall, 1977). In this task subjects were auditorially presented with a series of single digit numbers and, with each additional number, asked to add the last two numbers presented. Another index of information processing speed is the Sternberg memory scanning task (Sternberg, 1969). In this task, subjects are asked to memorize a set of 1, 2 or 4 digits. Then they are shown a series of additional digits one at a time, and asked to press one of two keys indicating whether the digit shown was one of the digits memorized. Reaction time and accuracy are recorded. The mean reaction time is plotted for each set (1, 2, and 4), and the slope of the resulting line indicates rate of mental scanning independent of motoric response. MS subjects have been found to have significantly slowed rate of mental scanning compared to normals (Rao et al., 1991; Rao, St. Aubin-Faubert, & Leo, 1989). These studies that indicate slowed information processing speed is a rather widespread phenomenon in MS.

A number of emotional or affective changes have been noted with MS patients. One common personality change often identified is depression (Trimble & Grant, 1982), which is thought to be a reaction to the functional limitations of the disease rather than a symptom of it (Devins & Seland, 1987). However, there is recent evidence that cerebral changes identified through brain imaging is correlated to affective states (Schiffer, 1990), calling to question the purely reactive nature of depression in MS. In addition to depression, blunted affect, lability, apathy, and euphoria have also been observed (Trimble & Grant, 1982). Two studies have investigated the relationship of affective changes to cognitive impairment using cluster analysis (Peyser, Edwards, & Poser, 1980; Rao et al., 1984). These studies found that patients with little or no cognitive dysfunction were more likely to respond in a typically neurotic style, whereas those patients with relatively greater cognitive impairment responded in a unusual or bizarre style. It appears that while no distinctive personality pattern has emerged consistently in the literature (Peyser & Poser, 1986), those

MS patients with a greater degree of cognitive dysfunction appear to develop a different pattern than those with no cognitive impairment.

The most common cognitive impairment in MS has been that of memory impairment (Grafman et al., 1990). Memory deficits have been reported in numerous studies (Beatty et al., 1988; Beatty, Goodkin, Beatty, et al., 1989; Carroll, Gates, & Roldan, 1984; Fischer, 1988; Grafman, Rao, Bernardin, & Leo, 1991; Grant, McDonald, Trimble, Smith, & Reed, 1984; Litvan, Grafman, Vendrell, Martinez, et al., 1988; Minden, Moes, Orav, Kaplan, & Reich, 1990; Rao et al., 1984; Rao, Leo, St. Aubin-Faubert, 1989). Since memory functioning in MS is central to the thesis of this paper, the literature related to memory deficits in MS will be reviewed separately after a discussion of memory in general.

A number of studies have attempted to correlate neuroimaging findings with neuropsychological deficits. While CT has been less successful in identifying areas of demyelination, it is useful in evaluating structural changes in the brain, which can indicate the degree of cerebral atrophy. Two common measures of structural changes are ventricular size and ventricular-brain ratio (VBR), which is the ratio of width of the lateral ventricles to width of the brain. Several studies (Brooks et al., 1984; Rabins et al., 1986; Rao et al., 1985) have compared measures of cerebral atrophy on CT with measures of cognitive deficits. These have generally found that greater ventricular size is related to cognitive impairment, however this relationship is small, probably due to the inadequacies of ventricular size as a measure of cerebral damage from MS (Rao, 1990).

Two studies have found weak correlations between MRI findings and cognitive dysfunction (Franklin, Heaton, Nelson, Filley, & Seibert, 1988; Huber et al., 1987). However these studies have been criticized for using subjective ratings of neurological impairment based on MRI scans (Rao, 1990). In a study by Rao, Leo, Haughton, St. Aubin-Faubert, and Bernardin (1989), lesions on MRI scans were traced and totaled, yielding a total lesion area (TLA) score. Also measured were the size of the corpus callosum (SCC) and VBR. MS patients were given a five hour battery of neuropsychological tests, and a step-wise multiple regression analysis was performed. Eighteen of the 34 cognitive variables correlated significantly with TLA. TLA was related to a wide variety of cognitive functions, but most consistently predicted memory function. Eight cognitive variables correlated with SCC, most notably those that involved sustained attentional deficits. No cognitive variable correlated significantly with VBR alone. Thus, the more direct measures of lesion involvement obtained by MRI appear to be superior to the gross measures of cerebral atrophy obtained by CT (Rao, 1990).

Thus, various neuropsychological deficits have been associated with patients with MS. The pattern of cognitive deficits does not appear to resemble a uniform, global dementia. Rather, skills such as memory retrieval, conceptual reasoning, and visuospatial abilities appear to be more affected than skills such as verbal intellectual and language functions (Rao, 1986). Recently, Rao (1986) and Mahler and Benson (1990) compared the pattern of neuropsychological deficits found in MS to other diseases which affect primarily the subcortical structures of the brain (e.g., Parkinson's disease and Huntington's disease). These subcortical dementias have similar features and are distinguishable from cortical dementias such as Alzheimer's disease. In subcortical dementias language functions are relatively spared. However, conceptual reasoning is diminished, memory decline is aided by cues, information processing speed is slowed, speech is dysarthric, and muscle tone and gait are commonly abnormal. Cortical dementias, on the other hand, are marked by severe language disturbances, memory decline which is not aided by cues, and acalculia (Cummings, 1986). Use of the concept of subcortical dementia may aid in the understanding of MS.

In summary, numerous neurological and neuropsychological deficits appear to be common among MS patients. The pattern of neuropsychological deficits in MS is similar to other diseases affecting the subcortical structures of the brain, and appear to comprise a subcortical dementia. One consistent finding in this pattern of deficits is a decline in memory abilities. This decline can perhaps be understood best when viewed within the context of an information processing approach to memory. This approach is reviewed in the next section, along with specific models which may be helpful in explaining the memory deficits in MS.

Memory

Historical background. The scientific study of memory began in the late nineteenth century with Ebbinghaus when he applied the experimental methods of Fechner to learning and forgetting (Gregg, 1986). Ebbinghaus established a good deal of control over the conditions of learning by using himself as a subject, testing at the same time each day, using nonsense syllables with which he had no prior history, and presenting these syllables at a constant rate. He was sharply criticized for creating such an artificial laboratory environment and it was commonly believed that his findings had little relevance to understanding everyday human memory (Baddeley, 1976; Gregg, 1986).

A more recent approach to memory has been based on the principles of information processing, a term borrowed from computer science (Klatzky, 1980), and comparisons are often made between human and computer information processing. In this approach information enters the system, proceeds through various stages as it is processed, and when called upon may exit the system. The process of entering the system is called encoding (Gregg, 1986). A stimulus may be encoded in a variety of ways. As an example, consider the presentation of the word, "car." This may be encoded in terms of the visual qualities of the letters, the acoustic qualities of the word as a whole, or in terms of its semantic meaning. In experimental studies, there have been various encoding paradigms employed to bring about a specific type of encoding (Cermak, 1972). To induce encoding of visual information, subjects may be asked to attend to specific letters in a word or whether the word is in uppercase or lowercase letters. For acoustic encoding (sometimes called phonemic encoding), subjects may be asked to make judgments about the word's phonetic sound. Similarly, to induce semantic encoding, subjects may be asked about a word's meaning. Items presented in the encoding phase are often called target items (Cermak, 1972; Klatzky, 1980).

Once the information is encoded, it must be stored in some way so that it can be used in the future. Most models of memory incorporate a number of storage structures, with information flowing from one to another (Baddeley, 1976; Gregg, 1986). These multi-store models are described below. In order for the stored information to be useful, it must be retrieved from the system. For retrieval to occur, the information must be both available and accessible (Tulving, 1974). The availability of information to be retrieved depends upon its successful storage. Accessibility, on the other hand, depends upon the ability of the system to make use of stored information. Two retrieval paradigms have been used to distinguish between errors of availability and accessibility (Gregg, 1986). The free recall paradigm is one in which a subject is asked to recall in any order as many items from the encoding phase as possible. The items generated would be available and accessible to the subject. The recognition paradigm differs in that the subject is asked to choose the target items from a list containing both target and bogus items. Target items chosen correctly would be those that were available, but not necessarily freely accessible. Target items that were not chosen are assumed not to be accessible. Therefore, words that are recalled on the recognition task but not the free recall task have been stored, but are not accessible. Words not retrieved on either task have not been stored. Using these two tasks in combination can allow a comparison of storage and retrieval (Gregg, 1986).

In the second half of the twentieth century, a comprehensive model of memory began to appear based on information processing theory (Baddeley, 1976; Gregg, 1986). This model consisted basically of three storage structures in which information is organized and processed. The first structure is the sensory register, where stimuli from each of the senses enters the system and is held for a brief time before it decays. Some of the information in the sensory store is passed on to the next storage system, short-term or primary memory. In this system, patterns are recognized and meaning is given to the sensory information. Information is held in primary memory through the process of rehearsal, which is the continuous repetition of material to prevent decay (Gregg, 1986). Information can be held in primary memory for longer periods than the sensory store, however if rehearsal ceases, it is lost from the system. Primary memory is limited in its capacity to hold material, so that if new material enters some older material may be lost. In order for information to be stored on a more permanent basis, it must pass from primary memory to long-term or secondary memory (Gregg, 1986). Once material is consolidated in secondary memory, rehearsal is no longer necessary to prevent forgetting. Secondary memory is considered an unlimited memory store. Much of the work on memory from the information processing perspective has focused on the primary and secondary memory stores, and many theorists have developed similar models (Atkinson & Shiffrin, 1968; Broadbent, 1958; Wippich, Mecklenbrauker, & Halfter, 1989). In fact, a book by Norman (1970) included 13 variations of this model that emphasized primary and secondary memory as resulting from two distinct stores. Due to its predominance in the field, this model has become known as the "modal model" (Murdock, 1971).

The popularity of the modal model arose partly out of its ability to explain a number of phenomena which previously eluded scientists. One such phenomenon is the primacy-recency effect (Murdock, 1962). If subjects are given a list of 20 words and asked to recall these words immediately following their presentation, not all words in the list are recalled at the same rate. If the percentage of words recalled is plotted against the serial position of the word in the list, this curve indicates that the words at the beginning of the list (primacy) and end of the list (recency) are more frequently recalled. In terms of the modal model, the words at the beginning of the list have had more rehearsal time and can be consolidated in secondary memory. These words do not need to be sustained by continued rehearsal and are recalled even though additional words have taken their place in primary memory. Thus the primacy effect is the result of words in secondary memory. The recency effect, on the other hand, is the result of words retained in primary memory. These words are being rehearsed as the trial ends and are generally reported as soon as the recall test begins. Words in the middle of the list are not recalled as well because they do not have time to be stored in secondary memory and have been forced out of primary memory by the last words in the list. Thus, the modal model provides a cogent explanation for the primacy-recency effect (Gregg, 1986).

A distinction for primary and secondary memory was suggested also by errors made by subjects during free recall (Baddeley & Dale, 1966). On tasks of primary memory with words, where the retrieval test is given immediately after the encoding task, subjects' errors are likely to be phonetically similar to the target word (e.g., "deck" for "desk"). In contrast, on tasks of secondary memory, where the retrieval task may be an hour later, subjects' errors are likely to be semantically similar to the target word (e.g., "chair" for "desk"). This suggested that encoding is essentially phonetic in primary memory, whereas encoding is essentially semantic in secondary memory, again distinguishing the two memory stores (Baddeley & Dale, 1966).

An additional set of data that suggested two separate memory stores came from work by Milner (1972). She found that patients with bi-hippocampal lesions showed a dramatic impairment in long-term storage of information since the lesions were acquired. These patients were notable for a normal ability to retain information immediately after it was presented and to retain this information for as long as they could rehearse it. Once rehearsal ceased, however, the information was permanently lost. In these patients, primary memory appears to be intact with the disruption of incorporation of information into secondary memory, suggesting the presence of two memory stores.

Overall, the modal model explained a good deal of data and was the widely accepted view in psychology (Baddeley, 1976). Over the years, new evidence has accumulated that calls into question some of the basic tenants of the model. Baddeley (1986), for example, has criticized the concept of primary memory as oversimplified, while still retaining the notion of memory stores. Another criticism has been leveled at the structural nature of memory stores and lack of emphasis on the functional processing that takes place (Craik & Lockhart, 1972). Two alternatives to the modal model which emphasize memory processes, the levels of processing model and the transfer-appropriate processing model are presented in the next section.

Levels of processing model. In 1972, Craik and Lockhart suggested a reinterpretation of the evidence used to support the modal model. Their objections lay primarily in the concept of a structural system, relying on memory stores or hold mechanisms to explain the retention of information. In a critique of the memory store model, Craik and Lockhart (1972) suggested that the evidence for a distinction between primary and secondary memory did not appear adequate on several grounds. One of the ways in which primary memory was traditionally distinguished from secondary memory was in terms of capacity. As in the previous section, primary memory was presumed to have a limited capacity, whereas secondary memory has an unlimited capacity. Studies designed to test the limits of primary memory capacity have been equivocal, ranging from as few as two units (Baddeley, 1970) to as many as 20 (Craik & Masani, 1969). An attempt to account for this theoretically has been to define capacity in terms of chunks, with a chunk containing a variable number of items. However, this notion of chunks is limited in that it is difficult to define independently of the memory task (Craik & Lockhart, 1972).

Another basis for the distinction between primary memory and secondary memory was in terms of the qualities of the encoded stimuli. A common distinction was that information stored in primary memory was acoustic and information stored in secondary memory was primarily semantic (Baddeley, 1966; Conrad, 1964). However, subsequent studies have not held this distinction: coding in primary memory can be articulatory (Levy, 1971), visual (Kroll, Parks, Parkinson, Beiber, & Johnson, 1970), or possibly even semantic (Shulman, 1970). Thus, it is difficult to distinguish between primary memory and secondary memory in terms of type of information encoded. A final criticism of the memory store was on the forgetting characteristics of the various stores. The durability of the memory trace from the sensory store has been equivocal, ranging from one second (Neisser, 1967) to as many as 25 seconds. (Kroll et al., 1970). Further, Craik and Lockhart (1972) stated that the forgetting characteristics of primary memory vary according to the paradigm used.

