EFFECTS OF ELECTROCONVULSIVE THERAPY ON IMPLICIT AND EXPLICIT MEMORY

by

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M.A. Carleton University, Ottawa, 1988

THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

In the Department of

PSYCHOLOGY

SIMON FRASER UNIVERSITY

April, 1998

0-612-37690-7

Abstract

The effects of electroconvulsive therapy (ECT) on the strength and duration of implicit and explicit memory was assessed in 30 patients with different diagnostic backgrounds including: major depression, bipolar disorder, schizophrenia, and dementia. The same study cues, study instructions, and retrieval cues were used; only the retrieval instructions (i.e., implicit and explicit) varied. Two orienting or study conditions were used; a semantic (rating pleasantness of words) and a non-semantic (counting the vowels in words) condition. Participants studied the to-be-remembered (TBR) words under both these study conditions. Retention was assessed after delay periods of 15, 90, and 180 minutes using a stem-completion task. Subjects were tested prior to the administration of the first ECT and also on the day of the sixth ECT treatment. Patients receiving explicit memory instructions recalled significantly fewer TBR words after ECT as compared to before ECT, their recall was significantly better for words studied in the semantic than non-semantic study condition, and their recall deteriorated significantly from the 15 to the 90 and from the 90 to the 180 minute delay period, both before and after ECT. On the other hand, patients receiving implicit retrieval instructions performed equally well before and after ECT (i.e., completed word-stems with TBR words as opposed to non-TBR words), they performed equally well in the semantic and non-semantic study conditions, and although their performance deteriorated from the 15 to the 90 minutes delay period, it did not deteriorate from the 90 to the 180 minute delay period, in fact after ECT their performance improved significantly from the 90 to the 180 minute delay period. These findings support the view that implicit and explicit memory are governed by different underlying mechanisms.

Acknowledgements

I wish to express my appreciation to my research committee for their help in seeing me through my dissertation: to Barry Beyerstein for his continuing support and feedback which was always given in a positive and encouraging manner, to Peter Graf for his valuable contribution in the conceptual and theoretical aspects of my research, to Paul Sungaila for his guidance in almost every aspect of this endeavor, and to Steve Hart for his input in the statistical analysis of the results. A heartfelt thanks to Ray Koopman for his expertise in statistical analysis and in making himself available for consultation whenever I needed him.

I would also like to thank the directors of Sunrise Pavillion and Cloverdale Senior's Center, Traci Smith and Steven Whalley respectively. Thanks to Dr. Kang, director of ECT department at Riverview Hospital. Thanks to all the doctors for completing the depression scale, nurses, and ECT crew at Riverview and St. Vincent Hospital who helped coordinate data collection.

To all the men and women who shared and participated in this research project I am indebted, for without their involvement this dissertation would not have been possible.

Finally, I wish to thank my family members whose love, support, and patience has been of particular importance to me: Vishal, my son, Prasanna, my niece, Pratap, my husband, thanks a lot.

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Introduction

The study of amnesia has greatly aided our understanding of the organization of memory and its neurological foundations. Amnesic[1] patients typically exhibit impaired recall and recognition performance on tests of memory. Nonetheless, they often demonstrate a preserved capacity to acquire and retain certain kinds of information or skills; for example, they can learn and retain perceptual-motor and cognitive skills at about the same level as normal subjects (Baddeley, 1982; Cohen & Squire, 1980; Corkin, 1968; Milner, 1962). Amnesic patients also exhibit normal priming[2] effects (Graf, Squire, & Mandler, 1984; Jacoby & Witherspoon, 1982; Warrington & Weiskrantz, 1970, 1974).

Early demonstrations of preserved memory functions in amnesic patients were reported in the landmark experiments with the amnesic patient H.M. whose memory problems were the result of temporal lobe surgery. Post-surgically, H.M. could learn a number of perceptual-motor skills, such as mirror tracing and rotary pursuit, at about the same rate as normal subjects. However he was unable to report verbally at a later time that he had engaged in these tasks, despite the fact that his performance showed the effects of the earlier practice (Milner, Corkin, & Teuber, 1968). Compared to normal control subjects, however, H.M. showed less of this priming effect.

In 1968 and 1970, Warrington and Weiskrantz gave amnesic patients (3 with Korsakoff's syndrome and 1 with a temporal lobectomy) a list of words to read and later presented them with three-letter word-stems and word-fragments in which some letters of

[1] "Amnesia" is a neurological disorder characterized by memory loss.
[2] "Priming" refers to the change in performance, typically facilitation, of a task as a result of being recently exposed to it.

the printed words were missing. They found that the probability of identifying word-fragments was higher for words that were previously studied, compared to those that were not presented previously. Somewhat surprisingly, at the time, the performance of amnesic subjects was found to be equivalent to that of normal subjects. These priming effects were apparent despite the patient's failure to discriminate previously presented stimuli from new ones in a recognition memory test, and despite their failure to recall the words in a free-recall test. Although amnesic subjects exhibited normal priming at times, there were other times when they showed impaired performance. This was later clarified when it was found that they showed normal priming effects when they received indirect or implicit retrieval instructions and showed impaired performance when given explicit retrieval instructions (Graf et al., 1984; Shimamura & Squire, 1984). Thus it became apparent that retrieval instructions play a crucial role in priming.

Experiments of the foregoing kind with amnesic patients led researchers to conclude that some form of memory for the original input had been preserved at near-normal levels despite patients' inability to recall or recognize these materials at a conscious level. These observations raised fundamental questions concerning the nature of memory. Researchers sought to understand how those memories for which people had explicit awareness differed from those which were accompanied by no subjective awareness, but which could nonetheless be shown to affect subsequent behaviors. Several experimental paradigms to explain these research findings and theoretical positions were developed.

The purpose of the present study was to examine the effects of electroconvulsive therapy (ECT) on implicit and explicit memory. In the sections to follow, the historical development of research in implicit and explicit memory will be reviewed. Next, the characteristics of priming in normal and amnesic subjects will be discussed, followed by a review of the theoretical underpinnings of implicit and explicit memory. Thereafter, the relationship between ECT, depression, and implicit and explicit memory will be highlighted. Finally, a detailed description of the present study will be presented, together with an explanation of how the background review relates to the present work.

Historical Background of Implicit and Explicit Memory Research

An influential paradigm put forth by Graf and Schacter (1985) and Schacter (1987) states that there are two fundamentally different ways in which memory for prior experiences can be expressed, these are referred to as *implicit memory* and *explicit memory*. Explicit memory refers to the intentional recollection of previous experiences, while implicit memory is inferred from the fact that a previous experience influences subsequent performance in situations that do not require conscious or deliberate recollection of that experience (Graf & Schacter, 1985). The terms "implicit memory" and "explicit memory", then, are descriptive labels that refer to the different ways in which the influence of past experiences can be expressed.

The concepts of implicit and explicit memory, however, are not entirely new. For decades researchers have been intrigued with the distinction between conscious and unconscious mental processes. Although they did not actually use the terms implicit and explicit memory, they did describe situations in which memory for past experiences was expressed in the absence of conscious recollection. Different terms that have been used to delineate these two types of memories include, direct and indirect memory (Johnson & Hasher, 1987), episodic versus presemantic memory (Tulving, 1972, 1983), intentional versus automatic memory processes (Jacoby, 1984), and procedural versus declarative memory (Squire, 1987). The terms implicit and explicit have become prominent in the past decade because they capture underlying distinctions between conscious and unconscious memory processes which can be studied with relative ease experimentally.

When Graf and Schacter (1985) introduced the concepts of implicit and explicit memory, they stated that implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection; explicit memory is revealed when performance on a task requires conscious recollection of previous experience. Although "awareness" or "consciousness" is a key element that differentiates the two types of memories, the term "conscious recollection" is potentially confusing. Consciousness (or lack of it) is difficult to define and it is not universally agreed as to what essential features constitute consciousness and unconsciousness. Researchers use these terms liberally but they rarely define precisely what they mean. As a result, different researchers use them in different ways.

Schacter (1989) attempted to clarify this confusion. He proposed two ways in which these terms could be used. First, conscious recollection can refer to *intentional* retrieval of recently studied material, i.e., when the subject deliberately or voluntarily "thinks back" to a learning episode and searches for the target information (the "intentionality criterion"). Used in this sense, the term refers to the way in which retrieval is initiated (the subject deliberately tries to remember the studied items). Second, conscious recollection can refer to the phenomenological experience associated with the output of the retrieval process: a "recollective experience" (Tulving, 1983). This involves awareness of remembering which includes a re-experiencing of the study episode. Following from the first usage, the notion that performance on a task can be facilitated "in the absence of conscious recollection" (Graf & Schacter, 1985) means that performance can be influenced by recently studied information, even though the subject does not "intentionally" think back to the study episode. Alternatively, when conscious recollection is used in the second sense, the assertion that performance facilitation occurs "in the absence of conscious recollection" implies that subjects are not aware that the responses they have produced were acquired during a prior episode (by contrast, in explicit remembering, subjects are aware that the image or proposition that came to mind is a product of previous experience). Schacter, Bowers, and Brooker (1989) point out that the second usage - that is, presence or absence of recollective experience (also referred to as awareness versus unawareness of remembering) - poses a problem because it is difficult to ascertain whether or not subjects lack recollective experience or awareness of remembering at the time of testing. Schacter et al. (1989) therefore prefer to use the terms "consciousness/ unconsciousness" in the first sense, that is, intentional versus unintentional retrieval processes. The present study adopts the terms "conscious" and "unconscious" in the sense suggested by Schacter et al. because it is possible to influence whether or not subjects deliberately think back to the study episode. This can be achieved by means of retrieval instructions which ask them either to think back to the study episode or not.

Although implicit retrieval instructions may not direct subjects to think back to the study episode during an implicit task, the argument is that there is nothing to actually prevent them from doing so. This issue is especially important when normal subjects are involved. However, in the case of amnesic patients, performance on implicit tasks is not influenced by conscious retrieval strategies because these processes are, by definition, impaired in such individuals. However, there is still a possibility that unconscious processes facilitate explicit remembering, but again this is not an issue because, despite such facilitation, amnesic patients' performance on explicit tasks is usually quite impaired.

Manifestations of implicit memory have come from studies employing a variety of experimental paradigms. These include: priming (e.g., Gardner, Boller, Moreines, & Butters, 1973; Graf, Shimamura, & Squire, 1985), savings during relearning (e.g., Ebbinghaus, 1885, in Tulving, 1995; Slamecka, 1985), effects of subliminally encoded stimuli (e.g., Eriksen, 1960; Poetzl, 1960), learning and conditioning without awareness (e.g., Hull, 1933; Thorndike & Rock, 1934). Of all these, priming has been the most thoroughly researched as the priming paradigm is more amenable to comparisons between explicit/direct and implicit/indirect tests. It is to this research that we now turn.

Priming

The bulk of research on implicit memory is comprised of studies of priming. Priming refers to the change in performance (typically facilitation) of a task as a result of being recently exposed to it. Priming can occur independently of any conscious or explicit recollection of a previous encounter with a stimulus (Schacter, 1992).

Data generated from priming studies indicated that repetition priming effects on implicit memory tests could be experimentally dissociated from explicit recall and recognition in a number of ways. For example, several studies demonstrated that variations in level or type of processing of stimulus information have different effects on priming and explicit remembering. Similarly, changes between study and test sessions in modality of presentation or other types of surface information produced differential effects on implicit and explicit memory. More recently, researchers have become interested in developmental differences between the two forms of memory and in differential effects due to aging, neurological conditions, and emotional or pharmacologically induced states. Although dissociations between implicit and explicit memory tasks have been reported, there have also been demonstrations of parallels between implicit and explicit tasks (e.g., Jacoby, 1983; Jacoby & Witherspoon, 1982). These results suggest that the two kinds of memory are not entirely independent and that they may share common processes and/or that they can influence each other. Much work remains to be done to elucidate the exact nature of these influences.

The Nature of Priming in Amnesic Subjects

Preserved ability to exhibit priming has been demonstrated in patients with a variety of memory disorders; for example, post-traumatic amnesia (Schacter, 1985; Shimamura, 1986), Korsakoff's syndrome (Albert, Butters, & Levin, 1979; Cohen & Squire, 1981), neurodegenerative disorders such as Alzheimer's disease and Huntington's disease (Butters, Heindel, & Salmon, 1990; Moscovitch, Winocur, & McLachlan, 1986), anoxia or ischaemic episodes (Graf et al., 1984; Graf, Shimamura, & Squire, 1985), encephalitis (Warrington & Weiskrantz, 1978), and medial temporal lesions (Nissen, Cohen, & Corkin, 1981). A few studies have also investigated the relationship between implicit and explicit memory using ECT-induced amnesia (Graf et al., 1984; Squire, Cohen, & Zouzounis, 1984; Squire, Shimamura, & Graf, 1985).

Subsequent to the works of Warrington and Weiskrantz and the H.M. studies, which set the direction for future research into the underlying processes of amnesia, a stream of research followed that not only improved our understanding of the amnesic syndrome, but also shed light on the nature of implicit and explicit memory processes.

Researchers became interested in investigating the conditions under which priming could or could not be observed in amnesic and normal subjects and could be dissociated from performance on explicit memory tasks. They manipulated a variety of experimental variables and studied their effects on subjects' performance on implicit and explicit tasks. From this, they were able to make inferences about the nature of the mechanisms underlying implicit and explicit memory.

Implicit Instructions. Priming is observed to be spared in amnesic patients only when subjects are given implicit retrieval instructions, although there are instances when priming is not observed even under these conditions (Squire, Shimamura, & Graf, 1987). Researchers found that when amnesic subjects were given explicit instructions to recall previously studied material, their performance was impaired; but when they were given implicit instructions contained in requests to respond with the first words that came to mind, their performance was normal (Gardner et al., 1973; Graf et al., 1984). Thus retrieval instructions play a crucial role in determining how memory will be affected.

Level or Type of Processing (LOP) at Study. Squire et al. (1987) showed that manipulations of study conditions (semantic, which focussed attention on the meaning of the stimulus words versus nonsemantic, which focussed attention on the structural aspects of the stimulus words) did not affect priming on word completion tests in amnesic patients. However, performance on explicit memory tests (recognition) was affected by the orienting condition at study, with performance being better in the semantic than nonsemantic condition. Similarly, Graf and Mandler (1984) found that whereas priming on word completion was normal, it was not affected by manipulations of study condition, but recognition performance was better in the semantic than nonsemantic condition. These findings suggest that some of the processes involved in priming differ from those involved in explicit remembering; i.e., priming appears to be automatic and not influenced by elaborative processing, while the opposite is true of explicit memory. One study, however, found effect of study condition on stem completion performance (Graf et al., 1984).

On the basis of this research it has been suggested that implicit tests are largely perceptual in nature, either in terms of the representational systems they activate or in terms of the processes they evoke. For example, Schacter (1990) and Tulving and Schacter (1990) suggested that implicit tests are predominantly dependent on a presemantic perceptual representation system while explicit tests are dependent on an episodic/semantic system.

Time Course of Priming in Amnesia. It was previously believed that priming is relatively short-lived in amnesic patients. This conclusion was based primarily on findings that these patients did not show priming on fragment completion and word completion tests when tested at long delay periods (Graf et al., 1984; Shimamura & Squire, 1984; Squire et al., 1987). However, Squire et al. (1984) showed that amnesic patients had the capacity for acquiring and retaining skills (such as reading mirror-reversed text) even after 35 days. Similarly, Tulving, Hayman and MacDonald (1991) showed that the profoundly amnesic patient K.C. exhibited normal and extremely long-lasting priming on a fragment completion task, even though he showed no explicit memory. He showed little or no reduction in priming over a period of 12 months. MacAndrews, Glisky, and Schacter (1987) showed that patient K.C. and another severely amnesic patient showed priming after a one-week delay period on a conceptual priming task that involved solving sentence puzzles. Cave and Squire (1992) demonstrated normal and long-lasting priming effects (over a seven-day retention interval) on a picture-naming task.

Most studies reporting long-lasting priming effects in amnesia have been carried out with patient K.C. To assume their generality, these findings need to be replicated with a broader range of amnesic patients. Hence, resolution of the debate over how long priming effects last in amnesic patients awaits further research.

Priming Across Sensory Modalities. Priming effects can be found in both within-modality and across-modality conditions, but the magnitude of priming is generally larger in the within-modality condition. Research indicates that amnesic patients show normal word completion priming not only when study and test materials are presented in the same modality, but also when the study list and the test items are presented in different sensory modalities (Graf & Mandler, 1984; Graf et al., 1985; Jacoby & Dallas, 1981; Kirsner, Milech, & Standen, 1983; Roediger & Blaxton, 1987). These findings contradict the view that priming activates only sensory-specific representations (Jacoby, 1983b) and show that priming can activate representations across sensory modalities.

Priming Across Semantic Boundaries. Priming effects are observed even when cues which are themselves not presented during study are presented during the testing phase - that is, cues that are semantically related to the study material - are presented during the testing phase. Shimamura and Squire (1984) presented amnesic patients with words for study (e.g., BABY) and later asked them to "free associate" to semantically related words (e.g., CHILD). Their findings indicated that intact priming occurred for semantic associates (i.e., CHILD). Similarly, Graf et al. (1985) reported normal priming when subjects were presented related words (e.g., uncle, sister, aunt) intermixed with other words and later asked to give eight exemplars in response to category names (e.g., relatives). These studies suggested that priming is not only restricted to activation of perceptual representations but that priming can activate semantic representations as well.

Priming of Unfamiliar Material. Initially, it was thought that amnesic patients could exhibit priming only for familiar words, pictures, or semantic associates. It was assumed that priming effects in amnesia are dependent on the activation of preexisting information. Early studies indicated that priming in amnesic patients was either absent or impaired for novel verbal stimuli, such as pseudo-words in stem completion tasks (Diamond & Rozin, 1984) and perceptual identification tests (Cermak et al., 1985).

Recent studies have reported that amnesic patients do exhibit intact priming for non-words on lexical decision tasks (Gordon, 1988; Smith & Oscar-Berman, 1990), on newly acquired associations (Graf & Schacter, 1987; Shimamura & Squire, 1989), and on perceptual identification tasks (Cermak, Verfaellie, Milberg, Letourneau, & Blackford, 1991). Gabrieli and Keane (1988) reported normal non-word priming effects on a perceptual identification task in patient H.M., despite near-chance levels of recognition memory. Musen and Squire (1991) reported repetition effects in amnesic patients for nonwords on a reading task. Both normal control and amnesic patients were given a list of words to read. Reading time improved as a consequence of repetition; moreover, non-word reading time showed greater improvement than did word reading time for both amnesics and controls.

Some investigators have demonstrated preserved priming for other kinds of novel information, such as repeated but unfamiliar melodies (Johnson, Kim, & Risse, 1985). Intact priming was also observed in patient H.M. for abstract drawings (Gabrieli, Milberg, Keane, & Corkin, 1990) and for abstract objects (Schacter, Cooper, & Delaney, 1990). Thus it was established that priming is not restricted to activation of preexisting representations.

Priming of Nonverbal Material. Priming effects in amnesic patients have also been observed in studies using nonverbal materials, including novel objects (Schacter, Cooper, Tharan, & Reubens, 1991) and dot patterns (Gabrieli et al., 1990; Musen and Squire, 1992). Cave and Squire (1992) found normal priming of picture-naming latency which persisted over a seven-day retention interval in a mixed group of amnesic patients. Schacter et al. (1991) showed intact priming of novel objects in a possible/impossible object decision task in which subjects studied drawings of novel objects, half of which are structurally possible and half of which are structurally impossible. Subjects were then given brief exposures of studied and nonstudied objects and asked to make "possible/impossible" decisions. Priming for novel nonverbal material has been obtained consistently in amnesic patients.

Effects of Study-to-Test Changes in Surface Features. Priming in amnesic patients appears not to be sensitive to study-to-test changes in specific surface features of target material. Kinoshita and Wayland (1993) demonstrated that priming effects on a fragment completion task were the same when surface features of target words (handwritten vs. typed) were the same at study and test, compared to when they were different.

Priming in Normal Subjects

Priming effects have also been reported in normal subjects. The characteristics of priming in normal subjects are as follows.

Processing Differences at Study. Investigators have shown that recall and recognition benefit substantially more from semantic elaboration during study that focuses subjects' attention on meaningful properties of a word (e.g., judging the semantic category to which a word belongs, or judging the pleasantness of a word) than they do from nonsemantic study that focuses attention on the physical features (e.g., counting the number of vowels in a word). By contrast, performance in normal subjects on implicit memory tests does not benefit from semantic processing as opposed to nonsemantic processing (Graf & Mandler, 1984; Graf, Squire, & Mandler, 1984; Jacoby & Dallas, 1981). These studies used word completion, where word stems could be completed to form many different words. Similarly, Schacter and Graf (1986) found that variations in degree and type of elaboration have large effects on explicit/direct tests but had little or no effect on implicit/indirect memory tests. Schacter et al. (1990) reported that object decision priming is observed only following tasks that require encoding of information about the global structure of target objects, but not following tasks that require generating semantic elaborations. However, generating semantic elaborations greatly enhanced subsequent explicit memory performance. These findings suggest that implicit memory tasks such as word completion are relatively automatic since they are not affected much by declarative or elaborative strategies.

Squire et al. (1987), however, reported that manipulation of orienting condition during study (semantic vs. nonsemantic) affected performance of normal subjects but not amnesics (Korsakoff's patients) on two kinds of stem completion tasks (fragment completion and stem completion with unique solutions). Specifically, healthy control subjects performed better on fragment completion and stem completion tests (with multiple solutions) in the semantic condition than in the nonsemantic condition, but amnesic patients performed similarly in these two conditions on these implicit tests. Furthermore, in the nonsemantic condition, the control subjects performed similarly to the amnesic subjects. Squire et al. (1987) concluded that declarative retrieval strategies were mediating the performance on the implicit task of the control subjects. Similarly, Challis and Brodbeck (1992) and Brown and Mitchell (1994) in their reviews of previous investigations of LOP variable reported significant effect of this variable. Hence, it appears, as noted above, that implicit and explicit memory may share similar processes.

Studies that have examined the effect of generating versus reading words during study (the generation effect) have reported that explicit memory for words that were generated at the time of study (e.g., political killer - assa__n) was more accurate than for words that were simply read during study (e.g., political killer - assassin) (Slamecka & Graf, 1978). A striking reversal was observed for implicit tests such as word identification (Jacoby, 1983a; Winnick & Daniel, 1970), fragment completion (Blaxton, 1985), and lexical decision (Monsell, 1985) where priming effects were greater in the read than in the generate condition. In fact, no priming was observed in the generate condition.

However, more recent findings have demonstrated generation effects on implicit tests. For example, Bassili, Smith, and McLeod (1989) and Schwartz (1989) reported generation effects on word- and picture-fragment completion, Masson and McLeod (1992) and Toth and Hunt (1990) found generation effects on word identification. Similarly, a processing effect on implicit tests has been reported by Challis and Brodbeck (1992) and by Reingold and Merikle (1991). Some researchers therefore suggest that although implicit tests may be predominantly perceptual, they can also involve conceptual processes (Roediger & Srinivas, 1993). Others have argued that since these effects are observed on implicit tests only when normal subjects are used, this shows that performance of normal subjects on implicit tests can be contaminated by explicit or conscious strategies (Squire et al., 1987).

Retention Interval. Initial failures to observe long-lasting priming on stem completion (Graf & Mandler, 1984) led to the belief that priming is short-lived. This conclusion appears to be incorrect since Roediger et al. (1992) found that when word fragments and stems were constructed from the same set of target materials and tested under identical experimental conditions, long lasting (one week) priming effects were observed for both fragments and stems.

