EFFECTS OF LEARNING INSTRUCTIONS AND SPATIAL LOCATION OF

WORDS ON IMPLICIT AND EXPLICIT MEMORY

IN INDIVIDUALS WITH A HISTORY OF MILD TRAUMATIC HEAD INJURY

AND NORMAL CONTROLS

by

SIMONE FRANCESCA MARGUERITE COLLYMORE

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

1996

UMI Number: 9707081

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

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

6/3/96 — Wilma A. Winnick
Date — Chair of Examining Committee

6/3/96 — Kay Deaux
Date — Executive Officer

Doreen Berman, Ph.D.

Rhea Dornbush, Ph.D.

Thomas Kay, Ph.D.

Chair: Wilma A. Winnick, Ph.D.

Supervisory Committee

Outside Reader: George Carnevale, Ph.D.

THE CITY UNIVERSITY OF NEW YORK

Abstract

EFFECTS OF LEARNING INSTRUCTIONS AND SPATIAL LOCATION OF WORDS ON IMPLICIT AND EXPLICIT MEMORY IN INDIVIDUALS WITH A HISTORY OF MILD TRAUMATIC HEAD INJURY AND NORMAL CONTROLS

by

Simone Francesca Marguerite Collymore

Adviser: Dr. Wilma A. Winnick

In two experiments, two groups of persons with mild traumatic head injury (rehabilitation outpatients and college students) were compared with normal controls on explicit and implicit memory for intentionally and incidentally studied words shown in different lateral positions, and at near and far locations in word pairs. In Experiment 1, students with mild traumatic head injury (mTHI) recognized significantly fewer incidentally learned words than students without mTHI. In Experiment 2, the outpatient group with mTHI performed more poorly than either the student group with mTHI or normals on intentional learning aspects of both memory tasks. However, students with mTHI completed fewer intentionally learned words from the far format than normals. Group differences in memory were most apparent under intentional learning conditions, particularly recognition of intentionally learned words from closely spaced pairs (close format), a potentially distracting context, and completion of word stems from widely spaced pairs (far format), an integratively difficult context.

Scores from standardized measures of processing speed-attention, verbal IQ (VIQ), postconcussive symptoms (PCS) and depression indicated that despite relatively normal VIQ, the outpatient group with mTHI was slower, more distractible and reported more numerous and more severe PCS, including depression, than did the student group with good functional outcome post-mTHI and normals. Lower intentional learning scores on both memory tasks, particularly completion, were associated with reduced processing speeds, distractibility and more numerous and severe PCS. Performance on standardized tests was similar in groups of normals and students with mTHI, with the exception of complaints of PCS experience and severity.

These results support views that residual effects of mTHI emerge under conditions that strain information processing capacity, that impaired groups, such as outpatients are at particular risk for such relapsing effects, but that even minimally symptomatic individuals with mTHI are not immune to these effects.

Acknowledgements

This dissertation is dedicated to my parents, Bruce (deceased) and Winifred Collymore, without whose help, my graduate studies would not have been possible. My mother has been especially supportive in her selfless commitment to the completion of this dissertation.

I would like to thank a truly extraordinary person, Dr. Wilma Winnick, who took the time from her many academic duties as professor and Department of Psychology chair, to serve as my mentor and chair of my dissertation committee. This research would not have been as successful as it was without Dr. Winnick's guidance and wealth of knowledge in the areas of learning and memory, and experimental research design.

I would also like to thank the other members of my advisory committee: Drs. Doreen Berman, Thomas Kay and Rhea Dornbush for providing the necessary intellectual support. In their wisdom, the members of my supervisory committee have guided me towards the dawning of my knowledge. Special acknowledgments are extended to: Dr. George Carnevale, whose dual role as the outside reader on this dissertation and source of participants for this research study is much appreciated.

Expressions of appreciation are extended to Drs. Mary Hibbard and Wayne Gordon, Dr. Alan Blau, and Dr. Jerry Weissman, who also provided the requisite access to persons with mTHI used in the study.

I would also like to thank John Zhu without whose computer programming genius, implementation of this project would have been difficult. Sincere thanks are extended to the staff at the Queens College Computer Laboratories Help Desk who facilitated printing this draft at times beyond their normal laboratory hours. The participants in this research were also vital components of this dissertation and their cooperation is deeply appreciated.

Expressions of gratitude are conveyed to another truly remarkable person, Dr. Richard Bodnar, whose advice has helped to guide me through the doctoral program. I would also like to thank Dr. Elizabeth Bostock, my original research adviser in the doctoral program, who realized my interest in cognitive neuropsychology, thereby introducing me to Dr. Winnick's research world of human learning and memory to further my research endeavours. Dr. Bostock, like my parents and friends, reassured me that it was okay to be an independent thinker.

Special thoughts and gratitude are extended to my dear friends: Concetta Decaria, Veronica Hinton, Anita Islam, Jacqueline Kiefel, Kathleen McKay and Nancy Madigan, and my siblings: David, Christopher, Shelley and Patricia Collymore whose emotional support bolstered my determination to complete this research.

Finally, I would like to thank my wonderful husband, Patrick Henry and daughter, Nailah who are truly my special gifts from God. These two people have added meaning and purpose to my graduate studies in the broader context of life.

Table of Contents

List of Tables

List of Figures

List of Appendixes

Introduction

This study examined influences of instructions, use of different memory tasks and spatial location of study words on memory performance in two groups of persons with a history of mild traumatic head injury (mTHI) compared to healthy normals. Instructions/no instructions to learn one word in a word pair were included to investigate intentional and incidental encoding difficulties noted in persons with mTHI (Gronwall, 1989; Mutter, Howard, Howard & Wiggs, 1990). Previous research by Mutter et al. (1990) had found that after mTHI, retrieval difficulties were apparent when memory was assessed with deliberate explicit retrieval measures, but not with implicit retrieval measures which made no reference to the learning situation. Two kinds of memory tasks, recognition and word stem completion (completion), which differed in retrieval demands were used to examine explicit and implicit memory performance after mTHI. The influences of spatial aspects of the study material, separation and lateral position, were examined as they might affect attention and speed of processing which may be impaired after mTHI (Gronwall, 1991; Russell & D'Hollosy, 1992). These factors are separately examined in the following sections, which are preceded by a review of mTHI and memory difficulties after mTHI. The two groups with mTHI included in the study were college students who had not sought rehabilitation and clinic outpatients who had received rehabilitation.

Mild Traumatic Head Injury and Memory Deficits after mTHI

Mild THI refers to mild closed head injury in which a person experiences physical trauma to the head caused by an impact with a surface or sudden jolting of the contents of the skull (Dikmen & Levin, 1993; Kay, Newman, Cavallo, Ezrachi, &

Resnick, 1992; Jeret et al., 1993). In the current study, the term mTHI is used to describe a concussion or externally induced head injury in which there is an alteration of mental state with a brief loss of consciousness (LOC) and/or posttraumatic amnesia (PTA) of less than 24 hours (Kay et al., 1993). Mild THI does not necessarily imply brain injury and in the initial postconcussive stages, the sequelae may reflect direct brain dysfunction in which the brain itself is damaged or indirect brain dysfunction caused by swelling of non-brain tissue or hemorrhage. In many instances, traditional diagnostic tests, such as computerized tomography, performed in the emergency room are not able to detect the minimal brain injury that has occurred, and in instances where a diagnosis of mild traumatic brain injury is given, this reflects a probable diagnosis, subject to neuropathological confirmation.

About 15 % of the estimated incidence of 180/100,000 persons who have sustained mTHI, (Alexander, 1995; Kay & Lezak, 1990) continue to complain of a constellation of chronic symptoms, such as attentional, information processing and memory problems, collectively referred to as the postconcussive syndrome, PCS, (Binder & Rattok, 1989; Bohnen et al., 1994; Kay & Lezak, 1990). Chronic memory difficulties are common complaints after mTHI and may persist for months or even years (Alexander, 1995; Kay & Lezak, 1990; Ruff et al., 1989, Gronwall, 1989) but are often dismissed as psychosomatic or are attributed to malingering (Kay, 1992). This may be because memory difficulties, as measured by traditional declarative neuropsychological tests, are generally thought to have resolved by 1-3 months postinjury in the majority of persons who have sustained mTHI (Dikmen & Levin, 1993; Ruff et al., 1989).

Contrary to the belief that the post-mTHI sequelae are mainly psychosomatic, magnetic resonance imaging (MRI) studies have indicated the presence of intracranial lesions (Levin, Williams, Eisenberg, High Jr. & Guinto Jr., 1992) and white matter degeneration in many cases of mTHI (Blumbergs et al., 1994; Gale, Burr, Bigler & Blatter, 1993). Similarly, in animals, there are diffuse cerebrocortical changes after mild head injury (Povlishock & Coburn, 1989). Interestingly, deficits on memory tests may persist in mild to moderate THI even after apparent resolution of lesions, as detected by MRI (Levin et al., 1992). Other researchers have reported impairment in cognitive functions after mTHI. Gentilini, Nicheli & Schoenhuber (1989) have noted impaired performance on attentional tasks. Gronwall (1989) has suggested that slowed information processing after mTHI has a significant impact on memory performance.