Thus, Craik and Lockhart (1972) found that the predominantly structural nature of the multi-store model was not sufficient to explain much of the existing evidence. As an alternative, they suggested a process-oriented model emphasizing the depth at which information is coded. Specifically, they advocated a series of hierarchical stages of processing in which information is first processed at a shallow level, incorporating the "physical or sensory features" (Craik & Lockhart, 1972, p. 675). In successive or deeper stages, information is processed in terms of its pattern recognition and finally, in terms of its semantic meaning. Instead of limited-capacity memory stores, they suggested a limited-capacity central processor that is independent of processing depth. Thus, primary memory was explained as information recirculating at one level of processing, without advancing to deeper levels. This so-called Type I processing does not lead to improved memory performance, and "when attention is diverted, information is lost at a rate that depends essentially on the level of analysis" (Craik & Lockhart, 1972, p. 677). Type II processing is described as processing at progressively deeper levels, which leads to more durable memory. Thus, retention is greater at deeper levels of processing. Other factors, such as processing time and amount of attention contribute to retention indirectly by the depth of processing.

In the levels-of-processing paradigm, the primary-secondary memory distinction is thought of as a difference in depth of processing. Variables that inhibit long-term retention do so by inhibiting deeper levels of processing. For example, increasing processing rate reduces the central processor's ability to process deeply. Also, unfamiliar words would require greater processing to achieve a semantic level. To explain the serial position effect, Craik and Lockhart (1972) suggested that the initial items, generally thought to be held in secondary memory, are processed semantically, whereas the final items, held in primary memory are processed phonemically. Thus the memory trace for initial items would be superior to that of the subsequent items, with the final items having the least durable memory trace. This is precisely what has been found to occur (Craik, 1970).

Craik and Lockhart (1972) drew further support for their model from the studies that showed little or no effects of rehearsal in certain tasks. When subjects were asked merely to repeat items (Glasner & Meinzer, 1967) or to repeat items without intending to learn them, (Tulving, 1966) the act of repetition did not facilitate learning.

Thus, the levels of processing model arose out of a dissatisfaction with the emphasis on qualities or properties of memory stores rather than on encoding operations themselves. Craik and Tulving (1975) carried out ten experiments designed to test the general tenant of the levels of processing theory that words that were processed more deeply would yield greater retention than words processed at a shallow level. Their design, now firmly established as a prototype, comprised an incidental learning task in which subjects were asked to answer an orienting question about a word that was subsequently presented in a tachistoscope for 200 msec. The question required a "yes" or "no" response and was designed to engage the subject in a specific level of processing. There were three levels of processing tested: structural, phonemic, and semantic, progressing from shallow to deep processing. Structural orienting questions consisted of asking if the word was printed in capital letters, whereas phonemic questions asked if another word rhymed with the target word. Semantic orienting questions took two forms. One form asked if the target word would fit into a category (e.g., "Is it a type of fish") and the other asked if the target word would fit into a sentence (e.g., "He met a ____ on the street"). Subjects responded to the questions by pressing one of two buttons, indicating "yes" or "no". After the presentation of all the items, subjects were given a retention test for the words. Prior to the retention task, no mention was made that the words were to be remembered. This type of task is called a incidental learning task and is often used to prevent subjects from using their own strategies for encoding the words. It is distinguished from an intentional learning task in which the subject is aware that a retention test would follow (Gregg, 1986).

As predicted, these experiments (Craik & Tulving, 1975) did support the levels of processing framework: words processed at deeper levels were retained better than those processed at shallow levels. It was also found that words that were processed at deeper levels required more time to process. This would be predicted from Craik and Lockhart's (1972) framework, although it left open the question that processing time per se may have been responsible for better retention. However, when the data from this experiment were divided into long and short response latencies, long latencies were not found to be related to better retentions. Moreover, within each latency group the original retention differences were retained among levels.

Further support came from another experiment (Craik & Tulving, 1975), that showed that a complex, time-consuming structural task produced higher levels of recognition than a brief, semantic task. In the complex nonsemantic task, subjects were asked to make a decision about the consonant-vowel pattern of a word. Prior to being shown the target word, subjects were shown a card with a particular consonant-vowel pattern represented by C's and V's (e.g., the word "uncle" would be correctly represented by "VCCCV".) Upon presentation of the word, the subject would decide if the consonant-vowel pattern was correct for that word. The semantic task was the sentence task from previous experiments in the study in which the subjects were shown a sentence with a word removed and asked if the target word would fit into the sentence. The results showed that the proportion of words recognized was greater for the semantic task even though the nonsemantic task took longer to complete. Thus, it was argued that the nature of the orienting task, rather than response time, was the determining factor in memory performance.

A possible alternative explanation for the depth of processing effect was that the orienting questions for each level differed on another dimension. The question in the structural level ("Is the word in capital letters?") remained identical regardless of the word presented. In the phonemic level ("Does the word rhyme with ___?") differed with each word, but only slightly. Orienting questions asked in the semantic level, however, differed dramatically. Could this difference in uniqueness of orienting question, rather than depth on encoding, have been responsible for the disparity in memory performance? Craik and Tulving (1975) varied the number of times each type of question was given: 4, 16, or 40. They found that a decrease in the number of times an orienting question was asked did improve memory performance for phonemic questions and, to a lesser extent for, semantic questions. However, these improvements were relatively small when compared to the large effects of question type. It was concluded that the relatively poor recall of structural encoding could not be explained in terms of uniqueness, but when phonemic questions were distinct, recall increased. Thus, distinctiveness of encoding may have played a part in memory performance, but was not sufficient to account for memory performance entirely.

Throughout the experiments performed by Craik and Tulving (1975), the words requiring a positive or "yes" response were found to be remembered better than words requiring a negative response within processing levels. This finding did not fit with the depth of processing predictions since "it does not seem intuitively reasonable that words associated with 'yes' responses require deeper processing before the decision is made" (p. 281). Therefore, an additional factor was needed to account for this finding. An examination of the semantic condition, in which subjects were asked to judge if the target word fit into a sentence, showed that in the positive condition ("The boy met a ____ on the street. - friend") the target word formed an integrated, congruent unit. On the other hand, in the negative condition ("The boy met a ____ on the street. - cloud") no such integration or congruity occurred for the target word. This integration may also have occurred for the phonemic question with regard to rhyme. Craik and Tulving (1975) suggested that this additional elaboration required descriptive attributes that were salient and unique to the event. The positive condition allowed this elaboration, whereas the negative condition did not.

To test this hypothesis, Craik and Tulving (1975) devised positive and negative conditions that required equivalent degrees of elaboration. Target words for this experiment (Craik & Tulving, 1975) were words that varied on one of eight dimensions (e.g., size, length, temperature, etc.). For each dimension, words were chosen to represent either extreme on that dimension. A reference object was chosen such that half of the words represented objects greater than the reference and half were less than. Subjects were given an orienting question containing the reference object and the direction of comparison to make, then asked to make a "yes" or "no" decision based on the target word (e.g., "taller than a man": child-no). Thus, both negative and positive questions would require similar degrees of elaboration. The results showed that recall was equivalent for "yes" and "no" responses, suggesting that the differences between negative and positive questions in the previous experiments in this study were due to poor elaboration in the negative condition.

A second test of encoding elaboration came from an experiment (Craik & Tulving, 1975) in which the degree of elaboration was varied by presenting differing levels of sentence complexity. For example, the target word "watch" would be used with orienting sentences ranging from "He dropped the ___." to "The old man hobbled across the room and picked up the valuable ___ from the mahogany table." (Craik and Tulving (1975), p. 283). It was argued that the second sentence should encourage a more elaborate encoding of the target word. Target words either fit or did not fit, yielding both positive and negative conditions. As would be predicted, sentence complexity had no effect upon the "no" responses. Since these words did not fit into the sentences, it would not be expected that a more complex sentence would affect elaboration of encoding. On the "yes" responses, however, a systematic increase in recall was observed as sentence complexity increased. Thus, Craik and Tulving's (1975) results from these experiments introduced an additional factor to the original depth of processing view. That is, the degree to which the subject formed an integrated, meaningful pattern would be positively related to memory performance. Further, this pattern was facilitated by elaboration of the encoded stimulus.

Craik and Tulving's (1975) final experiments were designed to test the depth of processing framework outside the laboratory. Subjects were presented the three types of questions (structural, phonemic, and semantic) as a group in a classroom. Target words were presented at a rate of every 6 seconds. The subjects were told initially that they would be shown words that they would be asked to remember, making this an intentional learning condition. The results were similar to the previous experiments: the deeper processing conditions yielded better memory performance. These results were found even when subjects were paid more to remember the words in the structural or phonemic conditions.

As a result of their experiments, Craik and Tulving (1975) modified the original and somewhat simplistic view of levels of processing. The original view (Craik & Lockhart, 1972) held that analysis was carried out in a continuum of hierarchical stages until the demands of the task were met. This formulation appeared unlikely since the three levels postulated have little to do with one another. An alternative view of "domains" of processing (Craik & Lockhart, 1972; Lockhart, Craik, & Jacoby, 1975) concedes that the analyses performed are distinctive yet retain some of the sequential characteristics of levels. While some processing could be done at lower domains before reaching the semantic domain, a complete analysis is generally not necessary. Only those analyses necessary to proceed to the next domain are completed. The notion that processing time can serve as an independent index of depth must also be discarded, since time-consuming phonemic decisions lead to poorer memory performance than brief semantic decisions.

A number of criticisms of the levels of processing approach have been made since the framework was introduced (Eysenck, 1978; Lockhart, et al., 1975; Nelson, 1977). Some of these criticisms have been leveled at the basic assumptions of the framework, whereas others deal with the framework itself. The notion that repetition at the same level of processing does not facilitate memory is an assumption on which levels of processing is based. Nelson (1977) and Baddeley (1978) have questioned this assumption. Nelson (1977) performed several experiments similar to Craik and Tulving (1975) with the exception that half of the subjects were allowed to process each word once, whereas the other half were allowed a repetition of each word. He found that repetition at the same level (phonemic) did in fact increase recall of words. Another basic assumption of levels of processing is that only semantically encoded information could produce durable memory traces. However, there are a number of studies that have found memory traces of phonemic and orthographic material over one year after encoding (Baddeley, 1978).

The levels of processing model itself has suffered from a number of shortcomings. Almost from its inception, the absence of an independent definition of depth (Baddeley, 1978; Eysenck, 1978) has plagued the model. Without such a measure, "there is the danger of using retention-test performance to provide information about the depth of processing, and then using the putative depth of processing to 'explain' the retention-test performance." (Eysenck, 1978, p. 159). Thus according to Eysenck (1978), the framework becomes a useless theoretical construct, no matter how correct it may be because it cannot be disconfirmed. Another criticism is that the distinction of domains into two or three attributes is overly simplistic, not incorporating the wide variety of known memorial attributes (Eysenck, 1978). Also, this distinction is made intuitively rather than by means of scientific validation.

Despite the criticisms directed at the model, the levels of processing framework has been used in numerous studies to produce a wealth of data (Lockhart & Craik, 1990). A more recent line of research which uses a similar framework has been concerned with transfer-appropriate processing. This research program and the modifications related to the levels of processing model are reviewed in the next section.

Transfer-appropriate processing model. Perhaps one of the most cogent criticisms of the levels of processing framework is the failure to recognize the retrieval situation. According to Eysenck (1978), "the greatest understanding of an intervening variable such as the memory trace is likely to emerge from a simultaneous consideration of input and output operations" (p. 164). Morris et al. (1977) made an attempt to include retrieval variables in the model and remove the vague and circular definition of levels of processing. They claimed that merely attending to the semantic meaning of a word may not necessarily be more "meaningful" than attending to a non-semantic or superficial aspect of a word if the retrieval task is not related to its semantic aspects. For example, attending to word meaning may not produce better recall than attending to the phonetic characteristics of a word if the recall task is set up so that the rhyming characteristics of the target words are paramount. In the Craik and Tulving (1975) experiments, recognition tasks may have had an inherent bias for semantically processing words. In such case, the recognition task would not tap the information learned in the non-semantic encoding conditions.

To test this hypothesis, Morris et al. (1977) used a 2 x 2 x 2 factorial design. Within subjects factors included an encoding task which was either semantic or phonemic and a congruency factor, where the encoding prompt was either congruent or incongruent with the target word. Type of retrieval test was varied between subjects and was either a standard recognition task, where the target words were presented along with foil words, or a rhyming recognition task, where rhymes of target words were presented along with foils (words that did not rhyme with any target word). Thirty-two target words were used, eight in each of the four within subjects factors: Semantic-Yes, Semantic-No, Rhyme-Yes, Rhyme-No. A 2 x 2 x 2 factorial analysis of variance showed main effects for all three factors, indicating superiority of the standard recognition task, the semantic encoding task, and congruency of encoding task. In addition, there was a significant encoding x retrieval interaction effect, with the nature of the interaction varying between the congruent and incongruent conditions. In the congruent conditions, the semantic encoding was superior to rhyming encoding when using the standard retrieval test. However, when using the rhyming retrieval test, the rhyming encoding was superior to the semantic encoding.

This pattern of findings did not hold in the incongruent conditions. The rhyming retrieval task produced lower retention for both the semantic and rhyming encoding tasks. To explain this, Morris et al. (1977) suggest that in the Rhyme-No (incongruent) condition where no rhyme is presented for the target word, subjects may be confused as to which word is the target word. Despite the lack of findings in the incongruent conditions, the results suggested that the nature of both the encoding task and retrieval task needed to be considered in determining strength of retention. This phenomenon has been termed transfer-appropriate processing, acknowledging the importance of matching encoding with retrieval strategy (Morris et al., 1977). An additional experiment (Morris et al., 1977) showed that transfer-appropriate processing held even after a 24 hour period. Encoding and retrieval strategies that were matched in terms of the way in which they were processed produced superior retention than mismatched strategies.