Studies using stem completion tests with stems that have unique completions found that priming effects lasted at least 4 days (Squire et al., 1987). Other studies with normal subjects using word identification tests (Jacoby & Dallas, 1981; Jacoby, 1983) and lexical decision tests (Scarborough et al., 1977) have also reported persistence of priming effects over similar time intervals.

Resistance to forgetting, however, is not well replicated and may depend on a number of factors. For example, certain tasks such as stem completion may be more prone to forgetting than perceptual identification. Other factors accounting for variability in persistence of priming on implicit tests are: encoding conditions and number of possible completions of test cues. With regard to encoding conditions, the role of attention at encoding has been suggested to produce longer-lasting priming effects. Forster and Davis (1984) reduced the role of attention in the initial encoding of an item by masking the first presentation of repeated stimuli in a lexical decision paradigm. They observed that priming decayed rapidly as a function of the number of items intervening between first and second presentation of a word, reaching chance when 17 items intervened. Lexical decision studies in which the role of attention was not reduced reported persistence of priming over similar or even longer delay periods (e.g., Scarborough et al., 1977).

With respect to the role of cueing conditions in retention interval, Squire et al. (1987) showed that persistence of priming in word completion tests was inversely related to the number of possible completions of the test cue. As described above, stems and fragments with 10 or more completions were more susceptible to decay than those with one possible completion. Schacter and Graf (1986a) further showed that if contextual conditions which are present at encoding are reinstated at the time of testing (reinstating a word that had been associated with the to-be-completed word when it was studied) then priming effects last over 24 hours.

Retention interval effects have also provided a basis for differentiating implicit from explicit measures of memory. Researchers have manipulated the interval between study and test presentation and showed that performance on implicit tasks is slower to decay than performance on explicit tasks. These findings have been reported in studies involving delays from minutes to an hour, using perceptual identification tasks (Feustel, Shiffrin, & Salasoo, 1983) and lexical decision tasks (Moscovitch, 1985). Studies that involved longer retention intervals of 24 hours to 7 days also reported dissociations between implicit and explicit tests (Jacoby & Dallas, 1981; Tulving, Schacter, & Stark, 1982. Similarly, effects of prior exposure on affective preference persisted after a week (Seamon, Brody, & Kauff, 1983). Savings effects in reading geometrically transformed text were found at 2 weeks (Moscovitch et al., 1986) and at 3 months (Cohen & Squire, 1980) in memory-impaired subjects and at a year in normal subjects (Kolers, 1976). Savings effects in maze learning, pursuit rotor performance and jigsaw puzzle assembly were observed after a week in Korsakoff amnesics (Brooks & Baddeley, 1976). In the same studies, performance on direct measures of memory decayed more rapidly than performance on indirect measures. These results have been taken as evidence of dissociation between implicit and explicit memory.

Study-to-Test Changes in Modality of Presentation. It was earlier believed that visual word priming is largely modality specific. Priming in word identification and word completion tests was reduced and sometimes eliminated by study-to-test changes in modality of presentation, even though modality changes did not have an impact on explicit memory tests (Jacoby & Dallas, 1981; Roediger & Blaxton, 1987). For example, Jacoby and Dallas (1981) found that changing the modality of presentation from study (auditory) to test (visual) severely attenuated priming effects on word identification performance but had little or no effect on recognition performance (explicit test). Similarly, other researchers found that priming effects on a stem completion test (Graf et al., 1985) and a word-fragment completion test (Roediger & Blaxton, 1987) were reduced by study-to-test shifts in modality, whereas cued-recall (explicit test) (Graf et al., 1985) and recall and recognition (explicit tests) (Roediger & Blaxton, 1987) were not significantly affected. Other studies have however, have reported cross-modality priming on various implicit tests, for example, word identification (Clark & Morton, 1983), fragment completion (Blaxton, 1989), and stem completion (Rajaram & Roediger, 1993). Within-modality priming, however, is generally twice that observed across-modality.

Priming of Unfamiliar Material. With regard to priming of novel verbal material, studies have shown that non-word (pseudo-word) priming on lexical decision tasks, although significant, is exceedingly transient (Bentin & Moscovitch, 1988; Scarborough, Cortese,

& Scarborough, 1977). By contrast, longer-lasting effects have been observed with priming of newly acquired associations between previously unrelated word pairs. Graf and Schacter (1985) presented subjects with unrelated word pairs (e.g., ship-castle) for study and later gave them a stem completion test in which the target stem was paired with either its study list cue (e.g., ship-cas___, same context condition) or with some other unrelated word (officer-cas___, different context condition). Graf and Schacter (1985) found significant priming of newly acquired associations, as indicated by higher completion scores in the same context than in the different context condition. Schacter and Graf (1989) reported that priming of newly-acquired associations, in contrast to explicit memory, exhibits modality specificity. Furthermore, it is little affected by elaborative and organizational encoding manipulations. However, in contrast to priming of familiar words, priming of new associations appears to involve some minimal degree of semantic study processing (Graf & Schacter, 1989).

Priming of Non-Verbal Material. With respect to visual object priming, priming effects have been reported in picture naming (Mitchell & Brown, 1988). Priming effects have also been reported in the possible/impossible object decision task, however, only for the possible objects in picture-naming (Biederman & Cooper, 1992) and in object decision (Cooper, Schacter, Ballesteros, & Moore, 1992).

Within-Modality Changes in Surface Features. Within-modality changes of surface information between study and test (changes in typeface or other features between study and test) have, however, yielded a mixed picture. Within the visual modality, priming effects on lexical decision, fragment completion, and reading tasks are reported to be highly sensitive to study-to-test changes in surface information (Kolers, 1976; Roediger & Blaxton, 1987; Roediger & Weldon, 1987). These studies also showed that recall and recognition are either unaffected or slightly affected by study-to-test changes in surface features. However, other studies reveal no such effects (Clarke & Morton, 1983; Biederman & Cooper, 1992). Graf and Ryan (1990) tested priming with a word identification task. Subjects were required either to rate the readability of the words at study (nonsemantic) or else they rated the words for pleasantness (semantic condition). The typeface was either held constant between study and test or else it was varied between these two conditions. The authors found less priming in the different-typeface than the same-typeface condition in the nonsemantic condition but found no effect of changing typeface following the pleasantness task.

Consistent evidence of within-modality perceptual specificity has been reported in studies of auditory word priming, where study-to-test changes in speaker's voice affect priming significantly (Schacter & Church, 1992). Finally, Roediger, Weldon, Stadler, and Reigler (1992) showed that priming on a word fragment completion test could be completely eliminated by presenting a picture of a word's referent rather than the word itself at the time of study. On the other hand, explicit memory was considerably better following study of the picture rather than the word.

Implicit Memory in Old Age

Normal aging produces a substantial decline in explicit memory on tests such as recall and recognition (e.g., Salthouse, 1988). With respect to implicit memory, Graf (1990) concluded that age differences on implicit memory tasks were very small, averaging around 4%. Similarly, Parkin (1993) summarized the literature, concluding that there is little deterioration in implicit memory across the adult life span. However, Light and La Voie (1993) reported the results of a meta-analytic study in which they concluded that, although implicit memory is more robust than explicit memory in older adults, there are nonetheless age differences in implicit memory. They found that older adults score lower on implicit tests than do younger adults. The inconsistency of these two conclusions may be due to the fact that whereas Parkin and Graf reviewed studies that examined implicit and explicit memory across the life span (with some studies including children as young as three years of age), Light and La Voie reviewed studies that compared the two types of memories in younger and older adults.

The general pattern that emerges when comparing performance of younger and older adults over several studies is that age differences in priming, although statistically not significant, often favour young adults on various tasks such as fragment completion (Light, Singh, & Capps, 1986), lexical decision (Moscovitch, 1982), category judgement (Rabbit, 1984), word stem completion (Java & Gardiner, 1991; Light & Singh, 1987), identification of degraded or briefly presented words (Light & Singh, 1987); homophone spelling (Howard, 1988), word pronounciation (Light & La Voie, 1992), and free association to a category name (Light & Albertson, 1989). In most these studies, performance of younger adults was superior to that of older adults on explicit tests such as free recall, cued recall, or recognition. Thus it appears that implicit memory is more robust than explicit memory with respect to memory impairment associated with aging.

Theoretical Approaches

At least three different theories have been suggested to account for the mechanisms underlying the two forms of memory, these are the activation theory, the processing view, and the memory systems view. The bulk of the debate, however, centers around the processing and the memory systems views because the activation theory has since been discredited.

Activation Theory. According to the activation theory, implicit memory represents the temporary activation of pre-existing representations or knowledge structures (Diamond & Rozin, 1984), whereas explicit memory involves the creation of new memory traces. For example, when subjects study the word TABLE, the pre-existing representation for TABLE is assumed to be activated automatically and to remain activated beyond the span of short-term memory. The activated representation is more readily available than a nonactivated representation and this provides the basis for priming on various tasks. An activated representation readily "pops into mind" on an implicit memory test but it contains no contextual information about an item's occurrence as part of a recent episode and therefore does not contribute to explicit remembering of the episode (Schacter, 1987). Activation is assumed to occur automatically and independently of the elaborative processing that is necessary to establish new explicit or episodic memory traces (Mandler, 1979, 1980). Amnesia is attributable to a consolidation failure that impairs the acquisition of all new memory representations that are usually acquired in a single episode. Intact priming in amnesia is assumed to be a result of spared activation processes that act on pre-existing memory traces, rather than the establishment of new memory traces which is thought to account for explicit remembering (Rozin, 1976).

This view of implicit and explicit memory was eventually discredited by data showing that priming effects extend beyond the limits of pre-existing representations. For example, Cermak et al. (1991), Gabrieli and Keane (1988), and Musen and Squire (1991) showed that amnesic subjects exhibit normal priming of nonwords. Graf and Schacter (1985) and Moscovitch et al. (1986) provided evidence for priming effects for new associations between previously unrelated words. Similarly, Johnson et al. (1985) demonstrated priming effects in amnesia for repeated but unfamiliar melodies. Although it may be the case that priming depends on the process of activation, it is clear that it is not restricted to the activation of pre-existing representations.

Overall with respect to aging, evidence supports the view that activation is spared in old age, whereas contextual processing is impaired. However, given the findings of intact priming of novel stimuli, this issue is again undecided. It is possible that once new representations have been formed, activation mechanisms account for priming. However, prior to that, some other processes are necessary to account for the observed priming of novel material.

Processing Theory. The basic notion of the processing theory is that a single memory system (i.e., episodic) mediates both implicit and explicit memory tests. Dissociations of performance on these tests reflect operations of different underlying processes.

Kolers postulated that memory is mediated by specific sensory-perceptual and conceptual analyzing processes that are engaged during encoding and retrieval of to-be-remembered material. Engaging in these operations during initial study increases the fluency and efficiency with which these operations can be carried out subsequently. Kolers' early theory shaped subsequent views of the processing account of memory. For example, the Transfer-Appropriate Processing theory (TAP) (Morris, Bransford, & Franks, 1977) postulated that performance on a memory test is determined by the degree of overlap between study and test processing. Together, these ideas suggested that performance on a memory test is facilitated to the extent that it engages the same set or similar set of cognitive operations as were used for a preceding study task (Graf, 1991; Graf & Ryan, 1990).

Following from this, specific kinds of processes that mediate implicit and explicit memory test performance have been postulated. For example, there is an assumption that most explicit tests draw on the encoded meaning of concepts, or on semantic and elaborative processing (Craik & Tulving, 1975; Jacoby & Craik, 1979). Hence they are sensitive to conceptual elaboration, but are insensitive to changes in surface features of material to be recalled. Most implicit tests, on the other hand, are assumed to rely on the match between perceptual operations between study and test (Graf, 1991).

Jacoby (1983) and Roediger, Weldon, and Challis (1989) explained differences in implicit and explicit memory performance by attributing them to data-driven/perceptual (implicit) and subject-driven/conceptual (explicit) processing. Conceptually-driven processes (i.e., top-down processes) reflect subject-initiated activities such as elaborating, organizing, and reconstructing. These tests are less affected by the physical match of stimuli between study and test condition. By contrast, data-driven bottom-up processes depend on the physical similarity between the material studied and the test items. Data-driven tests are initiated and guided by the information that is presented in the test materials (i.e., driven by perceptual properties of stimuli). This theoretical position allowed Roediger and his colleagues to account for the finding that semantic-elaborative study processing improves explicit but not implicit memory, whereas changes in modality and other physical features of target material affect implicit memory more than explicit memory. Although both explicit and implicit tests can have data-driven and conceptually-driven components, explicit memory tests typically draw more on conceptually-driven processes because the subject uses semantic-associative information to reconstruct the study episode mentally. In contrast, implicit memory tests draw primarily on data-driven processes because the subject focuses on external perceptual stimuli. Dissociations between data-driven and conceptually-driven memory tests would be expected as a consequence of the type of information (semantic-associative vs. perceptual) encoded in a prior episode.

Other researchers have explained similarities and differences between implicit and explicit memory test performance in terms of different processing distinctions; e.g., automatic versus controlled processing (Cermak, Verfaellie, Sweeney, & Jacoby, 1992), aware versus unaware processes (Mandler, 1980; Jacoby, 1984), integrative versus elaborative processing (Graf & Mandler, 1984; Light, 1991), and environmentally-driven versus subject-driven processing (Craik, 1983).

With regard to aging, Craik (1983) hypothesized that there should be age-related differences in memory on conceptually-driven tasks that require self-initiated constructive operations but offer little environmental support for retrieval (e.g., free recall), whereas, age-related differences should be minimal on tasks that are data-driven and provide substantial environmental support (e.g., perceptual identification). This hypothesis was supported in one study by Craik and McDowd (1987). However, studies that held environmental support constant by using the same cues for both implicit and explicit tests, varying only the retrieval instructions, also found that the magnitude of age-related differences was greater on explicit than implicit tasks (e.g., Howard, 1991; Light & Albertson, 1989; Park & Shaw, 1992). This suggests that the critical variable is not the amount of environmental support, but the intention to remember. When Park and Shaw (1992) held the intention to remember constant within a task while varying the amount of environmental support, they found that cued recall was higher in the young than in the old, but the age difference in priming was not stable. Furthermore, environmental support improved performance on both cued recall and word stem completion but the benefit from greater environmental support was the same across age. If anything, the young benefited more from it than did the old, thus underscoring the importance of the role of intentional remembering.

Multiple Memory Systems. The concept of separate memory systems evolved mainly from studies of brain-damaged patients who suffered various kinds of amnesia (Cohen, 1984; Schacter & Moscovitch, 1984; Warrington, 1979; Weiskrantz, 1987). A consensus emerged that the amnesic syndrome selectively affects the memory system responsible for conscious recollection but leaves the system responsible for implicit memory relatively intact. These findings led researchers to postulate various functional and anatomical distinctions between memory systems. This could explain the fact that implicit memory is relatively intact in amnesics whereas explicit memory is dramatically impaired (Schacter, 1985). Other distinctions between memory systems that have been postulated are skill learning versus conscious recollection (Moscovitch, 1982), integration versus elaboration (Mandler, 1980), presemantic versus episodic memory (Cermak, 1984; Schacter, 1990; Tulving & Schacter, 1990), and semantic memory versus cognitive mediation (Warrington & Weiskrantz, 1982). The episodic memory system is viewed as the basis for explicit remembering, while the semantic system is seen as responsible for performance of implicit tasks. Distinctions have also been made between perceptual representation systems (PRS) and episodic memory (Schacter, 1990; Schacter, Chiu, & Ochsner, 1993) and, in the past, between working memory and long-term memory (Baddeley, 1986).

Squire and Cohen (1984) proposed that conscious or explicit recollection is supported by a "declarative" (i.e., verbalizable knowledge) memory system that mediates the formation of new representations or data structures. By contrast, implicit learning phenomena, such as skill learning and repetition priming effects, are attributed to a "procedural" memory system that directs performance of skilled behaviors without the need for conscious recollection. In the latter system, memory is expressed through its ability to modify observable procedures or processing operations. The declarative system allows the individual to retain knowledge that a specific task has been learned. The procedural system permits acquisition and retention of how to perform a task and does not require declarative knowledge of the learned task (Squire & Cohen, 1984). The procedural system is assumed to be spared in amnesic patients (allowing normal acquisition of skills, post-traumatically). The declarative system is assumed to be damaged (resulting in impaired performance on explicit tasks).

Going a step further, researchers have postulated anatomically distinct brain structures associated with implicit and explicit memory. These views share the idea that explicit memory depends on the integrity of the medial temporal and diencephalic regions of the brain which are damaged in amnesia. These mechanisms can be tapped by traditional explicit tests of memory. The structures implicated include the basal forebrain, hypothalamus, anterior and dorsomedial thalamus, and parts of the mesial surface of the temporal lobe (Ostergaard & Jernigan, 1993). Another kind of memory which can be established and maintained independently of these brain regions, is thought to involve the posterior cortical regions of the brain. These systems are believed to remain intact in amnesia and are assumed to be tapped via implicit or indirect tests of memory (Squire et al., 1984).

Squire (1987), however, suggested that implicit memory is not a single entity but is composed of many information-processing systems which may be supported by different brain structures. He suggested that posterior cortical areas (association cortices) may be important for word priming effects, whereas the basal ganglia may be important for motor skill learning. Gabrieli et al. (1990) distinguished between a system involved in perceptual priming, which they suggest resides in the occipital cortex, and another involved in lexical-semantic priming, localized in temporo-parietal association cortex. They based their interpretation on the observation of spared perceptual priming in

Alzheimer's Disease (AD) patients who also show impaired lexical-semantic priming. They corroborated their finding with functional imaging studies that showed that occipital lobe metabolism is relatively intact in AD patients, although temporo-parietal function is consistently affected. Similarly, Schacter et al. (1991) suggested that the presemantic perceptual representation system, which is responsible for priming effects, consists of posterior cortical structures, particularly in inferior temporal areas, extrastriate occipital lobe, or parietal lobe, depending on the kind of representations primed.

Ostergaard and Jernigan (1993) used magnetic resonance imaging (MRI) in an attempt to assess the degree to which damage to different brain structures is related to priming and explicit memory functions. These researchers examined the caudate nuclei, the mesial temporal lobes, and the posterior temporo-parieto-occipital cortex in patients with Alzheimer's disease (AD), Huntington's disease (HD), alcoholic Korsakoff's (AK) syndrome, and anoxia induced amnesia compared with normal subjects. Thus they obtained a range of levels on both performance and anatomical measures. Priming effects were measured using a tachistoscopic identification task in which subjects were asked to identify words presented very briefly. The authors examined the relationship between the anatomical measures and performance of priming and recognition memory. They found that, relative to caudate and posterior neocortical damage, volume loss in the structures of the mesial temporal lobe was specifically related to poor recognition memory, whereas temporal limbic loss was associated with decreased priming.

With respect to aging and multiple memory systems, Mitchell (1989, 1993) proposed that only episodic memory is impaired in old age, whereas procedural memory is intact. Research evidence is not entirely consistent with this assertion however. It is not clear that procedural memory is entirely preserved or that all aspects of episodic memory are impaired in old age (Light & Burke, 1988). Charness (1987), Welford (1985) and Woodruff-Pak and Thompson (1988) have shown that some forms of procedural memory, for example, cognitive skill learning, motor skill learning, and classical conditioning, are not all spared in old age.

Although each of the foregoing approaches can accommodate certain phenomena, no single theoretical position accounts satisfactorily for all findings. Shimamura (1989) asserts that the debate between the transfer-appropriate processing and multiple systems views simply represents two different research perspectives. Processing interpretations are tested by manipulations of variables that are associated with encoding, storage, and retrieval of information. The memory systems approach evolved out of human and animal lesion studies in which memory impairment is associated with damage to specific areas of the brain. The two perspectives emphasize different features of the mechanisms involved in memory and do not necessarily conflict with one another. In fact, together, the two perspectives help delineate a more precise picture of both the structures and functions that contribute to memory performance and may be complementary to each other.

Shimamura suggests that the multiple systems view can, instead, be viewed as a multiple subsystems or components view in which numerous brain processes and structures are necessary for memory performance and one of these components (i.e., the hippocampus) is necessary for the expression of explicit memory, while the cortical system is necessary for the expression of implicit memory. The system that mediates explicit memory may depend in part on the cortical representations that are used by the implicit memory system, and vice versa.

An Integrated Model. Recently, Tulving has attempted to integrate the processing and the memory systems approaches into a comprehensive framework. Tulving (1995) combined the previous conceptual dichotomies of proposed memory systems and processes and identified at least five major categories of human memory, or memory systems, and a number of subcategories or subsystems. The major categories or systems he proposed are: a procedural memory system, a perceptual representation system or perceptual priming, a semantic memory system, a primary memory, and an episodic memory system. The operations of the procedural memory system are expressed as skilled behavioral and cognitive actions, e.g., skillful performance of various perceptual-motor and cognitive tasks such as reading text (Tulving, 1995). Semantic and episodic memory systems are sometimes categorized together as declarative (Squire, 1982) or propositional (Tulving, 1983). The semantic memory system makes possible the acquisition and retention of factual information and provides the individual with the material for cognitive operations. The episodic memory system enables the individual to remember his or her personal life history. Perceptual priming is a special form of perceptual learning. A perceptual encounter with an object primes or facilitates the perception of the same or a similar object on a subsequent occasion. Finally, the primary memory system (also known as the short-term/working memory) registers and retains incoming information in a highly accessible form for a short time after input.

According to Tulving (1995), implicit memory is the expression of stored information without awareness of its acquisition; i.e., the expression of *what* the individual has learned without necessarily remembering *how*, *when*, or *where* the learning occurred. Explicit memory, on the other hand, refers to the expression of what the person is consciously aware of as a personal experience (Tulving, 1995). Retrieval operations in the procedural, perceptual representation, and semantic systems are implicit, whereas those in the episodic and primary memory systems are explicit (Tulving, 1995).

Tulving further postulates that the relationship among the different cognitive systems is process-specific, that is, the relationship among systems depends on the nature of the processes involved. Specifically, 1) information is encoded into systems serially, 2) information in the different systems is held in parallel, and 3) information from each system and subsystem can be retrieved independently of other systems or subsystems. Information about the structural aspects of the stimulus, (e.g., words), is registered in the Perceptual Representation (word form) System (PRS). The products of processing in the PRS can be retrieved directly, as happens in priming experiments, or they can be forwarded to the semantic system for processing of the relations among the words and their meaning. The output normally reaches both the working (primary) memory and the episodic memory systems. The former allows further elaboration of the information in terms of various kinds of encoding and rehearsal operations; the latter computes the spatio-temporal and contextual coordinates of the incoming information in relation to already existing episodic information. The different systems are dependent on one another for the operations of interpreting, encoding, and initial storing of information.

Once encoding has been completed, different kinds of information about the same initial event are held in various systems in parallel. Depending on the nature of the information and the evolved properties of the system, access to different kinds of information about a given event is possible in any system, independently of what happens in other systems. This model has not been tested experimentally. It does, however, represent a fruitful attempt to integrate various empirical findings in a number of related domains.

Electroconvulsive Therapy and Memory Impairment

To date, most demonstrations of spared ability to learn new information have involved patients who are already amnesic. Few studies have used amnesic patients where amnesia was induced by a course of ECT treatment. Electroconvulsive therapy (ECT) used for the treatment of severe depression has long been known to produce amnesia. ECT causes transient impairment in memory, both anterograde and retrograde. That is, difficulty acquiring new information as well as difficulty remembering information acquired prior to the ECT treatment.