Diffuse axonal damage which may occur after mTHI has a mild to moderate effect on memory functions and is reflected in poor performance on tasks such as stimulus cued recall (Evans, 1992; Mutter et al., 1990) and incidental learning (Kay & Lezak, 1990). Damage to medial temporal and frontal lobe structures, as sometimes occurs with head injury, also produces moderate to severe impairment of explicit memory abilities, that is memory induced by deliberate intention to retrieve information (Bassett & Slater, 1992; Goldman-Rakic, 1987; Levin, 1990; Levin et al., 1992; Squire, 1987a; Zola-Morgan & Squire, 1990). In addition, individuals with mTHI tend to be more depressed than healthy controls (Evans, 1992; Schoenhuber & Gentilini, 1988), and clinically depressed persons are impaired on implicit and explicit memory tasks relative to controls (Elliott & Greene, 1992). Therefore as Blakely and Harrington (1993) point out, "mild head injury is not always mild..." (p. 231).

Individuals with mTHI represent a diverse group who have received assorted medical services (physical examination only, neuroimaging, cognitive rehabilitation). Initial indices of head injury severity, such as the Glasgow Coma Scale (GCS) and LOC, are important factors in identifying functional outcome after mTHI (Levin et al., 1992). However, functional outcome after mTHI is influenced by the cumulative effect of physical, neurological and psychological factors, among others which occur within the context of the head injured person's social milieu (family, medical, work). Thus, in the absence of definitive evidence of structural brain damage after mTHI (which entails neuropathological confirmation), there is difficulty in determining underlying substrates of chronic postconcussive sequelae, and postconcussive sequelae may circumspectly be considered to reflect the cumulative interactions of subjective physical factors. For a more detailed analysis of these factors, see Kay et al. (1992).

The extent to which postconcussive memory impairment is demonstrated may reflect functional outcome which is determined by both physical and psychological factors (Kay et al., 1992). Mittenberg, DiGiulio, Perrin and Bass (1992) using a 30 symptom checklist, found that healthy individuals who had only imagined having sustained mTHI reported identical rates of PCS as head injured participants. Such findings have led to the hypothesis that individuals with mTHI histories, as a group, may complain of persistent postconcussive memory difficulties which adversely affect performance for a variety of reasons which may reflect the cumulative effect of subjective and neurological factors. It is assumed that the prevalence of PCS is about 15% in persons with a history of mTHI and, as a group, individuals with mTHI may evidence difficulties under cognitively demanding situations. In support of this notion, Beers, Goldstein and Katz (1994) reported that a group of college students with a history of mTHI, with good recovery as assessed by the Glasgow Outcome Scale, were impaired on neuropsychological memory tests relative to normal controls. Ewing, McCarthy, Gronwall and Wrightson (1980) also found that under mildly hypoxic conditions, university students with good functional outcome post-mTHI demonstrate attentional and memory difficulties. Therefore, residual postconcussive deficits after mTHI may be revealed in a wide range of situations, particularly those that strain the somewhat reduced processing capacities of individuals who have incurred mTHI (Beers et al., 1994; Ewing et al., 1980). Intentional-incidental learning of words under conditions which require distributed (simultaneous) and divided (serial) attention is an example of such a situation.

Intentional-incidental learning instructions

Memory performance is partially determined by the extent to which words are deliberately or intentionally encoded, which may reflect the depth of processing or degree of conceptual (semantic) analysis (Craik & Tulving, 1975). In explaining the superiority of intentional over incidental recall, Craik and Tulving (1975) suggest that in the intentional condition "... further processing was carried out ... " (p. 278). Conceptual analysis refers to processing that relies on the establishment of meaningful, associative attributes of stimuli (Greene, 1986; Neill, Trammell, Beck, Bottalico & Molloy, 1990). It is proposed that intentional learning initiates active mnemonic strategies, such as rehearsal and imagery, although no specific instructions structure these strategies to conceptualize meaningful word attributes.

In order for material to be available for memory testing, it must be encoded at input. Many encoding activities are possible, varying in strength from those activated by strong motivation to learn to those invoking minimal attention to materials (Craik & Lockhart, 1972; Mechanic, 1962a). To increase motivation and to effect deliberate learning in human participants, instructions to learn or to employ particular learning strategies have proved to be effective in producing higher memory scores, compared to scores without such instructions (Craik & Lockhart, 1972; Postman, 1964). The first instance has come to be called intentional learning, in contrast to the second or "instructionless" instance, which has been dubbed incidental learning. Incidental learning refers to automatic encoding of material without conscious intention to remember it. Studies using healthy individuals have found poorer explicit memory for incidentally learned material as compared to intentionally studied material (Greene, 1986; Neill et al., 1990; Russell & D'Hollosy, 1992). The superiority of intentional over incidental learning has proved to be a highly robust finding, though there are variables that have been found to erase this difference, such as rate of presentation (Dornbush & Winnick, 1967; Neimark & Saltzman, 1953) and orienting instructions (Postman & Adams, 1956). The benefit of intentional study on explicit memory performance is well documented, but the impact of intentional study on implicit memory tasks is less clear (Greene, 1986; Neill et al., 1990).

Intentional learning, a deliberate, effortful process, has been examined using word pairs with instructions to learn one of the words as denoted by its underlining. Instructions to learn one word of a pair introduces the need to locate that word in the context of another word. Duncan and Humphreys (1989) have suggested that locating a target within a display is made more difficult by the similarity between target and

distractor items. Therefore, intentional learning of words paired with incidentally presented words presents a difficult task for distractible persons with a history of mTHI to locate and encode the intentional word (Gronwall, 1989; Parasuraman, Mutter & Molloy, 1991). The encoding demands of rapid distributed, divided and deliberate attention are expected to provide a challenging test of the capacity of the "frayed" neurological system characteristic of individuals with mTHI, as a group. The term frayed is used here to make the analogy between diffuse axonal injury involved in some instances of mTHI and frayed connections of insulated electrical
wires in which the insulation and/or metallic cable conductors may be damaged.

Earlier studies demonstrated that intentional learning was impaired after mTHI because of the deliberate, effortful requirements of this procedure (Gentilini et al., 1989; Gronwall, 1989; Mutter et al., 1990). However, people with mTHI also present with subtle difficulties in incidental learning/memory, attention and information processing (Kay, 1986; Kay et al., 1992). Anecdotal accounts of impaired incidental learning after mTHI (Kay & Lezak, 1990) have been cited in the literature. Notwithstanding this, most research on memory functions after mTHI has used intentional learning and explicit memory tasks (Chitra Mariadas, Rao, Gangadhar & Hegde, 1989; Gentilini et al., 1989; Gronwall & Wrightson, 1981; Ruff et al., 1989), and hence little is known about incidental learning and implicit memory functions after mTHI. As such, one has to refer to studies using related concepts, such as attention and speed of information processing to formulate hypotheses which predict memory performance after incidental learning in persons with a history of mTHI.

Previous studies have described impaired attention (Gentilini et al., 1989) and processing speed (Gronwall & Wrightson, 1981) after mTHI. After mTHI, the limited encoding opportunities afforded by incidental learning may be further reduced by slowed information processing and attentional difficulties (Arcia & Gualtieri, 1993; Lezak, 1983; Parasuraman et al., 1991). Relative to healthy controls, these difficulties after mTHI may increase the effort required to focus attention on intentionally encoded material in the context of distracting, analogous incidental material, such as word pairs. Intentional learning of a word involves deliberate, effortful processing which is thought to be impaired after mTHI (Mutter et al., 1990). Individuals with mTHI who have difficulties distributing attention are impaired relative to unimpaired controls on tasks that require focussed yet distributed attention across both visual fields (Gentilini et al., 1989) and may also be impaired on incidental aspects of these tasks. Related to difficulties in distributed attention are those of divided attention. Subtle processing differences are inferred by mechanisms involved in distributed attention which requires simultaneous processing and divided attention which implies serial/sequential processing. This distinction is useful in understanding the complexity of a task in which material is presented simultaneously, although these two attentional processes are not differentiated in this study.

Tacitly, instructions to learn one word in a word pair also creates a condition in which there is divided attention, that is the ability to sequentially divide attention between concurrent tasks (Gentilini et al., 1989), such as attending to the incidentally presented word and the word to be learned intentionally. Thus, intentional learning occurs at the expense of full processing of the incidentally presented word, and these incidental learning deficits are augmented by presenting words briefly (Gronwall &

Wrightson, 1981). As such, rapidity in encoding, a deficient characteristic after mTHI is crucial in remembering both words, particularly the incidental word. Based on previous findings by Mutter et al. (1990) performance on explicit recognition, the more effortful, conceptually-demanding task was more likely to be impaired by both intentional learning and mTHI than implicit completion.