Several conclusions can be drawn from the results of the studies of Morris et al. (1977). First, non-semantic processing is not necessarily inferior to semantic processing, but rather may not be directly related to the retention task. Thus, the notion of "levels" of processing needs to be revised to reflect the relationship between what is learned during acquisition and the testing situation. A transfer-appropriate processing model could explain this relationship better. Semantic processing is not necessarily more meaningful than non-semantic processing; it may merely be more relevant to a certain task. Secondly, despite the superiority of matched versus unmatched processing, semantic encoding and retrieval was superior to rhyming encoding and retrieval. This leaves open the possibility that semantic processing is superior to non-semantic processing. In response to this, Morris et al. (1977) suggested that optimal memory may be a function of past knowledge and skills. Semantic knowledge is more commonly used in the everyday world, and particularly by college students, the most prevalent group of subjects used in these experiments. Perhaps the skills of an expert in speech perception would predispose her or him to superior phonemic processing. From this perspective semantic processing would be beneficial only to the extent that it is used more. Fisher and Craik (1977) conducted a similar set of experiments and found retention was best when encoding strategy was matched to retrieval strategy. Again main effects were also found for encoding and retrieval, indicating the semantic strategies were better than phonemic strategies for both. However, these authors cited this as evidence that semantic processing is inherently better than phonemic processing. They proposed that semantic processing allows more distinctive and discriminable processing than more shallow domains.

Further differentiation between the levels of processing and transfer-appropriate processing frameworks was suggested by Moeser (1983). She commented that explaining retention in terms of levels or domains is suggesting qualitative differences in the type of encoding use at each level. According to this view, a word could be represented as a unit of phonemic features, without any of its semantic characteristics. This representation would be accomplished via phonemic encoding. Similarly, a word could be represented entirely by its semantic characteristics via semantic encoding. These two qualitatively different systems would account for the differences in retention. Moeser (1983) interpreted the transfer-appropriate processing results as evidence for a task-demand explanation, where the content of the memory trace is the variable accounting for retention differences. When encoding and retrieval tasks are most similar, the content of the memory trace is tapped to a greater degree. This explanation "assumes that an encoded event is always represented in a semantic memory code, whether this be information about the referential characteristics of the item or surface-structure characteristics" (Moeser, 1983, p. 317). If asked to attend to the letter case of a word, the encoded information would be the semantic unit, "the word was presented in uppercase type." Similarly, when attending to phonemic properties, the encoded semantic unit would be "the word rhymed with 'bat.'"

Moeser (1983) performed a series of experiments which supported her claim. Similar to previous experiments, three encoding strategies were used: 1) case questions, in which the subject made decisions about the case of the typeface; 2) letter questions, in which the subject made decisions about the presence of a specific letter; and 3) semantic questions, in which subjects made decisions regarding the word meaning. Unlike previous experiments in which all encoding questions were asked preceding the presentation of the target word, in half the instances encoding questions were asked before words and in the other half encoding questions were asked following words. This 3 x 2 factorial design of encoding strategy and encoding order (before or after) was manipulated between subjects such that six groups of subjects each were assigned to one condition. Thus, each group consistently received the same encoding strategy. The levels of processing framework would predict no differences between the question-before and the question-after conditions. The transfer-appropriate processing framework would predict superior performance in the letter-question-after compared to the letter-question-before, with results similar to levels of processing in the remaining conditions. The rationale for the difference in the letter-question conditions is as follows: In the letter-before condition the subject consistently expected to be asked whether a specific letter was contained in the following word. All the subject needed to remember was whether or not the letter was present, not the entire word. In the letter-after condition, the subject is unaware of the specific letter in question until after she or he has seen the word. Thus, the entire word must be remembered in order to answer the encoding question correctly. Since the retrieval task required subjects to recognize the entire word presented, rather than just the specific letter from the encoding task, the letter-after group should perform better then the letter-before group. In fact, the results bore out the transfer-appropriate processing hypothesis.

In a study of similar design, Glover et al. (1985) used sentences as the to-be-remembered material. Three encoding prompts were use: semantic questions, in which content was emphasized; word questions, in which a specific word was emphasized; and case questions, in which letter case was emphasized. Questions were asked before the sentence was presented in half the groups and after the sentence was presented in the other half. Similar to Moeser (1983), the word question conditions were the key factor in differentiating levels of processing from transfer-appropriate processing. Word question-before would be inferior to word question-after in the transfer-appropriate processing framework because subjects need only attend to words if the key word were presented before the sentence, whereas the entire sentence would need to be learned if the subject were unaware of the word to detect until after the sentence was presented.

Of the three experiments conducted on memory for sentences (Glover et al., 1985), two yielded a significant improvement in memory for sentences in the word question-after group over the word question-before group. The third experiment found a non-significant trend in the same direction. This last result brings up an important question in using this design to differentiate transfer-appropriate processing from levels of processing. The levels of processing framework could accommodate, to a degree, an improvement in the conditions in which the encoding prompt is presented after the target memory item because the target item could be processed at a semantic level until the encoding question is presented. This degree of improvement is presumed to be less in the levels of processing framework than the transfer-appropriate processing framework (Glover et al., 1985; Moeser, 1983), but it is not clear how much less or when a set of data provides support for one framework over the other. Thus, it appears a different design would be needed to provide support for either framework.

The literature reviewed to this point has established the relative superiority of semantic processing over non-semantic processing on tasks of free recall and recognition (Craik & Tulving, 1975). Morris et al. (1977) have criticized these measures of memory as biased toward semantically processed material and used a phonemically cued recall to try to eliminate this bias. These studies used retrieval tests which required the subject to conduct an effortful search of their memories. The more recent research on transfer-appropriate processing has come from studies which involved retrieval tests which such a search was not made. The former retrieval tasks is said to tap explicit memory, whereas the latter taps implicit memory (Schacter, 1987). Implicit and explicit memory are defined in the next section, followed by a review of the studies that have used the implicit/explicit memory distinction to investigate transfer-appropriate processing.

Explicit vs. implicit memory. The memory tasks described above have relied upon various recall and recognition tasks during the retrieval phase. Even though some task have not been presented to subjects as a memory task during the encoding phase, all have required subjects to make a conscious effort to retrieve the material to which they were previously exposed. This conscious effort of a subject to search her or his memory is the hallmark of explicit memory (Schacter, 1987). Researchers have noted, however, that performance on some tasks increase after encoding material even though the task does not require the subject to make a conscious or effortful search of memory (Graf & Schacter, 1985; Schacter & Graf, 1986). Tasks such as completing a word fragment, reading a briefly-presented word, or reading a mirror-inverted word are enhanced by previously encoding the word. During these tasks the subjects are not told that they have previously been exposed to the words and are not specifically asked to recall any information. There is no explicit reference to the prior encoding episode. Take, for example, a word fragment completion task. Subjects may be shown a list of several words and asked to perform some task with each word, such as responding to a specific letter or creating a sentence with the word. Then, in the second phase they are shown a fragment of the word with certain letters missing. For example, "L_DD__" could be the word fragment for the target word "LADDER". Word fragments are shown for target words and bogus words that were not in the list. If the subject recalls more words that were in the list than bogus words, then implicit learning has occurred. This facilitation from previously exposed words is called priming (Schacter, 1987).

Jacoby (1983) compared different levels of processing on a standard explicit memory test (recognition) and on a implicit memory test. The implicit memory test required subjects to say words aloud after seeing them for only 35 ms.

If they were able to identify more previously encoded words than nonstudied words, then evidence for implicit memory was found. Three encoding conditions were compared: no-context, context and generate. In the no-context condition, subjects viewed a neutral stimulus before viewing the target word (XXX-cold). Subjects in the context condition viewed an antonym followed by the target word (hot-cold). In the generate condition, subjects viewed an antonym, but were required to generate the target word on their own without ever seeing the target word (hot-???). The three conditions were designed to produce increasing levels of semantic processing. On a recognition test, the familiar relationship of semantic processing with retention was found: generate condition was better than context which was better than no-context. However, on the implicit memory test the reverse was found. Context was superior to generate, with no-context superior to both. Thus, a dissociation between explicit and implicit memory can be found by varying processing strategy. From these results, semantic processing is not always beneficial in memory tasks. Jacoby (1983) proposed that explicit memory relies upon processing of semantic or conceptual material and termed this conceptually driven processing. On the other hand, implicit memory relies upon processing of the physical features and termed this data-driven processing. The terms "conceptually driven" and "data-driven" have come to represent theoretically semantic and phonemic processing, respectively. Other studies have also made this distinction between explicit and implicit memory (Roediger & Blaxton, 1978; Roediger, Weldon, & Challis, 1989).

Blaxton (1989) attempted to dissociate five different memory tasks using encoding procedures that were similar to Jacoby (1983). Encoding conditions were again no-context, context, and generate; however, the context and generate conditions used cues which were semantically similar, rather than antonyms. Three of the five retrieval conditions were intended to tap conceptually driven processing: free recall, semantic cued recall, and general knowledge. The semantic cued recall test provided subjects with semantically similar words. Subjects in the general knowledge condition received questions that had the target words as an answer. For example, "What metal makes up 10% of yellow gold?" was the general knowledge question for "COPPER". Two retrieval tests were intended to tap data-driven processing: graphemic cued recall and word fragment completion. The graphemic cued recall test provided subjects with words that had similar spellings but were semantically dissimilar. The word fragment completing test provided subjects with partial spellings of target words and required them to complete the spellings.

An interesting aspect of this study is that two of the memory tasks (word fragment completion and general knowledge) are implicit memory tasks, whereas the other three (free recall, semantic cued recall, graphemic cued recall) are explicit memory tasks. This allowed for a comparison between the explanatory powers of memory system (implicit versus explicit) and type of processing (conceptually driven versus data-driven). If the implicit-explicit distinction were supported, the implicit tasks should show higher performance in the no-context condition than the generate condition; whereas the reverse should be true for the explicit tasks. Alternatively, if the processing distinction were supported, the data-driven tasks should show higher performance in the no-context condition than the generate condition; whereas the reverse should be true for the conceptually driven tasks. The results supported the processing distinction, showing that retention in the free recall, semantic cued recall and general knowledge tasks was better in generate condition than the no-context condition, whereas the word fragment completion and graphemic cued recall showed the reverse findings.

Thus, the view that implicit memory relies primarily upon data-driven processing, whereas explicit memory relies upon conceptually driven processing has generally been supported in the literature. Further, implicit memory measures reflect the overlap of data-driven processing in encoding and retrieval, whereas explicit memory measures reflect the overlap of conceptually driven processing in encoding and retrieval. This supports the transfer-appropriate processing framework and helps establish it as a useful framework for memory research. This framework allows for the investigation of both encoding and retrieval functions, as well as the interaction of these functions. This type of investigation is potentially useful in exploring memory deficits in MS. The next sections provides a broad review of the research on memory deficits in MS, followed by a more specific review concerning conceptually driven and data-driven strategies.

Memory deficits in MS

Numerous studies have demonstrated a memory impairment in MS patients (Beatty & Monson, 1990; Beatty, Goodkin, Beatty, et al., 1989; Carroll et al., 1984; Litvan, Grafman, Vendrell, Martinez, 1988; Rao et al., 1984; Rao, Leo, St. Aubin-Faubert, 1989). However, certain aspects of memory are more affected than others (Grafman et al., 1990). Studies dealing with primary memory have found that MS patients tend to have a normal digit span (Heaton et al., 1985; Litvan, Grafman, Vendrell, Martinez, 1988; Litvan, Grafman, Vendrell, Martinez, et al., 1988; Rao, Leo, St. Aubin-Faubert, 1989), normal recency effect (Caine, Bamford, Schiffer, & Shoulson, 1986; Rao, Leo, St. Aubin-Faubert, 1989), and a normal rate of forgetting from primary memory (Litvan, Grafman, Vendrell, Martinez, et al., 1988; Rao, Leo, St. Aubin-Faubert, 1989).

Research on secondary memory of MS patients has shown consistent deficits. When asked to remember a story that is several sentences in length, MS patients remember less information on immediate recall and after a 30-minute delay than normals (Caine et al., 1986; Rao et al., 1984; Rao, Leo, St. Aubin-Faubert, 1989). In addition, MS patients have shown deficits in the primacy effect during free recall of a supraspan word list (Caine et al., 1986; Rao, St. Aubin-Faubert, et al., 1989), indicating a deficit in secondary memory. On the other hand, recognition memory may be relatively preserved in MS patients. Studies that have asked subjects to discriminate test items from bogus items on a list containing both have found that MS patients perform normally (Carroll et al., 1984; Rao, St. Aubin-Faubert, et al., 1989) or at least better than free recall (Caine et al., 1986; Rao et al., 1984). Thus, it appears that MS patients have normal or near normal encoding with a deficit in retrieval.

One study has examined the effects of encoding of semantic information. Carroll et al. (1984) showed slides of line-drawn objects to MS and normal controls. Half of the subjects were asked to indicate whether the slide represented an object that could be picked up and carried (conceptually driven), whereas the other half were asked to indicate the presence of a small "x" that had been drawn on the slide (data-driven). The retrieval test was a recognition test in which subjects were shown the previous slides and unfamiliar slides and then asked to indicate whether the slide was previously presented. Conceptually driven stimuli were recognized more frequently than data-driven stimuli for both MS and controls. Also, MS subjects failed to recognize previously presented slides more frequently than normals. However, since there was no significant group by encode interaction, it is difficult to attribute the poorer performance of MS subjects to a failure to encode conceptually driven information. In a second experiment (Carroll et al., 1984), MS and normal subjects were presented words visually and told they would be expected to recognize the words later. They were told to use any strategy they wanted to try to remember the words. The words were chosen such that there were nine groups of five words each fitting into a semantic category and one group of nine words that were unrelated to the other words presented. After the retention task, subjects were asked what strategy they used to remember the stimuli. On the recognition test, normals performed better than MS subjects. Of those who acknowledged using at least one of the semantic categories (a conceptually driven strategy), no differences were found between normals and MS. However, since strategy was determined post hoc, it can not be used as an independent variable in the analyses. These findings replicated previous studies that show memory impairment in MS, but did not allow a comparison of strategies between MS and controls.