ECT-induced amnesia offers a unique opportunity to manipulate variables prior to the induction of amnesia and to compare memory performance before the onset of amnesia with performance after its onset. The notion that certain forms of memory might remain intact after ECT is worth exploring as this may shed further light on the neurological effects of ECT and may also, in the future, be useful in helping patients' functional rehabilitation by engaging intact implicit memory functions.

Although ECT is a widely used treatment for severe depression, there remain concerns about its possible side effects. ECT is known to cause various neuropsychological side-effects including retrograde and anterograde amnesia (Price, 1982; Squire, 1982b). Patients are typically disoriented and confused for 30-40 minutes immediately following bilateral ECT. They also exhibit anomia (Rochford & Williams, 1962), impaired perceptual aftereffects (Robbins, Weinstein, Berg, Rikin, Wecshler, & Oxley, 1959), and slowed choice reaction time (Pascal & Zeaman, 1951). These cognitive deficits are usually most intense in the minutes to hours following treatment.

In addition to these short-term cognitive impairments, some studies have reported that impairment of memory and concentration can persist for several months. For example, Halliday, Davison, Drowne, and Kreeger (1968) found that deficits in some verbal learning tasks persist for as long as three months. Similarly, Cronin et al. (1970) found that bilateral ECT was associated with greater deficits than unilateral ECT on the Weschler memory scales approximately four to six weeks after treatment. In contrast, however, Bidder, Strain, and Brunschwig (1970) found that performance returns to pre-ECT levels within 30 days after treatment. Similarly, Squire and Chace (1975) and Devanand, Verma, Tirumalasetti, and Sackeim (1991) found no evidence of specific learning deficits six to nine months after treatment. Similarly, Frith et al. (1983) found that, although real ECT, as compared to sham ECT, produced impairments of concentration, word list recognition, and learning in the hours following the treatment, these impairments were no longer detectable at a six month follow-up. Hence, it is now generally accepted that memory function is completely recovered within three to six months after ECT, although some memories (from the few weeks prior to, during, and shortly after the treatment) may be lost permanently.

ECT and Implicit Memory Research

Studies examining the effects of ECT on memory have concentrated primarily on tests of explicit memory. Consequently, very little is known about the effects of ECT on implicit memory. Despite profound retrograde and anterograde amnesia following ECT, there is certain evidence suggesting that some kinds of information can be acquired and retained normally, as is true in other forms of amnesia (Squire et al., 1984; Graf et al., 1984; Squire et al., 1985). Squire et al. (1985) used a stem-completion task. They presented word lists to patients 45 minutes, 60 minutes, 85 minutes, and 9 hours after the fourth, fifth, and the sixth ECT sessions. This study was designed to examine the time-course of recovery in learning after ECT. However, only one retention interval was used in the study (15 minute). These authors tested retention by measuring both recognition of the words and word completion ability 15 minutes after each presentation. They found that 45 minutes after bilateral ECT, recognition was no better than chance. Recognition memory increased to about 80% correct nine hours after ECT. However, patients exhibited normal priming on a word completion task 45 minutes after ECT and this did not change thereafter. This study focussed on the time course of recovery of memory after ECT. Similarly, Squire et al. (1984) showed that, despite retrograde memory loss (impairment in ability to recognize words they had learned to read in mirror-reversed format prior to and during the early part of a prescribed course of ECT), patients receiving ECT exhibited intact learning and retention of the mirror-reading skill that they had acquired before the administration of ECT. Graf et al. (1984) compared performance on three types of explicit tests (free recall, recognition, and cued recall) and on a stem-completion test. They used retention intervals of 0, 15, and 120 minutes to examine the time-course of decay of implicit and explicit memory. It was found that amnesic patients, including a group of eight who received ECT, were impaired on all three explicit tests of memory after the 15-minute delay period. In contrast, these patients performed like normal subjects on the word completion test. However, priming declined to chance level by the end of the 120-minute delay period.

Mechanisms Causing Cognitive Effects After ECT

The physiological effects of ECT that bring about cognitive changes are not well understood. Squire (1984, 1986) suggested that the temporal location of the shock electrodes affect the hippocampus and other medial temporal brain locations associated with memory. Similarly, Sackeim et al. (1991) proposed that pronounced memory impairment occurs after ECT because the hippocampus and other medial temporal brain locations associated with memory have lower seizure thresholds during ECT.

Fink (1980) and Christie, Whalley, Brown and Dick (1982) used neuroendocrine data to show that, during the generalized grand mal seizure produced by ECT, there is a diencephalically-mediated synchronization that potentiates the monoaminergic pathways to the hypothalmus, there is also a concurrent activation of monoaminergic pathways to other limbic areas. This specific activity in these areas of the brain associated with both depressive symptoms and mood and also certain kinds of memory (particularly explicit memory) may account for the therapeutic effects of ECT on depression and may also explain the adverse side effects of ECT on certain kinds of memories (especially explicit ones). Caution must be exercised in accepting these proposed explanations, however, because other researchers have suggested that ECT causes diffuse neuronal changes (e.g., Weiner, 1984). Reports that suggest a role for these variables in mediating the adverse cognitive effects associated with ECT are preliminary and the results await replication.

Depression and Implicit Memory

The study of the relationship between implicit and explicit memory and depressive states follows the same general lines as with other populations; that is, researchers tend to select one or two types of implicit and explicit tasks and compare results of the tests across the variables of interest. Roediger and McDermott (1992) summarized the results of these studies (Hertel & Hardin, 1990; Denny & Hunt, 1992; Elliot & Greene, 1992; Watkins, Mathews, Williamson, & Fuller, 1992). The conclusion was that depressive mood does not affect the amount of priming seen on several implicit memory tests under conditions for which marked effects are shown on explicit tests. All except the Elliot and Greene study reported equal priming for depressed and control subjects on implicit measures of retention. In the three studies that reported preserved priming in depressed patients, each one used different explicit as well as implicit memory tests: Hertel and Hardin (1990) used recognition (explicit) and homophone spelling (implicit) tests, Denny and Hunt (1992) used free recall (explicit) and word fragment completion (implicit) tests, and Watkins et al. (1992) used cued recall (explicit) and word stem completion (implicit) tests. This wide range of implicit and explicit tests used in these studies adds weight to the conclusion that there is a generalized effect of priming across a variety of implicit tasks.

The results of the Elliot and Greene (1992) study were, as noted above, in disagreement with the other studies cited. Elliot and Greene using homophone spelling and word stem completion tests found that depression affected performance on both explicit and implicit memory tasks. Roediger and McDermott (1992) suggest that this discrepancy may be partly due to the fact that Elliot and Greene used normative data from the literature to estimate baselines for implicit memory tests, whereas the other studies obtained their baselines by comparing studied and non-studied items. Roediger and McDermott suggest that the former method of obtaining baseline performance is problematic, particularly when individual differences among subjects are being examined. There is no guarantee that the normative baselines accurately characterize true baseline performance for either group being compared. If baseline differences exist, then any observed difference in priming could be illusory. Another reason for the discrepancy could be that the severity of depression in patients varied across studies. However, this was only true for the Hertel and Hardin (1990, experiment 3) study, which, unlike the other studies, did not use severely depressed patients. There is evidence that severity of depression may contribute to the degree of cognitive impairment observed in patients (e.g., Sternberg & Jarvik, 1976). However, despite these possibilities, there is also the possibility that the Elliot and Greene (1992) conclusion, that priming is impaired in depressed patients, is the correct one. Further research under better controlled conditions is required to clarify the relationship between depression and priming.

Of interest to the present study is the fact that memory dysfunction is a common consequence of both depression and ECT. Thus, interpretation of studies reporting amnesia following ECT are complicated by the fact that memory impairments are also associated with depression itself (Cronholm & Ottoson, 1961; Sternberg & Jarvik, 1976) and that they typically improve with recovery from depressed mood. Therefore, pre-treatment levels of functioning cannot be taken as representative of pre-morbid levels. Moreover, memory impairment at the end of treatment might reflect failure to recover from depression rather than adverse sequela of ECT (Frith et al., 1983). Thus, in order to gain a better understanding of the effects of ECT on memory, it is crucial to separate the effects of ECT from those of changes in the level of depression. Most studies to date have failed to do this.

The Present Study

The purpose of this study was fourfold: (1) to examine the effects of ECT on the strength and time-course of implicit and explicit memory performance in a group of geriatric in-patients; (2) to investigate the relationship among ECT, implicit and explicit memory, retention interval, and study/orienting conditions; (3) to explore the relationship between both ECT and memory (implicit and explicit) and depression; and (4) to explore the degree to which attentional abilities mediate the effects of depression and ECT on implicit and explicit memory.

The present study departs from previous experiments that have examined the relationship between ECT and implicit memory in several ways. Of the earlier studies cited, one examined mirror reading skills, another looked at the time-course of recovery of priming after ECT, and the third examined the course of priming in ways that were different from the present study in a number of key aspects.

First, the work reported in this dissertation represents the only attempt to date to examine the effects of ECT on the strength and duration of the two types of memory by comparing pre-ECT to post-ECT memory performance. Second, since depression itself is known to cause impairment of memory, the present study was designed to separate the effects of ECT on memory from those due to depression. This was done by comparing pre-treatment performance with post-treatment performance and also by looking at post-ECT performance after partialling out the effects of pre-treatment performance. Third, in the present study, a stem completion task was used to examine performance on both implicit and explicit memory.

Another important feature of this study was that it held all variables - including study words, study instructions, study conditions, and retrieval cues - constant and varied only the retrieval instructions. Hence, implicit and explicit memory tests were operationally defined and distinguished from each other solely on the basis of the retrieval instructions. This minimizes variability in performance between implicit and explicit tasks due to variables other than retrieval instructions. Finally, baseline measures were collected by comparing performance on studied items with performance on unstudied ones at each delay period, rather than some set criterion, thus minimizing prior group differences.

An implicit memory task was operationally defined as one in which retrieval instructions did not make reference to the to-be-remembered (TBR) list - i.e., the retrieval instructions only referred to the retrieval task at hand. The dependent measure of interest was facilitation in task performance due to prior exposure to the target list. This was calculated by comparing performance following the relevant prior exposure to the target list to performance without exposure to the target list. An explicit memory task was operationally defined as one in which retrieval instructions made reference to the target event of studying the TBR list and the subjects were asked to complete the word stems with words from the study list. Successful performance was defined in terms of the number of stems completed with words from the study list.

Stem Completion Task

A stem completion task was used for several reasons. First, this test can be used both as an implicit and an explicit test by merely varying the instructions (Graf & Williams, 1987). This minimal difference between tests facilitates comparison of performance between explicit and implicit memory tests. Second, stem completion allows many possible completions, and each subject can readily come up with one completion and thus experience the positive effect of success. This is an especially important consideration with depressed patients who are generally known to exhibit cognitive and motivational deficits. When several completions are possible for each stem, priming is revealed by a bias in favour of recalling recently-studied words rather than non-studied words. In contrast, for cues that have only one possible completion (as with certain stem completion items, such as ONI____, and most fragment completion items, such as CA__ER__LAR), priming is indicated by an increase in the proportion of items that are completed. Using this type of cue has some disadvantages. First, performance is usually affected by possible response criterion differences. Second, these tests are administered under time-limited conditions (because, given enough time many subjects could eventually figure out the appropriate word for each cue) and thus there is a potential for the results to be confounded with speed of response (Graf & Williams, 1987). This is an important consideration, since depressed patients typically have retarded motor functions.

Study Conditions

Two study conditions were employed in order to examine their effects on implicit and explicit memory. The two study conditions differed in the type of processing they required. The non-semantic condition required subjects to focus on the structural aspects of the words rather than their meaning, while the semantic study condition required subjects to focus on the meaning of the word.

Primary Hypotheses

1. What are the effects of ECT on implicit and explicit memory?

a. It was hypothesized that the performance of the ECT group receiving explicit instructions would show significant deterioration when tested after the sixth ECT treatment compared to their performance prior to the first ECT treatment.

b. It was hypothesized that the performance of the ECT group receiving implicit instructions, however, would be similar on both, pre-ECT and post-ECT testing sessions (i.e., ECT would not impair implicit memory).

2. What are the effects of study condition manipulations on explicit and implicit memory following a course of ECT?

a. It was hypothesized that manipulation of study condition would affect performance in the explicit condition (i.e., performance on the explicit memory test would be better for words that were studied in the semantic compared to the nonsemantic condition).

b. It was hypothesized that the study condition manipulation would not affect performance in the implicit condition (i.e., performance of subjects receiving implicit retrieval instructions would be similar in the two study conditions).

3. What is the time course of decay in performance after the administration of ECT on implicit vs. explicit measures of memory?

a. It was hypothesized that performance of the group receiving explicit instructions would decrease significantly over the three delay periods. However, the current state of our knowledge does not permit exact predictions regarding the effect of delay period on performance of the group receiving implicit instructions.

Secondary Hypotheses

Out of clinical interest, the relationship between severity of depression and ECT was examined.

4. It was expected that there would be a significant decrease in severity of depression as measured by the Hamilton Depression Rating Scale following ECT, as compared to pre-ECT levels.

The relationship between severity of depression and memory was also explored.

5. It was predicted that the greater the severity of depression, the greater would be the impairment in explicit test performance. Depression was not expected to affect implicit test performance.

The relationship between ECT and attention was also examined.

6. It was expected that there would be significant deterioration in post-ECT attention

scores as measured by the Verbal Series Attention Test (VSAT) as compared to pre-ECT scores.

The relationship between attention and implicit and explicit memory was also examined.

7. It was expected that while explicit memory would be affected by level of attention, implicit memory would not.

Method

Participants

Thirty geriatric in-patients from Riverview and St. Vincent Hospitals who were scheduled to receive a course of ECT were recruited following institutionally-approved (by Simon Fraser University and Hospital Ethics committees) procedure for obtaining voluntary informed consent (consent form - Appendix A). The mean age of the experimental subjects was 68.4 years. The mean age of patients in the implicit group was 69.3 years (SD = 19.01) and in the explicit group it was 67.47 years (SD = 16.05). There were no differences in age between the implicit and explicit conditions. The diagnoses of the participants ranged from major depression or bipolar disorder to schizophrenia and/or dementia. In the implicit group there were 12 subjects with a diagnosis of major depression, 2 patients with bipolar disorder, and 1 patient who did not have a diagnosis of depression. These patients also had concomitant disorders as follows: 9 patients with psychotic features, 2 patients with a diagnosis of dementia, and 3 patients with a history of substance abuse disorder. In the explicit group there were 12 subjects with a diagnosis of major depression, and 3 patients with bipolar disorder. These patients also had concomitant disorders as follows: 4 patients with psychotic features, 3 patients with a diagnosis of dementia, and 6 patients with a history of substance abuse disorder. There were no group differences (between subjects in the implicit versus explicit conditions) in diagnostic status. There were 10 females and 5 males in the implicit, as well as, the explicit condition (20 females and 10 males in total). Only those subjects participated who spoke English fluently and had not received ECT in the six months prior to testing.

A control group of non-psychiatric subjects, matched for age and gender, was also recruited. Subjects in the control group were recruited from the Sunrise Pavillion and Cloverdale Seniors' Centers. None of these subjects had a current diagnosis of a psychiatric disorder and none had ever received ECT. This group was tested only once, receiving only the memory tests and the VSAT. The testing schedule was otherwise similar to the pre-ECT testing schedule of the experimental group. The mean age of the control subjects was 70.6 years.

ECT

Patient subjects received their ECT treatments before breakfast. ECT sessions were scheduled 3 times a week (Monday, Wednesday, and Friday). ECT treatment was administered with an MECTA ECT machine. The wave form was a brief pulse wave delivered with bilateral electrode placement. This apparatus produces a maximum stimulus duration of 2 seconds and maximum current strength of 0.8 amps. It has a pulse width of up to 2 msecs., and pulse frequency ranging between 40 to 90 msecs. ECT was delivered according to Duke University's dosing procedure. Duration of the resulting cerebral seizure was monitored on an electroencephalograph (EEG). An EEG seizure duration of at least 25 seconds is required for therapeutic effect. Patients received general anesthesia (Breital) and muscle relaxant (Succinocholine) prior to administration of ECT. Patients also received a beta blocker, Esmolol, to reduce heart rate and blood pressure. Caffeine augmentation was used only when maximum parameters reasonable for the individual were not adequate. Antidepressant medications were withheld a week prior to the administration of ECT. Patients continued to take psychotropic, neuroleptic, and other medications as indicated for physical problems. Lithium was usually withheld the night before ECT was administered. It is likely that some memory impairment may be due to these interventions (medications and anesthetic) and contributed to error variance.

There were no group differences (between implicit and explicit conditions) on diagnoses or medication status.

Materials

Memory Measure

Target Words. The target lists, which were presented during the study phase, consisted of 42 words each. All words were between 5 and 9 letters long. Each word began with a different three-letter stem for which the American College Dictionary (Barnhart & Stein, 1958) has at least four words beginning with that prefix. The words had a frequency on Kucera and Francis' (1967) norms ranging between 1 to 40 and none was the most frequent or infrequent completion for its stem. Words (nouns) were selected from Rajaram and Roediger's (1993) and Roediger et al.'s (1992) word lists. The word lists are reproduced in Appendix B.

To avoid ceiling effects, words that have very high levels of baseline performance (i.e., items that would be completed by all subjects, even without having recently studied the corresponding target word) were not included. Similarly, items that are rarely or never completed were excluded to avoid floor effects.

Two target lists were created (for pre-ECT and post-ECT testing). An additional 6 words with the same properties were chosen to be fillers. Filler words were presented, 3 at the beginning and 3 at the end of the list, to reduce primacy and recency effects.

Three additional words served as practice items (see Appendix B for word lists).

The two target lists were presented equally often in the pre-and at post-ECT epochs in order to counterbalance for order of presentation. Similarly, the order in which subjects studied the words in the semantic and non-semantic study conditions was also counterbalanced (Note: 21 of the 42 words were studied under the semantic and 21 under the nonsemantic study condition). Test lists were presented equally often at the three delay periods. Finally, half the subjects received unstudied words (words which were not presented during the study phase) as study words (words which were presented during the study phase) and the other half received study words as unstudied words, i.e., counterbalancing was also done for studied and unstudied items.

In order to obtain a measure of baseline performance for the implicit task, a set of 42 words (21 for the pre-ECT and 21 for the post-ECT lists), matching in all respects to the target words, was included. These items were not presented for study. During each retrieval session, 7 words stems corresponding to the unstudied words were presented together with 14 stems corresponding to the studied words.

Thus, there were two main lists of 42 words each, List A and List B. For each of the two lists, four sub-lists were created in order to counterbalance the foregoing factors. The lists were labeled as follows: List A NS-S (with non-semantic processing occurring prior to semantic processing), A S-NS (with semantic processing occurring prior to non-semantic processing, the order of the words was identical to list A NS-S), X/A NS-S, and X/A S-NS (the unstudied words in list A became the studied words in list XA and vice versa). The words in all the 4 sets of List A were identical. Similarly, for List B there were 4 sub-lists: List B NS-S, List B S-NS, List X/B NS-S, and List X/B S-NS, (words in the List B were completely different from the words in List A). The four sets of List B had similar distinctions as in the list A and XA series. The same subject did not receive the combinations from List A for pre and post ECT testing sessions (since the lists contained the same words). Similarly, the same subject did not receive the combination from List B for pre-and post-ECT testing.

In order to test retention, word stems corresponding to the TBR words and the unstudied words were presented during the retrieval phase.

Hamilton Depression Scale (HAM-D). The HAM-D (Hamilton, 1967) is a 21-item instrument that measures the severity of depression in patients already diagnosed as having depressive illness. It is a standard measure in clinical studies of depression. The items are rated on a 2- or 4-point scale of severity, depending on the type of symptom. The scale is generally administered by the attending psychiatrist. It has a correlation of .82 (in psychiatric patients) with the Beck Depression Inventory (Beck & Steer, 1987). The HAM-D was completed by the psychiatrist twice, once prior to the first ECT and once following the ECT session.

Verbal Series Attention Test (VSAT). The VSAT (Mahurin & Cooke, 1996), a research instrument, is a simple test of attention comprised of a set of items (e.g., reciting the alphabet, counting backward from 20 to 1, reciting the days of the week and months of the year (forward and backward), and tapping a pencil every time the letter O is heard). The VSAT provides 2 dependent measures: elapsed response time and number of errors. Preliminary norms are provided for ages 50 and above; separate norms are provided for those with a high school education or less and greater than high school education.

The VSAT measure was used because attention is an important factor that affects memory. It is desirable to examine the relationship between ECT, attention, and memory and to determine the variability in this factor at the time of memory testing.

The Modified Mini-Mental State Examination (3MS). The 3MS (Teng & Chui, 1987) is a brief screening test for dementia. Originally it was used to aid differential diagnosis in psychiatric hospital settings. It is also used in research to assess cognitive abilities of older persons. The 3MS is an extended version of the Mini-Mental State Examination (MMS) (Folstein, Folstein, & McHugh, 1975). However, it samples a wider range of cognitive abilities than the MMS, has better reliability and validity scores, and has extended floor and ceiling of the test (Teng et al., 1987). It is also better than the MMSE for differentiating nondemented from demented persons.

Retrieval Instructions

Implicit instructions: "I am going to show you a series of three-letter word stems (beginning letters of words), one at a time. For each word stem, I want you to say aloud the first word that comes to your mind that begins with the three letters that you are shown. You can say any English word except proper nouns; that is, names of people (like George) or places (like Canada) - but say aloud the first word that comes to mind".

Explicit instructions: "You are now going to receive a memory test for the words you studied earlier today. I am going to show you a series of three letter word-stems (beginning letters of words), one at a time. I want you to complete each word-stem with a word that was on the study list. Some of these word-stems are new and cannot be completed with words from the study list. Please don't guess".

Procedure

Subjects were tested individually. Testing occurred prior to the first ECT session and again on the day the subjects received their sixth ECT treatment. The post-ECT testing began approximately one-and-a-half hour after the ECT treatment. The pre- and post-ECT testing format followed the same pattern (Table 1).

During the study phase, a target list of 42 words, plus 6 filler words, were presented for study. Words were presented in lower case lettering printed in 36 point Times Roman font. The words were laser-printed individually with bold lettering on index cards. Three additional words were used for practice. Half of the study words were rated for pleasantness (semantic condition) and for the other half, subjects counted the number of vowels in the words (nonsemantic condition). To facilitate rating of pleasantness, an index card showing numbers from 1 (extremely unpleasant) to 5 (extremely pleasant) was displayed continuously in front of the subjects. To facilitate judgments in the nonsemantic study condition, the vowels A,E,I,O,U were displayed on an index card in front of the subjects. Subjects studied the list twice.

During each retrieval session subjects received 21 word stems, of which 14 corresponded to words they had previously studied and 7 were words they had not previously studied. Of the 14 studied words, 7 corresponded to words studied in the semantic condition and 7 corresponded to words studied in the nonsemantic condition. Subjects were randomly assigned to either the implicit or the explicit condition. They were given as much time as they needed to complete the task. Retention was tested at.

Table 1

Procedure

	Pre ECT	Post 6^{th} ECT
	3MS	3MS (one-and-half hour post ECT)
Study Phase	TBR (twice) (42 words)	TBR (twice) (42 words)
Retrieval Phase		
Delay1	word-stems (14 from TBR) (7 unstudied)	word-stems (14 from TBR) (7 unstudied)
Delay2	word-stems (14 - TBR) (7 unstudied)	word-stems (14 - TBR) (7 unstudied)
Delay3	word-stems (14 - TBR) (7 unstudied)	word-stems (14 - TBR) (7 unstudied)
	VSAT	VSAT

Delay1 - 15 minutes
Delay2 - 90 minutes
Delay3 - 180 minutes

three delay periods, namely, 15, 90, and 180 minutes. Subjects were also administered the orientation questions of the 3MS prior to the study phase. They received the VSAT at the end of the third delay period.