Explicit and Implicit Memory

Mutter et al. (1990) examined the dissociation between implicit and explicit memory task performance in the acute stages (1 - 17 days) post-mTHI after intentional learning. They reported a dissociation between explicit and implicit memory performance which was similar to that observed in more impaired amnesics (Warrington & Weiskrantz, 1970); explicit memory task performance was impaired relative to healthy controls but implicit memory performance was normal. Warrington and Weiskrantz (1970) had found that the method of retrieval, and not merely learning, determined the extent to which amnesics showed memory deficits. When assessed implicitly using fragmented words or word stems, memory appeared normal. However, recognition and recall in these same individuals were impaired relative to normal controls. This difference in memory performance is best understood by examining retrieval measures used to assess memory performance.

The traditional view of memory is that it entails conscious intention to retrieve information from an earlier episode. Task instructions on traditional measures of memory, such as free recall and recognition, make direct reference to a prior study episode by asking participants to retrieve specific items. This type of memory is also referred to as explicit memory (Schacter, 1987; Squire, 1987a). This monolithic view of memory has been sharply challenged by research endeavors having origins in observations of memory disorders in amnesic patients (Graf & Schacter, 1985; Warrington & Weiskrantz, 1970).

Amnesics, by definition, suffer from memory dysfunctions, but such a characterization should by no means suggest that they experience total memory loss. Instead, previous research has found that on certain memory tasks amnesics will do as well as normals (Warrington & Weiskrantz, 1970). Such tasks share the important feature that they do not invoke active search for the materials (retrieval) previously studied; rather, these materials are presented in the tasks but instructions make no reference to the earlier study of the materials (Warrington & Weiskrantz, 1970; Squire, 1987a). Thus, recent views of memory include performance on tests of an individual's knowledge of the occurrence of prior events, explicit memory, as well as tests of implicit memory in which memory for past events is elicited without conscious recollection (Richardson-Klavehn & Bjork, 1988).

Implicit memory refers to a facilitation of memory test performance by prior exposure to material. Instructions on implicit tasks make no reference to the episode targeted on the task. In contrast to explicit tasks, implicit task performance does not demand knowledge of the circumstances of the past episode (Bowers & Schacter, 1990). The term implicit memory encompasses a wide range of learning and memory experiences such as priming and conditioning and typically describes performance on tasks such as word stem completion, lexical decision and fragment completion (Squire, 1987a).

Researchers have approached the study of memory from many theoretical perspectives (Richardson-Klavehn & Bjork, 1988; Roediger, Rajaram & Srinivas, 1990), and the theoretical perspective which one adopts influences how interpretations are formulated to account for group differences, such as those anticipated based upon a history of mTHI in the present study. Current views delineate three main theoretical approaches, memory systems, activation and processing (Blaxton, 1995; Gabrieli, 1995; Pitarque, Algarabel & Meseguer, 1992; Roediger, 1990).

From a systems perspective, explicit memory, referred to as declarative memory, is thought to be dependent upon the integrity of medial temporal and frontal lobe structures (Mishkin & Appenzeller, 1987; Squire, 1987b). Support for this viewpoint comes from work with amnesics and lesioned animals (Goldman-Rakic, 1987; Mishkin & Appenzeller, 1987; Squire, 1987b; Warrington & Weiskrantz, 1970). Damage to medial temporal lobe structures, as sometimes occurs with head injury, produces moderate to severe impairment of explicit memory abilities (Bassett & Slater, 1992; Levin, 1990; Zola-Morgan & Squire, 1990). Supporters of a systems approach view implicit memory as a function of specific neuroanatomical structures which are yet to be determined (Hamann, Squire & Schacter, 1995; Squire, 1987b). Some researchers hypothesize that implicit memory is a by-product of sensory processing by the cortex with limited medial temporal lobe involvement (Gabrieli, 1996; Grady, 1996). Others report that implicit memory functions (as evidenced by conditioning in animals) are impaired when there is partial damage to medial temporal lobe structures (Bachevalier, 1990; Grady, 1996; Jernigan & Ostergaard, 1993; Hamann et al., 1995; Woodruff-Pak, Logan & Thompson, 1990). Thus, a systems view of memory functioning tries to establish the neuroanatomical basis for memory systems which are implicated in explicit and implicit memory task performance.

Activation theorists (Diamond & Rozin, 1984; Graf & Mandler, 1984) operating within a systems framework posit that implicit memory results from the activation of pre-existing representations. Activated representations are more available for retrieval than non-activated representations. However, recent findings of priming by nonwords which have no pre-existing representations (Bowers, 1994) pose problems for activation views of priming. To circumvent these difficulties, Schacter (1990) posited a new framework called the perceptual representation system (PRS). In the PRS, processing is seen as the establishment of representations within a particular perceptual system. For instance, visual processing of a word pair is presumed to create a representation of its specific features in a word form system. Priming of a target word would therefore reflect facilitation created by a match between the test stimulus and this newly created representation. Blaxton (1995) and other proponents of a processing approach criticize this view of memory systems because of its lack of parsimony.

Proponents of a memory processing approach (Blaxton, 1995; Pitarque et al., 1992; Roediger, 1990) view memory as a reflection of the procedures used to elicit and measure memory performance. The difference between the systems and processing approaches arises not in the definition of the two forms of memory but from the need to postulate specific systems to account for the memory phenomena. From a processing perspective, a more parsimonious explanation of the differences between explicit and implicit forms of memory is to view these two memory experiences as a function of the different cognitive procedures required by the tests (Roediger, 1990;

Weldon, 1991). Performance on explicit memory tasks, considered a conceptually demanding, is affected by semantically elaborative processing (conceptually driven). Explicit memory is significantly impaired if little attempt is made to actively encode information (Craik & Tulving, 1975; Graf & Mandler, 1984; Greene, 1986; Hirsh, 1980; Neill et al., 1990; Vakil, Blachstein & Hoofein, 1991). Performance on implicit memory tasks tends to be directed by perceptual processing (data driven) and is thought to be sensitive to changes in the structural, perceptual features of stimuli (Greene, 1986; Jacoby, 1983; Neill et al., 1990). Implicit memory task performance is relatively unaffected by manipulations of elaborative/semantic encoding and attentional focus (Greene, 1986).

A modified version of the processing approach is that of transfer of processing (Morris, Bransford and Franks, 1977) which proposes that performance on explicit and implicit memory tests is not exclusively governed by conceptual and perceptual processes respectively. Rather, performance on a memory task is apparently dictated by task demands and the congruence between those demands during the encoding and retrieval stages. Winnick and Daniel (1970) refer to this concept as the equivalence between word stimuli at study and test. Morris, Bransford and Franks (1977) have characterized this congruency between study and test demands as transfer appropriate processing. More recently, Blaxton (1989) devised an experiment to test this hypothesis and demonstrated that data driven implicit (word fragment completion) and explicit memory (graphemic cued recall) tasks were more sensitive to perceptual encoding manipulations than were conceptually-driven tasks. Conversely, conceptually driven implicit (general knowledge) and explicit memory (free recall) tasks were more susceptible to conceptual manipulations than data-driven tasks.

The extent to which memory performance is facilitated by conceptual encoding apparently also depends on the integrity of the neurological system (Beers at al., 1994). In the cases where brain injury has occurred, mTHI is thought to involve diffuse cerebrocortical damage (Gronwall, 1989; Povlishock & Coburn, 1989) and is thought to reduce performance on explicit memory tasks which required deliberate effort (Mutter et al., 1990). Diffuse damage implicated in mild traumatic brain injury frays the neuronal connectivity in the brain without apparent focal damage. As such, information processing is slowed (Gronwall, 1989) and performance on tasks which require deliberate effort is reportedly deficient after mTHI (Mutter et al., 1990). Explicit memory, an effortful, conceptually-demanding task by definition, should be affected by mTHI, a condition which reduces information processing. By inference, performance on perceptually or data-driven, less effortful tasks, such as implicit tasks may be less affected by mTHI.

Mutter et al. (1990) reported slightly lower cued recall scores in persons with mTHI as compared to those without, whereas completion scores were unaffected by mTHI. To reiterate, recall and completion tasks place different demands upon retrieval of information from memory. In explicit memory tasks, participants have to try to remember material from a prior event whereas on implicit tasks such as completion, they need only produce the first word that comes to mind without reference to the learning situation. Remembering words explicitly requires deliberate evocation of the specific details of a learning situation, such as the spatiotemporal context of time, date and environment, in which the word was learned (Richardson-Klavehn & Bjork, 1988).

On the completion task, memory attempts require no deliberate effort and is inferred by an enhanced tendency to complete the stem with previously seen words (Schacter, 1990). Thus, the extent to which deliberate effort is required to retrieve target words varies with the retrieval measure used, and performance on explicit tasks is assumed to be more effortful than that of implicit tasks. It is this deliberate, effortful component of memory retrieval that is presumed to be deficient after mTHI (Mutter et al., 1990).

Performance on completion, a seemingly automatic process is revealed by facilitated performance or priming on a task, by instructions to perform a task using a previously seen, but seemingly unsuspected degraded stimulus, a three letter word stem. As such, performance on implicit tasks, such as completion, being less effortful is predicted to be less affected by mTHI than explicit tasks. However, recent studies have implicated primary processing, sensory cortical areas, such as occipital cortex, in performance on perceptually-based memory tasks such as completion (Blaxton, 1996). Therefore, performance of perceptually-based tasks, such as completion, may also be impaired if there is diffuse cortical damage after mTHI, by virtue of its presumed reliance on a cortical neuroanatomical substrate. Data driven or perceptual features of a task are thought to be important features in facilitating memory on perceptually based tasks (Blaxton, 1989; Greene, 1986; Roediger, 1990).