Two studies (Beatty, Goodkin, Beatty, et al., 1989; Rao et al., 1992) have examined semantic memory of MS patients using the release from proactive interference (PI) paradigm. In this design, subjects are given several lists of words which all belong to the same semantic category and finally given a list of words from a different category. Normal subjects demonstrate progressively poorer performance on the lists containing semantically similar words due to interference from the previous lists. Upon presentation of the different lists, this interference is released, and performance increases. Failure to show the release from PI would indicate impaired semantic memory (Wickens, 1970). When this design was applied to MS patients, they were found to exhibit a release from PI similar to normal subjects (Beatty, Goodkin, Beatty, et al., 1989; Rao et al., 1992). Beatty, Goodkin, Beatty, et al. (1989) concluded that "the structure of semantic memory and thus the capacity for semantic encoding remains largely intact in MS" (p. 83).

To further examine semantic memory in MS, Beatty and Monson (1990) used a semantic priming paradigm in which subjects were asked to rate the relatedness of word pairs which varied in strength of semantic association. In the test phase, subjects were shown the first word of the word pairs along with distracter words and then asked to say the first word that came to their mind. The subjects were not told that the test phase was related to the presentation of word pairs. Priming was indicated if the second word of the pair was given as a response to the first word of the pair, and was evidence of semantic processing of the word pair. Beatty and Monson (1990) found that MS patients showed the same level of semantic priming as normal controls. Thus, the essential structure of semantic memory in MS appears to be functional, however MS patients may not always make use of this ability (Beatty & Monson, 1990).

Several studies have examined aspects of memory in MS which relate to data-driven processing. These have relied upon the working memory model of Baddeley and Hitch (1974). At the heart of this model is a central executive processing system. This system is regulated by means of our attention and is limited in capacity. To process specific information, the central executive is equipped with two slave systems: the articulatory loop and the visuo-spatial sketch pad. The articulatory loop is specialized for processing language information, whereas the visuo-spatial sketch pad is specialized for visual-spatial information. Since the central executive is not dependent on the slave systems, subjects are capable of holding a substantial amount of information in memory while performing other cognitive tasks (Baddeley, 1988). Much of the experimental support for this model has examined the articulatory loop. In this system, encoding is phonological, based on the subject's vocal or subvocal speech production. Evidence for phonological encoding in the articulatory loop comes in part from studies that have examined the word length effect: differences in recall between long words and short words (Baddeley, 1986). Further evidence that the word length effect reflects the phonological capacity of the articulatory loop comes from studies that show that the effect is abolished during articulatory suppression or prevention of subjects from subvocally rehearsing the words (Baddeley, 1986). Deficits in the operation of the articulatory loop could relate to inadequate processing of phonemic (data-driven) information.

Litvan, Grafman, Vendrell, Martinez, et al. (1988) explored the articulatory loop of MS patients. They compared MS patients to normals on a task designed to show the word length effect. Lists of five words were generated from word pools of either one- or five-syllable words. During presentation of half of the lists for each word length, subjects were required to count out loud from one to eight. This suppression task has been found to eliminate the word length effect in normals and is attributable to the suppression of articulatory encoding (Baddeley, 1966). Lists were presented to subjects auditorially, and subjects wrote their recall responses on a piece of paper. The results showed that MS subjects had significantly poorer recall than normals on five-syllable words during the suppression condition. This suggests an impairment in the articulatory loop of MS patients (Grafman et al., 1990).

Recently, Rao et al. (1992) examined aspects of the articulatory loop in MS patients. In this study words were generated from two lists of 10 words (i.e., one containing monosyllabic words and the other containing five-syllable words). During presentation of half of the lists for each word length, subjects performed an articulatory suppression task (i.e., counting out loud from one to eight). MS patients were found to have impaired recall for long words relative to normals, again suggesting an impairment in the articulatory loop in MS patients. However, in this study the word length effect was eliminated during articulatory suppression to the same degree in MS and normal subjects. This would be expected if the articulatory loop were impaired. Thus, Rao et al. (1992) provided stronger evidence that the articulatory loop of MS patients is impaired.

In summary, little research has directly examined the encoding and retrieval strategies of MS patients. There is some evidence that patients with MS have poorer retention than controls for semantic material, even though their semantic memory system may be intact. Also, studies have shown that phonological processing in MS is inferior to that of controls. However, the designs of these studies have not allowed a comparison of the contributions of encoding and retrieval skills to the deficits seen in MS. Such a comparison could help explain more fully why the deficits occur. The designs used to study transfer-appropriate processing makes the direct comparison of encoding and retrieval skills possible. To date no study has used the transfer-appropriate processing framework to compare the relative contributions of conceptually driven and data-driven strategies for encoding and retrieval in memory of MS patients. The study described in what follows uses this framework in an attempt to understand more fully the memory deficits among individuals with MS.

CHAPTER III

METHOD

Subjects

MS subjects. MS subjects were chosen from a pool of subjects who had previously agreed to participate in an ongoing longitudinal study of cognitive dysfunction (Rao et al., 1991). These original subjects were drawn from 730 prospective patients who were randomly solicited from a membership listing of a local MS society. Rao (1986) reported that this method of obtaining MS subjects is considered more representative of the MS population than using MS patients who are hospitalized or attend a hospital clinic because the hospital patients are more likely to be in a exacerbating stage of the illness. Of the total number (730) of prospective patients 41.0% (299) expressed an interest in participating in the study. After a careful review of their medical records, 197 patients were excluded from the study because they 1) did not meet the criteria established by Poser, Paty, Scheinberg, McDonald, and Davis (1983) for definite or probable MS; 2) had a history of alcohol or drug abuse or a nervous disorder other than MS; 3) had severe motor or visual impairment that could interfere with cognitive testing; 4) resided in an institutional setting and could not be easily transported to the medical center; or 5) had previously undergone a neuropsychological evaluation at the center.

The remaining 102 patients were given an MRI scan and a neurological evaluation to provide additional evidence for a diagnosis of MS. One patient was subsequently excluded from further study because of an inappropriate diagnosis and one was excluded because of a failure to meet Poser et al.'s (1983) criteria for probable or definite MS. During the neurologic examination, patients provided information concerning disease course, duration of illness, and severity of physical disability using the Kurtzke Expanded Disability Status Scale (EDSS; Kurtzke, 1983). Twenty three of the original 100 subjects selected in the original investigation were used as subjects in this study. Of these 23, 19 (82.6%) met the criteria for clinically definite MS, 3 (13.1%) were laboratory-definite MS, and 1 (4.3%) was clinically probable MS. Of the 23, 9 (39.2%) of the patients had MS that followed a relapse-remitting course, 7 (30.4%) followed a chronic-progressive course, and 7 (30.4%) followed a chronic-stable course. The mean EDSS score was 4.20 (SD = 2.33). The mean number of years since the onset of the first symptoms was 16.07 (SD = 7.70) and the mean number of years since MS was first diagnosed was 9.25 (SD = 5.46).

Control subjects. Control subjects were chosen from a pool of 100 healthy adults who were part of the original group solicited through newspaper advertisements to participate in an ongoing longitudinal study of cognitive dysfunction (Rao et al., 1991). The original 100 control subjects were matched individually to the original 100 MS patients on age (±3 years), education (±1 year), and sex. After a detailed medical and psychosocial history were obtained, control subjects were excluded on the basis of a history of substance abuse, psychiatric disturbance, head injury or any other nervous system disorder, or use of prescription medications. The control subjects also underwent a neurologic exam and MRI scan. For this study, 23 normal control subjects were chosen. No significant differences were found in age ($t[44] = 0.38$, $p = .71$) or education ($t[44] = 1.13$, $p = .26$) among these control subjects. The means and standard deviations for age and years of education for both groups are presented in Table 1. Finally it should be noted that all subjects were paid for their participation and signed a consent form (Appendix 1).

Design

The study was configured as a 2 X 2 X 3 X 2 design (group X encoding strategy X retrieval cue X congruency). Encoding strategy, retrieval strategy, and congruency were varied within subjects, making this a repeated measures design. Group (MS and control) was the only between-subjects

TABLE 1

MEANS AND STANDARD DEVIATIONS OF AGE AND EDUCATION

		Age	Education
MS			
(n = 23)	Mean	46.94	13.83
	SD	8.60	2.95
Control			
(n = 23)	Mean	48.35	14.78
	SD	8.09	2.78

variable. A visual representation of the overall design of the study is presented in Figure 1. Words were encoded using a conceptually driven or data-driven strategy. Words were conceptually encoded by having the subject answer a semantic prompting question about the word's membership in a category. Words were encoded using a data-driven strategy by having subjects answer a phonemic prompting question about whether the word rhymed with another word according to the rules described below. Retrieval cues were presented as either conceptually driven, data-driven, or passive (no cue). In the conceptually driven condition, cues were semantic category cues similar to those used by Craik and Lockhart (1972). In the data-driven condition, cues were words that rhymed with the target words. The passive (no cue) condition was essentially a free recall condition. Encoding and retrieval were manipulated simultaneously to test the

	Encoding Prompts	Concept-driven			Data-driven		
	Retrieval Prompts	Concept-driven	Data-driven	Passive	Concept-driven	Data-driven	Passive
Group	MS	List 1 congruent	List 2 congruent	List 3 congruent	List 4 congruent	List 5 congruent	List 6 congruent
		incongruent	incongruent	incongruent	incongruent	incongruent	incongruent
	Control	List 1 congruent	List 2 congruent	List 3 congruent	List 4 congruent	List 5 congruent	List 6 congruent
		incongruent	incongruent	incongruent	incongruent	incongruent	incongruent

Figure 1. Design

Note. There were 23 subjects per cell, with all MS cells containing the same 23 subjects and all control cells containing the same control subjects. Each list contained 20 words: 10 words with congruent encoding prompts and 10 words with incongruent encoding prompts.

transfer-appropriate processing hypotheses. The congruency factor pertained to the encoding strategy and was either congruent or incongruent. Encoding was congruent when the prompting question was true for the target word, whereas encoding was incongruent when the prompting question was false for the target word.

<u>Materials</u>

<u>Word lists</u>. One-hundred twenty words were grouped into six lists of 20 words each. Each list conformed to one of the 2 X 3 (encoding X retrieval) conditions. Words were

chosen such that all words were 1 to 2 syllables in length. The words within each list bore little semantic or phonetic similarity to other words in that list. In addition, words were chosen such that lists did not differ in terms of frequency of usage in written English ($F[5, 114] = 0.06$, $p = .99$) based upon the norms of Francis and Kucera (1982). Frequency means and standard deviations for each list are presented in Table 2.

TABLE 2

MEANS AND STANDARD DEVIATIONS OF FREQUENCY OF USAGE IN THE ENGLISH LANGUAGE FOR EACH WORD LIST

	List					
	1	2	3	4	5	6
Mean	91.70	86.30	85.70	85.80	81.55	81.35
SD	90.41	57.77	59.75	77.47	57.44	64.86

Encoding prompts. For each word in the conceptually driven encoding conditions, two prompting questions about the word's category membership were generated such that one question was true about the word (congruent) and one question was false (incongruent). For example, the target word, "film," used the true prompting question, "Is the word used with a camera?" and the false prompting question "Is the word a type of terrain?" For each word in the data-driven encoding conditions, two prompting questions about the word's rhyming characteristics were generated such that one question was true about the word (congruent) and one question was false (incongruent). For example, the target word, "tax," used the true prompting question, "Does the word sound like 'jacks'?" and the false prompting question "Does the word sound like 'hook'?". Rhymes were chosen such that the rhyming words differed from the target word on the first consonant sound only, with all subsequent phonemes identical to the target word. No encoding rhymes were semantically similar to any other rhyme or any target word in that list; in addition, rhymes were not phonetically similar to any non-target word in the list.

Retrieval cues. One retrieval cue was generated for each word in the conceptually driven and data-driven retrieval conditions. These cues were generated in a similar fashion to the encoding prompts. For example, in the conceptually driven retrieval condition, the target word "film" used the retrieval cue "Which word was associated with photographs?". Similarly, in the data-driven retrieval condition, the word "tax" used the retrieval cue "Which word sounded like 'wax'?". While the retrieval cues were similar to the encoding cues, no retrieval cue was identical to the encoding cue for that target word or any other target word in the same list. For the passive retrieval conditions, no retrieval cues were used. A complete list of words, encoding prompts and retrieval cues used in the study is presented in Appendix 2.

All target words, encoding prompts, and retrieval cues were digitally recorded on an Apple Macintosh LC microcomputer for presentation to the subjects. Simultaneously with the auditory stimuli, the text of all target words, prompts, and cues was presented visually on an Apple 12 inch monitor (resolution: 64 dpi). Target words were presented in 36 point Times font. Prompts and cues were presented in 24 point Times font.

Procedure

Subjects were accompanied into a room individually by an experimenter in which they signed the appropriate consent forms and read a brief description of the study (Appendix 3). Words were visually and auditorially presented via a computer. The six lists were presented in a random sequence for each subject. The 20 words within each list were also presented in a random sequence for each subject. Each target word was randomly assigned either the true prompting question (congruent) or false prompting question (incongruent) with the constraint that each list included ten congruent prompts and ten incongruent prompts. Before each word was presented, the prompting question was presented for 2 seconds. Then the target word was presented for 1 second. The subject was then asked to respond "yes" if the question was true about the word and "no" if the question was false about the word.

Subjects' responses were manually recorded by the experimenter. There was a 2 second pause between each target word to allow for a subject's response. One target word was presented every 5 seconds.

At the end of each list, subjects were administered a retrieval task. For words in the conceptually driven and data-driven retrieval conditions, the corresponding type of cue was presented both visually and auditorially on the computer. Rate of presentation of the retrieval cues varied according to the time needed to respond by each subject. However, subjects were encouraged to proceed to the next cue if no response was given after ten seconds. Words presented in the passive condition were not given any cue; the subject was merely asked to recall all words in the preceding list. Again, subjects' responses were manually recorded by the experimenter.