Design

Factors:

1. Retrieval instructions - 2 levels (implicit and explicit). Between-subject factor.
2. Study condition - 2 levels (nonsemantic and semantic). Within-subject factor.
3. Retention interval - 3 levels (15 minutes, 90 minutes, and 3 hours). Within-subject factor.
4. ECT - 2 levels (pre-ECT and post-ECT). Within-subject factor.

Thus a 2 x 2 x 3 x 2 factorial design was used (Table 2).

Table 2

Design

	ECT					
	Pre-ECT			Post-ECT		
	Delay					
	15 min.	90 min.	180 min.	15 min.	90 min.	180 min.
Implicit						
Semantic	S_{1-15}	S_{1-15}	S_{1-15}	S_{1-15}	S_{1-15}	S_{1-15}
Nonsemantic	S_{1-15}	S_{1-15}	S_{1-15}	S_{1-15}	S_{1-15}	S_{1-15}
Explicit						
Semantic	S_{15-30}	S_{15-30}	S_{15-30}	S_{15-30}	S_{15-30}	S_{15-30}
Nonsemantic	S_{15-30}	S_{15-30}	S_{15-30}	S_{15-30}	S_{15-30}	S_{15-30}

RESULTS

The present study used a mixed factorial design combining between-subject and within-subject variables. The between-subject variable was retrieval instructions with two levels (implicit and explicit). The within-subject variables included (1) delay period with three levels (15, 90, and 180 minutes), (2) ECT with two levels (pre-and post-ECT), and (3) study conditions/instructions with two levels (semantic and non-semantic). The dependent measure was the frequency with which the subjects completed a three-letter word stem with a previously studied word.

The effects of all the variables were tested using a repeated-measure analysis of variance (ANOVA) at the .05 level of significance. The effects of other variables (sex, age, depression, and attention) were assessed using regression analyses.

There was no effect of sex or age on recall or stem completion performance, $F(1,26) = .393, p > .05$ and $F(1,27) = .613, p > .05$ respectively. Nor were there significant interactions of sex or age with any of the other variables. Subsequent analyses were performed by pooling over these variables.

Baseline Data

Baseline rates, i.e., completion performance for words that had not been presented for study, did not differ across the different conditions (retrieval instructions, ECT, and delay periods). Mean proportion of baseline score for the different conditions, together with priming scores, are presented in Table 3.

Statistical analyses were computed on baseline-corrected scores; that is, subjects' overall baseline scores were subtracted from their completion scores (the baseline-

Table 3

Mean Proportion of Stem Completion and Cued-Recall Rates in Experimental Group

Delay	15			90			180		
STUDY	NS	S	UN	NS	S	UN	NS	S	UN
IMPLICIT Pre-ECT	.67	.57	.10	.46	.47	.07	.52	.46	.09
Priming	.57 (.05)	.47 (.07)		.39 (.07)	.40 (.06)		.44 (.08)	.37 (.05)	
Post-ECT	.68	.66	.07	.38	.41	.07	.53	.53	.04
Priming	.61 (.04)	.59 (.04)		.31 (.06)	.34 .09)		.50 (.05)	.50 (.06)	
EXPLICIT Pre-ECT	.45	.62	.08	.23	.44	.08	.23	.31	.07
Baseline-corrected	.37 (.05)	.54 (.06)		.15 (.05)	.36 (.06)		.16 (.07)	.25 (.07)	
Post-ECT	.24	.45	.05	.17	.22	.05	.08	.10	.04
Baseline-corrected	.19 (.07)	.40 (.07)		.12 (.07)	.17 (.05)		.04 (.04)	.06 (.04)	

NS: non-semantic S: semantic UN: unstudied/baseline performance

Cell entries represent mean proportion of stems completed with previously studied words.

Standard error of proportion are given in brackets.

Priming scores/baseline-corrected scores are calculated by subtracting unstudied from studied completion rates.

7 correct responses are possible in semantic, nonsemantic, and unstudied conditions at each delay period.

Table 3.a

Marginal Means (Corrected for Baseline)

Variable	level	Mean	SE
Retrieval instructions	Implicit	3.19	.244
	Explicit	1.64	.244
Delay	15 minutes	3.27	.186
	90 minutes	1.98	.254
	180 minutes	2.02	.180
ECT	Pre	2.61	.207
	Post	2.23	.195
Study	Nonsemantic	2.24	.164
	Semantic	2.59	.199

corrected scores are the priming scores). Similarly, on the explicit test, recall scores were corrected for intrusion rates (proportion of unstudied items recalled).

The main analyses were performed only on the experimental group. Subsequently, priming effects were examined in the control group and compared with those in the experimental group.

Priming Effects

Priming rates were analyzed for the full model (experimental group) using a 3 x 2 x 2 x 2 mixed factorial ANOVA (with all the principal variables in the analysis). There was a significant priming effect on the implicit test at all three delay periods (at pre- and post-ECT). On the explicit test, recall was significantly different from baseline at pre-ECT at all three delay intervals. However, at post-ECT on the explicit test, recall was significantly different from baseline at the 15 minute delay but was at baseline at the 90 minute delay (and thereafter) in the nonsemantic condition (but not in the semantic condition). At the 180-minute delay period, it was at baseline in both semantic and nonsemantic conditions (Table 3).

Main Effects

The following main effects were significant: retrieval instructions, $F(1,28) = 20.16, p < .001$; delay period, $F(2,56) = 25.65, p < .001$; and study condition, $F(1,28) = 8.77, p < .01$. The main effect of ECT, on the other hand, was not significant, $F(1,28) = 3.26, p > .05$. Since there were significant 2-way interaction effects, main effects need to be interpreted with caution (i.e., the significant interaction effects show that the main effects of the three variables may each be dependent upon the levels of the other independent variable/s). The main theoretical interest in the present study centers upon these interaction effects.

2-Way Interaction Effects

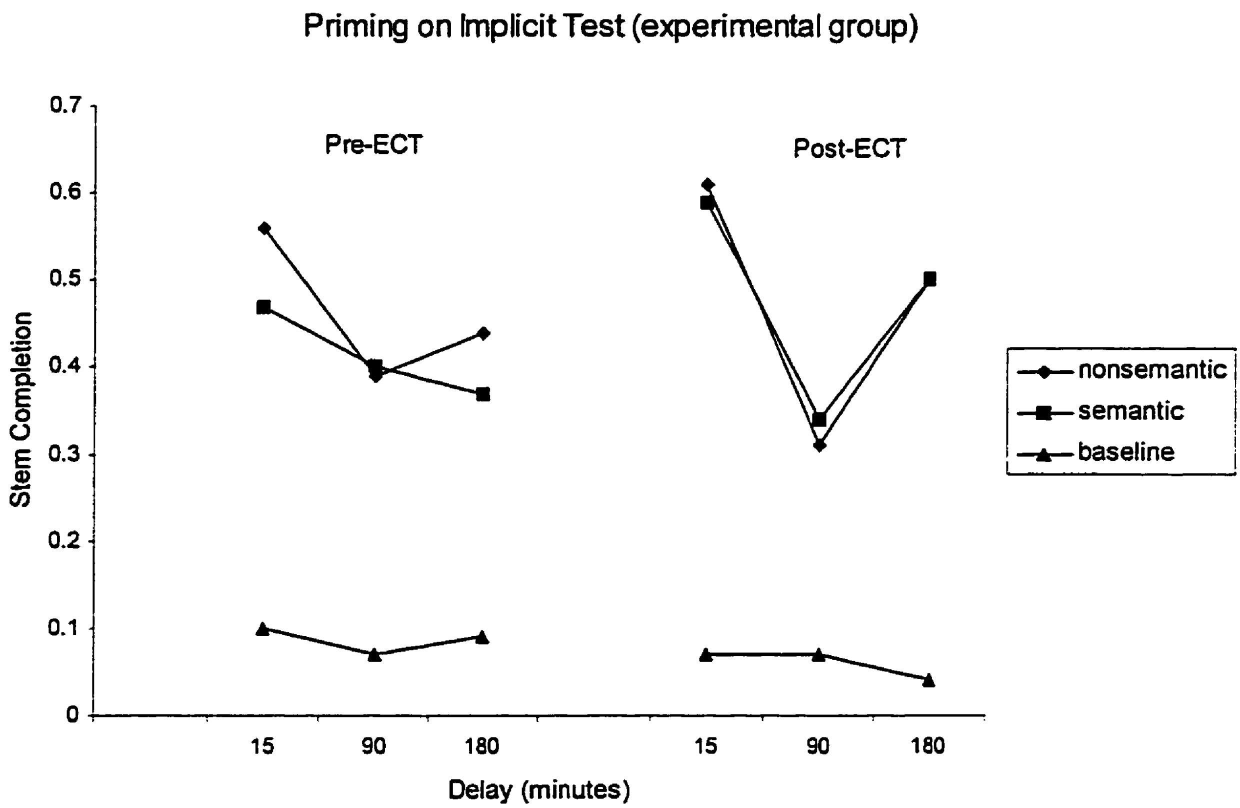
The study predicted the following 2-way interaction effects:

Hypothesis 1: A significant 2-way interaction between retrieval instructions and ECT was predicted. It was hypothesized that stem completion performance on the implicit test would not differ significantly from pre-to-post ECT testing sessions (i.e., the administration of ECT would not significantly affect performance in the implicit group). However, on the explicit test, it was expected that subjects would recall fewer words from the study list after ECT as compared with performance before ECT.

As predicted, the 2-way interaction between retrieval instructions and ECT was significant, $F(1,28) = 9.28, p < .01$ (Table C1 - Appendix C). This effect is clearly visible in the plots of mean proportion priming and recall effects (Figures 1 and 2). It is apparent from these plots that performance on the implicit test did not differ significantly from pre-to post-ECT. However, on the explicit test, there was significant deterioration in performance from pre-to-post-ECT. To test the significance of this effect, separate ANOVAs were performed on implicit and explicit test data. On the implicit test, the main effect of ECT was not significant: pre-ECT $M = 3.07$, post-ECT $M = 3.32$; $F(1,14) = .05, p > .05$ (Table C2 - Appendix C). By contrast, on the explicit test, the main effect of ECT was significant: pre-ECT $M = 2.14$, post-ECT $M = 1.44$; $F(1,14) = 10.68, p < .01$ (Table C3 - Appendix C).

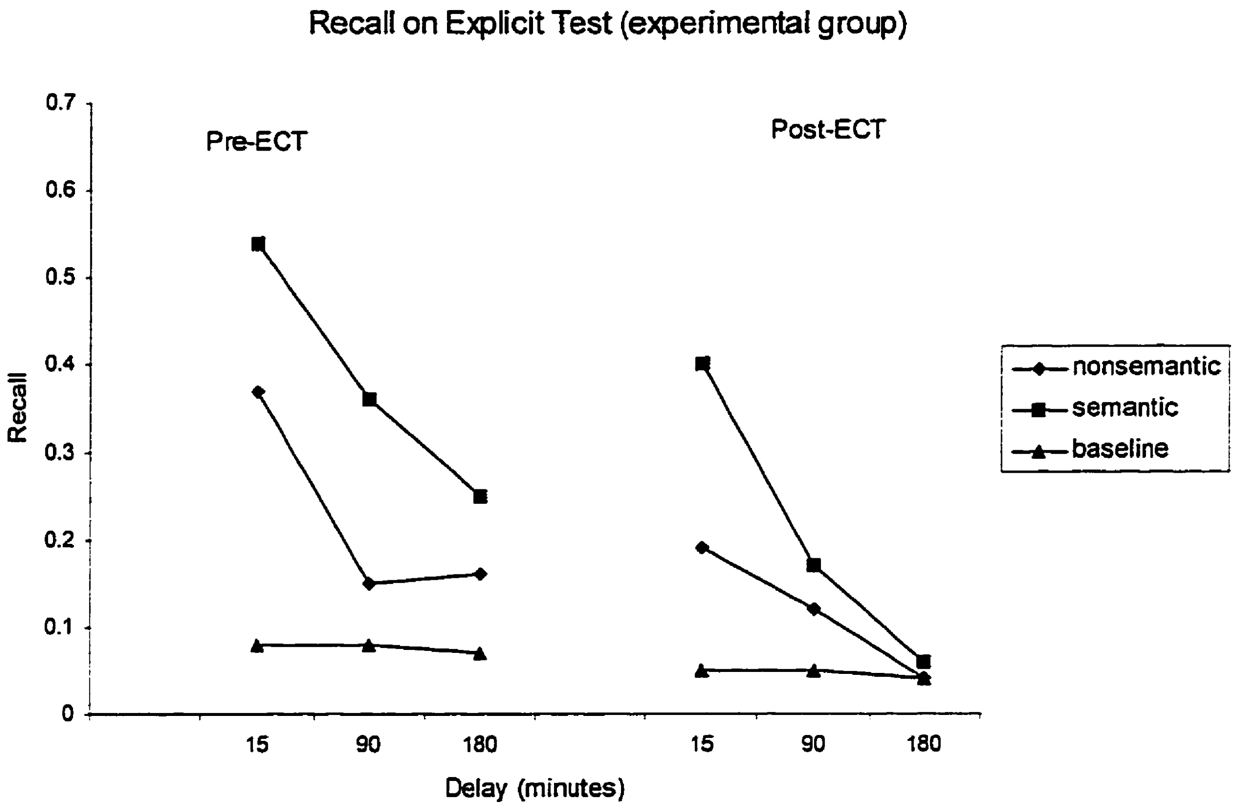
The foregoing results show that ECT had a detrimental effect on cued word recall

Figure 1



Priming on Implicit Test (experimental group)
Pre-ECT
Post-ECT
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Stem Completion
15
90
180
15
90
180
Delay (minutes)
nonsemantic
semantic
baseline

Figure 2



Recall on Explicit Test (experimental group)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Recall
Pre-ECT
Post-ECT
15
90
180
15
90
180
Delay (minutes)
nonsemantic
semantic
baseline

(retrieval with explicit instructions). On the implicit task, however, stem completion performance did not deteriorate after ECT as compared to pre-ECT averages.

Hypothesis 2: A significant 2-way interaction between retrieval instructions and study conditionwas predicted. It was hypothesized that subjects receiving explicit recall instructions would recall more studied words in the semantic than in the nonsemantic study condition. On the other hand, subjects receiving implicit retrieval instructions were expected to complete the same number of
stems from the studied list in both the semantic and nonsemantic study conditions; i.e., performance would not be affected by study condition.

The 2-way interaction between retrieval instructions and study condition was significant, and was as predicted, $F\,(1,28) = 19.11, p < .001$ (Table C1 - Appendix C). The separate ANOVAs for the implicit and explicit conditions showed that, in the explicit condition, the main effect of study was significant, $F\,(1,14) = 24.23, p < .001$ (Table C3 - Appendix C). Conversely, the main effect of study condition was not significant in the implicit condition, $F\,(1,14) = 1.12, p > .05$ (Table C2 - Appendix C). That is to say, for the explicit group, recall of studied words was greater in the semantic than the nonsemantic study condition: semantic $M = 2.08$; nonsemantic $M = 1.21$ (Table C3 - Appendix C). For the implicit group, there was no significant difference in performance under the two study conditions: semantic $M = 3.11$; nonsemantic $M = 3.28$ (Table C2 - Appendix C). This trend is apparent in Figures 1 and 2.

Hypothesis 3: A significant 2-way interaction between retrieval instructions and delay period was predicted. It was hypothesized that performance on the explicit task would deteriorate significantly over the three delay periods, whereas the performance on the implicit task would not deteriorate over the same periods.

Although there was a significant 2-way interaction between retrieval instructions and delay, $F(2,56) = 4.65, p < .01$ (Table C1 - Appendix C), this was not entirely as predicted. It was found that performance of subjects in both the implicit and explicit conditions differed significantly over the three delay periods. The separate ANOVAs for implicit and explicit conditions (Tables C2 and C3 - Appendix C) showed that there was a main effect of delay in both the implicit, $F(2,28) = 8.27, p < .005$ and the explicit condition, $F(2,28) = 29.41, p < .001$. The nature of the effect was, however, different in the two conditions.

In order to examine separately how performance differed from one delay period to the next in the implicit and explicit conditions, pair-wise comparisons were performed. These tests examined the difference in performance from 15 (delay1) to 90 (delay2) and from 90 (delay 2) to 180 (delay3) minute intervals. The outcome was that performance on the explicit test deteriorated significantly from delay1 to delay2: $M = 2.63$ vs. 1.42; $t(1,14) = 4.94, p < .001$, and from *delay2* to *delay3*, M *delay3* $= 0.88$; $t(1,14) = 2.93, p <$ .001 (Table 4). However, performance on the implicit test deteriorated significantly from delay1 to delay2, $M = 3.90$ vs. $M = 2.53$; $t(1,14) = 3.39, p < .005$, but it did not change significantly from delay2 to delay3, M delay3 $= 3.15$; $t(1,14) = -1.78, p > .05$ (Table 4). At post-ECT, however, there was a significant improvement in performance from the 90 to the 180 minute delay interval: $t(1,14) = -2.79, p < .05$.

Hence, it is clear that the variable "retrieval instructions" interacted significantly

Table 4

Stem Completion and Cued-Recall: Comparisons Between Delay Periods (Paired T-Tests)

ECT	Pre		Post		Pre & Post	
Delay	15-90	90-180	15-90	90-180	15-90	90-180
Implicit	3.48 (.068)	-.15 (.883)	3.54 (.003*)	-2.79 (.015*)	3.39 (.004*)	-1.78 (.096)
Explicit	5.83 (.000*)	1.22 (.240)	2.89 (.012*)	2.17 (.048)	4.94 (.000*)	2.93 (.001*)

Values in each cell are the t-values
Values in brackets are p-values
* represents significant differences

with all of the other three variables, namely, ECT, delay, and study. That is, the main effects of the three variables, ECT, delay, and study were different on the implicit and the explicit tests. No other 2-way interactions between the other variables (study x delay, study x ECT, and delay x ECT) were significant. Explicit and implicit recall were affected differently by study conditions and ECT, and they behaved differently over time. The following features of implicit and explicit recall emerged from this study: In the explicit condition, performance deteriorated from the pre- to post-ECT period. Performance was better when words were studied in the semantic condition than when they were studied in the nonsemantic condition (at both pre- and post-ECT) intervals, and there was deterioration in performance from 15 to 90 and from 90 to 180 minute delay periods (at both pre- and post-ECT sessions). In the implicit condition, performance did not deteriorate from pre- to post-ECT; performance was similar when words were studied under the semantic or the nonsemantic conditions (at both pre-and post-ECT sessions). Performance in the implicit group deteriorated from the 15 to the 90-minute delays. Performance did not change significantly from the 90 to the 180 minute delay period - in fact, there was a slight improvement in performance from the 90 to the 180 minute delay period (this was statistically significant at post-ECT but not at pre-ECT).

It should be noted that despite having patients with different diagnostic backgrounds (adding "noise" or error variance) the magnitude of the present results was impressive. This indicates that the present findings are robust.

Examining the Effects of ECT Using Pre-ECT Memory Scores as a Covariate

An ANCOVA with pre-ECT memory scores as covariates made it possible to examine the effects of ECT on memory by controlling the variability in memory due to depression (at pre-ECT subjects were depressed but not amnesic). The results of the ANCOVA showed the pattern of results remained the same, indicating that the obtained results are reliably due to the effects of ECT on implicit and explicit memory. With respect to HAM-D scores, it was noted that there were no differences in depression scores, at pre-or post-ECT, between implicit and explicit conditions, $t(2,28) = 1.14$, $p > .05$ and $t(2,28) = -1.7$, $p > .05$, respectively.

Priming Effects in Control Group

Baseline rates did not differ across the different delay periods or between implicit and explicit conditions. Similarly, baseline rates were similar between control and experimental groups at pre-ECT and between control and experimental groups at post-ECT. There was significant priming on the stem completion test and recall on the explicit test was significantly different from baseline at all three delay intervals.

In the control group, the main effect of retrieval instructions was not significant, $F(1,28) = 0.68$, $p > .05$, implicit $M = 2.40$ and explicit $M = 2.67$ (Table 5). That is, performance on the two types of tests (implicit and explicit) was similar. Main effects of delay and study conditions were significant. Only one interaction effect, i.e., between retrieval instructions and study conditions was significant, $F(1,28) = 7.36$, $p = < .05$. That is, implicit and explicit tests were affected differently by manipulation of the study condition. Examining separate ANOVAs for implicit and explicit conditions, it became apparent that there was a significant difference in

performance between nonsemantic and semantic conditions on the explicit test (nonsemantic $M = 1.78$, semantic $M = 3.56$, $F(1,28) = 20.09$, $p < .005$), but not on the implicit test (nonsemantic $M = 2.20$, semantic $M = 2.60$, $F(1,28) = 1.59$, $p > .05$) (Table 5). The main effect of delay was significant on both implicit and explicit tests, $F(2,28) = 18.15$, $p < .001$ and $F(2,28) = 18.93$, $p < .001$, respectively.

Next, performance of the control and experimental group (at pre-ECT) was compared. The following trends became apparent: the overall ANOVA (comparing control and experimental groups [at pre-ECT]) showed that there was a significant interaction between group and retrieval instructions, $F(1,56) = 5.06$, $p < .05$. Examining this effect further, it became clear

that the patient group's performance was better on the implicit than the explicit test, $F(1,28) = 4.97$, $p < .05$. On the explicit test, their performance was impaired in the semantic but not in the nonsemantic study condition. The control subjects' performance on the implicit and explicit tests, however, did not differ, $F(1,28) = .658$, $p > .05$. Separate ANOVAs for implicit and explicit tests showed that the main effect of group was not significant for either test type, $F(1,28) = 3.74$, $p > .05$ (implicit test) and $F(1,28) = 1.07$, $p > .05$ (explicit test). That is, there were no group differences on either the implicit or the explicit test. Stem completion performance (implicit test) was affected by delay, $F(2,56) = 15.65$, $p < .001$ (performance deteriorated over the three delay periods). However, there was no group x delay interaction, $F(2,56) = 2.12$, $p > .05$. Similarly, on

Table 5

Mean Proportion of Stem Completion and Cued-Recall Rates for Control Group

Delay	15			90			180		
Study	NS	S	UN	NS	S	UN	NS	S	UN
Implicit	.59	.65	.11	.30	.34	.09	.34	.42	.10
Priming	.48 (.03)	.53 (.04)		.22 (.05)	.26 (.06)		.25 (.06)	.32 (.04)	
Explicit	.45	.81	.07	.29	.50	.06	.21	.39	.06
Baseline-Corrected	.38 (.06)	.74 (.06)		.23 (.06)	.45 (.08)		.15 (.06)	.33 (.07)	

NS: nonsemantic S: semantic UN.: unstudied/baseline
Priming scores/baseline-corrected scores are calculated by subtracting unstudied from studied completion rates.
Numbers in cells represent mean proportion of stems completed with previously studied words
Numbers in brackets represent standard error of proportion..
7 correct responses are possible in semantic, nonsemantic, and unstudied conditions at each delay period.

Marginal Means (corrected for baseline)

Variable	Level	Mean	SE
Retrieval Instructions	Implicit	2.40	.233
	Explicit	2.67	.233
Delay	15 min.	3.73	.164
	90 min.	2.02	.237
	180min.	1.85	.245
Study	Nonsemantic	1.99	.191
	Semantic	3.08	.224

the explicit test, recall was affected by delay, $F(2,56) = 36.71, p < .001$. Once again, there was no group by delay interaction effect, $F(2,56) = .476, p > .05$. Recall on the explicit test was significantly affected by study condition, $F(1,28) = 31.30, p < .001$. Performance was better in the semantic than the nonsemantic condition. These effects can be seen in figures 3 and 4.