Perceptual features of the word pair stimuli

Perceptual-spatial features of stimuli, in this case word pairs, may also be used to examine memory processing differences in persons with mTHI and normals. This hypothesis is based on the idea that spatial characteristics, such as lateral position and word separation may affect performance on conceptually-based tasks, such as recognition and perceptually-based tasks, such as completion.

In support of this view, Naveh-Benjamin (1987) demonstrated that memory for spatial information is not exclusively an automatic process but is influenced by instructions to learn. In that study, participants who intentionally learned the locations of specific items on a sheet of paper, had better recall of the locations of these items than participants who learned the information incidentally. Similarly, memory for words may also be facilitated by remembering perceptual attributes of words, as in the case of priming, (Blaxton, 1989; Greene, 1986).

The use of two words to effect incidental-intentional learning imposes a spatial component on the encoding task, and an ancillary focus of the current study was to examine the role of lateral position and separation distance on memory processing of words in persons with mTHI. In a word pair, one has to scan the display to locate the word to be learned and memory performance may be influenced by differences associated with separation format. Lateral position of a word to be learned in a pair may also affect memory, and Heilman, Chatterjee and Doty (1995) suggest that although both hemispheres are activated when a person looks to the right or left without restriction of eye movements, the direction of gazing may activate the hemisphere opposite to the gaze to a greater extent. These researchers also suggest that the left hemisphere tends to direct attention toward the body and the right, away from the body. Thus, with respect to encoding word pairs that are close together or far apart, it could be hypothesized that words from closely spaced word pairs would be best processed by the left hemisphere which directs attention inward, and the right hemisphere which directs attention outward could best process words from the far format.

In support of this notion, lateral position of the word and separation distance between words was shown to have an effect on memory performance in preliminary studies using students in this laboratory at Queens College (Appendix A). In those studies, words from pairs that were far apart were best remembered on the left side, and words from pairs that were close together were best remembered on the right side. Accordingly, it was hypothesized that differential hemispheric proclivities in information processing may be invoked in the initial encoding stage of memory processing which may be reflected in visual field differences. Visual field differences are inferred from a lateralized preference for words in either the left or right positions in word pairs. Thus, the physical format in which words to be learned were presented established a basis for visual field differences. Memory differences in groups with a history of mTHI and normals may also be revealed in different separation formats since persons with mTHI have difficulties attending to material across both visual fields, distributed attention, (Gentilini et al., 1989) as well as integrating information (Beers et al., 1994; Gronwall, 1989).

These features of memory processing are captured in the theoretical writings of Goldberg and Costa (1981) who hypothesized that there is a relationship between stimulus context and hemispheric processing, such that when words are presented in familiar formats, such as the conventional distance between words, processing by the left hemisphere, indicated by a right field advantage, is superior to that of the right hemisphere in decoding specific details from this "well-routinized descriptive system". Conversely, in familiar formats, processing of left positioned words is less efficient, suggestive of reduced proficiency of right hemispheric processing in well-routinized, familiar formats. However, in unfamiliar, novel formats, a left field advantage may reflect a right hemispheric advantage at integrating information (Goldberg & Costa, 1981; Gur et al., 1980). In reading English words, it is unusual to find two consecutive words separated by wide distances, and hence this separation format is considered unfamiliar. In the unfamiliar format of widely spaced words, this relationship between stimulus context and right hemispheric processing is tempered by a left hemispheric facility in processing intentionally learned words, which is revealed by a right visual field advantage and over time, as more familiarity is gained with the material, left hemispheric processing predominates (Goldberg & Costa, 1981).

In healthy persons, lateralized processing is masked by rapid inter- and intra-hemispheric integration (Lezak, 1983). Rapid information processing within and across hemispheres facilitates integration of information garnered from both hemispheres. This view is supported by Arguin, Joanette and Cavanaugh's (1990) findings that in healthy persons, the rate at which spatial attention can be shifted across stimuli does not differ between hemispheres. However, head injury compromises rapid information processing between hemispheres and diminishes information integration (Beers et al., 1994; Gronwall & Wrightson, 1981). Individuals with mTHI who presumably have difficulties in information integration, attention and processing speed may demonstrate lateralized effects when words are learned in the two formats. Thus, attentional and integrative difficulties, characteristic of mTHI where diffuse damage has occurred, may determine differences between groups of normals and persons with mTHI in perceptually demanding contexts. Therefore, in addition to the effect of specific learning instructions, encoding of words is influenced by the spatial context in which words are placed. The experimental task used in the study was designed to assess the suggested differential encoding and retrieval processes induced by instructions within the context of word pairs.

The Experiments

Two experiments were conducted in this dissertation. In the original experimental design, experimental task performance was to be compared between clinic outpatients and normal student controls. However, demographic and medical history information obtained from the preliminary interview given to all participants revealed that many of the "normal" recruits had incurred a single mTHI within the past 1-5 years and met the study criteria for mTHI classification. Therefore, Experiment 1 was a modification of the original experiment to examine memory performance of unimpaired students and students with a self-reported history of mTHI. The ultimate intent was to establish a basis for using a criteria-appropriate group of college students with mTHI along with mTHI outpatients to examine the role of mTHI on learning and memory. In Experiment 2, memory performance in two groups with different functional outcomes post-mTHI (outpatients and college students) were compared with normals and with each other. The control group consisted of heathy normal students. College students with a history of mTHI were thought to reflect a less impaired group with mTHI with good functional outcome. However, as a group, this less impaired group was expected to perform more poorly relative to normals, on tasks that strained information processing capacities.

It was hypothesized that comparisons of memory performance under relatively difficult encoding and retrieval conditions in two groups with mTHI (a presumably more impaired group, the clinic outpatients, and a less impaired group, the students with mTHI who had not sought rehabilitation) would provide further evidence that persistent effects of mTHI emerge on tasks which strain the limited information and hence memory processing capacities of even in instances of minimal impairment from mTHI. Therefore, both groups of individuals with mTHI were expected to show memory deficits relative to healthy controls.

Technological and financial constraints limit the amount of information that can be obtained concerning the precise neurophysiological nature of information processing in the brain. Therefore, in this behaviorally-oriented investigation of implicit and explicit memory functions, it was imperative that both encoding and retrieval conditions be clearly defined.

Learning and memory after mTHI were investigated using a computerized task in which intentional and incidental learning conditions were operationalized using a word pair. Processing was varied both at encoding and retrieval. The experimental paradigm allowed participants the opportunity to simultaneously learn words intentionally and incidentally by instructions to learn one of the words in a pair and to merely perceive the other word without instructions directing attention to that word.

Explicit recognition and implicit completion performance for both intentionally and incidentally learned words in word pairs was assessed. The word to be learned was made more distinctive by underlining. Reading that word aloud also ensured that the correct word was attended to (Mechanic & Mechanic, 1967). If seen, the incidental word would be subject to some degree of data-driven, if not conceptually based processing. In this way the impact of incidental and intentional learning after mTHI could be assessed under two retrieval conditions. Learning of the intentional word would be mediated by efficient perceptually based processing (Mechanic & Mechanic, 1967) effected by reading the word aloud and conceptually based processes (Graf & Ryan, 1991).

The use of word pairs in the paradigm to represent parallel incidental and intentional conditions imposed a spatial component on the experimental task. Laterality, inherent to the word pair, and an additional variable, separation between words (separation format), could easily be accommodated by the word pair paradigm. Thus, a word pair arrangement provided the chance to assess the effect of contextual influences: lateral placement of words in a pair as well as separation format within a word pair. These features of the word pair stimuli afforded an opportunity to further examine possible information processing differences involved in normal memory performance and that of persons with mTHI which may be based on differential inter- and intra-hemispheric, and attentional processing, although inferences as to hemispheric involvement in a behavioral study such as this is only theoretical. The findings from pilot studies did not support the idea that lateralized preferences in memory processing were simply the effect of reading habits (left to right). Based on the theoretical perspectives of Goldberg and Costa (1981) and this pilot work, it was believed that examination of the effects of separation format and lateral position of words in a pair on memory would provide evidence for the augmentation of lateralized processing after mTHI in the two separation formats due to less effective information integration.

The arrangement in which words were placed close together was thought to represent a more familiar context, and the widely spaced format provided an unfamiliar, novel context. Difficulties manifest in the two separation formats may be lessened or made more apparent by hemispheric proclivities and differences in these preferences after mTHI (Goldberg & Costa, 1981). Therefore, manipulation of contextual influences of separation format and lateral position provided the opportunity to further examine factors which may affect intentional learning in persons with and without mTHI. An interaction between lateral position and separation format was predicted based on Goldberg and Costa's (1981) hypothesis of differential hemispheric adeptness at processing information in familiar and unfamiliar contexts which would be most pronounced in groups with mTHI. This interaction was expected to indicate a right visual field advantage in the close format and a left visual field advantage in the far format. Individuals with mTHI were expected to demonstrate augmented lateralized processing of words in the two separation formats because of reduced inter- and intra-hemispheric integration and attentional deficits. This lateralized augmentation was expected to be most pronounced in the more impaired group with a history of mTHI.