Hypotheses

Several hypotheses were tested within the context of the 2 X 2 X 3 X 2 (group X encoding strategy X retrieval cue X congruency) design of the study. A number of hypotheses were tested with respect to the overall main effects of the variables included in the analyses. After which, several hypotheses were tested related to the normal control group data set. These findings were used to support previous work in the area. The last set of hypotheses tested were focused on documenting specific deficits in the MS group which are based on the current literature.

Main effects. There will be a main effect for group such that controls' will be superior to MS in the proportion of words recalled. There will be a main effect for encoding strategy with the conceptually driven conditions superior to data-driven conditions. There will also be a main effect for retrieval strategy such that the conceptually driven conditions will be superior to the data-driven conditions which will in turn be superior to the passive conditions. Finally, there will be a main effect for congruency such that words encoded with congruent prompts will be recalled better than those encoded with incongruent prompts.

Control group. For the normal controls, there will be an interaction between encoding and retrieval strategy such that words that are encoded with conceptually driven prompts will be retrieved better when given conceptually driven cues than either data-driven or passive cues. Similarly, words that are encoded with data-driven prompts will be retrieved better when given data-driven cues than either conceptually driven or passive cues. In other words, transfer-appropriate learning will be demonstrated.

MS group. With MS subjects, due to the relatively greater impairment in processing phonetic material (Litvan, Grafman, Vendrell, Martinez, et al., 1988; Rao et al., 1992), there will not be an interaction effect between encoding and retrieval strategy. Thus, no transfer-appropriate processing will occur.

CHAPTER IV

RESULTS

The means and standard deviations for proportion of words recalled in each list in the 2 X 2 X 3 X 2 (group X encoding X retrieval X congruency) matrix are presented in Table 3. A four way (group X encoding X retrieval X congruency) repeated measures analysis of variance (ANOVA) was performed with encoding, retrieval, and congruency treated as within subjects variables. The results of this repeated measures analysis are presented in Table 4. The alpha level was set at $p < .05$ for all analyses performed in this study. Since the retrieval variable had three levels, the f values from the repeated measures ANOVA for analyses involving retrieval rest on the assumption of sphericity. If the cells in the design are independent of each other, then the assumption of sphericity is met. The Mauchly test of sphericity (Keselman, Rogan, Mendoza, & Breen, 1980) was performed on each significant effect involving retrieval, and the results are presented in Table 5. This table shows that for each effect involving retrieval, we fail to reject the assumption of sphericity. Thus, the assumptions of the repeated measures ANOVA are met, and the f values are valid.

TABLE 3

MEAN PROPORTIONS OF WORDS RECALLED FOR ALL LISTS

MS (N = 23)

	Encoding	Concept-driven			Data-driven		
	Retrieval	Concept-driven	Data-driven	Passive	Concept-driven	Data-driven	Passive
Congruency	Congruent	.561 (.246)	.387 (.174)	.248 (.186)	.335 (.170)	.213 (.110)	.178 (.128)
	Incongruent	.422 (.219)	.357 (.162)	.196 (.182)	.261 (.195)	.213 (.146)	.122 (.138)

Control (N = 23)

	Encoding	Concept-driven			Data-driven		
	Retrieval	Concept-driven	Data-driven	Passive	Concept-driven	Data-driven	Passive
Congruency	Congruent	.639 (.156)	.452 (.181)	.396 (.238)	.322 (.213)	.291 (.153)	.278 (.202)
	Incongruent	.465 (.227)	.526 (.207)	.361 (.210)	.309 (.176)	.270 (.158)	.204 (.227)

Note: Standard deviations are in parentheses beneath means.

TABLE 4

FOUR-WAY (GROUP X ENCODING X RETRIEVAL X CONGRUENCY) REPEATED MEASURES ANALYSIS OF VARIANCE OF PROPORTION WORDS RECALLED

Source	SS	df	MS	F	p
Group (G)	1.00	1	1.00	7.40	.009
Within subjects variables					
Encoding (E)	3.88	1	3.88	232.76	<.001
Retrieval (R)	2.55	2	1.28	25.39	<.001
Congruency (C)	0.34	1	0.34	16.82	<.001
G X E	0.10	1	0.10	5.79	.020
G X R	0.17	2	0.08	1.68	.192
G X C	0.01	1	0.01	0.56	.458
E X R	0.30	2	0.15	6.62	.002
E X C	0.01	1	0.01	0.53	.471
R X C	0.26	2	0.13	6.60	.002
G X E X R	0.00	2	0.00	0.06	.939
G X E X C	0.00	1	0.00	0.16	.688
G X R X C	0.01	2	0.01	0.26	.769
E X R X C	0.15	2	0.08	4.11	.020
G X E X R X C	0.07	2	0.04	1.94	.150

In the section that follows, the significant main effects are discussed first, followed by a discussion of the significant interaction effects.

Main effects

Each of the four main effects were found to be significant at the $p < .05$ level. There was a significant main effect found for group ($F[1, 44] = 7.40$, $p = .009$), indicating that MS subjects ($M = .291$, $SD = .209$) recalled

TABLE 5

TESTS OF SPHERICITY FOR ALL EFFECTS INVOLVING RETRIEVAL

Effect	w	chi-square	df	p
Main effect				
R	0.980	0.876	2	.645
Interaction effects				
E X R	0.985	0.017	2	.724
R X C	0.970	1.311	2	.519
E X R X C	1.000	1.017	2	.992

Note: R = Retrieval; E = Encoding; C = Congruency

fewer words overall than controls (M = .376, SD = .228). This finding corroborates previous researchers who reported that memory was impaired in MS subjects compared to normal control subjects (Grafman et al., 1990). There was a significant main effect found for encoding strategy ($F[1, 44] = 232.76$, $p < .001$), indicating that recall was superior for words encoded with a conceptually driven prompt (M = .417, SD = .231) compared to words encoded with a data-driven prompt (M = .250, SD = .179). Thus, the levels of processing hypothesis that conceptually driven encoding is superior to data-driven encoding (Craik & Tulving, 1975) was supported. In addition, there was a significant main effect found for retrieval strategy ($F[2, 88] = 25.39$, $p < .001$). Since there were more than 2 means to compare for the retrieval strategy, a post-hoc test was used to show which means were significantly different from each other.

Tukey's (1953) HSD (honestly significant difference) test was used as a pairwise comparison test for the differences across means for the retrieval conditions. The results of these comparisons are shown in Table 6. Words were retrieved significantly better with a conceptually driven cue than either a data-driven cue or passive condition. Also, words were retrieved significantly better with a data-driven cue than in the passive condition. This

TABLE 6

DIFFERENCES AMONG MEANS FOR RETRIEVAL CONDITIONS

	Concept driven (M = .414)	Data-driven (M = .339)	Passive (M = .248)
Data-driven	.075 $p < .005$		
Passive	.166 $p < .001$	.091 $p < .001$	

finding essentially replicates previous studies which have shown conceptually driven strategies to be superior to data-driven retrieval strategies (Fisher & Craik, 1977; Morris et al., 1977).

Finally, there was a significant main effect found for congruency ($F[1, 44] = 16.82$, $p < .001$), indicating that words encoded with congruent prompts ($M = .358$, $SD = .224$) were recalled better than words encoded with incongruent prompts ($M = .309$, $SD = .219$). Again, this finding is similar to that reported in previous studies in which similar encoding questions were used (Craik & Tulving, 1975; Fisher & Craik, 1977; Morris et al., 1977), and strongly suggests that true encoding questions (whether conceptually driven or data-driven) evoke more elaborate encoding (Craik & Tulving, 1975).

Interaction effects

Four significant interaction effects were found significant at $p < .05$. There was an encoding X retrieval interaction effect ($F[2, 88] = 6.62$, $p = .002$), suggesting that while conceptually driven encoding was always superior to data-driven encoding, this discrepancy increased when data-driven or conceptually driven cues were used (see Figure 2). While there was an encoding X retrieval interaction, the transfer-appropriate interaction was not observed with both groups combined. The transfer-appropriate hypothesis would have predicted that words recalled under the data-driven encode/data-driven retrieve condition would have been higher than words recalled under the data-driven encode/conceptually driven retrieve condition. In other words, the lines in Figure 2 would slope in the opposite direction. In order to

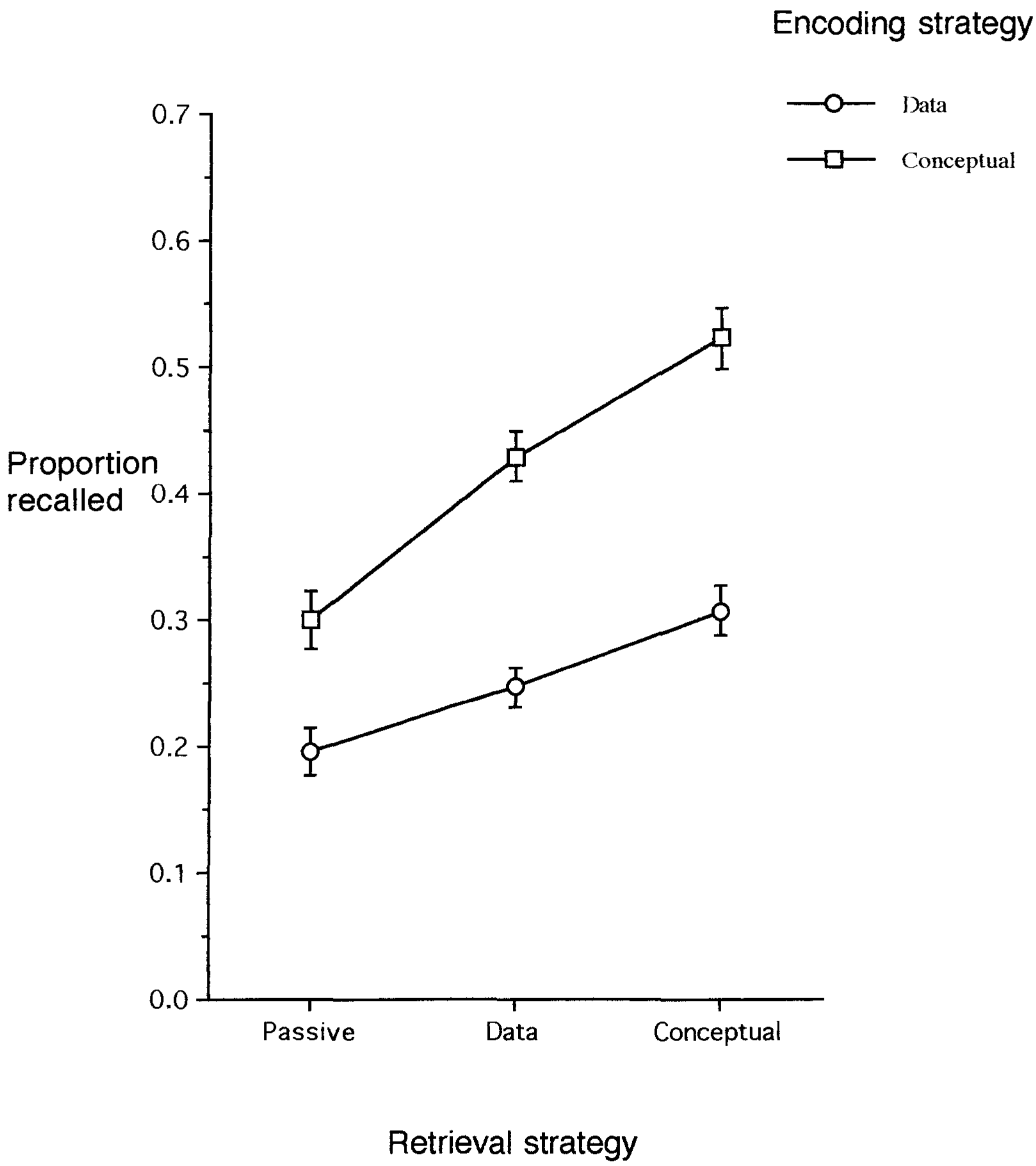

Figure 2. Interaction between encoding and retrieval.

compare the results of this study with previous studies that have found encoding X retrieval interaction effects using similar manipulations (Fisher & Craik, 1977; Morris et al., 1977), means for congruent words only were plotted separately for MS and controls in Figure 3. Again, it can be seen that the transfer-appropriate effects were not borne out for either group. Thus, no further analyses of the data set were considered to be necessary to test the transfer-appropriate processing hypothesis.