Comparing the performance of control and experimental subjects (post-ECT), the general pattern of results was as follows: there was a significant interaction effect between group and retrieval instructions, $F(1,56) = 22.95, p < .01$. Separate ANOVAs for control and experimental (pre-ECT) groups showed that the patient group performed better on the implicit as compared to the explicit test, $F(1,28) = 31.16, p < .001$. By comparison, the control subjects' performance on the implicit and explicit tests did not differ, $F(1,28) = .658, p > .05$.

Separate ANOVAs for implicit and explicit tests revealed that the main effect of group was significant on both the implicit and explicit tests, $F(1,28) = 9.59$, $p < .01$ (implicit test) and $F(1,28) = 13.50, p < .001$ (explicit test). That is, there were group differences on both implicit and the explicit test performance. On the implicit test, performance of the control and ECT groups differed only at the 180-minute delay (in both study conditions). On the explicit test, performance of the two groups was significantly different at all three delay periods in the semantic condition but, in the nonsemantic condition, it was different only at the 15-minute delay. Finally, stem completion performance (implicit test) was affected by delay, $F(2,56) = 22.80, p < .001$; but there was no group x delay interaction,

Figure 3

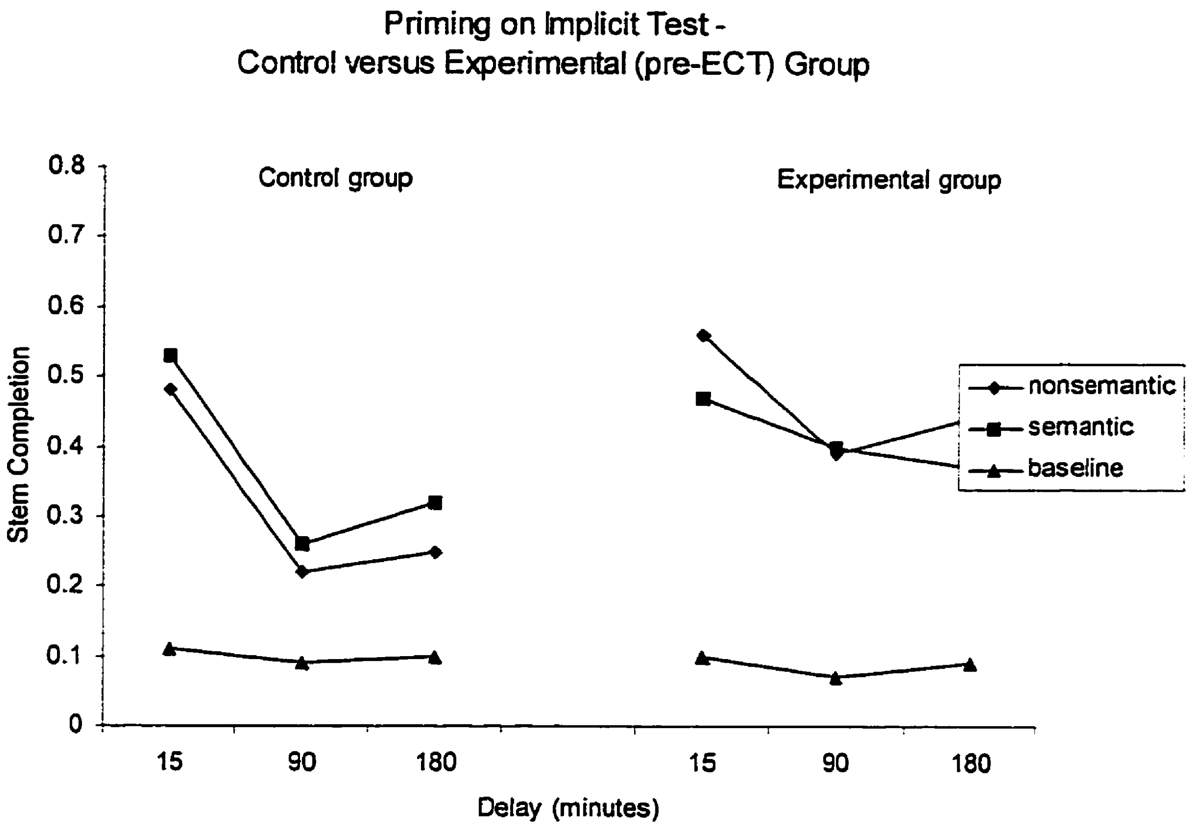
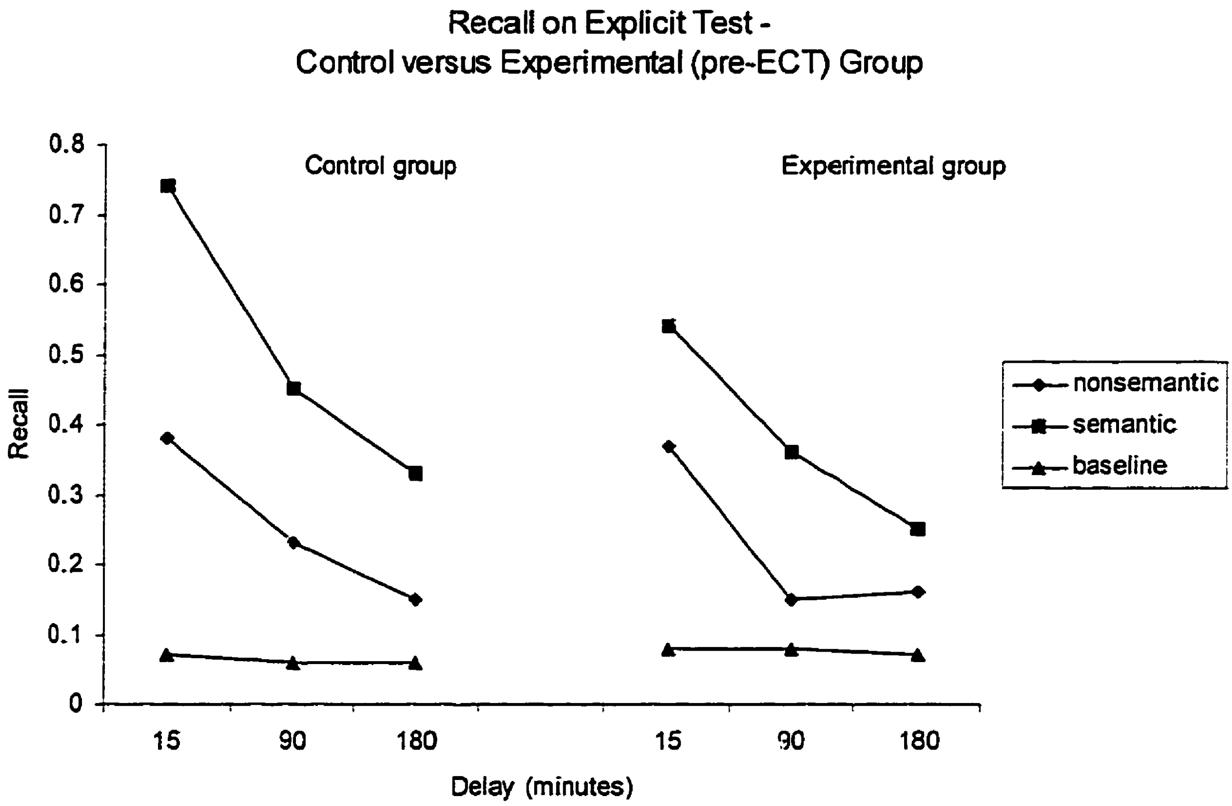

Priming on Implicit Test -
Control versus Experimental (pre-ECT) Group
Control group
Experimental group
Stem Completion
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15
90
180
15
90
180
Delay (minutes)
nonsemantic
semantic
baseline

Figure 4



Recall on Explicit Test -
Control versus Experimental (pre-ECT) Group
Control group
Experimental group
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Recall
nonsemantic
semantic
baseline
15
90
180
15
90
180
Delay (minutes)

$F(2,56) = 1.41, p > .05$. Similarly recall on the explicit test was affected by delay, $F(2,56) = 36.71, p < .001$; and once again, there was no group x delay interaction effect, $F(2,56) = .676, p > .05$. Recall on the explicit test was significantly affected by study condition, $F(1,28) = 31.30, p < .001$ - with performance being better in the semantic than nonsemantic condition. These relationships are apparent in Figures 5 and 6.

Secondary Hypotheses

A number of secondary hypotheses were also explored; the results were as follows:

Hypothesis 4 - the relationship between depression and ECT.

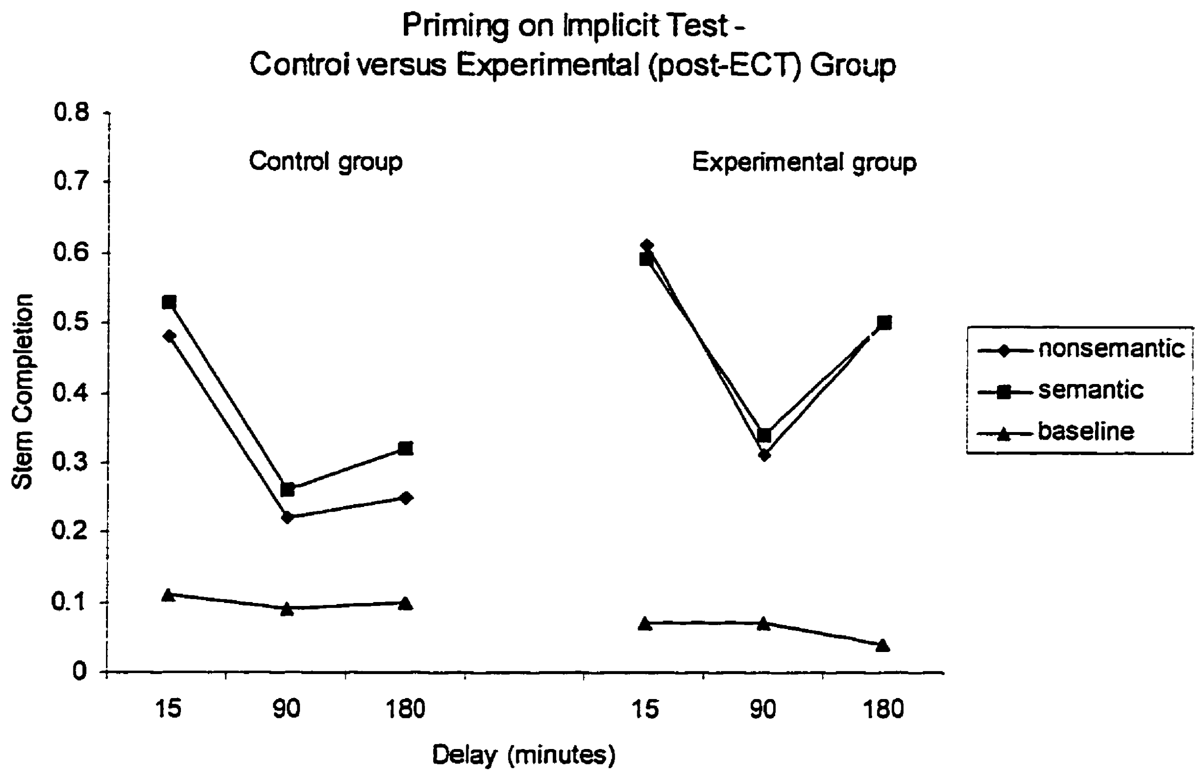
It was expected that there would be a significant decrease in severity of depression, as measured by the Hamilton Depression Rating Scale (HAM-D) following ECT as compared to the period before ECT.

There was, in fact, a significant reduction in the severity of depression following ECT treatment. The mean HAM-D score prior to ECT was 27.17 and the mean HAM-D score following ECT was 10.50. A paired t-test of pre-and post-ECT HAM-D scores confirmed that the difference between the pre-and post-ECT HAM-D scores was statistically significant, ($t(1,29)$
$= -7.50$, $p<.001$). Thus, there was significant improvement in the severity of depression after the sixth ECT session compared to before ECT.

Hypothesis 5 - the relationship between severity of depression and memory.

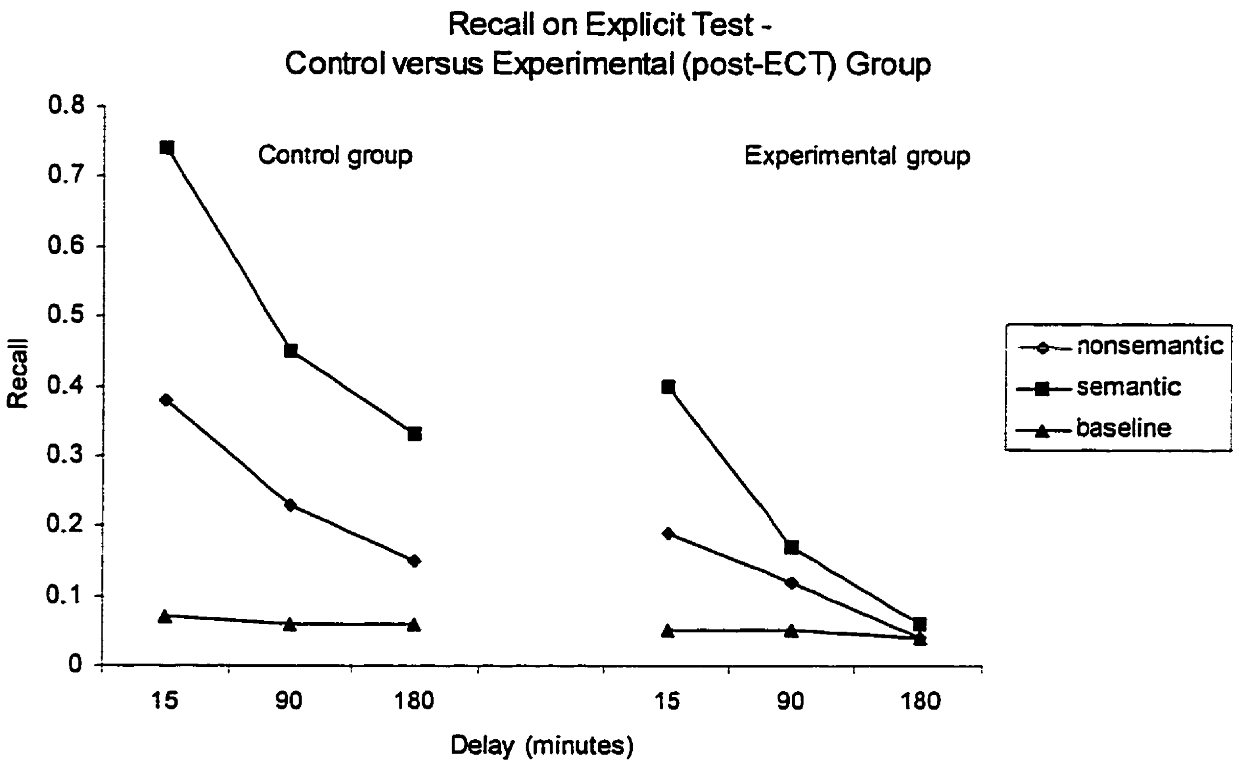
It was predicted that the greater the severity of depression, the greater would be the impairment in explicit memory performance. Depression was not expected to affect

Figure 5



Priming on Implicit Test -
Controi versus Experimental (post-ECT) Group
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Stem Completion
Control group
Experimental group
nonsemantic
semantic
baseline
15
90
180
15
90
180
Delay (minutes)

Figure 6


Recall on Explicit Test -
Control versus Experimental (post-ECT) Group
Control group
Experimental group
Recall
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15
90
180
15
90
180
Delay (minutes)
nonsemantic
semantic
baseline

implicit memory performance.

The mean HAM-D score of the implicit group at pre-ECT was, *M* = 29.20 (SD = 9.89) and the post-ECT the mean was, *M* = 7.93 (SD = 6.54). The mean HAM-D score of the explicit group at pre-ECT was, *M* = 25.13 (SD = 9.59) and at post-ECT it was, *M* = 13.07 (SD = 9.12). The difference between the means of the explicit and implicit groups was not significant, $t(2,28) = 1.14$, $p > .05$ and $t(2,28) = -1.7$, $p > .05$, respectively.

Separate regression analyses were performed for implicit semantic, implicit nonsemantic, explicit semantic and explicit nonsemantic conditions (separately for pre- and post-ECT conditions). In all of these conditions, scores were averaged across the three delay periods. HAM-D scores were entered as the predictor variable and recall/stem completion scores as dependent variables. Contrary to prediction, it was found that depression scores did not significantly account for the variability in the recall/stem completion scores for any of the conditions. That is, level of depression did not affect memory scores in either implicit or explicit conditions (semantic or nonsemantic).

One possible explanation for this lack of a relationship between depression and memory may be the fact that many of the subjects were in fact not depressed (these patients had diagnoses of bipolar disorder, anxiety, or schizophrenia). Subsequent analyses using only data from depressed patients (12 in the explicit and 12 in the implicit condition) showed that the pattern of the results remained unchanged. The small sample size may have contributed to the lack of effect of depression on memory.

Hypothesis 6 - the relationship between ECT and attention as measured by the Verbal Series Attention Test (VSAT).

It was expected that there would be significant deterioration in post-ECT attention scores, as measured by the VSAT, when compared to the pre-ECT scores.

There were two VSAT measures (total number of errors and total time taken to complete the items). Paired t-tests were performed on pre-and post-ECT VSAT scores. Contrary to what was hypothesized the results showed that the post-ECT performance was not significantly different from the pre-ECT performance. For VSAT-Errors, the pre-ECT mean was 7.60 and the post-ECT mean was 5.97, $t(1,29) = -1.95, p > .05$. Similarly, for VSAT-Time, the pre-ECT mean was 151.03 and the post-ECT mean was 138.53, $t(1,29) = -1.56, p > .05$. Hence, attention scores did not deteriorate after the administration of ECT.

It is possible that the relationship between ECT and VSAT may have been obscured since, on the day of the sixth ECT (as during pre-ECT test) the VSAT was administered at the end of the memory testing sessions. Thus, there was a gap of approximately 5 hours between the time when the subjects were administered ECT and the time they received the VSAT. It is possible that the subjects' ability to attend (as measured by the VSAT) could have recovered substantially during this interval. Had it been practical to do so, it would have been desirable to test attention at the time of study and also at the 15 and 90-minute delay intervals.

Hypothesis 7 - the relationship between attention and memory.

The mean VSAT(error) score of the implicit group at pre-ECT was, $M = 7.87$ (SD = 4.80) and the post-ECT the mean was, $M = 5.73$ (SD = 6.87). The mean VSAT (error) score of the explicit group at pre-ECT was, $M = 7.33$ (SD = 7.53) and at post-ECT it was,

M = 6.20 (SD = 6.81). The mean VSAT(time) score of the implicit group at pre-ECT was, M = 153.33 (SD = 56.51) and the post-ECT the mean was, M = 139.73 (SD = 59.87). The mean VSAT (error) score of the explicit group at pre-ECT was, M = 148.73 (SD = 74.42) and at post-ECT it was, M = 137.33 (SD = 59.48). The difference between the means of the explicit and implicit groups on VSAT(error) scores was not significant, $t(2,28) = .231$, $p > .05$ and $t(2,28) = -.187$, $p > .05$, respectively. Similarly, the between the means of the explicit and implicit groups on VSAT(time) scores was not significant, $t(2,28) = .191$, $p > .05$ and $t(2,28) = .110$, $p > .05$, respectively

Separate regression analyses were performed with VSAT scores as the predictor variable and individual recall and stem-completion scores in each cell in the full-model design (24 cells - for the 4 factors: retrieval instructions, delay period, study conditions, and ECT), separately, as the dependent variables. It was found that VSAT scores (both total errors and total time) did not significantly account for the variability or predict cued recall/stem-completion scores in any of these cells. That is, level of attention did not affect performance on either implicit or explicit tests.

The VSAT was administered only at the end of the memory testing sessions. It would have been preferable to administer the VSAT immediately after presentation of study list and also at all delay intervals. This would make it possible to examine separately the relationship between attention and short-term memory (immediate recall) as well as between attention and long-term memory (recall at 15, 90 and 180 minute intervals), as attention would be more likely to affect short-term than long term memory. This was an unfortunate oversight in the design of the present study.

DISCUSSION

Electroconvulsive therapy (ECT) has long been known to cause time-limited amnesia. However, the evidence for this has come mainly from studies examining explicit forms of memory. Relatively little was known about the effects of ECT on implicit memory. The present study explored the effects of ECT on implicit memory and compared them with previously reported effects of ECT on explicit memory. The effects of two variables (study conditions and delay/retention interval) on implicit and explicit memory were examined in order to learn more about some of the underlying processes affecting the two forms of memory.

Effect of ECT on Implicit and Explicit Memory:

The results of the present study showed, as expected, that ECT had a detrimental effect on explicit memory, but not on implicit memory. That is, performance on the implicit test remained intact after ECT. It is possible that performance on stem completion task at post-ECT might reflect an element of practice effect, however, if this was the case then performance should have improved or at least remained steady in the explicit condition too, which was not the case. Hence, it can be concluded that the results do not solely reflect practice effect.

The present findings are consistent with the findings of Graf et al. (1984) and Squire et al. (1984, 1985). These studies found that explicit memory was impaired after ECT, whereas implicit memory was spared. Squire et al. (1984) used a mirror-reading task to test implicit memory and a recognition memory test for words to test explicit memory. They found that mirror-reading skills acquired prior to ECT were intact after

ECT, despite retrograde amnesia for word recognition tasks. Similarly, Squire et al. (1985) examined the recovery of word-stem completion and recognition memory after the administration of bilateral ECT. They found that stem completion performance was normal at 45 minutes after ECT and that it did not change thereafter (with a retention interval of 15 minutes). However, patients scored at chance levels on recognition tests given 45 minutes after ECT. Graf et al. (1984) also found that amnesic patients, including a group of 8 patients receiving ECT, were impaired in three explicit tests of memory, namely, free recall, recognition, and cued recall. However, these patients showed normal performance on stem completion tasks. Word completion performance declined at a normal rate, reaching chance level after about 120 minutes.

Intact implicit memory has been demonstrated in studies that employed patients whose amnesia was caused by factors other than ECT and also in studies that used implicit memory tests other than stem completion. For example, Graf et al. (1985) reported intact priming in Korsakoff's patients, using a category generation task. Warrington and Weiskrantz (1970) reported that Korsakoff's patients performed normally when given a word fragment and a degraded word identification task (implicit memory tasks). Similarly, Warrington and Weiskrantz (1968) found normal performance in temporal lobectomy as well as Korsakoff's patients on fragmented or degraded object/picture identification tests. In all of these studies, amnesic patients exhibited impaired performance on explicit memory tests. Squire et al. (1987) showed that Korsakoff's patients' performance on implicit tasks was intact, compared to their impaired performance on explicit tasks. When compared to a control group of normal individuals, the amnesic patients did not perform as well on the implicit tasks, but exhibited smaller and shorter-lasting priming effects. Other studies have shown that amnesic patients perform as well as normal controls on implicit tasks.

The present study also found that the patient group, prior to receiving ECT, performed as well as normal control subjects on the implicit test, as well as the explicit (in the nonsemantic study condition) test of memory. After ECT, the patient group's performance deteriorated significantly on the explicit test but their performance on the implicit test was as good as that of the normal control subjects. Thus, in these patients, implicit memory was spared, relative to explicit memory.