Performance on the two memory tasks may be differentially affected by spatial attributes of the word pair because the ability to focus, distribute and divide attention in word pairs may be influenced by separation between words. In closely spaced formats, the incidental word may interfere with intentional learning of the other word in a pair. Thus, performance on recognition, a conceptually demanding task, which is more affected by intentional learning than is the completion task, may be reduced because performance on this task is sensitive to factors such as interference by another word in the display. Recognition of words encoded in the far format in which there is less distraction from the other word in the pair should be better than in the close format. Furthermore, increased distractibility after mTHI may amplify encoding difficulties associated with interference from the incidental word in the close format.

Separation between words also affects scanning, attention and passivity (spontaneity) in encoding. Completion, a perceptually demanding task, may be dependent upon rapid processing and the formation of a holistic word pair perceptual representation unit (Schacter, 1990). As such, words that are widely spaced may be difficult to automatically encode and integrate into a sensory or perceptual representation unit (Graf & Ryan, 1991; Schacter, 1990). This may be partially due to this physically challenging array, as well slower and hence longer times to scan the display to locate a word in the unfamiliar context of words in the far format than in familiar formats, such as closely spaced word pairs (Graf and Ryan, 1991). Therefore, an interaction between task and separation was expected, which was predicted to be more pronounced in groups with mTHI than normals because of difficulties in attention, processing speed and information integration.

Standardized Tests

Memory performance is influenced by subjective factors such as attentional abilities, VIQ, depression and experience of PCS (Alexander, 1995; Lezak, 1983; Mittenberg et al., 1992; Schoenhuber & Gentilini, 1988). The relationship between standardized measures and experimental task performance provided a framework for interpretation of experimental task performance among groups. Standardized tests were also used to compare participant groups on measures of processing speed (WAIS-

R: Digit Symbol) and depression (Zung) which are reportedly impaired in head injured persons. Performance on the Digit Symbol task, which is timed, also gives estimates of attention and distractibility (Lezak, 1983, p. 241, 273; Schmitter-Edgecombe, 1996). The New York University Head Injury Family Interview, Personal Checklist for the person with head injury (PCL-PHI) which assessed PCS provided an important comparison measure of current subjective postconcussive complaints. Estimates of verbal IQ (VIQ), apparently unaffected by mTHI (Correll, Brodginski & Rokosz, 1993), were obtained using the National Adult Reading Test-USA. Differences in memory performance among the groups were expected based on accuracy and reaction time speeds to targets.

The expected performance on the standardized measures used in the study was as follows. The scores on the Digit Symbol task and its modified incidental learning version were expected to be lower for groups with mTHI than for persons without a mTHI history (Evans, 1992). Individuals with mTHI were also expected to report significantly more symptoms of depression listed on the Zung Depression scale and other symptoms associated with mTHI, the Problem Checklist for the Person with Head Injury (PCL-PHI), taken from the HI-FI Version 2.0, New York University (Kay, Cavallo & Ezrachi, 1994) than persons without a mTHI history (Kay & Lezak, 1990). Estimates of verbal IQ using the National Adult Reading Test-USA Version (NART) are reportedly an accurate measure of pre-mTHI IQ (Correll et al., 1993; Moss & Dowd, 1991). Since all participants were matched according to educational status, VIQ estimates were expected to be similar for all three groups.

Predictions based on mTHI history

The experimental task examined memory performance using two memory measures under two encoding conditions. Task demands in both encoding and retrieval conditions varied the extent to which deliberate effort was used to effect these operations. At the encoding stage, intentional learning produced by instructions to learn one of the words in a pair is a more effortful and conceptually demanding task than incidental learning. At the retrieval stage, recognition of words is a more conceptually demanding and effortful task than completion. As such, group differences were expected based upon task demands at the encoding and retrieval stages.

Three possible features of chronic postconcussive effects were proposed to account for potential experimental task performance differences between the two groups with mTHI and normal controls, based on the premise that subjective experiences of PCS (i.e., cognitive or psychological) in the two groups with mTHI would influence memory performance. First, in the most likely case, both groups with mTHI would be impaired relative to controls, with the outpatient group more impaired than the student group. The student group would less likely complain of PCS than the outpatient group with mTHI who had sought and received remediation of cognitive difficulties. The assumption made here is that subjective experience of PCS may partially determine whether a person seeks further medical help after initial postconcussive screening by a health professional and also assumes that access to health care resources was similar for the two groups of individuals with mTHI used in the study. Therefore, individuals who had not sought remediation of cognitive difficulties were expected to be less debilitated by PCS. An increased number of PCS, such as distractibility, would result in lower overall learning and memory scores in recruits with mTHI from rehabilitation facilities than in students with mTHI who had fewer symptoms. These difficulties would make it more difficult to learn any type of material effectively. In light of anticipated difficulties in encoding and retrieval of words under conditions which strained their somewhat reduced information processing capacities (Beers et al., 1994; Ewing et al. 1980), the less impaired group of students with mTHI would also have difficulty on the learning and memory tasks relative to normal controls.

Second, both groups with mTHI would be impaired on the memory tests relative to controls but not different from each other. In this case, the two groups with mTHI histories would report similar postconcussive experiences in terms of number and severity but would not differ in this regard from each other.

Third, both groups with mTHI would be impaired on the memory tasks relative to normal controls, with the student group more impaired than the outpatient group. Here, it would be hypothesized that rehabilitation would provide coping strategies that could partially compensate for some of the cognitive deficits after mTHI. Further, this assumption would be based upon initially comparable postconcussive experiences in the two groups with mTHI, which seems unlikely, given the fact that rehabilitation was deemed necessary in the outpatient group with mTHI. If this were a feasible event, individuals with mTHI histories who had received rehabilitation would report fewer PCS than those who had not sought remediation because rehabilitation of PCS would partially remediate some of the problems associated with mTHI by providing compensatory strategies in outpatients. Therefore, in the face of similar initial disabilities from mTHI, rehabilitation postinjury would provide recipients as compared to nonrecipients with coping strategies, such as directed attention, to better deal with the experimental task at hand. Findings in support of either of the latter two cases would lead to the suggestion that special consideration be given to providing early remedial intervention to facilitate learning for all individuals with mTHI.

Mild traumatic head injury was expected to cause significant reduction in memory for intentionally (Mutter et al., 1990) and incidentally (Kay & Lezak, 1990) learned words relative to learning in unimpaired individuals. The explicit rather than implicit memory task was considered more likely to be affected by mTHI (Mutter et al., 1990) as slowed processing and general apathy which are common features of post-mTHI functioning would make it more difficult to learn briefly presented words when task demands require deliberate effort.

In Experiment 2, given the most likely difference between the two groups with mTHI based on PCS experience, these difficulties on the two memory tasks were expected to be more pronounced in outpatients who are seemingly more debilitated by PCS than the other group with mTHI, students who had not sought rehabilitative services. However, the less impaired group of students with mTHI was expected to perform slightly worse than healthy controls because good performance on the experimental memory task required simultaneous attention to both intentionally and incidentally learned words. This aspect of the task which required divided as well as distributed attention was expected to strain the capacities of many persons who had experienced mTHI with some alteration in mental state, even those who had not sought rehabilitation and were presumably less affected by PCS (Beers et al., 1994).

Therefore, an interaction between group and instructions, suggestive of the differential effects of learning on the two tasks was expected on the basis of mTHI history.

In general, slowed information processing across and within cerebral hemispheres and generalized apathy due to mTHI were expected to reduce memory performance on recognition, but not completion, tasks. However, the spatial format in which a word pair was placed was expected to differentially influence memory task performance. In the close format, learning of the intentional word was predicted to be made more difficult by the proximity and similarity (that is another word) of the incidental word. Recognition, a conceptually-driven retrieval task was predicted to be more difficult in the close as compared to the far format because of increased interference from the incidental word. Individuals with a history of mTHI who are presumably more distractible than normals would have more difficulty intentionally encoding words in closely spaced words pairs. In contrast, wide spacing of words as compared to close may enhance conceptual encoding but may make it more difficult to rapidly scan and locate the intentional word. Hence, completion of words was expected to be more difficult in the far as compared to close format because of potential difficulties in forming a perceptual representation unit in the far format. Difficulties in distributing attention across visual fields in the far format were expected to be more pronounced after mTHI (Gentilini et al., 1989), hence, the groups with mTHI were predicted to complete fewer words from the far format than normals. In general, mTHI was expected to worsen encoding difficulties in the two formats because of slowed processing, attentional difficulties and reduced inter- and intra-hemispheric integration; and in the most probable case, the more impaired group of clinic outpatients was expected to be most impaired on the tasks because of more debilitating PCS.