There was a significant group X encode interaction effect ($F[1, 44] = 5.79$, $p = .02$). This interaction suggested that even though controls recalled more words than MS subjects with both conceptually driven and data-driven encoding prompts, this discrepancy was greater with respect to the conceptually driven encoding condition than the data-driven encoding condition. The group X encode interaction is depicted in Figure 4. This result is somewhat surprising given the findings from other studies in which it was reported that the structure of semantic memory of MS patients is generally intact when compared to normal controls (Beatty & Monson, 1990; Beatty, Goodkin, Beatty, et al., 1989). There was also a significant retrieval X congruency interaction effect ($F[2, 88] = 6.60$, $p = .002$). This interaction suggests that the congruent prompts were superior to incongruent prompts only in the conceptually driven prompts condition or the no prompts condition. In the

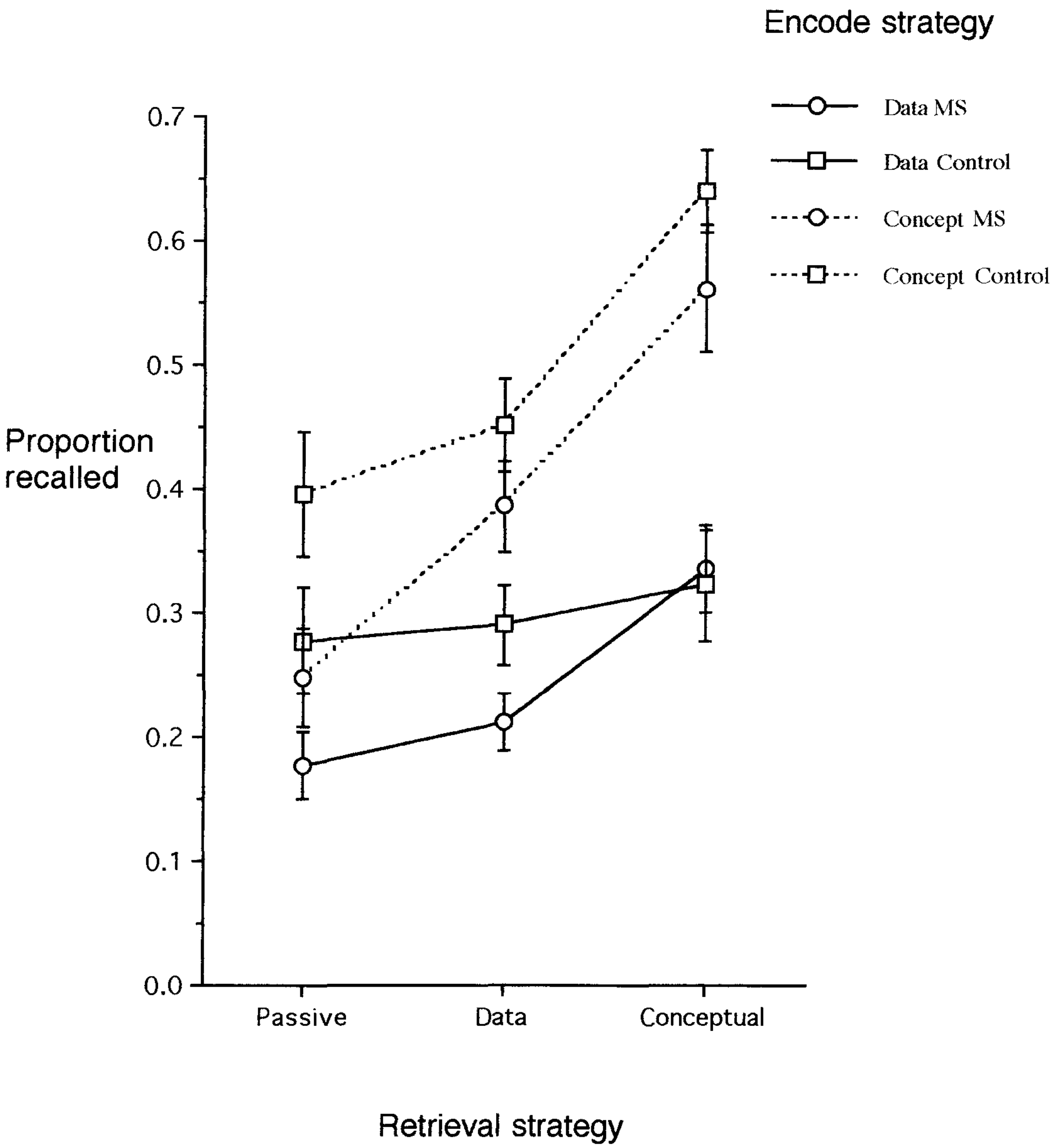

Figure 3. Interaction between encoding and retrieval on congruent prompts for MS and controls.

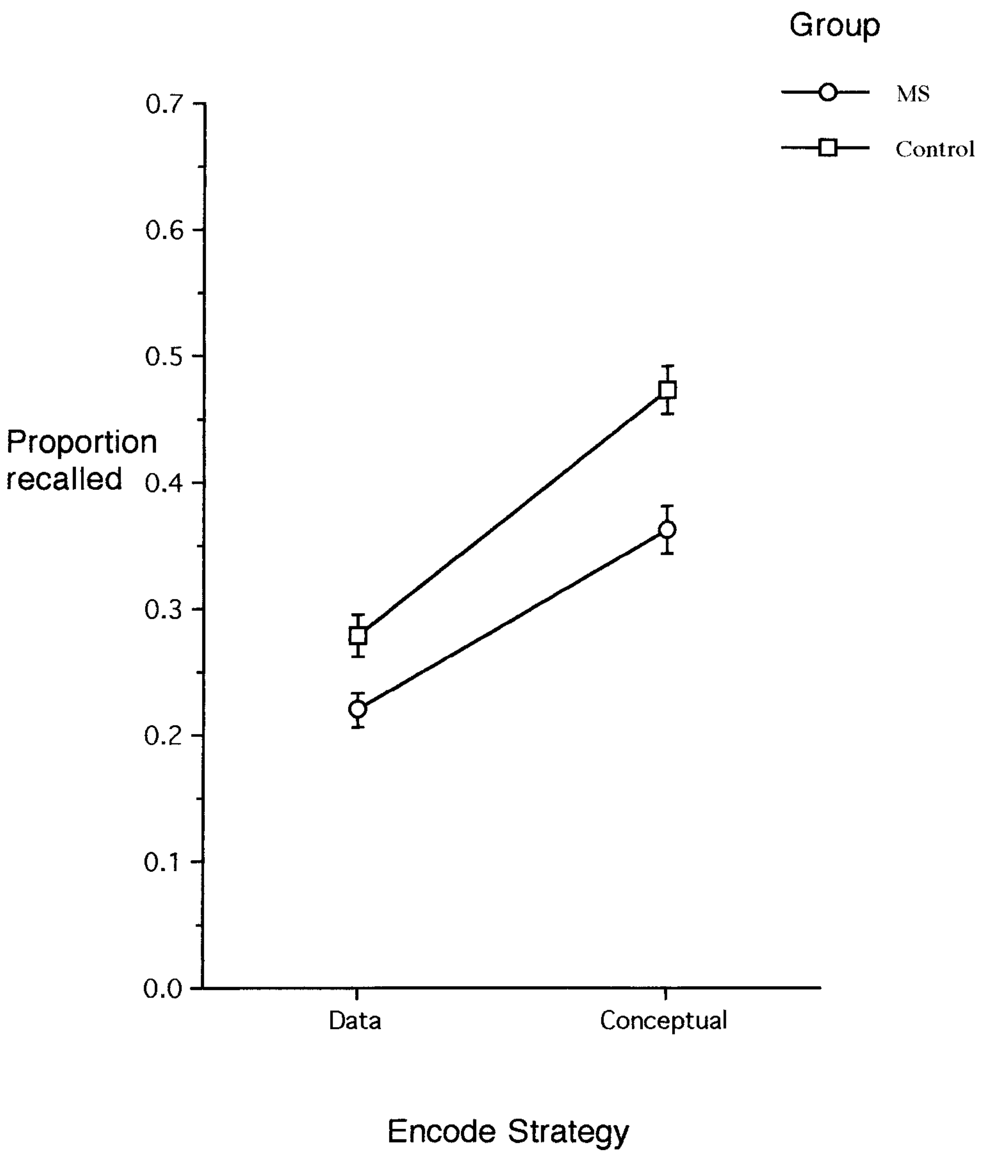

Figure 4. Interaction between group and encoding.

data-driven retrieval condition, congruent and incongruent prompts were found to be essentially the same. This interaction is shown in Figure 5.

Finally, it should be noted that there was one significant three-way interaction among encoding X retrieval X congruency ($F[2, 88] = 4.11$, $p = .02$). This interaction suggests that under the data-driven retrieval condition, congruent and incongruent conceptually driven encoding strategies are similar. Also, under the data-driven retrieval condition, congruent and incongruent data-driven encoding strategies are similar. However, the congruent conceptually driven strategies become superior to the data-driven strategies in the conceptually driven and passive retrieval conditions. This superiority is particularly evident in the conceptually encode/conceptually retrieve condition. This interaction is shown in Figure 6.

The percentage of correct responses to encoding prompt (i.e., responding "true" to a true prompt and "false" to a false prompt) were quite high per list overall ($M = .995$, $SD = .016$).

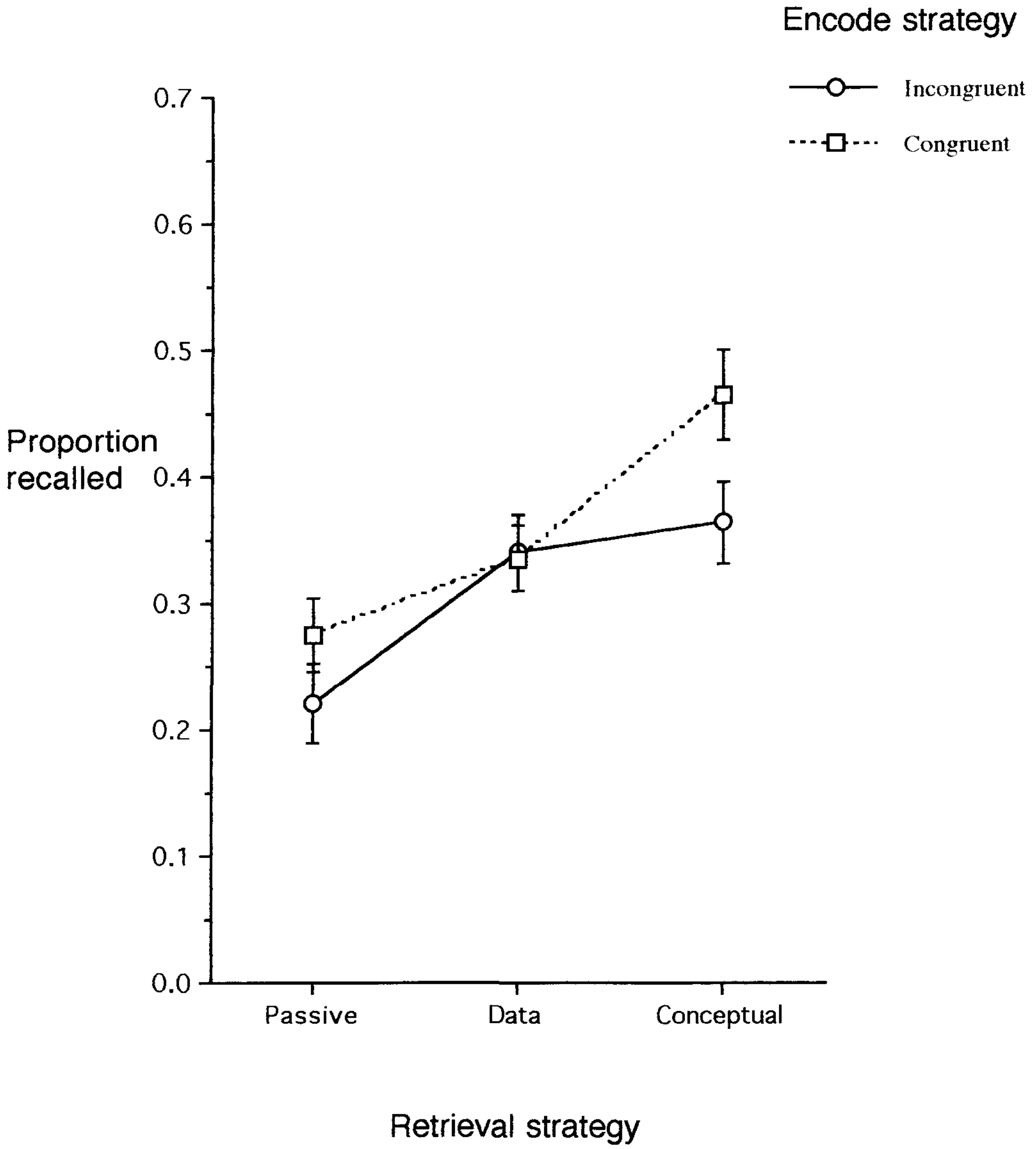

Figure 5. Interaction between retrieval and congruency.

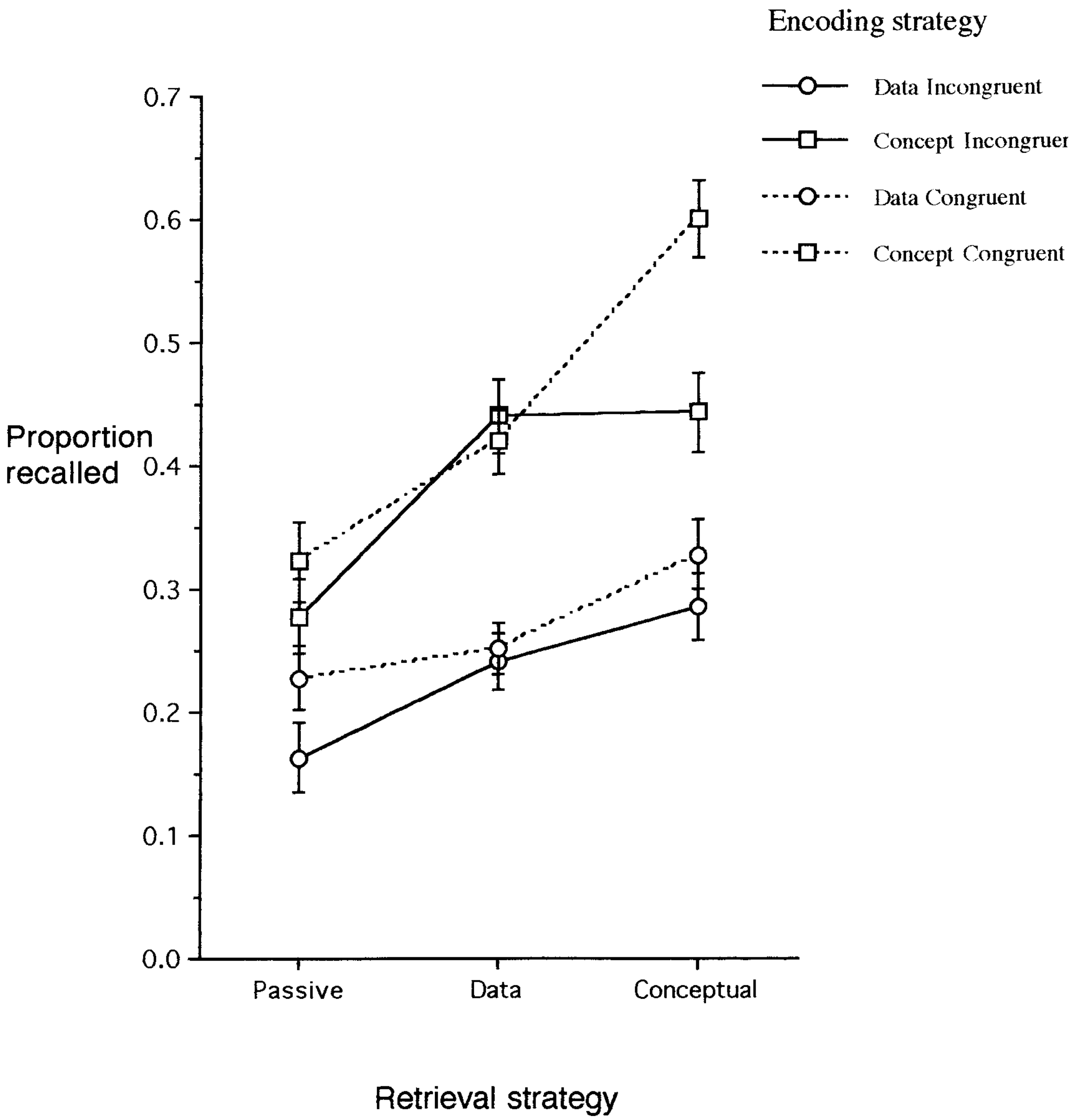

Figure 6. Interaction between encoding, retrieval, and congruency.