The results of the present study highlight the role of retrieval instructions on memory performance. Performance after ECT is normal when instructions simply define the task as one of word completion. In contrast, performance is impaired when instructions draw attention to the memory aspects of the task and define the task as cued recall; i.e., when subjects are asked to engage in deliberate attempts to remember. The environmental support or cues provided to the subjects (word-stems) in both tests were the same, yet performance on the two tests differed. Thus, it was not simply what was contained in the memory test that was important in determining the effects of ECT on performance, but rather what the subjects were asked to do with the test material.

The main question of theoretical interest, then, is why was stem-completion performance unaffected by ECT while explicit memory performance was impaired?

According to Graf et al. (1984) and Mandler (1979, 1980), performance on word stem completion depends on a process of activation that is spared in amnesia. That is, amnesia seems to spare the process whereby a presented word activates the preexisting representations of its features, thereby increasing its availability and facilitating its subsequent detection and production. This process is also referred to as perceptual fluency (Jacoby & Witherspoon, 1982). However, if amnesia spares the process of activation, then it would be expected that performance on cued-recall should also be bolstered. That is because performance on cued-recall is also dependent, in part, on the process of activation. It seems that there is an additional requirement with cued-recall that is not present with stem-completion tasks. On a stem-completion test, the subject is expected to give his or her automatic reaction without making any further judgement via memory search about whether or not the activated representation was present on the study list. Cued-recall, on the other hand, requires this additional memory search and judgement for successful performance. Thus, it appears that this process is affected by ECT, while the activation process is left intact.

From a memory systems perspective, the present results suggest that, while ECT impairs the memory systems responsible for explicit memory, it does not influence the systems responsible for implicit retrieval. Although no single brain structure is responsible for all forms of explicit nor all forms of implicit memory, research suggests that explicit memory depends on the integrity of the medial temporal and diencephalic regions of the brain, including the basal forebrain, hypothalamus, and anterior and dorsomedial thalamus. On the other hand, the posterior cortical regions of the brain are implicated in implicit forms of memory. Squire (1987) suggested that posterior association cortices might be important for word priming effects, whereas, the basal ganglia may be important for motor skill learning. Based on findings with amnesic patients, which were corroborated with functional imaging techniques (Gabrieli et al., 1990), it was suggested that perceptual priming is processed in the occipital cortex while lexical-semantic priming is processed in the temporo-parietal association cortex.

With respect to ECT, Daniels and Crovitz (1983) have reported that current density is greatest in diencephalic structures and the geometric center of the brain in bilateral ECT. Similarly, Fink (1980) speculated that the diencephalically-mediated synchronization that occurs during the generalized ictus potentiates monoaminergic pathways to the hypothalamus and this is responsible for both the beneficial and the adverse effects of ECT. Hence the findings that ECT affects primarily the medial temporal lobe and the diencephalic structures predict that explicit memory should be more impaired relative to implicit memory following ECT. Consistent with these assumptions, the present study found greater impairment in explicit memory relative to implicit memory after ECT.

The cortical structures of the brain developed earlier during evolution than the diencephalic or medial temporal regions. This could suggest one reason why cortical structures and thus implicit memory may be more resistant to various insults to the brain, including ECT.

The issue of whether ECT affects storage or retrieval processes or systems cannot be resolved at this point. In the present study, the explicit and implicit tasks were identical except for retrieval instructions. It can be assumed therefore, that the difference in performance was due to retrieval processes. However, such a conclusion could only be drawn if encoding, storage, as well as retrieval processes were systematically varied and their effects on memory performance examined. Since the present study did not do this, it is premature to say that ECT caused deficits in retrieval processes rather than storage.

Examining the Effects of ECT Using Pre-ECT Scores as Covariate

An ANCOVA with pre-ECT scores as covariates made it possible to examine the effects of ECT on memory by controlling the variability in memory due to depression, thus reducing the effects of chance differences between groups. The results of the ANCOVA showed the pattern of results remained the same, increasing our confidence that the obtained results are, in fact, attributable to the effects of ECT on implicit and explicit memory.

Effects of Study Condition on Implicit and Explicit Memory

The present results show that study condition has an effect on explicit memory. At pre- as well as at post-ECT epochs, subjects' cued recall of words was superior in the semantic compared to nonsemantic study condition at all the three delay periods/retention intervals. Study conditions did not affect stem completion performance. Similar findings have led other researchers to postulate that priming is not affected by processing manipulations because it is automatic and is primarily data-driven, while explicit memory is deliberate and is largely conceptually-driven (Jacoby, 1983b, Roediger, 1990). Warrington and Weiskrantz (1974), Shimamura and Squire (1984), Tulving et al. (1991), and others, have used similar findings to suggest that implicit memory depends on a presemantic perceptual system and does not benefit from elaborative strategies during study, whereas, explicit memory depends on a declarative (or, alternatively, episodic or semantic) system and benefits from semantic encoding.

Some researchers have argued that subjects can employ conscious and elaborative strategies to enhance their performance on an implicit task (Jacoby, 1991; Richardson-Klaven & Bjork, 1988). In the present study, subjects were amnesic following ECT and, as their explicit memory was impaired, they could not employ such strategies to enhance their performance. At pre-ECT, they were not amnesic and may have employed explicit strategies to enhance their implicit performance. However, the results suggest otherwise. Stem completion performance was no different at post-ECT, compared to pre-ECT. This suggests that subjects' stem completion performance at pre-ECT was not contaminated by explicit retrieval strategies.

Semantic processing is typically thought to be deeper, and hence better for retention for tests of memory; however, the present results show that performance on stem completion did not benefit from semantic processing. This suggests that the efficacy of orienting tasks depends on the nature of the task requirement in the test and the appropriateness of prior processing for the test (Roediger, 1990). The present data show that dissociations can be obtained on implicit and explicit tests with the same test cues as a function of level of processing.

Effect of Retention Interval or Delay Period on Implicit and Explicit Memory

The results of this study show that retention curves for implicit and explicit retrieval are different. As expected, there was a significant deterioration in explicit recall from the 15 to the 90 and from the 90 to the 180-minute delayed recall. In the case of implicit retrieval prior to ECT, there was a decline in performance from the 15 to the 90-

minute retention interval but performance did not change from the 90 to 180-minute delay period. Post-ECT performance improved slightly from the 90 to the 180-minute delay period.

Most studies find a slower decay for implicit retrieval over a particular retention interval than for explicit retrieval. In perceptual identification (Feustel et al., 1983) and lexical decision tasks (Moscovitch, 1985; Scarborough et al., 1977), priming effects showed no significant decrease over short retention intervals. Even over longer retention intervals, priming appears quite robust - for example, over periods of 24 hours, in perceptual identification (Jacoby & Dallas, 1981), and 7 days in fragment completion (Tulving et al., 1982; Komatsu & Ohta, 1984). However, other studies have reported reduction in perceptual identification over 24 hours (Jacoby, 1983a; Salasoo, Shiffrin, & Feustel, 1985), in lexical decision after 2 days (Scarborough et al., 1977), in fragment completion over 7 days (Roediger & Blaxton, 1987) and over 1 to 5 weeks (Komatsu & Ohta, 1984). Although these studies reported decreases in priming, they nonetheless found that priming effects were still observable at the longest interval studied.

A few studies examining priming in free association and stem-completion tasks with multiple solutions have shown rapid decay, reaching baseline at about 2 hours in both normal and amnesic subjects (e.g., Diamond & Rozin, 1984; Graf et al., 1984; Squire et al., 1987). An interesting finding in the present study was that although word stem completion performance deteriorated from the 15 to the 90-minute delay period, there was significant improvement in performance from the 90-minute to the 3-hour retention interval (at post-ECT). Pre-ECT, the improvement was very slight and did not reach significance, a possible explanation is that implicit memory undergoes a process of consolidation and that during this process there is some temporary decline in the ability to recall. Furthermore, once consolidation has occurred, access might be regained to the "lost" material. The study by Graf et al. (1984) did not include retention periods longer than 2 hours and the one by Squire et al. (1987) examined delay periods of 0 hours, 2 hours, and 4 days. It is possible that these studies missed a crucial feature of the consolidation process for priming by not including retention intervals of intermediate lengths. On the other hand, it is possible that the present findings are unreliable. Resolution of the issue of the longevity of priming effects awaits further research. To explore the nature of consolidation of implicit memory processes further, it might be profitable to examine implicit memory with retention intervals of varying lengths, including intervals greater than 3 hours, in order to determine the entire curve of the consolidation process of implicit memory.

Overall, the results of the present study support the view that implicit and explicit retrieval are governed by different underlying mechanisms.

Effect of ECT on Depression

As expected from clinical experience and previous research, the results of the present study showed that ECT had a beneficial effect on depression. The severity of depression as measured by the HAM-D improved significantly after ECT, compared to pre-ECT levels. Thus, while it was not the primary interest of this dissertation, it is gratifying, nonetheless, to be able to offer further evidence for the effectiveness of ECT.

Effect of Depression on Memory

Past research has shown that depression has a detrimental effect on memory (e.g., Cronholm & Ottoson, 1963; Sternberg & Jarvik, 1976). At least three studies have shown that implicit memory remains intact in depressed patients, even though explicit memory is impaired (e.g., Hertel & Hardin, 1990; Denny & Hunt, 1992; Watkins et al., 1992). The present study examined the relationship between depression and implicit and explicit memory.

Contrary to past research, the results of the present study failed to show any relationship between depression and memory (both implicit and explicit) using a regression analysis. A possible explanation for this incongruent finding is that while previous studies used only depressed patients in their sample, the present study used subjects with various diagnoses, including schizophrenia, bipolar disorder, dementia, and major depression. Thus, the ability of the present study to examine the effects of depression on memory was limited. Regression analyses were subsequently performed using only those subjects who were depressed. The pattern of the experimental results did not change, however. It is possible that small sample size may have contributed to the present findings of a lack of relationship between depression and implicit and explicit memory.

Compared to a group of normal control subjects, the depressed group (experimental subjects at pre-ECT) appeared to perform equally well on the implicit memory task. These results are consistent with those of Denny and Hunt (1992), Watkins et al. (1992), and Hertel and Hardin (1990). With respect to explicit memory, when depressed subjects processed the structural aspects of the words (nonsemantic study condition), their explicit performance was intact. However, their performance was impaired when words were studied in the semantic condition (at the 15-minute delay period). Semantic processing requires subjects to consider the meaning of the word. The results show that semantic processing, perhaps due to the elaboration and deeper level of processing that it requires, interfered with recall. Alternatively, it is possible that rating words for their pleasantness highlights the emotional salience of the words. Research suggests that mood-congruent memory (MCM), the tendency to recall information that is congruent with one's mood, may play an important role in depression (e.g., Ingram, 1984; Teasdale, 1983). Watkins et al. (1992) found an MCM bias on an explicit memory test but not in implicit memory test. Since elaborative processes are related to explicit memory, these authors concluded that elaborative mechanisms are involved in MCM. The present study found that subjects' recall of words was impaired when, during study, they had to rate the pleasantness of the words. Although the words in the present study did not have a depressive salience, depressed subjects tended to give them low pleasantness ratings at pre-ECT.

Relationship Between Attention, ECT, and Memory

Research suggests that attentional functions usually affect performance in explicit memory tasks more than they do in implicit tasks (Eich, 1984; Jacoby & Brooks, 1984). While other studies have found that both implicit and explicit test performance benefit from attentional factors during encoding (e.g., Fisk & Schneider, 1984). The results of the present study, however, did not find a relationship between attentional functions (as measured by the VSAT) and implicit or explicit memory. While previous studies actually manipulated the level of attention at encoding, the present study simply measured the level of attention at the end of the third testing session, this prevented us from examining the issue of how attentional factors during study affected memory.

It was noted that, compared to a group of normal control subjects, attentional abilities of the experimental subjects were impaired (at pre-ECT). It might be, then, that attentional deficits might have contributed to the seemingly poor performance on the explicit task (with semantic orientation) at pre-ECT compared to control subjects. However, systematic manipulation of attentional variables and statistical comparisons between control and experimental subjects would be required in order to draw such conclusions.

Second, with respect to the issue of the relationship between ECT and attention, in the present study, attention functions were at pre-ECT levels when assessed 5 to 6 hours after the administration of ECT. Studies examining attentional functions in relation to ECT have found that immediately after ECT, and for a few hours thereafter, attentional functions are impaired (Sackeim, 1992). However, studies examining longer delay periods of 1 week or more have reported improvement in attention functions after ECT (Malloy, Small, Miller, Milstein, & Stout, 1982; Small, Milstein, Miller, Malloy, & Small, 1986). Since, in the present study, attentional functions were assessed only at the end of the third retention interval, it was not possible to examine the course of recovery of these functions during the period immediately after ECT and a few hours thereafter.

Limitations of the Present Study

The memory measure used in the present study was developed from the word list used by Rajaram and Roediger (1993) and Roediger et al. (1992). The reliability of this measure has not been firmly established; hence the reliability of the present results is somewhat tentative and they must be interpreted with caution. The need to improve the reliability and validity of memory measures is high priority for future research. The same can be said with respect to the measure of attention. That is, the VSAT is primarily a research instrument and its reliability has not been established. This reduces the degree of confidence that can be placed in the present findings. The relationship between implicit and explicit memory to attentional states is thus in need of further examination.

The sample size used in this study was relatively small given the number of independent variables that were manipulated. Originally a larger sample size was planned, however, due to the nature of the clinical population available, the study could only sample a relatively modest number of people. Thus the power of the study to detect subtle effects may have been compromised especially in the case of detecting the effects of depression on memory. Moreover, the sample consisted of only in-patients who consented to participate in the study. A number of severely depressed patients, especially those with poor motivation (a hallmark of clinical depression) declined to participate. The sample differs from an out-patient population in a number of relevant ways such as severity of symptoms, recovery process, and so on. Furthermore, most of the experimental group and all of the control group subjects were seniors. Hence, the generalizability of the results to other populations (out-patients and younger adults) is limited.

The VSAT was administered at the end of the third testing session, so this did not allow us to examine the effect of attentional abilities on short-term memory or to compare them to the effects of attention on delayed recall. It would be have been of interest to measure attentional abilities during the study period and at every testing session to allow such comparisons.

Finally, the present results are part of an ongoing area of inquiry designed to understand the mechanisms of the brain and its relationship to human behavior. The present findings are not definitive but need further confirmation with both similar and varying populations.

Summary and Implications

The present study was undertaken for several reasons. One was to help clarify the relationship between ECT and implicit memory. The study was unique in its design in that it compared pre- and post-ECT memory performance. It showed that, compared to explicit memory, priming was relatively intact after ECT. Furthermore, although there was some reduction in priming as time between study and test elapsed, it was still substantial, even at the longest delay period of three hours. The importance of assessing memory at intermittent retention intervals was highlighted with respect to understanding the consolidation process of implicit memory. Longer retention intervals of a few days and even weeks need also to be included in order to examine the longitudinal aspects of implicit and explicit retention and also to examine the long-term effects of ECT on memory.

In examining the relationship between ECT and memory, the present study also measured several relevant parameters such as depression and attention, which have been shown to be related both to ECT and memory. This was done in order to study how these variables affect each other and also how they influence the relationship between ECT and memory. With respect to the relationships among depression, ECT, and memory, the present study showed that ECT affects explicit memory, over and above the effects of depression. In fact, depression only affected explicit memory for words that were semantically processed. It did not affect explicit memory for nonsemantically processed words. Implicit memory was unaffected by either depression or ECT. With respect to attention and how it might influence memory, this study proved flawed in certain design aspects, limiting its ability to assess some crucial aspects of this relationship. The study nonetheless showed that attentional abilities are more or less recovered by approximately five hours after the administration of ECT. However, this relationship was not examined immediately after and during the few hours following ECT.

The present study has important clinical implications for memory rehabilitation subsequent to brain trauma causing memory loss. In the past, memory rehabilitation has dealt only with restitution or else substitution of lost memory abilities, which has yielded limited success. The present findings may have implications for memory rehabilitation via intact implicit memory processes. For example, it may be possible to access different kinds of memories (e.g., everyday memory) through priming (which is relatively intact) which are otherwise unavailable via explicit memory (which is impaired) thereby improving the daily functioning of patients with memory impairment.

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APPENDIX A

Experimental group consent form

INFORMED PATIENT CONSENT

Investigators: Charu Chopra, Ph.D. student, Psychology Department, SFU, Phone: 291-3354
Dr. Barry Beyerstein, Psychology Department, SFU, Phone: 291-3354

Title:

Examining the Effects of Electroconvulsive Therapy on Implicit and Explicit Memory

Purpose:

Electroconvulsive therapy is given to severely depressed patients to help relieve their depression. The researcher (Charu) has told me that the research is being done in order to understand how electroconvulsive therapy (ECT) affects the patient's depressive symptoms, their ability to pay attention, and their memory, that is, how these functions change after ECT.

Background:

I understand that I am being invited to participate in this study because I have depression and my doctor has prescribed a course of electroconvulsive therapy (ECT) for the treatment of my depression.

I understand that the ECT treatment I am going to receive will be given to me according to my doctor's advise and will not in anyway be altered for the purpose of the present study. I also understand that I am not receiving ECT for the purpose of the present study.

I understand that the present study has nothing to do with my treatment at the hospital.

Study Procedures:

I will be asked to complete tests measuring my, attention, concentration, and memory. There will be a total of 6-7 testing sessions, of which 3 sessions will be on the day before I start my ECT treatment, and 3-4 sessions on the day of my sixth ECT treatment. Each assessment session will take approximately 10 - 15 minutes.

I understand that the researcher will obtain information from my clinical chart regarding my current and past diagnosis, severity of depression, medication, age, education, and the details of the ECT that will be administered to me.

Exclusion:

I will not be selected for the study if I have any of the following: a diagnosis of any type of dementia, history of substance abuse disorder, or seizure disorder.

Risks:

The researcher (Charu) has informed me that she does not foresee any physical or emotional harm resulting from participation in this study.

Benefits:

I am told that the results of this study might be useful in planning future ECT treatments for patients.

Confidentiality:

I have been assured by Charu that any information I give will be kept confidential. My name will be erased from all data and the data I provide will be given a code number. My name and other identifying information will be kept separately assuring strict privacy and will be destroyed after the research and its publication is completed.

Contact:

I understand that if I have any questions or desire further information with respect to this study, or if I experience any adverse effects, I should contact Charu Chopra or Dr. Beyerstein at 291-3354. If I have any concerns about this research or my rights as a research subject I may contact the chair of the department of psychology at Simon Fraser University, Dr. Krane at 291-3354.

New Findings:

I will be informed of any new information that becomes available that may affect my willingness to remain in this study.

Voluntary:

I understand that my participation in this study is voluntary and that I may refuse to participate or I may withdraw from the study at anytime without any consequences to my continuing medical care. I have received a copy of this consent form for my own records.

Consent:

I have understood the contents of this form and I consent to participate in this study.

Name (please print):________________________

____

Patient's Signature Date

____

Witness Signature Date

____

Investigator's Signature Date

Control group consent form

INFORMED CONSENT FORM

Investigators: Charu Chopra, Ph.D. student, Psychology Department, SFU, Phone: 291-3354
Dr. Barry Beyerstein, Psychology Department, SFU, Phone: 291-3354

Title:

Examining the Effects of Electroconvulsive Therapy on Implicit and Explicit Memory

Purpose:

Electroconvulsive therapy (ECT) is given to severely depressed patients to help relieve their depressive symptoms. The researcher (Charu) has told me that this study is being done in order to understand how ECT affects the patient's depressive symptoms, their ability to pay attention, and their memory, that is, how these functions change after ECT.

Background:

I understand that I am being invited to participate in this study because the investigator also needs to collect data from non-depressed individuals, who have never received ECT, for comparison.

Study Procedures:

I will be asked to complete tests measuring my attention, concentration, and memory. There will be a total of 3 - 4 testing sessions, all on the same day (within the span of 4 hours). I understand that each assessment session will take approximately 10 minutes.

Exclusion:

I will not be selected for the study if I have ever received ECT in the past, or if I have Alzheimer's, Parkinson's, Huntington's disease or dementia, history of substance abuse disorder, or seizure disorder.

Risks:

The researcher has informed me that she does not foresee any physical or emotional harm resulting from participation in this study.

Benefits:

I am told that the results of this study may help understand how ECT affects some of the cognitive functions of patients who receive this treatment and it may help to better plan future treatments for patients.

Confidentiality:

I have been assured by Charu that any information I give will be kept confidential. My name will be erased from all data and the data I provide will be given a code number. My name and other identifying information will be kept separately assuring strict privacy and will be destroyed after the research and its publication is completed.

Contact:

I understand that if I have any questions or desire further information with respect to this study, or if I experience any adverse effects, I should contact Charu Chopra or Dr. Beyerstein at 291-3354. If I have any concerns about this research or my rights as a research subject I may contact the chair of the department of psychology at Simon Fraser University, Dr. Krane at 291-3354.

New Findings:

I will be informed of any new information that becomes available that may affect my willingness to remain in this study.

Voluntary:

I understand that my participation in this study is voluntary and that I may refuse to participate or I may withdraw from the study at anytime without any prejudice. I have received a copy of this consent form for my own records.

Consent:

I have understood the contents of this form and I consent to participate in this study.