Related to difficulties with distributed attention after mTHI was the anticipated problem of integrating information. Assuming that differential hemispheric proclivities are invoked by lateralized gazing which enhances activation of the hemisphere contralateral to the gaze (Heilman et al., 1995), these preferences may enhance or diminish memory for words placed to the left or right of a word pair stimulus in the two separation formats; and it was proposed that impaired inter- and intra-hemispheric processing may reflect these lateralized biases. Slowed information processing may occur after mTHI and was expected to reduce inter- as well as intra-hemispheric integration so that less information about a laterally placed word would be available to both hemispheres. Greater lateralization of perception was expected in persons with mTHI as compared to healthy controls (Goldberg & Costa, 1981; Lezak,1983) an lateralized perception was expected to be reflected in a left or right field advantage for words.

<u>Theoretical and practical significance of the study.</u>

In investigations of memory functions, Gabrieli (1995) espoused the need to define a memory systems framework in which neural networks mediate specific memory processes. Although the present study was not designed to identify neural networks, its findings may indicate processing mechanisms implicated in a hypothetical brain neural network subserving memory functions. Investigations into the memory processes of individuals with a history of mTHI do not directly address the question of a neuroanatomical dichotomy in memory systems. Rather, mTHI provides an opportunity to gain insight into the changes that occur in learning and memory with impaired attention (Alexander, 1995) and slowed information processing (Gronwall & Wrightson, 1981; Kay et al. 1992). Studies using individuals with a history of mTHI demonstrate how slowed information processing differences affect quantitative and qualitative aspects of encoding and retention of material.

In the broader context of memory processing, the results of this study were expected to provide support for an integrative rather than a dissociative information processing system (Roediger et al., 1990; Tulving, 1985). In an integrative information processing system, manipulation of an independent variable, such as instructions to intentionally learn material, affects performance on several different types of memory tasks (in this instance, recognition and completion). In this view, a variety of neural mechanisms involved in perceptual, conceptual and retrieval processes interact in a task-dependent manner. Impairments in any of the stages required to perform the task, as may occur in encoding and retrieval after mTHI (Kay & Lezak, 1990; Mutter et al., 1990) will consequently affect memory task performance. Accordingly, the performance on the tasks is said to be dependent on a shared memory processing system. A dissociative (dichotomous) system is one in which stochastic independence (Tulving, 1985) is demonstrated. Stochastic independence refers to a situation where performance on one task is not correlated with performance on another type of task (Roediger et al, 1990).

In light of the hypothesized interactions between instructions to learn material and performance on the two memory tasks, the development of a behavioral measure such as the experimental task, which measures performance on both explicit and implicit memory tasks, may be useful in assessing cognitive strengths and weaknesses in individuals after mTHI. Additionally, the information obtained in the present dissertation may be useful in classification of mTHI. In view of rising health care costs, litigation following mTHI, special consumer interests and the need to identify individuals with valid postconcussional complaints, accurate classification is of practical concern (Hinnant & Tollison, 1994).

Experimental task performance was expected to differentiate individuals with mTHI from healthy controls. Further, the functionally less impaired group with mTHI, who had not sought rehabilitation, was expected to have less difficulty in performing the experimental task than the more impaired outpatient group with mTHI because of fewer physical, neurological and psychological complaints.

Experiment 1

Rationale for Experiment 1.

The primary impetus for Experiment 1 was to assess potential differences in memory performance between normal students and those with a history of a single mTHI. It was proposed that, despite predictions of normal performance on standardized neuropsychological tasks, such as those measuring attention and VIQ, an experimental learning and memory task in which encoding and retrieval were varied could be used to explicate some of the details of postconcussive memory difficulties in minimally impaired individuals. Experiment 1 pretested the notion that a group of students with self-reported mTHI represented a group which had incurred mTHI, had a good functional outcome, but nevertheless showed subtle adverse sequelae.

The variables introduced into these experiments: intentional-incidental study, explicit-implicit memory and perceptual effects, seemed ideal to tap the potential memory difficulties of persons who have had mTHI. The learning and memory variables focussed on effortfulness of encoding and memory retrieval. It was predicted that the effects of mTHI would emerge in these situations. It was also hypothesized that the effects of lateral placement and degree of separation of the paired words (spatial location) provided encoding contexts which would amplify attentional and integrative differences between learning-memory impaired individuals with mTHI and normals. Lateralized and integrative processing were expected to be affected by mTHI, such that students with mTHI would demonstrate greater lateralization of memory in far and close formats, and remember fewer words from the far format than normals.

Method

Participants. Thirty four Queens College undergraduates participated in partial fulfillment of course requirements. A visual acuity screen (Snellen visual acuity chart) and a brief interview (Appendix B) were given before administration of the experimental task and test battery. Inclusion criteria for the study were an age range between 17-45 years, English as a first language, no neurological or psychiatric conditions (other than those associated with a single head injury for students with head injury), no history of multiple mTHI for students with mTHI and minimal visual acuity of 20/40. Chronic drug and alcohol abusers were excluded. Upon interview, it was determined that some of the students tested had a history of mTHI but met the other inclusion criteria. Students were classified as having a history of mTHI if they had a self-reported history of at least one of the following: traumatic head injury with symptoms of LOC less than 30 minutes, alteration of mental state or PTA of less than 24 hours. The end of PTA was defined as that time when a person reported being oriented to time, place and person and when s(he) could correctly indicate what had happened to him/her (Gronwall, 1989). Individuals with mTHI were tested within 1 - 5 years postinjury. Informed consent was obtained from all participants (Appendix C).

Demographic data. Of the 34 students included in the study, 21 (13 females and 8 males) were normal controls and 13 (9 females and 4 males) had a history of mTHI. Table 1 shows the demographic characteristics for the two groups. The group of students with no history of head injury were older than the group with a history of mild head injury, t (32) = 2.60, p = .01. Students with a history of head injury complained of more psychomotor symptoms, such as being restless, than those without a history of head injury, t (32) = 2.03, p = .05.

Refer to Table 1

Materials and apparatus. The word pair stimuli were presented on a 486SLC/25MHz laptop computer (Texas Instruments). The study materials consisted of 64 words arranged as pairs (i.e., 32 pairs) and 8 word pair buffers. Four word pair buffers were presented at the start and end of each study list to minimize primacy and recency effects. The words were taken from lists used by Brown and Ure (1969) and Matthews, Mogg, May and Eysenck (1989). Words were five to nine letters long. Words on these study lists were initially rated on a 7-point Likert scale as neutral words (promoting neither positive or negative affect). Each word pair on a study list consisted of two unrelated words In addition, the beginning three letter stems of each word could be completed by at least five to seven alternate words. The word to be learned intentionally was underlined. A sample of a study list is shown in Appendix D.

Each participant was given one of four study lists (A, A', B, B'). Lists A and A' contained the same word pairs, as did lists B and B', and the lists, A and A' (B, B') differed with respect to the word to be learned intentionally (underlined). The intentionally studied words in word pairs were reversed on the duplicate list. Lateral position of underlined words was counterbalanced in word pairs on each study list, such that half of the words were presented on the left and the other half on the right. Similarly, half of the paired words were presented close together and the other half, far apart. Words in the close separation format were separated by one space (0.083") and those in the widely spaced format (far), by 50 spaces (4.15") on the computer screen.

Two test lists, each consisting of 64 words, 32 targets (words seen on a study list) and 32 foils (words selected from the other study list that was not seen), were used to assess recognition and completion performance. In this way, all participants saw the same words in the memory phase. A sample test list is shown in Appendix E.

Half of the words on each memory test list had been underlined (intentional learning condition) and the other half had not been underlined (incidental learning condition). Equal numbers of words had been presented in the close and far separation formats as well as in the left and right positions in the study phase.

Experimental Design. A 2 (group: mTHI history, no mTHI history) x 2 (study condition: intentional, incidental) x 2 (separation distance: close, far) x 2 (memory test: recognition, completion) x 2 (lateral position: left, right) mixed analysis of variance (ANOVA) was used to analyze the effects. The word list used in the learning phase and the order in which memory tests (recognition and completion) were given were counterbalanced across subjects. Within-subjects comparisons investigated the effects of study condition, separation distance, lateral position and memory task.

Procedure. The experimental procedure was briefly described to participants by the experimenter (see Appendix F) with a practice trial. Six word pairs (three in the close and three in the far formats) were shown in the practice session. The experimental paradigm incorporated three stages: study followed by two memory tasks. Participants were given instructions on the computer before the start of each of the stages of the experimental session.

In the study phase, a random sequence of word pairs in a study list was presented. Each word pair was displayed for a fixed period of time (1 s) and fixed interstimulus interval (1 s). The word pair was preceded by a ready signal indicated by an asterisk at the center of the screen. During presentation of word pairs for study, half of the underlined and non-underlined words were randomly positioned on the right and the other half on the left. Instructions directed participants to say the underlined word aloud and remember it (intentional condition). The other word formed the incidental condition. No reference was made to this word. In this way, the participant's attention was focussed on the target word, which was to be learned intentionally, and was presumably minimal for the incidentally presented word.