CHAPTER V

DISCUSSION

In this chapter, the results of the study are discussed and integrated within the context of the current literature. First, the results are discussed within the context of the memory processing research literature. After which, specific patterns of recall for MS and controls are compared and evaluated with respect to the literature on memory deficits in individuals with MS.

Memory processing

Several results from this study supported the findings reported by previous investigators. The results of this study consistently indicated that conceptually driven encoding was superior to data-driven encoding. This result was found in the original levels of processing studies (Craik & Tulving, 1975), as well as the transfer-appropriate processing studies (Fisher & Craik, 1977; Morris et al., 1977). Whether conceptually driven encoding is inherently superior to data-driven encoding, or merely superior because of the greater experience with semantic retrieval situations is still debated (Lockhart & Craik, 1990). Nevertheless, the superiority of conceptually driven encoding compared data-driven encoding remains a widespread phenomenon. The studies that have varied retrieval strategies have found a general superiority of conceptually driven over data-driven retrieval strategies (Fisher & Craik, 1977; Morris et al., 1977). This finding was supported in this study. The general finding that congruent encoding prompts were superior to incongruent encoding prompts is also a rather robust, finding appearing in much of the memory processing research literature (Craik & Tulving, 1975; Fisher & Craik, 1977; Morris et al., 1977). Similar results were found in the study reported here. Lockhart and Craik (1990) suggested that congruent prompts allow more enriched or elaborate encoding than incongruent prompts, since incongruent prompts have little relationship to the target word. Thus, the general superiority of conceptually driven encoding over data-driven encoding, conceptually driven retrieval over data-driven retrieval, and congruent encoding over incongruent encoding was found in this study. These findings replicated previous research efforts using similar methodologies (Fisher & Craik, 1977; Morris et al., 1977).

However, one prediction with respect to the results anticipated of this study was not clearly demonstrated. The results from this study did not support the transfer-appropriate processing hypothesis with either normal controls or MS subjects. While there was an encoding X retrieval interaction, this interaction showed that conceptually driven retrieval was superior to data-driven retrieval in both encoding conditions. Previous studies that have investigated transfer-appropriate processing have shown that data-driven encoding was superior to conceptually driven encoding in the data-driven retrieval condition, whereas the opposite was true in the conceptually driven retrieval condition (Fisher & Craik, 1977; Morris et al., 1977).

A comparison between the results of this study and the results of previous studies may prove useful in explaining this negative finding. In the study by Morris et al. (1977), the proportion of words recalled overall was typically much higher than what was reported in this study (.524 in Morris et al., 1977 compared to .367 for normals in this study). Also, the range of mean proportions across conditions was greater in the Morris et al. (1977) study than in this study (.660 in Morris et al., 1977 compared to .435 for normals in this study). Thus, there may be a floor effect influencing the data in this study. One reason for this floor effect may be that the retrieval task was too difficult. In this study, the retrieval task consisted of a cued recall condition in which subjects were given a cue and asked to recall the target word. Morris et al. (1977), on the other hand, used an easier recognition condition for the retrieval task in which subjects were given a list of target words and foils and then asked to choose the target words. This method of retrieval allowed for a broader range of scores to be obtained.

Thus, the difference in level of difficulty of retrieval strategy can partially explain the disparate findings between this and previous studies on transfer-appropriate processing. However, even with a broader range of scores, the data would still favor a position that conceptually driven retrieval is superior to data-driven retrieval regardless of encoding strategy. Several differences between the design of the present study and previous studies may explain the differences in findings.

The study by Fisher and Craik (1977) differed slightly from this study with respect to its methodology. While they used a cued recall paradigm for the retrieval conditions, some retrieval cues were identical to the encoding prompts used for the same target word. Words that were matched on encoding and retrieval strategy and in the congruent condition received the same (intralist) encoding and retrieval questions. The remaining conditions used extralist or unique retrieval cues. Thus, the conditions that would show transfer-appropriate processing are the same ones that have intralist cues. It may be that intralist cues are easier because of a learned association between the encoding prompt and the target word. This procedure confounds the effects of matched encoding/retrieval strategy and intralist cues.

This study used only extralist cues, which eliminates the confounding element of intralist cues. However, there may be a drawback to using extralist cues in the data-driven conditions matched on encoding and retrieval. An examination of the errors made by subjects in these conditions, show that a common error response was the word used in the data-driven encode prompt, a word that rhymed with the target word. For example, consider the target word "leaf", that was in the data-driven encode and data-driven retrieve conditions. The congruent encoding prompt used the word "beef", and the retrieval prompt used the word "thief". A common error response was to give the word "beef" instead of "leaf". This confusion between encoding prompt and target word was not possible in the study conducted by Fisher and Craik (1977) because they used intralist retrieval cues. Hence, the word "beef" would have been used for both encoding and retrieval and could not have been confused with another word rhyming with the target word. The consequences of using only extralist retrieval cues in this study may be both positive and negative. Using only extralist cues removes the confounding effect of matched encoding/retrieval conditions and intralist cues. However, it also introduces a potentially confusing effect for subjects.

Two interaction effects were found in this study that were not reported in previous studies. These interaction effects both involved the congruency factor (see figures 5 and 6). These interactions show that congruent and incongruent encoding prompts were similarly effective in the data-driven retrieval conditions. However, in the passive and conceptually driven retrieval conditions congruent prompts tended to be superior to incongruent prompts. This superiority tended to be greatest in the data-driven encode/passive retrieve and conceptually driven encode/conceptually driven retrieve conditions. Thus, the congruency of encoding prompt was not important in the data-driven retrieval conditions. The lack of difference between congruent and incongruent conceptually driven prompts in the data-driven retrieval condition is understandable: whether a subject received a true or false category prompt made no difference in recall when rhymes were used to cue the target word. However, the same result was found between the congruent and incongruent data-driven prompts. Thus, prompts that were rhymes or non-rhymes were similarly effective when rhymes were used to cue the target word. Rhymes tended to be more effective than non-rhymes when a category cue or no cue was given. Therefore, it is recognized that something about the data-driven retrieval task may have been ineffective.

In summary, the differences in findings between this and previous studies may be explained in terms of the differences in methodology. The increased difficulty in retrieval task was primarily detrimental; it appeared to restrict the range of proportion of words recalled and create a floor effect.

The exclusive use of extralist cues may have had positive and negative effects. On one hand, it eliminated the confounding effect of intralist cues. On the other hand, it may have introduced confusion on the part of the subject with respect to what word was to be remembered. Even with these potential flaws, the three manipulations (encoding, retrieval, and congruency) showed highly significant main effects. The finding of a general superiority of conceptually driven encoding and retrieval over data-driven encoding and retrieval has been used as evidence against the transfer-appropriate processing model (Lockhart & Craik, 1990). This argument is weakened by studies showing interaction effects that suggest that data-driven encoding is superior when data-driven prompts were used (Fisher & Craik, 1977; Morris et al., 1977). However, the superiority of matched encoding/retrieval conditions may not be as robust as the general superiority of conceptually driven encoding and retrieval. Future studies may answer this question.

Deficits in MS

There were two findings involving group differences. First, when MS subjects were compared to normals, there was a general deficit in proportion of words recalled across the cells. This finding was predicted and is similar to the great majority of studies that find memory to be impaired in MS (Grafman et al., 1990). The mean proportion of words recalled for MS subjects was .291 compared to .376 for controls. Thus, MS subjects recalled 23% fewer words than controls. One unusual aspect of the data is that the standard deviation was smaller for MS subjects than controls (SD = .209 for MS and SD = .228 for controls). While this difference is not great, typically there is a larger variation in memory scores for MS than control (Rao, 1986). A larger variation would make sense given that MS patients generally range from normal memory to severely impaired.

One explanation for the homogeneity of MS subjects on the memory tasks in this study is that the subjects sampled coincidentally have similar deficits. However, this explanation is weak because of the characteristics of the MS sample. The MS sample used in this study was taken from members of a local MS society, and thus represent subjects with a broader range of impairment than MS patients in a clinic setting who are likely experiencing an exacerbation of the disease. In addition, a previous study that used a larger group of subjects from which this sample was drawn found larger variations in MS subjects than controls on 7 out of 9 measures of memory (Rao et al., 1991). With these considerations in mind, it appears unlikely that these MS subjects are impaired in the consistent manner suggested by the data.

An alternative explanation for these discrepant findings would be based on the floor effect discussed above. Since the means for both MS and controls were quite low, it seems likely that the range of scores would be small due to the proximity of the mean to the lowest possible score. Since the overall mean proportion of words recalled was less for MS than for controls, a lower range, and thus standard deviation, appears likely. Again, it appears that the retrieval test was too difficult to allow the expression of the full range of scores. The use of easier recall cues or a recognition test might have allowed greater variation in scores.

The second finding involving group was a group X encode interaction effect. This interaction suggests that there is a greater impairment in conceptually driven encoding than data-driven encoding in MS. Two points about this finding are contrary to previous findings. First, the structure of semantic memory is generally thought to be preserved in MS. Individuals with MS have shown the same release from PI as normals (Beatty, Goodkin, Beatty, et al., 1989; Rao et al., 1992), and they respond similarly to normals on semantic priming tasks (Beatty & Monson, 1990). Thus, some aspects of semantic memory appear to be intact. However, neither release from PI nor semantic priming are intentional learning paradigms that require the subject to put forth effort to recollect information. The impairment in conceptually driven encoding found in this study could be due to a specific deficit in the intentional learning of semantic material. Similar deficits have been found on tasks of category fluency

(Beatty et al., 1988; Caine et al., 1986; Rao, Leo, St. Aubin-Faubert, 1989). These tasks require subjects to make an effortful search of memory for words that belong to a specific semantic category. The difference between the conceptually driven encoding task in this study and the category fluency task is that the fluency task is presumed to tap deficits in retrieval of information already stored in memory. In this study, specific deficits in conceptually driven encoding were found.

The second aspect of the group X encode interaction effect that is novel is that a specific impairment appears to have occurred at the encoding stage of memory. In previous studies, it was suggested that the impairment in memory is primarily involved with the retrieval stage rather than the encoding stage of memory. Some investigators have used the relative differences between MS and controls on recall and recognition tests to suggest a retrieval problem (Grafman et al., 1990; Rao, 1986). That is not to say that there was no impairment at the retrieval stage in this study. In fact, there was no interaction between group and retrieval, indicating that the MS subjects performed equally poorly across all retrieval conditions. However, there appeared to be a specific encoding impairment when encoding was conceptually driven.

It should be noted that the interpretation of an encoding deficit must be made cautiously considering the type of retrieval test that was used. This study used a recall task exclusively. Poor performance on a recall task does not necessarily lead to a conclusion regarding the contribution of encoding and retrieval. As mentioned above, studies that apply both a recall and recognition test have been used to distinguish impairment due to encoding from retrieval. MS subjects have been found to have normal or near normal recognition memory and impaired memory from recall (Grafman et al., 1990; Rao, 1986). This suggests that MS subjects are able to encode information, but less able to retrieve this information compared to normals. One drawback from these studies is that they did not yield specific information regarding the type of encoding that is impaired.

In one study, apart from the present study, the encoding strategy with MS subjects was varied. Carroll et al. (1984) used data-driven and conceptually driven strategies to encode a series of pictures. They found that MS subjects performed poorer overall, but they did not find a group X encode interaction. Thus, contrary to the findings reported in this study, MS and controls were found to encode information in a similar but inferior fashion. However, several aspects of the study by Carroll et al. (1984) make it difficult to determine the relative contributions of encoding and retrieval. Only the encoding strategy was varied with a single strategy used for retrieval, essentially a passive strategy. Also, only one type of retrieval task was used, a recognition task. From this design it is difficult to ascertain whether the poorer performance in retention is due to encoding deficits or retrieval deficits. An additional difference between the present study and Carroll et al. (1984) was their use of pictorial stimuli rather than words. It may be that the specific deficit in conceptually driven encoding only applies to language related material rather than visuo-spatial material. This hypothesis appears unlikely, however, given that MS subjects have been found to perform worse on visuo-spatial tasks than language tasks (Rao et al., 1991).

A final comment related to the finding of a deficit in conceptually driven encoding is necessary. As noted above, the possibility of a floor effect exists. The data-driven encoding conditions for both MS and controls were quite low and may influence the range of responses obtained. This was not the case for the conceptually driven encoding conditions; these means were higher and may have allowed a greater spread of scores to occur (see Figure 4). There was a trend for data-driven encoding to be impaired in MS relative to controls. This trend may have been significant if the scores had not been restricted on the lower end.