Name (please print):_______________

____

Signature Date

____

Witness Signature Date

____

Investigator's Signature Date

APPENDIX B

MASTER WORD LIST (studied words)

Target Word	Stem	# letters	Freq.	Imagery	Familiarity
ACCORDIAN	ACC____	9	1	3.40	2.15
ALLIGATOR	ALL____	9	4	3.98	1.65
ANCHOR	ANC____	6	15	4.32	1.60
ARROW	ARR____	5	14	2.27	3.38
ASHTRAY	ASH____	7	1	3.20	3.56
BALLOON	BAL____	7	10	4.33	2.58
BANANA	BAN____	6	4	4.42	3.65
BARREL	BAR____	6	24	4.31	2.02
BASKET	BAS____	6	17	2.62	2.18
BICYCLE	BIC____	7	5	3.40	3.78
BLOUSE	BLO____	6	1	2.80	4.18
BREAD	BRE____	5	41	4.02	4.40
BROOM	BRO____	5	2	4.35	3.42
BRUSH	BRU____	5	44	3.20	3.80
BUTTON	BUT____	6	10	4.48	3.85
CAMEL	CAM____	5	1	3.92	2.08
CANDLE	CAN____	6	18	3.85	3.08
CARROT	CAR____	6	1	4.50	3.55
CELERY	CEL____	6	4	3.75	3.40
CHICKEN	CHI____	7	37	3.62	2.42
CIGAR	CIG____	5	10	2.75	2.35
CLOCK	CLO____	5	20	2.20	4.38
CROWN	CRO____	5	19	2.85	1.52
DIAMOND	DIA____	7	8		
DOORKNOB	DOO____	8	3	3.90	4.25
ELEVATOR	ELE____	8	12		
ENVELOPE	ENV____	8	21	4.70	4.12
ESCALATOR	ESC____	9	7 (escalation)		
FINGER	FIN____	6	40	4.60	4.78
FIREPLACE	FIR____	9	6		
FLOWER	FLO____	6	23	3.25	3.88
FOLDER	FOL____	6	1		
FOOTBALL	FOO____	8	36	4.18	3.55
GLASSES	gla____	7	29	3.81	4.00
GLOVE	GLO____	5	9	3.65	3.38
GRAPES	GRA____	6	7	4.31	3.65
GUITAR	GUI____	6	19	4.20	3.58
HAMMER	HAM____	6	9	4.10	3.48
HANGER	HAN____	6	1	4.73	4.52
JACKET	JAC____	6	33	2.22	4.00
LADDER	LAD____	6	19	3.75	3.35
LEMON	LEM____	5	18	4.35	3.25
LETTUCE	LET____	7	0	3.05	3.42
LOBSTER	LOB____	7	1	3.62	2.58
MONKEY	MON____	6	9	3.12	2.58
MOUNTAIN	MOU____	8	33	3.52	2.70
MUSHROOM	MUS____	8	2	3.78	2.88
OCTOPUS	OCT____	7	1		
PARCEL	PAR____	6	1		

PEANUT	PEA____	6	6	4.30	3.00
PENCIL	PEN____	6	34	4.40	4.42
PENGUIN	PEN____	7			
PINEAPPLE	PIN____	9	9	4.60	2.95
PITCHER	PIT____	7	21	3.62	3.50
PLIERS	PLI____	6	1	4.22	3.38
POTATO	POT____	6	15	3.97	3.46
PRETZEL	PRE____	7			
PUMPKIN	PUM____	7	2	4.18	3.08
PYRAMID	PYR____	7	2		
RABBIT	RAB____	6	11	4.20	2.95
RACCOON	RAC____	7	1	3.08	2.20
RULER	RUL____	5	3	3.98	3.58
SAILBOAT	SAI____	8	1	3.25	2.92
SANDWICH	SAN____	8	10	3.55	4.45
SCISSORS	SCI____	8	1	4.40	3.98
SCREW	SCR____	5	21	3.67	3.20
SHIRT	SHI____	5	27	3.86	4.56
SKUNK	SKU____	5	1(skunks)	3.40	2.30
SNAKE	SNA____	5	44	3.54	1.90
SNOWMAN	SNO____	7		4.00	3.15
SPIDER	SPI____	6	2	2.95	2.28
SPOON	SPO____	5	6	4.10	4.50
SQUIRREL	SQU____	8	1	4.42	3.82
STOOL	STO____	5	8	4.12	3.08
SUITCASE	SUI____	8	20	2.98	3.65
SWEATER	SWE____	7	14	2.78	4.48
SWING	SWI____	5	24	4.15	3.02
TABLET	TAB____	6	3		
THIMBLE	THI____	7	1	4.26	2.48
THUMB	THU____	5	10	4.48	4.72
TIGER	TIG____	5	7	3.82	2.10
TOASTER	TOA____	7	0	3.92	4.08
TOMATO	TOM____	6	4	4.05	3.78
TORNADO	TOR____	7	1		
TRACTOR	TRA____	7	24		
TRUMPET	TRU____	7	7	2.89	2.60
TURTLE	TUR____	6	8	4.12	2.40
VIOLIN	VIO____	6	11	4.18	2.68
WHISTLE	WHI____	7	4	4.55	2.45
WRENCH	WRE____	6	0	2.51	2.72

MASTER WORD LIST (unstudied words)

Word	Stem	# Letters	Freq.	Imagery	Familiarity
BEETLE	BEE____	6	1	2.05	1.88
BLAZER	BLA____	6	1		
BOUQET	BOU____	6	4		
BRIDE	BRI____	5	33		
CABBAGE	CAB____	7	-		
CALIPERS	CAL____	8	1		
CLIMATE	CLI____	7	-		
COBBLER	COB____	7	1		
COCKPIT	COC____	7	16		
COMMA	COM____	5	2		
CRADLE	CRA____	6	7		
CROCODILE	CRO____	9	1		
DRAGON	DRA____	6	1		
FEATHER	FEA____	7	6		
FLAME	FLA____	5	17		
FORTUNE	FOR____	7	25		
GARLAND	GAR____	7	9		
GIRAFFE	GIR____	7	-	4.48	1.80
HARBOR	HAR____	6	37		
HEALTHY	HEA____	7	33		
LANTERN	LAN____	7	13		
LEGACY	LEG____	6	5		
LIBERTY	LIB____	7	46		
MAGAZINE	MAG____	8	39		
MAILBOX	MAI____	7	1		
MARBLE	MAR____	6	21		
MASCARA	MAS____	7	1		
NECKTIE	NEC____	7	2		
PILLOW	PIL____	6	8		
PORCUPINE	POR____	9	1		
POSTCARD	POS____	8	7		
PURSE	PUR____	5	14		
RADAR	RAD____	5	23		
ROBOT	ROB____	5	1		
ROCKET	ROC____	6	7		
SALIVA	SAL____	6	4		
SHADOW	SHA____	6	36		
SHOELACE	SHO____	8	1		
SLIPPER	SLI____	7	3		
SOLDIER	SOL____	7	39		
SPATULA	SPA____	7	-		
SWITCH	SWI____	6	43		
TONGS	TON____	5	1		
TOWEL	TOW____	5	6		
TRAILS	TRA____	6	16		
TREASURE	TRE____	8	4		
TROPHY	TRO____	6	8		
VANILLA	VAN____	7	1		

STUDY - WORD LIST A (NS-S)
Nonsemantic - Semantic

STUDY - RESPONSE SHEET

	Target Word	Response	

NON-SEMANTIC - COUNT THE VOWELS

FILLERS

	Target Word	Response	
	DOLPHIN	______________	
	SCHOOL	______________	
	COTTON	______________	
1	DIAMOND	______________	A2
2	GLOVE	______________	A3
3	TORNADO	______________	A1
4	ANCHOR	______________	A3
5	PYRAMID	______________	A2
6	BUTTON	______________	A1
7	WRENCH	______________	A3
8	MONKEY	______________	A1
9	SANDWICH	______________	A2
10	BREAD	______________	A2
11	FOOTBALL	______________	A3
12	SHIRT	______________	A2
13	BROOM	______________	A3
14	SQUIRREL	______________	A1
15	RULER	______________	A3
16	ARROW	______________	A1
17	PARCEL	______________	A2
18	TIGER	______________	A1
19	OCTOPUS	______________	A3
20	REPAIR	______________	A2
21	CELERY	______________	A1

SEMANTIC - RATE FOR PLEASANTNESS

	Target Word	Response	
22	JACKET	______________	A3
23	PRETZEL	______________	A1
24	ENVELOPE	______________	A2
25	TURTLE	______________	A3
26	DOORKNOB	______________	A3
27	TOMATO	______________	A2
28	HANGER	______________	A1
29	PLIERS	______________	A1
30	CIGAR	______________	A2
31	PITCHER	______________	A3
32	THIMBLE	______________	A2
33	LADDER	______________	A1
34	BICYCLE	______________	A3
35	ESCALATOR	______________	A1
36	SKUNK	______________	A2

37	SPIDER	____________	A3
38	BARREL	____________	A1
39	LETTUCE	____________	A2
40	FIREPLACE	____________	A2
41	GLASSES	____________	A1
42	SWEATER	____________	A3

FILLERS

	VULTURE	____________
	LITHIUM	____________
	PEPPER	____________

Note: There was another identical study list as this, with the exception that the first half of the words were studied in semantic and second half in nonsemantic condition.

STEM LIST A1 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	__________		
	ACC____	ACCORDIAN	__________		
	HOR____	HORSE	__________		
1	BAR____	BARREL	__________	A1	S
2	ROC____	ROCKET	__________	A1 (UN)	
3	VAN____	VANILLA	__________	A1 (UN)	
4	TIG____	TIGER	__________	A1	NS
5	HAN____	HANGER	__________	A1	S
6	CEL____	CELERY	__________	A1	NS
7	BRI____	BRIDE	__________	A1 (UN)	
8	TRE____	TREASURE	__________	A1 (UN)	
9	PLI____	PLIERS	__________	A1	S
10	ESC____	ESCALATOR	__________	A1	S
11	SQU____	SQUIRREL	__________	A1	NS
12	LAD____	LADDER	__________	A1	S
13	ARR____	ARROW	__________	A1	NS
14	HAR____	HARBOR	__________	A1 (UN)	
15	PUR____	PURSE	__________	A1 (UN)	
16	MON____	MONKEY	__________	A1	NS
17	BUT____	BUTTON	__________	A1	NS
18	SPA____	SPATULA	__________	A1 (UN)	
19	PRE____	PRETZEL	__________	A1	S
20	TOR____	TORNADO	__________	A1	NS
21	GLA____	GLASSES	__________	A1	S

STEM LIST A2 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	__________		
	ACC____	ACCORDIAN	__________		
	HOR____	HORSE	__________		
1	ENV____	ENVELOPE	__________	A2	S
2	CLI____	CLIMATE	__________	A2 (UN)	
3	SAL____	SALIVA	__________	A2 (UN)	
4	LET____	LETTUCE	__________	A2	S
5	BRE____	BREAD	__________	A2	NS
6	GAR____	GARLAND	__________	A2 (UN)	
7	TOM____	TOMATO	__________	A2	S
8	DRA____	DRAGON	__________	A2 (UN)	
9	SHI____	SHIRT	__________	A2	NS
10	PAR____	PARCEL	__________	A2	NS
11	THI____	THIMBLE	__________	A2	S
12	FIR____	FIREPLACE	__________	A2	S
13	CIG____	CIGAR	__________	A2	S
14	TOW____	TOWEL	__________	A2 (UN)	
15	REP____	REPAIR	__________	A2	NS
16	EYE____	EYEBALL	__________	A2 (UN)	
17	CAL____	CALIPERS	__________	A2 (UN)	
18	PYR____	PYRAMID	__________	A2	NS
19	SAN____	SANDWICH	__________	A2	NS
20	DIA____	DIAMOND	__________	A2	NS
21	SKU____	SKUNK	__________	A2	S

STEM LIST A3 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	__________		
	ACC____	ACCORDIAN	__________		
	HOR____	HORSE	__________		
1	DOO____	DOORKNOB	__________	A3	S
2	POS____	POSTCARD	__________	A3 (UN)	
3	ANC____	ANCHOR	__________	A3	NS
4	WRE____	WRENCH	__________	A3	NS
5	SPI____	SPIDER	__________	A3	S
6	BRO____	BROOM	__________	A3	NS
7	LEG____	LEGACY	__________	A3 (UN)	
8	OCT____	OCTOPUS	__________	A3	NS
9	SWE____	SWEATER	__________	A3	S
10	GLO____	GLOVE	__________	A3	NS
11	COC____	COCKPIT	__________	A3 (UN)	
12	BEE____	BEETLE	__________	A3 (UN)	
13	SOL____	SOLDIER	__________	A3 (UN)	
14	FOO____	FOOTBALL	__________	A3	NS
15	JAC____	JACKET	__________	A3	S
16	TUR____	TURTLE	__________	A3	S
17	ROB____	ROBOT	__________	A3 (UN)	
18	BIC____	BICYCLE	__________	A3	S
19	RUL____	RULER	__________	A3	NS
20	PIT____	PITCHER	__________	A3	S
21	FOR____	FORTUNE	__________	A3 (UN)	

STEM LIST A1 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA_____	CHAIR	___________		
	ACC_____	ACCORDIAN	___________		
	HOR_____	HORSE	___________		
1	BAR_____	BARREL	___________	A1	NS
2	ROC_____	ROCKET	___________	A1 (UN)	
3	VAN_____	VANILLA	___________	A1 (UN)	
4	TIG_____	TIGER	___________	A1	S
5	HAN_____	HANGER	___________	A1	NS
6	CEL_____	CELERY	___________	A1	S
7	BRI_____	BRIDE	___________	A1 (UN)	
8	TRE_____	TREASURE	___________	A1 (UN)	
9	PLI_____	PLIERS	___________	A1	NS
10	ESC_____	ESCALATOR	___________	A1	NS
11	SQU_____	SQUIRREL	___________	A1	S
12	LAD_____	LADDER	___________	A1	NS
13	ARR_____	ARROW	___________	A1	S
14	HAR_____	HARBOR	___________	A1 (UN)	
15	PUR_____	PURSE	___________	A1 (UN)	
16	MON_____	MONKEY	___________	A1	S
17	BUT_____	BUTTON	___________	A1	S
18	SPA_____	SPATULA	___________	A1 (UN)	
19	PRE_____	PRETZEL	___________	A1	NS
20	TOR_____	TORNADO	___________	A1	S
21	GLA_____	GLASSES	___________	A1	NS

STEM LIST A2 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	__________		
	ACC____	ACCORDIAN	__________		
	HOR____	HORSE	__________		
1	ENV____	ENVELOPE	__________	A2	NS
2	CLI____	CLIMATE	__________	A2 (UN)	
3	SAL____	SALIVA	__________	A2 (UN)	
4	LET____	LETTUCE	__________	A2	NS
5	BRE____	BREAD	__________	A2	S
6	GAR____	GARLAND	__________	A2 (UN)	
7	TOM____	TOMATO	__________	A2	NS
8	DRA____	DRAGON	__________	A2 (UN)	
9	SHI____	SHIRT	__________	A2	S
10	PAR____	PARCEL	__________	A2	S
11	THI____	THIMBLE	__________	A2	NS
12	FIR____	FIREPLACE	__________	A2	NS
13	CIG____	CIGAR	__________	A2	NS
14	TOW____	TOWEL	__________	A2 (UN)	
15	REP____	REPAIR	__________	A2	S
16	EYE____	EYEBALL	__________	A2 (UN)	
17	CAL____	CALIPERS	__________	A2 (UN)	
18	PYR____	PYRAMID	__________	A2	S
19	SAN____	SANDWICH	__________	A2	S
20	DIA____	DIAMOND	__________	A2	S
21	SKU____	SKUNK	__________	A2	NS

STEM LIST A3 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	________		
	ACC____	ACCORDIAN	________		
	HOR____	HORSE	________		
1	DOO____	DOORKNOB	________	A3	NS
2	POS____	POSTCARD	________	A3 (UN)	
3	ANC____	ANCHOR	________	A3	S
4	WRE____	WRENCH	________	A3	S
5	SPI____	SPIDER	________	A3	NS
6	BRO____	BROOM	________	A3	S
7	LEG____	LEGACY	________	A3 (UN)	
8	OCT____	OCTOPUS	________	A3	S
9	SWE____	SWEATER	________	A3	NS
10	GLO____	GLOVE	________	A3	S
11	COC____	COCKPIT	________	A3 (UN)	
12	BEE____	BEETLE	________	A3 (UN)	
13	SOL____	SOLDIER	________	A3 (UN)	
14	FOO____	FOOTBALL	________	A3	S
15	JAC____	JACKET	________	A3	NS
16	TUR____	TURTLE	________	A3	NS
17	ROB____	ROBOT	________	A3 (UN)	
18	BIC____	BICYCLE	________	A3	NS
19	RUL____	RULER	________	A3	S
20	PIT____	PITCHER	________	A3	NS
21	FOR____	FORTUNE	________	A3 (UN)	

STUDY - WORD LIST - X/A (S-NS)

Target Word

SEMANTIC - RATING FOR PLEASANTNESS

FILLERS

	DOLPHIN	________	
	SCHOOL	________	
	COTTON	________	
1	DRAGON	________	A2
2	GLOVE	________	A3
3	VANILLA	________	A1
4	ANCHOR	________	A3
5	PYRAMID	________	A2
6	BUTTON	________	A1
7	SOLDIER	________	A3
8	ROCKET	________	A1
9	SANDWICH	________	A2
10	BREAD	________	A2
11	TREASURE	________	A1
12	FORTUNE	________	A3
13	SHIRT	________	A2
14	BROOM	________	A3
15	SQUIRREL	________	A1
16	POSTCARD	________	A3
17	BRIDE	________	A1
18	PARCEL	________	A2
19	TIGER	________	A1
20	CALIPERS	________	A2
21	LEGACY	________	A3

NON-SEMANTIC - COUNTING VOWELS

22	CELERY	________	A1
23	JACKET	________	A3
24	SPATULA	________	A1
25	EYEBALL	________	A2
26	TURTLE	________	A3
27	DOORKNOB	________	A3
28	TOWEL	________	A2
29	PURSE	________	A1
30	PLIERS	________	A1
31	CLIMATE	________	A2
32	PITCHER	________	A3
33	THIMBLE	________	A2
34	LADDER	________	A1
35	BEETLE	________	A3
36	SALIVA	________	A2
37	COCKPIT	________	A3
38	HARBOR	________	A1
39	GARLAND	________	A2
40	FIREPLACE	________	A2

41	GLASSES	__________	A1
42	ROBOT	__________	A3

FILLERS

VULTURE
LITHIUM
PEPPER

Note: 1 There was another identical study list as this, with the exception that the first half of the words were studied in nonsemantic and second half in semantic condition.
2 List X/A is identical to list A except that the studied words in list A become unstudied words in list X/A and vice versa.

STEM LIST - X/A1 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	________		
	ACC____	ACCORDIAN	________		
	HOR____	HORSE	________		
1	BAR____	BARREL	________	A1 (UN)	
2	HAN____	HANGER	________	A1 (UN)	
3	ROC____	ROCKET	________	A1	S
4	TIG____	TIGER	________	A1	S
5	VAN____	VANILLA	________	A1	S
6	CEL____	CELERY	________	A1	NS
7	PLI____	PLIERS	________	A1	NS
8	ESC____	ESCALATOR	________	A1 (UN)	
9	BRI____	BRIDE	________	A1	S
10	SQU____	SQUIRREL	________	A1	S
11	LAD____	LADDER	________	A1	NS
12	TRE____	TREASURE	________	A1	S
13	ARR____	ARROW	________	A1 (UN)	
14	MON____	MONKEY	________	A1 (UN)	
15	HAR____	HARBOR	________	A1	NS
16	BUT____	BUTTON	________	A1	S
17	PRE____	PRETZEL	________	A1 (UN)	
18	PUR____	PURSE	________	A1	NS
19	TOR____	TORNADO	________	A1 (UN)	
20	GLA____	GLASSES	________	A1	NS
21	SPA____	SPATULA	________	A1	NS

STEM LIST - X/A2 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	________		
	ACC____	ACCORDIAN	________		
	HOR____	HORSE	________		
1	CLI____	CLIMATE	________	A2	NS
2	ENV____	ENVELOPE	________	A2 (UN)	
3	LET____	LETTUCE	________	A2 (UN)	
4	SAL____	SALIVA	________	A2	NS
5	BRE____	BREAD	________	A2	S
6	TOM____	TOMATO	________	A2 (UN)	
7	GAR____	GARLAND	________	A2	NS
8	SHI____	SHIRT	________	A2	S
9	PAR____	PARCEL	________	A2	S
10	DRA____	DRAGON	________	A2	S
11	THI____	THIMBLE	________	A2	NS
12	FIR____	FIREPLACE	________	A2	NS
13	CIG____	CIGAR	________	A2 (UN)	
14	REP____	REPAIR	________	A2 (UN)	
15	TOW____	TOWEL	________	A2	NS
16	PYR____	PYRAMID	________	A2	S
17	EYE____	EYEBALL	________	A2	NS
18	SAN____	SANDWICH	________	A2	S
19	DIA____	DIAMOND	________	A2 (UN)	
20	CAL____	CALIPERS	________	A2	S
21	SKU____	SKUNK	________	A2 (UN)	

STEM LIST - X/A3 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	________		
	ACC____	ACCORDIAN	________		
	HOR____	HORSE	________		
1	DOO____	DOORKNOB	________	A3	NS
2	POS____	POSTCARD	________	A3	S
3	ANC____	ANCHOR	________	A3	S
4	WRE____	WRENCH	________	A3 (UN)	
5	LEG____	LEGACY	________	A3	S
6	SPI____	SPIDER	________	A3 (UN)	
7	BRO____	BROOM	________	A3	S
8	COC____	COCKPIT	________	A3	NS
9	OCT____	OCTOPUS	________	A3 (UN)	
10	SWE____	SWEATER	________	A3 (UN)	
11	BEE____	BEETLE	________	A3	NS
12	GLO____	GLOVE	________	A3	S
13	SOL____	SOLDIER	________	A3	S
14	FOO____	FOOTBALL	________	A3 (UN)	
15	JAC____	JACKET	________	A3	NS
16	TUR____	TURTLE	________	A3	NS
17	BIC____	BICYCLE	________	A3 (UN)	
18	ROB____	ROBOT	________	A3	NS
19	RUL____	RULER	________	A3 (UN)	
20	PIT____	PITCHER	________	A3	NS
21	FOR____	FORTUNE	________	A3	S

STEM LIST - X/A1 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	________		
	ACC____	ACCORDIAN	________		
	HOR____	HORSE	________		
1	BAR____	BARREL	________	A1 (UN)	
2	HAN____	HANGER	________	A1 (UN)	
3	ROC____	ROCKET	________	A1	NS
4	TIG____	TIGER	________	A1	NS
5	VAN____	VANILLA	________	A1	NS
6	CEL____	CELERY	________	A1	S
7	PLI____	PLIERS	________	A1	S
8	ESC____	ESCALATOR	________	A1 (UN)	
9	BRI____	BRIDE	________	A1	NS
10	SQU____	SQUIRREL	________	A1	NS
11	LAD____	LADDER	________	A1	S
12	TRE____	TREASURE	________	A1	NS
13	ARR____	ARROW	________	A1 (UN)	
14	MON____	MONKEY	________	A1 (UN)	
15	HAR____	HARBOR	________	A1	S
16	BUT____	BUTTON	________	A1	NS
17	PRE____	PRETZEL	________	A1 (UN)	
18	PUR____	PURSE	________	A1	S
19	TOR____	TORNADO	________	A1 (UN)	
20	GLA____	GLASSES	________	A1	S
21	SPA____	SPATULA	________	A1	S

STEM LIST - X/A2 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	________		
	ACC____	ACCORDIAN	________		
	HOR____	HORSE	________		
1	CLI____	CLIMATE	________	A2	S
2	ENV____	ENVELOPE	________	A2 (UN)	
3	LET____	LETTUCE	________	A2 (UN)	
4	SAL____	SALIVA	________	A2	S
5	BRE____	BREAD	________	A2	NS
6	TOM____	TOMATO	________	A2 (UN)	
7	GAR____	GARLAND	________	A2	S
8	SHI____	SHIRT	________	A2	NS
9	PAR____	PARCEL	________	A2	NS
10	DRA____	DRAGON	________	A2	NS
11	THI____	THIMBLE	________	A2	S
12	FIR____	FIREPLACE	________	A2	S
13	CIG____	CIGAR	________	A2 (UN)	
14	REP____	REPAIR	________	A2 (UN)	
15	TOW____	TOWEL	________	A2	S
16	PYR____	PYRAMID	________	A2	NS
17	EYE____	EYEBALL	________	A2	S
18	SAN____	SANDWICH	________	A2	NS
19	DIA____	DIAMOND	________	A2 (UN)	
20	CAL____	CALIPERS	________	A2	NS
21	SKU____	SKUNK	________	A2 (UN)	

STEM LIST - X/A3 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	CHA____	CHAIR	________		
	ACC____	ACCORDIAN	________		
	HOR____	HORSE	________		
1	DOO____	DOORKNOB	________	A3	S
2	POS____	POSTCARD	________	A3	NS
3	ANC____	ANCHOR	________	A3	NS
4	WRE____	WRENCH	________	A3 (UN)	
5	LEG____	LEGACY	________	A3	NS
6	SPI____	SPIDER	________	A3 (UN)	
7	BRO____	BROOM	________	A3	NS
8	COC____	COCKPIT	________	A3	S
9	OCT____	OCTOPUS	________	A3 (UN)	
10	SWE____	SWEATER	________	A3 (UN)	
11	BEE____	BEETLE	________	A3	S
12	GLO____	GLOVE	________	A3	NS
13	SOL____	SOLDIER	________	A3	NS
14	FOO____	FOOTBALL	________	A3 (UN)	
15	JAC____	JACKET	________	A3	S
16	TUR____	TURTLE	________	A3	S
17	BIC____	BICYCLE	________	A3 (UN)	
18	ROB____	ROBOT	________	A3	S
19	RUL____	RULER	________	A3 (UN)	
20	PIT____	PITCHER	________	A3	S
21	FOR____	FORTUNE	________	A3	NS

STUDY - WORD LIST - B (NS-S)

STUDY - RESPONSE SHEET

	Target Word	Response	
NON-SEMANTIC - COUNTING VOWELS			
FILLER WORDS			
	KNIFE	________	
	ORANGE	________	
	FACTORY	________	
1	RACCOON	________	B1
2	GRAPES	________	B3
3	PEANUT	________	B2
4	FOLDER	________	B1
5	PUMPKIN	________	B3
6	SCREW	________	B2
7	THUMB	________	B1
8	CARROT	________	B3
9	HAMMER	________	B2
10	BANANA	________	B1
11	SUITCASE	________	B3
12	LOBSTER	________	B1
13	BASKET	________	B2
14	SPOON	________	B1
15	MOUNTAIN	________	B2
16	TRACTOR	________	B3
17	ALLIGATOR	________	B1
18	RABBIT	________	B3
19	WHISTLE	________	B2
20	BALLOON	________	B3
21	TABLET	________	B2
SEMANTIC - RATING FOR PLEASANTNESS			
22	POTATO	________	B1
23	VIOLIN	________	B2
24	GUITAR	________	B1
25	FLOWER	________	B3
26	ASHTRAY	________	B2
27	LEMON	________	B3
28	SCISSORS	________	B1
29	TRUMPET	________	B1
30	BRUSH	________	B3
31	PINEAPPLE	________	B2
32	MUSHROOM	________	B3
33	SAILBOAT	________	B2
34	CHICKEN	________	B1
35	FINGER	________	B2
36	ELEVATOR	________	B1
37	STOOL	________	B3
38	SNOWMAN	________	B2

39	DISGUISE	________	B3
40	PENCIL	________	B1
41	TOASTER	________	B3
42	CAMEL	________	B2

FILLER WORDS

BAKERY	________
TEACHER	________
SKIRT	________

Note: There was another identical study list as this, with the exception that the first half of the words were studied in semantic and second half in nonsemantic condition.