Immediately following the presentation of the final word pair on a study list, individuals were given the two memory tasks (recognition and completion). The order of administration of these two tests was counterbalanced across subjects. Both memory test lists were presented in a different random order for each subject. On the completion task, participants completed a three letter word stem with the first word that came to mind. The stem remained on the screen for 0.5 s if no typing response was made. If a letter was typed, then the stem remained on the screen until the enter key was pressed. On the recognition task, participants were directed to type "Y" (Yes) or "N" (No) if the word on the screen was recognized/not recognized from the previously studied list. There was no time limit for making a recognition response but when the response was made, a new word was presented 0.5 s later.

Standardized test measures. A visual acuity screen of 20/40 vision and an interview to determine demographic and medical history were given before the experimental task. Each participant also received a brief evaluation after the experimental task that included the Digit Symbol (WAIS-R subtest, standard and modified version which measured incidental learning), the NART-USA, the New York University Head Injury Family Interview (version 2.0) Problem Checklist for the Person with Head Injury (PCL-PHI)and Zung Self Rating Depression scale. These measures are described below.

The WAIS-R Digit Symbol test (Kaplan, Fein, Morris & Delis, 1991; Lezak, 1983, p. 241, 273), shown in Appendix G1, is a paper and pencil task of attention/concentration and visuomotor processing speed which requires transcription of symbols which have been paired with numbers seen on a template on the test sheet. The number of symbols accurately transcribed after 90 seconds is noted. Upon completion of the second to last line, the Kaplan et al (1991) incidental learning modification of the task was given. A sheet with only the items from the last line exposed was presented, and participants were asked to fill in the empty boxes with the appropriate symbols from memory. The incidental learning score was based on the number of symbols correctly recalled, with one proviso, that a symbol was considered correctly recalled if that symbol was supplied in all instances where it was presented. This score was referred to as Incidental Digit Symbol A.

The NART- USA version (Grober & Sliwinski, 1991) shown in Appendix H was administered as a measure of verbal IQ. Participants were asked to read a list of regular and irregular words. The number of pronunciation errors made was used in a formula to estimate the verbal IQ (Sliwinski, personal communication, 1994).

The HI-FI personal checklist for persons with head injury (PCL-PHI, Kay, T., Cavallo, M. & Ezrachi, O., 1994) shown in Appendix I1 was used as a measure of

PCS. Participants completed a checklist of symptoms commonly experienced after head injury. Affirmative responses were rated on a seven point scale in terms of the severity. The total number of symptoms and the sum of symptom severity for all items were calculated. Subscale scores for affective, cognitive and physical dependency symptoms and symptom severity were computed as indicated in Appendix I2.

The Zung Depression Scale (Zung, 1965) shown in Appendix J is a self-rating depression scale consisting of 20 items which relate to specific aspects of depression (affective, physiological, psychomotor and psychological). Each symptom was rated on a four point scale in terms of severity. Total depression and subscale indices were calculated.

Data analysis. Performance accuracy was indexed by the mean percentage of words correctly identified (recognition) or completed (completion). Baseline measures for the recognition task were the percentage of unstudied words identified as previously seen (false alarms). Baseline measures for the completion task were the percentage of words completed that were not presented at study (foil). An alpha level of .05 (p) was used to establish statistical significance. Probability levels of .01 were used to establish significance on the multicorrelational analyses because of the large number of comparisons. However, for the purposes of discussion and interpretation of the data, p values less than .10 (.05 for multicorrelations) but greater than .05 (.01 for multicorrelations) were reported as indicating a trend in statistical analyses.

The effects of task, instructions, separation, lateral position and group were studied using the multivariate analysis of variance (MANOVA) procedure provided by the Statistical Package for the Social Sciences (SPSS), PC+ version. Task, instructions, separation and lateral position were examined as within-subjects variables while the two groups by definition form a between-subjects variable. One-tailed t-tests were used to test the a priori expected group differences. The effect of age was covaried in reported statistical analyses of experimental task variables among groups, if age was found to have a significant effect in preliminary analyses.

Reaction times for recognition and completion of words were measured automatically by the computer. On the recognition task, the latency measures reflected the time taken to press either the "Y" or "N" key from the moment a word was presented. Reaction time on the completion task was the time taken to complete a response with a word from the moment a stem was presented to the time that a participant pressed the "Enter" key (signaling response completion).

Analysis of standardized tests. A correlational analysis was performed among the standardized measures (Digit Symbol, NART-USA, HI-FI and Zung) and the memory measures obtained under several experimental conditions. Independent groups analyses of variance were performed on neurobehavioral scores to determine possible group differences.

Results

Intentional-Incidental Learning Effects in Groups. Figure 1 shows the percentages correct for words learned intentionally and those perceived incidentally for the two groups (mTHI status), in addition to baseline values. Instructions to learn words can be seen to have a more pronounced effect in students with a history of mTHI than normal students. The difference scores between intentionally and incidentally learned words, which reflects the effect of intentional relative to incidental learning, was greater for students with a history of mild head injury than those without such a history and was evidenced by a significant interaction between learning condition and group on the MANOVA with Group as an independent variable, $F\ (1,32) = 4.10$, $p = .05$.

As depicted in Figure 1, recognition scores for incidentally learned words were lower for the group with mTHI than for healthy students, although no clear group differences were apparent for intentionally learned words. On the completion task, group differences were not reliably demonstrated for either intentionally or incidentally learned words. This differential group effect in instructions to learn words on the two tasks was confirmed by MANOVA within tasks, which revealed a significant group x learning interaction on the recognition task, $F\ (1,32) = 3.88$, $p = .05$, which was not reliably demonstrated on the completion task, $F\ (1,32) = 1.01$, $p > .10$. As such, the effect of intentional learning on the recognition task was greater for students with a history of mTHI than for those without. More detailed analyses of incidental learning effects within the two separation formats using the repeated measures paired t-test indicated that this group difference was mainly due to less accurate recognition of incidentally presented words from the widely spaced format in students with a history of head injury than in healthy controls, t (32) = 1.97, p = .05 (1-tailed).

Refer to Figure 1

Tasks and mTHI. Paired t-test comparisons between groups based on mTHI history indicated that baseline rates were essentially equivalent, t (32) = 0.29, p > .10; t (32) = 1.03, p > .10, for baseline group differences on recognition and completion respectively (see Figure 1). In general, recognition and completion target rates between the two groups were also not significantly different from each other, t (32) = .41, p > .10; t (32) = .92, p > .10, for group difference on recognition and completion respectively. However, as noted in the previous section, recognition of incidentally learned words from the far format was significantly less accurate in students with a history of mTHI. There were no significant differences in age-corrected reaction time scores between the two groups on either recognition or completion using the ANCOVA procedure with age as covariate, p > .10.

Lateral position and Separation format and mTHI. Figures 2 and 3 show mean percentages words correct for recognition and completion as a function of lateral position and separation format. For healthy student controls, when word pairs were close together, recognition, t (20) = 2.81, p = .00, (1-tailed), and completion scores, t (20) = 1.87, p = .04 (1-tailed) for words placed on the right were higher than words on the left. For students with a history of mTHI, only completion scores in the close format showed a differential effect of lateral position with significantly higher scores obtained by placement of words to the right than left of a pair, t (12) = 2.31, p = .02, (1-tailed). No group difference was found for these variables.

Refer to Figures 2 & 3

Findings from Standardized Tests used.

Correlations among standardized test measures, overall target and baseline rates as well as scores for experimental task performance variables that were clustered according to learning instructions and separation format were computed. Multicorrelations among standardized test and experimental task measures are displayed in Table 2. Significance levels for the multicorrelational analyses were set at p = .01, 1-tailed. Probability values < .05 but > .01 were described as indicating a trend.

Postconcussive symptoms and memory. Recognition and completion scores for the clustered target variables were generally not significantly correlated with postconcussive symptomatology ($PCL\text{-}PHI_{experience}$), p > .01. In general, there were no clear-cut relationships between reported increases in postconcussive symptom severity as measured on the $PCL\text{-}PHI_{severity}$ and experimental memory task performance. However, completion of closely-spaced incidental words was significantly negatively correlated with increased severity of depression symptoms measured by the Zung, r = -.42, p = .01.

Refer to Table 2

Digit Symbol and memory. The standardized Digit Symbol score (Digit Symbol) was not significantly correlated with memory scores for most of the clustered experimental task variables ($p > .01$). However, better scores on the Digit Symbol task were associated with lower completion of intentionally learned words from the close format across groups, $r = -.45$, $p = .00$.

Completion of words studied in the close format was significantly correlated with scores on the Incidental Learning Digit Symbol task (INCDIG A). More specifically, as shown in Table 2, better recall of digit-symbol combinations was associated with reduced completion of intentionally learned words from closely spaced pairs, $r = -.39$, $p = .01$. Nonetheless, there was a trend for higher completion scores of incidentally presented words in the close format during the study phase to be correlated with better recall of digit-symbol combinations, $r = .34$, $p = .02$. There was also a tendency for higher false alarm rates (not shown in Table 2) to be associated with better recall of incidentally learned digit-symbol combinations on the Digit Symbol task (Digit Symbol A), $r = .28$, $p = .05$.