No interaction between group and retrieval strategy was found. This suggests that while MS subjects perform poorer overall, they do not exhibit a different pattern with respect to retrieval strategy. Thus, retrieval appears to be less efficient in MS without regard to the type of information retrieved. Similarly, no interaction between group and congruency of encoding strategy was found. Thus, individuals with MS appear to benefit from congruent encoding prompts as do normals, but they benefit to a lesser degree than normals. Since congruency of encoding prompt is related to the elaborateness of encoding (Lockhart & Craik, 1990), there may be a general impoverishment in encoding without regard to type of encoding (conceptually driven or data-driven) in MS.

In summary, the findings in the present study concur with previous studies that have found memory deficits associated with MS. Apart from this general finding, the results from this study suggests that there may be a specific impairment in conceptually driven encoding relative to data-driven encoding in individuals with MS. This hypothesis is considered to be tentative since the retrieval task used was a recall task and may not have adequately measured encoding. Further, there appears to be an overall deficit in retrieval regardless of type of information retrieved. Finally, there appears to be a general impoverishment of encoding regardless of the type of encoding.

Suggestions for future research

As noted above, one limitation of the hypotheses generated from this study is the possibility of a floor effect. The mean proportion of words recalled was quite low in many conditions, possibly restricting the range of scores that were obtained. It appears likely that the level of difficulty of the retrieval task was too high. Future investigators in the area may benefit from using a retrieval task that allows a greater proportion of words to be retrieved. One way to achieve a higher retrieval rate would be to provide easier recall cues. Using the same questions for encoding and retrieval strategy (intralist cues) may make the retrieval task easier. However it is only possible for some conditions to have intralist cues. Those conditions that are not matched on encoding and retrieval strategy cannot use the same question.

An alternative procedure would be to use all extralist cues, but devise cues that are more closely associated with the target word. For example, in this study the target word "flame" used the conceptually driven retrieval cue, "something that is hot". A more closely associated cue would have been "associated with fire". Similarly, easier cues could be developed for the data-driven retrieval conditions that have a narrower scope of possible responses. Target words in these conditions could be chosen such that only a few rhyming words exist (e.g., "couch") so that the phonetic qualities of the cue are more distinctive. An additional method of providing a retrieval task with an appropriate level of difficulty would be to use a recognition task to measure retention. This type of task was used by Morris et al. (1977) to test transfer-appropriate processing, and was found to produce a greater proportion of words retrieved than was the case in this study. Such a task would consist of a list of words that were semantically or phonetically similar to the target words along with foils that were not similar. Subjects would be required to choose those words that were similar to the target words.

It is recognized that the interpretations from this study about encoding and retrieval must be made with considerable caution since only a recall test was used to measure retention. In order to determine more clearly the contributions of encoding and retrieval, future studies examining memory processing in MS might benefit from using both a recall and recognition test. In this way, one could examine the effects of encoding strategy on a measure of encoding and retrieval strategy on a measure of retrieval.

Finally, it has been suggested that the differences in retention between conceptually driven and data-driven encoding might be due to the elaborateness of encoding, rather than the type of information encoded (Anderson & Reder, 1979). It would be interesting to examine the differences in MS and normals on elaborateness of encoding. One way to do this would be to use conceptually driven encoding prompts that vary in terms of the number of semantic connections with the target word. Information about the elaborateness of encoding in MS could help explain associated memory deficits.

APPENDIX A

CONSENT FORM

MEDICAL COLLEGE OF WISCONSIN

STATEMENT OF VOLUNTEER CONSENT FOR CLINICAL STUDY

I, ____, hereby agree to participate in an investigation entitled ***Study of Cognitive and Emotional Functioning in Patients with Multiple Sclerosis***. I understand that, while the program will be under the supervision of Dr. Stephen Rao, other professional persons may be designated to assist or act for him.

PURPOSE OF THE STUDY: The purpose of this study will be to evaluate my abilities to pay attention, remember information, solve complex problems, and process emotional material. There is evidence to suggest that people with multiple sclerosis may have problems in these areas, though the exact nature of these difficulties is unclear. Improved understanding of these problems may help in the development of specific interventions; hence the reasons for the study.

PROCEDURES TO BE FOLLOWED: The study will be conducted at the Medical College of Wisconsin (MCW) Clinic at Froedert over a 1- to 2-day period. In addition to the psychological tests, I will also be asked to participate in a variety of tasks of emotional perception and expression. I understand that, as part of this latter portion of the study, I will be privately shown a series of film clips containing graphic material designed to elicit emotion and asked to rate my emotional response to each clip.

I may also be given some questionnaires to complete regarding psychological and emotional functioning.

I wish to limit my participation as a subject (if no limitations, write "NONE"): ________________

RISKS: I have been informed of the discomforts and risks which I may reasonably expect as part of the study. These include: stress associated with the length of the study, and possible discomforts associated with viewing potentially unpleasant material during the emotional perception tasks. I understand that there may also be some unanticipated discomforts or risks in addition to those specified above, but that every precaution will be taken to assure my personal safety and to minimize discomforts.

MEDICAL BENEFITS: I understand that the information which is obtained may be useful scientifically and possibly helpful to others. The direct benefits to me which may reasonably be expected from participating in this study are none.

ANSWER TO INQUIRIES: Dr. Stephen Rao, or one of his research assistants, has explained the above matters to me and I understand that explanation. Answers to my questions concerning the procedures involved in this study have been offered.

CONFIDENTIALITY: I have been promised that all information obtained from this investigation that can be identified with me will remain confidential, or will be disclosed only with my written permission. However, I understand that scientific data or medical information not identifiable with me resulting from the study may be presented at meetings and published so that the information can be useful to others.

FINANCIAL BENEFITS: I understand that I shall be paid $75.00 following completion of the study. There are no other financial benefits.

NO PREJUDICE: I have been informed that my decision about whether or not to participate will not prejudice my present or future relationship with the Medical College of Wisconsin or the staff of this institution, nor will it influence the quantity or quality of care which is otherwise available to me. If I participate, I understand that I am free to withdraw at any time without prejudice, and that withdrawal would not in any way affect the nature of the care or treatment otherwise available to me. I understand that I may contact the Chairman of the Human Research Review Committee of the Medical College at (414) 257-8505 for further information related to the research and my rights as a subject.

COMPENSATION FOR INJURIES: I agree to take the risks listed above. If unexpected injuries which are not discussed in the paragraph entitled, "Risks" occur, physician faculty of the Medical College of Wisconsin and Froedert Memorial Lutheran Hospital will provide me humanitarian emergency care without charging me a physician's fee for such treatment. Such free care does not mean that negligence has occurred; compensation may or may not be payable. I understand that I may contact the Chairman of the Human Research Review Committee of the Medical College at (414) 257-8505 for further information on the provision of medical care without charge under the terms of this paragraph.

FURTHER INFORMATION: If I have further questions concerning this project at any time, I understand that I am free to ask them of Dr. Stephen Rao (414-454-5660) or his research assistants (414-259-3614), who will be available to answer them.

The Human Subject Review Committee of the Medical College of Wisconsin has approved this investigation.

________________________________ ____________________
(Signature of subject or legal guardian) (Date)

________________________________ ____________________
(Signature of spouse, parent, or sibling) (Date)

I have defined and fully explained the study as described herein to the subject.

Stephen M. Rao, Ph.D.
Professor of Neurology and Psychiatry

or

____
Research Assistant

________________________________ ____________________
(Signature) (Date)

APPENDIX B

COMPLETE LIST OF WORDS, ENCODING PROMPTS, AND RETRIEVAL CUES

List 1

WORD	TRUE PROMPT	FALSE PROMPT	RETRIEVAL CUE
week	a division of time	associated with music	part of a calendar
dog	a type of animal	a legal profession	a type of pet
sign	used to give directions	a type of food	something on the highway
page	associated with a book	a foreign country	part of a magazine
film	used with a camera	a type of terrain	associated with photographs
king	a type of royalty	a type of physical activity	part of a deck of cards
park	a place where children play	a type of transportation	a wooded area
pool	a type of game	a time of the year	a recreational activity
kitchen	a room in a house	something found in the bathroom	a place where food is found
knife	a type of weapon	a type of entertainer	used to eat with
rain	a type of weather	used for making clothes	something wet
desk	a piece of furniture	a type of music	a place you sit at
bone	part of the anatomy	something found in the post office	found in a grave
grass	found in the yard	something you read	a type of plant
navy	associated with war	something kept in the refrigerator	part of the armed services
flame	used for cooking	a type of store	something that is hot
ruler	used to measure something	a type of material	associated with drawing
glove	a type of clothing	a type of medication	used in cold weather
copper	associated with a penny	something you hide things in	a type of metal
miner	a type of occupation	something that flies	associated with coal

List 2

WORD	TRUE PROMPT	FALSE PROMPT	RETRIEVAL CUE
fire	something that gives off light	a type of beverage	liar
horse	a type of animal	a place to sleep	source
tree	something found in a forest	a type of reptile	glee
spring	a time of the year	used to communicate	cling
blood	something inside the body	part of an airplane	mud
hill	a type of terrain	a type of jewelry	spill
inch	a unit of measurement	a child's toy	finch
rock	a type of mineral	used to eat with	stock
bank	a place of business	a writing instrument	thank
train	a type of transportation	found in a grave	crane
dance	a type of physical activity	a type of utensil	stance
talk	a means of communication	something in the sky	hawk
sport	a type of game	a type of weather	fort
cousin	a relative	an ingredient in a recipe	dozen
fruit	something you eat	something on the highway	suit
lamp	a type of furniture	something wet	camp
soap	something found in the bathroom	a place where food is found	hope
wool	used for making clothes	a room in a building	pull
singer	a type of entertainer	something very cold	ringer
pail	a type of container	a type of money	whale

List 3

WORD	TRUE PROMPT	FALSE PROMPT	NO CUE (PASSIVE)
table	a piece of furniture	part of a calendar	
plant	a form of life	used to give directions	
note	associated with music	a room in a house	
hotel	a place to sleep	part of a deck of cards	
hair	something on the body	a type of game	
sun	something in the sky	a type of occupation	
circle	a geometric design	a type of material	
box	a type of container	a division of time	
baby	a type of human	part of the armed services	
coffee	a type of beverage	a type of profession	
wing	part of an airplane	a place of business	
snake	a type of reptile	a type of royalty	
bullet	associated with a gun	part of the anatomy	
phone	used to communicate	part of an animal	
corn	a type of food	a place where children play	
ice	something very cold	something inside the body	
pencil	associated with writing	a relative	
boot	a type of apparel	a wooded area	
nurse	associated with medicine	something that is invisible	
coin	a type of money	part of a book	

List 4

WORD	TRUE PROMPT	FALSE PROMPT	RETRIEVAL CUE
student	prudent	pup	associated with school
list	mist	pillage	a number of items
meeting	greeting	ridge	a type of gathering
bed	dead	sea	a piece of furniture
boat	rote	saloon	a mode of travel
speech	each	keg	a form of communication
wage	cage	boil	a type of income
judge	smudge	tripe	a legal profession
tool	cruel	grain	used to fix things
bottle	throttle	sparrow	used to hold liquids
hat	sat	bid	a piece of clothing
snow	low	round	a type of weather
atom	datum	crop	associated with chemistry
fence	tense	braid	found in the yard
bag	wag	pleat	used to carry things
honey	funny	sink	a type of food
pond	wand	grey	a body of water
daisy	crazy	stark	a type of flower
brake	shake	tell	part of a car
claw	raw	booth	part of an animal

List 5

WORD	TRUE PROMPT	FALSE PROMPT	RETRIEVAL CUE
tax	jacks	hook	wax
sound	round	harm	found
test	best	flip	west
square	rare	loan	where
play	grey	rot	way
tooth	booth	shake	sleuth
phase	raise	pole	graze
shop	crop	bum	flop
kid	bid	slack	squid
threat	pet	cage	bet
check	wreck	binge	deck
gain	lane	slope	pain
card	yard	dead	guard
seat	pleat	bail	wheat
grade	braid	each	maid
flow	grow	cruel	doe
leaf	beef	funny	thief
shell	tell	wheel	dell
straw	draw	crazy	law
bark	stark	same	dark

List 6

WORD	TRUE PROMPT	FALSE PROMPT	NO CUE (PASSIVE)
book	hook	shield	
plane	grain	wag	
farm	harm	rote	
ship	flip	fudge	
bridge	ridge	sat	
village	pillage	throttle	
frame	same	greeting	
shot	rot	tense	
key	sea	wand	
soil	boil	raw	
stone	loan	best	
track	slack	rare	
cup	pup	jacks	
egg	keg	raise	
coal	pole	silk	
pipe	tripe	yard	
drum	bum	pet	
rope	slope	beef	
arrow	sparrow	wreck	
balloon	saloon	jeans	

APPENDIX C

INSTRUCTIONS

On this computer screen you are going to see many different words. Each word will be presented one at a time. As each word appears on the screen, a recorded voice will speak the word. All of the words you see will be presented in lists. For each word you will be asked a question about that word before I tell you the word. Then you will be shown the word. I would like you to answer "yes" or "no" whether the question was true or not about that word. Let me give you an example. You might be told, "Is the word found in the desert" *(wait 2 secs)* "cactus". That's right, you would say "Yes". Or, you might be told, "Is the word part of a tree" *(wait 2 secs)* "carpet". That's right, you would say "No". You will say "Yes" or "No" after each word is presented. After you go through all the words in the list, you will be asked to remember as many of the words from that list as you can.

After some lists you will be presented with a clue for each word in the list. The clue will be a word that sounds like each word in the list. After each clue you'll be asked to remember the word it sounded like. For example, if one of the words in the list were "car", you might be presented with the word "tar" to help you remember it. Try to use the sound of the clue to help you remember the word. After other lists you will be presented with a different kind of clue. In this case the clue will be a category that the word belongs in. For example, if one of the words in the list were "house", you might be told that "One word was a type of building." to help you remember it. No matter what kind of help you get, you'll be asked to give only the word that goes with each clue. However, sometimes you will not get any clue. In this case you'll just be asked to remember as many words from the list as you can, and you can remember them in any order.

Sometimes it will be very difficult to remember all of the words in a list. Just remember to do your best and don't worry if you can't get them all. If you need to take a break, it will be best to do so after we are finished with a list.

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