STEM - LIST B1 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	__________		
	DRE____	DRESS	__________		
	WAT____	WATERFALL	__________		
1	FOL____	FOLDER	__________	B1	NS
2	POT____	POTATO	__________	B1	S
3	BOU____	BOUQET	__________	B1 (UN)	
4	MAG____	MAGAZINE	__________	B1 (UN)	
5	ELE____	ELEVATOR	__________	B1	S
6	CHI____	CHICKEN	__________	B1	S
7	TRU____	TRUMPET	__________	B1	S
8	FEA____	FEATHER	__________	B1 (UN)	
9	SCI____	SCISSORS	__________	B1	S
10	TRO____	TROPHY	__________	B1 (UN)	
11	RAD____	RADAR	__________	B1 (UN)	
12	COB____	COBBLER	__________	B1 (UN)	
13	GUI____	GUITAR	__________	B1	S
14	PEN____	PENCIL	__________	B1	S
15	ALL____	ALLIGATOR	__________	B1	NS
16	PIL____	PILLOW	__________	B1 (UN)	
17	BAN____	BANANA4	__________	B1	NS
18	LOB____	LOBSTER	__________	B1	NS
19	THU____	THUMB	__________	B1	NS
20	RAC____	RACCOON	__________	B1	NS
21	SPO____	SPOON	__________	B1	NS

STEM - LIST B2 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	________		
	DRE____	DRESS	________		
	WAT____	WATERFALL	________		
1	CAM____	CAMEL	________	B2	S
2	POR____	PORCUPINE	________	B2 (UN)	
3	WHI____	WHISTLE	________	B2	NS
4	CRA____	CRADLE	________	B2 (UN)	
5	LAN____	LANTERN	________	B2 (UN)	
6	NEC____	NECKTIE	________	B2 (UN)	
7	WEA____	WEASEL	________	B2 (UN)	
8	HAM____	HAMMER	________	B2	NS
9	SNO____	SNOWMAN	________	B2	S
10	PEA____	PEANUT	________	B2	NS
11	ASH____	ASHTRAY	________	B2	S
12	VIO____	VIOLIN	________	B2	S
13	FIN____	FINGER	________	B2	S
14	SAI____	SAILBOAT	________	B2	S
15	PIN____	PINEAPPLE	________	B2	S
16	TAB____	TABLET	________	B2	NS
17	COM____	COMMA	________	B2 (UN)	
18	MOU____	MOUNTAIN	________	B2	NS
19	SHA____	SHADOW	________	B2 (UN)	
20	SCR____	SCREW	________	B2	NS
21	BAS____	BASKET	________	B2	NS

STEM - LIST B3 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	________		
	DRE____	DRESS	________		
	WAT____	WATERFALL	________		
1	LEM____	LEMON	________	B3	S
2	CAR____	CARROT	________	B3	NS
3	TON____	TONGS	________	B3 (UN)	
4	MAR____	MARBLE	________	B3 (UN)	
5	BAL____	BALLOON	________	B3	NS
6	STO____	STOOL	________	B3	S
7	PUM____	PUMPKIN	________	B3	NS
8	DIS____	DISGUISE	________	B3	S
9	FLA____	FLAME	________	B3 (UN)	
10	BLA____	BLAZER	________	B3 (UN)	
11	TRA____	TRACTOR	________	B3	NS
12	FLO____	FLOWER	________	B3	S
13	MUS____	MUSHROOM	________	B3	S
14	SUI____	SUITCASE	________	B3	NS
15	AUT____	AUTHOR	________	B3 (UN)	
16	TOA____	TOASTER	________	B3	S
17	SHO____	SHOELACE	________	B3 (UN)	
18	GRA____	GRAPES	________	B3	NS
19	BRU____	BRUSH	________	B3	S
20	GIR____	GIRAFFE	________	B3 (UN)	
21	RAB____	RABBIT	________	B3	NS

STEM - LIST B1 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	__________		
	DRE____	DRESS	__________		
	WAT____	WATERFALL	__________		
1	FOL____	FOLDER	__________	B1	S
2	POT____	POTATO	__________	B1	NS
3	BOU____	BOUQET	__________	B1 (UN)	
4	MAG____	MAGAZINE	__________	B1 (UN)	
5	ELE____	ELEVATOR	__________	B1	NS
6	CHI____	CHICKEN	__________	B1	NS
7	TRU___	TRUMPET	__________	B1	NS
8	FEA____	FEATHER	__________	B1 (UN)	
9	SCI____	SCISSORS	__________	B1	NS
10	TRO____	TROPHY	__________	B1 (UN)	
11	RAD____	RADAR	__________	B1 (UN)	
12	COB____	COBBLER	__________	B1 (UN)	
13	GUI____	GUITAR	__________	B1	NS
14	PEN____	PENCIL	__________	B1	NS
15	ALL____	ALLIGATOR	__________	B1	S
16	PIL_____	PILLOW	__________	B1 (UN)	
17	BAN____	BANANA4	__________	B1	S
18	LOB____	LOBSTER	__________	B1	S
19	THU___	THUMB	__________	B1	S
20	RAC____	RACCOON	__________	B1	S
21	SPO___	SPOON	__________	B1	S

STEM - LIST B2 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	________		
	DRE____	DRESS	________		
	WAT____	WATERFALL	________		
1	CAM____	CAMEL	________	B2	NS
2	POR____	PORCUPINE	________	B2 (UN)	
3	WHI____	WHISTLE	________	B2	S
4	CRA____	CRADLE	________	B2 (UN)	
5	LAN____	LANTERN	________	B2 (UN)	
6	NEC____	NECKTIE	________	B2 (UN)	
7	WEA____	WEASEL	________	B2 (UN)	
8	HAM____	HAMMER	________	B2	S
9	SNO____	SNOWMAN	________	B2	NS
10	PEA____	PEANUT	________	B2	S
11	ASH____	ASHTRAY	________	B2	NS
12	VIO____	VIOLIN	________	B2	NS
13	FIN____	FINGER	________	B2	NS
14	SAI____	SAILBOAT	________	B2	NS
15	PIN____	PINEAPPLE	________	B2	NS
16	TAB____	TABLET	________	B2	S
17	COM____	COMMA	________	B2 (UN)	
18	MOU____	MOUNTAIN	________	B2	S
19	SHA____	SHADOW	________	B2 (UN)	
20	SCR____	SCREW	________	B2	S
21	BAS____	BASKET	________	B2	S

STEM - LIST B3 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	__________		
	DRE____	DRESS	__________		
	WAT____	WATERFALL	__________		
1	LEM____	LEMON	__________	B3	NS
2	CAR____	CARROT	__________	B3	S
3	TON____	TONGS	__________	B3 (UN)	
4	MAR____	MARBLE	__________	B3 (UN)	
5	BAL____	BALLOON	__________	B3	S
6	STO____	STOOL	__________	B3	NS
7	PUM____	PUMPKIN	__________	B3	S
8	DIS____	DISGUISE	__________	B3	NS
9	FLA____	FLAME	__________	B3 (UN)	
10	BLA____	BLAZER	__________	B3 (UN)	
11	TRA____	TRACTOR	__________	B3	S
12	FLO____	FLOWER	__________	B3	NS
13	MUS____	MUSHROOM	__________	B3	NS
14	SUI____	SUITCASE	__________	B3	S
15	AUT____	AUTHOR	__________	B3 (UN)	
16	TOA____	TOASTER	__________	B3	NS
17	SHO____	SHOELACE	__________	B3 (UN)	
18	GRA____	GRAPES	__________	B3	S
19	BRU____	BRUSH	__________	B3	NS
20	GIR____	GIRAFFE	__________	B3 (UN)	
21	RAB____	RABBIT	__________	B3	S

STUDY - WORD LIST - <u>X/B (NS-S)</u>

STUDY - RESPONSE SHEET

Target Word

<u>NON-SEMANTIC - COUNTING VOWELS</u>

FILLER WORDS

	KNIFE	________	
	ORANGE	________	
	FACTORY	________	
1	RADAR	________	B1
2	CRADLE	________	B2
3	GIRAFFE	________	B3
4	PEANUT	________	B2
5	FEATHER	________	B1
6	PUMPKIN	________	B3
7	SCREW	________	B2
8	AUTHOR	________	B3
9	THUMB	________	B1
10	BOUQET	________	B1
11	SUITCASE	________	B3
12	LOBSTER	________	B1
13	BASKET	________	B2
14	SPOON	________	B1
15	LANTERN	________	B2
16	TRACTOR	________	B3
17	ALLIGATOR	________	B1
18	RABBIT	________	B3
19	WEASEL	________	B2
20	BALLOON	________	B3
21	SHADOW	________	B2

<u>SEMANTIC - RATING PLEASANTNESS</u>

22	POTATO	________	B1
23	VIOLIN	________	B2
24	GUITAR	________	B1
25	FLAME	________	B3
26	ASHTRAY	________	B2
27	LEMON	________	B3
28	TROPHY	________	B1
29	BLAZER	________	B3
30	NECKTIE	________	B2
31	MARBLE	________	B3
32	SAILBOAT	________	B2
33	COBBLER	________	B1
34	FINGER	________	B2
35	ELEVATOR	________	B1
36	SHOELACE	________	B3
37	PORCUPINE	________	B2
38	DISGUISE	________	B3

39	MAGAZINE	________	B1
40	TONGS	________	B3
41	COMMA	________	B2
42	PILLOW	________	B1

FILLER WORDS

BAKERY	________
TEACHER	________
SKIRT	________

Note: **List X/B is identical to list B except that the studied words in list B become unstudied words in list X/B and vice versa.**

STEM - LIST - X/B1 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	__________		
	DRE____	DRESS	__________		
	WAT____	WATERFALL	__________		
1	FOL____	FOLDER	__________	B1 (UN)	
2	POT____	POTATO	__________	B1	S
3	BOU____	BOUQET	__________	B1	NS
4	ELE____	ELEVATOR	__________	B1	S
5	MAG____	MAGAZINE	__________	B1	S
6	CHI____	CHICKEN	__________	B1 (UN)	
7	TRU____	TRUMPET	__________	B1 (UN)	
8	FEA____	FEATHER	__________	B1	NS
9	SCI____	SCISSORS	__________	B1 (UN)	
10	GUI____	GUITAR	__________	B1	S
11	TRO____	TROPHY	__________	B1	S
12	PEN____	PENCIL	__________	B1 (UN)	
13	ALL____	ALLIGATOR	__________	B1	NS
14	RAD____	RADAR	__________	B1	NS
15	BAN____	BANANA	__________	B1 (UN)	
16	LOB____	LOBSTER	__________	B1	NS
17	COB____	COBBLER	__________	B1	S
18	THU____	THUMB	__________	B1	NS
19	RAC____	RACCOON	__________	B1 (UN)	
20	PIL____	PILLOW	__________	B1	S
21	SPO____	SPOON	__________	B1	NS

STEM - LIST - <u>X/B2 - (NS-S)</u>

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	________		
	DRE____	DRESS	________		
	WAT____	WATERFALL	________		
1	CAM____	CAMEL	________	B2 (UN)	
2	POR____	PORCUPINE	________	B2	S
3	WHI____	WHISTLE	________	B2 (UN)	
4	HAM____	HAMMER	________	B2 (UN)	
5	CRA____	CRADLE	________	B2	NS
6	SNO____	SNOWMAN	________	B2 (UN)	
7	PEA____	PEANUT	________	B2	NS
8	LAN____	LANTERN	________	B2	NS
9	ASH____	ASHTRAY	________	B2	S
10	VIO____	VIOLIN	________	B2	S
11	NEC____	NECKTIE	________	B2	S
12	FIN____	FINGER	________	B2	S
13	SAI____	SAILBOAT	________	B2	S
14	WEA____	WEASEL	________	B2	NS
15	PIN____	PINEAPPLE	________	B2 (UN)	
16	TAB____	TABLET	________	B2 (UN)	
17	MOU____	MOUNTAIN	________	B2 (UN)	
18	COM____	COMMA	________	B2	S
19	SCR____	SCREW	________	B2	NS
20	BAS____	BASKET	________	B2	NS
21	SHA____	SHADOW	________	B2	NS

STEM - LIST - X/B3 - (NS-S)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	__________		
	DRE____	DRESS	__________		
	WAT____	WATERFALL	__________		
1	TON____	TONGS	__________	B3	S
2	LEM____	LEMON	__________	B3	S
3	CAR____	CARROT	__________	B3 (UN)	
4	MAR____	MARBLE	__________	B3	S
5	BAL____	BALLOON	__________	B3	NS
6	STO____	STOOL	__________	B3 (UN)	
7	FLA____	FLAME	__________	B3	S
8	PUM____	PUMPKIN	__________	B3	NS
9	DIS____	DISGUISE	__________	B3	S
10	BLA____	BLAZER	__________	B3	S
11	TRA____	TRACTOR	__________	B3	NS
12	FLO____	FLOWER	__________	B3 (UN)	
13	MUS____	MUSHROOM	__________	B3 (UN)	
14	SUI____	SUITCASE	__________	B3	NS
15	AUT____	AUTHOR	__________	B3	NS
16	TOA____	TOASTER	__________	B3 (UN)	
17	GRA____	GRAPES	__________	B3 (UN)	
18	SHO____	SHOELACE	__________	B3	S
19	BRU____	BRUSH	__________	B3 (UN)	
20	RAB____	RABBIT	__________	B3	NS
21	GIR____	GIRAFFE	__________	B3	NS

STEM - LIST - X/B1 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	________		
	DRE____	DRESS	________		
	WAT____	WATERFALL	________		
1	FOL____	FOLDER	________	B1 (UN)	
2	POT____	POTATO	________	B1	NS
3	BOU____	BOUQET	________	B1	S
4	ELE____	ELEVATOR	________	B1	NS
5	MAG____	MAGAZINE	________	B1	NS
6	CHI____	CHICKEN	________	B1 (UN)	
7	TRU____	TRUMPET	________	B1 (UN)	
8	FEA____	FEATHER	________	B1	S
9	SCI____	SCISSORS	________	B1 (UN)	
10	GUI____	GUITAR	________	B1	NS
11	TRO____	TROPHY	________	B1	NS
12	PEN____	PENCIL	________	B1 (UN)	
13	ALL____	ALLIGATOR	________	B1	S
14	RAD____	RADAR	________	B1	S
15	BAN____	BANANA	________	B1 (UN)	
16	LOB____	LOBSTER	________	B1	S
17	COB____	COBBLER	________	B1	NS
18	THU____	THUMB	________	B1	S
19	RAC____	RACCOON	________	B1 (UN)	
20	PIL____	PILLOW	________	B1	NS
21	SPO____	SPOON	________	B1	S

STEM - LIST - X/B2 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA____	AVACADO	________		
	DRE____	DRESS	________		
	WAT____	WATERFALL	________		
1	CAM____	CAMEL	________	B2 (UN)	
2	POR____	PORCUPINE	________	B2	NS
3	WHI____	WHISTLE	________	B2 (UN)	
4	HAM____	HAMMER	________	B2 (UN)	
5	CRA____	CRADLE	________	B2	S
6	SNO____	SNOWMAN	________	B2 (UN)	
7	PEA____	PEANUT	________	B2	S
8	LAN____	LANTERN	________	B2	S
9	ASH____	ASHTRAY	________	B2	NS
10	VIO____	VIOLIN	________	B2	NS
11	NEC____	NECKTIE	________	B2	NS
12	FIN____	FINGER	________	B2	NS
13	SAI____	SAILBOAT	________	B2	NS
14	WEA____	WEASEL	________	B2	S
15	PIN____	PINEAPPLE	________	B2 (UN)	
16	TAB____	TABLET	________	B2 (UN)	
17	MOU____	MOUNTAIN	________	B2 (UN)	
18	COM____	COMMA	________	B2	NS
19	SCR____	SCREW	________	B2	S
20	BAS____	BASKET	________	B2	S
21	SHA____	SHADOW	________	B2	S

STEM - LIST - X/B3 - (S-NS)

TEST - RESPONSE SHEET

	Stem	Target Word	Response		
PRACTICE ITEMS					
	AVA_____	AVACADO	__________		
	DRE_____	DRESS	__________		
	WAT_____	WATERFALL	__________		
1	TON_____	TONGS	__________	B3	NS
2	LEM_____	LEMON	__________	B3	NS
3	CAR_____	CARROT	__________	B3 (UN)	
4	MAR_____	MARBLE	__________	B3	NS
5	BAL_____	BALLOON	__________	B3	S
6	STO_____	STOOL	__________	B3 (UN)	
7	FLA_____	FLAME	__________	B3	NS
8	PUM_____	PUMPKIN	__________	B3	S
9	DIS_____	DISGUISE	__________	B3	NS
10	BLA_____	BLAZER	__________	B3	NS
11	TRA_____	TRACTOR	__________	B3	S
12	FLO_____	FLOWER	__________	B3 (UN)	
13	MUS_____	MUSHROOM	__________	B3 (UN)	
14	SUI_____	SUITCASE	__________	B3	S
15	AUT_____	AUTHOR	__________	B3	S
16	TOA_____	TOASTER	__________	B3 (UN)	
17	GRA_____	GRAPES	__________	B3 (UN)	
18	SHO_____	SHOELACE	__________	B3	NS
19	BRU_____	BRUSH	__________	B3 (UN)	
20	RAB_____	RABBIT	__________	B3	S
21	GIR_____	GIRAFFE	__________	B3	S

APPENDIX C

Table C1

Mixed ANOVA for Overall Design (Experimental Group) Corrected for Baseline Performance

SOURCE	SS	DF	MS	F	*P*
Retrieval Instructions (R)	216.23	1	216.23	20.16	.000
Delay (D)	129.31	2	64.65	25.65	.000
Study (S)	11.03	1	11.03	8.77	.006
ECT (E)	12.47	1	12.47	3.26	.082
D x R	23.45	2	11.73	4.65	.013
S x R	24.03	1	24.03	19.11	.000
E x R	35.47	1	35.47	9.28	.005
D x S	3.65	2	1.83	1.34	.270
D x E	2.71	2	1.35	0.71	.497
S x E	2.50	1	2.50	0.02	.898
D x S x R	5.62	2	2.81	2.06	.137
D x E x R	10.27	2	5.14	2.69	.077
S x E x R	3.80	1	3.80	2.53	.123
D x S x E	3.05	2	1.53	1.06	.354
D x S x E x R	0.97	2	0.49	0.34	.715

The Greenhouse-Geisser and Huynh-Feldt epsilon were close to 1.00 hence no adjustments to the degrees of freedom were necessary for testing significance.

Marginal Means (Corrected for Baseline)

Variable	level	Mean	SE
Retrieval instructions	Implicit	3.19	.244
	Explicit	1.64	..244
Delay	15 minutes	3.27	.186
	90 minutes	1.98	.254
	180 minutes	2.02	.180
ECT	Pre	2.61	.164
	Post	2.23	.199
Study	Nonsemantic	2.24	
	Semantic	2.59	

Table C2

Separate ANOVA for Implicit Condition (Corrected for Baseline Performance)

SOURCE	SS	DF	MS	F	*p*
Delay (D)	56.21	2	28.11	8.27	.002
Study (S)	1.25	1	1.25	1.12	.308
ECT (E)	2.94	1	2.94	0.86	.370
D x S	2.23	2	1.12	0.64	.536
D x E	11.74	2	5.87	2.76	.081
S x E	1.61	1	1.61	1.44	.251
D x S x E	0.34	2	0.17	0.12	.891

Marginal Means for Implicit Group
(Corrected for Baseline Performance)

Variable	Level	Mean	SE
ECT	Pre	3.07	.295
	Post	3.32	.238
Delay	15 min.	3.90	.207
	90 min.	2.53	.409
	180 min.	3.15	.249
Study	Nonsemantic	3.28	.206
	Semantic	3.11	.215

Table C3

Separate ANOVA for the Explicit Condition (Corrected for Baseline Performance)

SOURCE	SS	DF	MS	F	*p*
Delay (D)	96.54	2	48.27	29.41	.000
Study (S)	33.80	1	33.80	24.23	.000
ECT (E)	45.00	1	45.00	10.68	.006
D x S	7.03	2	3.52	3.63	.040
D x E	1.23	2	0.62	0.37	.697
S x E	2.22	1	2.22	1.18	.296
D x S x E	3.68	2	1.84	1.32	.285

Marginal Means for Explicit Group

Variable	Level	Mean	SE
ECT	Pre	2.14	.290
	Post	1.44	.309
Delay	15 min.	2.63	.309
	90 min.	1.42	.301
	180 min.	.88	.259
Study	Nonsemantic	1.21	.254
	Semantic	2.08	.289

Table C4

Separate ANOVAs for Pre and Post ECT Conditions (Corrected for Baseline Performance)

	PRE-ECT		POST-ECT	
SOURCE	F	*p*	F	*p*
Retrieval Instr. (R)	4.97	.034	31.16	.000
Delay (D)	57.48	.000	74.53	.000
Study (S)	6.05	.064	5.00	.045
R x D	7.54	.153	26.18	.008
R x S	23.47	.001	4.36	.060
D x S	3.90	.310	2.80	.311
R x D x S	1.21	.691	5.38	.111

Table C5

Separate ANOVAs for Study Conditions (Corrected for Baseline Performance)

	Semantic		Nonsemantic	
SOURCE	F	*P*	F	*P*
Retrieval Instr. (R)	6.71	.015	39.85	.000
Delay (D)	19.56	.000	14.77	.000
ECT (E)	2.50	.025	2.18	.151
R x D	5.34	.008	2.19	.121
R x E	11.50	.002	3.08	.090
D x E	1.79	.177	0.11	.895
R x D x E	1.08	.346	2.16	.125

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

APPLIED IMAGE . Inc
1653 East Main Street
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