NART-USA (estimated verbal IQ & task variables). In general, memory scores on the experimental task were not significantly correlated with VIQ. However, there was a trend for recognition of intentionally learned words from the close format to be positively correlated with higher VIQs, $r = .32$, $p = .03$; participants with higher VIQs tended to recognize more intentionally learned words from the close format than participants with lower VIQ estimates.

Discussion

Recognition scores of incidentally presented words were significantly lower in students who had a history of mTHI than in those who did not. This finding is consistent with anecdotal reports of diminished incidental learning after mTHI (Kay & Lezak, 1990). Of note is the finding that incidental learning of a word in the far format and not the close format was poorer in students with mTHI as compared to their peers without mTHI. This is suggestive of difficulties in deliberate and effortful scanning of material in a visually challenging display and is consistent with anecdotal clinical reports of inertia after mTHI. Mild THI is thought to be characterized by slowed information processing (Gronwall, 1989; Gronwall & Wrightson, 1981); this was not evident in this part of the study.

Age-corrected reaction times did not differ in the two student groups. Additionally, baseline scores on the two memory tasks were essentially equivalent. This indicated that similar response strategies were used to perform the tasks. In other words, both groups responded similarly when confronted with words that they had not seen. However, despite comparable reaction times, students with a history of mTHI appeared to have had difficulty distributing attention in the far format and recognition scores for incidental words in this group was significantly below normal students. Performance on standardized tests of attention did not provide much insight into the reason for this group difference, and it is likely that members of this student group with mTHI, who had originally identified themselves as "normal", represented that proportion of the 85% of persons who were minimally affected by mTHI, without experiencing significant PCS. The only significant non-experimental task difference between the two groups was in the self-reported experience of psychomotor symptoms of depression. Further investigation into processing differences after mTHI was carried out in Experiment 2.

Experiment 2

Rationale for Experiment 2.

Previous reports have described potential cognitive differences after mTHI based on functional outcome (Dikmen, Ross, Machamer & Temkin, 1995; Kay et al., 1992). Therefore, in Experiment 2, possible memory differences were examined in two groups of individuals who initially suffered similar mTHI episodes as reflected by LOC and PTA but who had different functional outcomes. One group with mTHI was obtained from rehabilitation sites and had actively sought remediation of cognitive symptoms. This group was thought to represent individuals with persistent postconcussive sequelae which were severe enough to warrant participation in a professional rehabilitation program. The other group consisted of students who were selected because they reported a history of mTHI but had not sought remediation of PCS and were thus considered to be less affected by persistent, debilitating PCS. Healthy students participated as normal controls.

Inclusion of a second group of individuals with mTHI also permitted examination of the notion that less impaired individuals with mTHI have relatively normal memory 1-5 years postinjury (Ruff et al., 1989). Based on the findings in Experiment 1, it was hypothesized that the students with mTHI would perform better than outpatients, but somewhat more poorly than healthy controls on the experimental task. As in Experiment 1, the experimental task measured recognition and completion performance under two learning conditions. Memory scores for incidental material were expected to be reduced by mTHI.

In Experiment 1, recognition of incidentally learned words from the far format was significantly lower in students with mTHI as compared to those with no mTHI history. Thus, consistent with these findings and anecdotal reports, it was expected that this effect would be duplicated in Experiment 2 and would be most pronounced in outpatients with a history of mTHI. Consistent with findings from previous research (Mutter et al., 1990), it was expected that recognition of intentionally learned words would be less accurate in outpatients with mTHI than in healthy controls and possibly in the less impaired group with mTHI. Latency (RT) on the two memory tasks in Experiment 1 were found to be essentially equivalent in students with mTHI and healthy controls. Therefore, no differences in reaction times were expected between the less impaired group of persons with mTHI and healthy student controls. However, RTs were expected to be lower in outpatients with mTHI compared to the other two groups because of slower processing speeds and a potentially greater incidence of apathy (a symptom of the PCS) in the outpatient group.

Outpatients with mTHI were expected to show greater lateralization than the other groups because of slowed processing. As described earlier, memory processing of the intentionally learned word was expected to be an arduous process in either separation format because of interference in the close and difficulty distributing attention in the far, and performance was predicted to be lower and marked by lateralized preferences in the outpatient group with mTHI. Lateralized processing in the less impaired group with mTHI, students, was expected to be less evident and comparable to normal controls. As previously described, it was also predicted that separation format would differentially modulate the effect of intentional learning in the two memory tasks, recognition influenced by interference from the incidental word and completion, by difficulties in scanning and forming perceptual representation units.

Method

Participants. The inclusion criteria were the same as in Experiment 1. However, participants were between 17-50 years old. In addition to the symptoms used to define mTHI in Experiment 1, a score between 13-15 on the GCS, a standardized rating scale in which points are assigned for different levels of eye opening, motor and verbal responses was used, when available (Teasdale & Jennett, 1974). A different set of students from that of Experiment 1 participated in Experiment 2. Sixty four persons took part in this experiment (21 with mTHI recruited from rehabilitation sites, 21 students with a history of mTHI who had not received rehabilitation, 22 students without a history of mTHI). Informed consent was obtained from all participants; students had the choice of one of two options, receiving $10.00 or fulfilling a course requirement, whereas outpatients were paid $10.00 for participation in the study.

Participants with mTHI from outpatient clinics were recruited from Kessler Institute for Rehabilitation, NJ, Mt. Sinai Medical Center, NY, Elmhurst Hospital Center, NY and Burke Rehabilitation Center, NY. Participants from these rehabilitation sites (13 females and 8 males) were selected from medical charts or referrals from rehabilitation medicine professionals and had received rehabilitation for cognitive difficulties.

The other group with mTHI was selected from a sample of students at the Queens College campus who identified themselves as having had a single incident of mTHI but who had never sought remediation of postconcussive cognitive symptoms from a health care professional. These students (14 females and 7 males) had responded to advertisements placed on bulletin boards at the college campus.

Students or volunteers without a history of head injury (15 female and 7 males), served as controls. Sixteen were recruited from Queens College, CUNY campus in Flushing, NY. The other six were non-Queens College student friends of the Queens College volunteers. This group was screened by telephone to ensure that participants had no history of mTHI. Five students (3 Queens College and 2 non-Queens College) chose to volunteer without compensation.

Demographic and standardized test data. Demographic and standardized test characteristics for the three groups were compared using ANOVA followed by Duncan's multiple contrasts. Table 3 shows that there were no significant differences among groups with respect to educational level and VIQ as assessed by self-report and the NART-USA, F (2,61) = 0.12 and 0.78 respectively, $p > 0.10$. Participants obtained from rehabilitation sites were older, F (2,61) = 29.01, $p = .00$ and reported more numerous PCS as reflected by scores on the PCl-PHI, F (2,61) = 39.14, $p = .00$, which were more severe, F (2,61) = 14.86, $p = .00$, than participants in the two other groups. Students with mTHI also reported more numerous PCS as reflected in PCL-PHI scores, particularly cognitive difficulties, than did healthy controls, t (41) = 2.58, $p = .00$ (1-tailed).

Refer to Table 3

Injury-related demographic characteristics for participants with mTHI are displayed in Table 4. As indicated, the two groups with mTHI were tested within comparable post-injury intervals, $t\ (41) = .02$, $p > .10$. Outpatients and students with mTHI did not differ with respect to LOC reported at the time of injury, mean - 7.77 min (SD 10.34 min). Fewer students with mTHI (9.5 %) than outpatients (33 %) reported PTA greater than one hour. Table 4 also shows that the most common cause of mTHI (38 % in outpatients & 48 % in students) in the sample was a driver or passenger related motor vehicle accident.

Refer to Table 4

Materials and Procedure. The materials and procedure for the experimental task were as described in Experiment 1.

Experimental Design. A 3 (group: $mTHI_{clinic}$, $mTHI_{college}$, no $mTHI_{college}$) x 2 (study condition: incidental, intentional) x 2 (memory task: recognition, completion) x 2 (separation distance: close, far) x 2 (lateral position: right, left) mixed design was used. The effects of learning instructions, memory task, separation and lateral position were examined as within-subjects variables with group membership, the sole between-subjects variable. The effects of study list and order of memory testing were analyzed between subjects.

Standardized Test Measures. The measures were as in Experiment 1 except that a further modification of the incidental learning part of the Digit Symbol task was used in this part of the study to facilitate equivalent stimulus exposure by all participants (Kay, T., personal communication, December 1993). This procedure is shown in Appendix G2.

Data Analyses. Data analyses were as described in Experiment 1.

Results

Incidental-Intentional Learning Effects among Groups. Figure 4 shows baseline values and scores for intentionally and incidentally learned words on the two memory tasks for the three groups. Immediately evident is that both of the groups with mTHI obtained lower than normal scores for intentionally learned words on both recognition and completion. The critical group differences occur in scores for intentionally learned words and are not as apparent for incidentally learned words. This is reflected in the significant interaction between Group and Learning condition, F (2,61) = 3.01; p = .05. Outpatients with mTHI remembered fewer intentionally learned words than either of the student groups. This observation was confirmed by separate one-way ANOVAs on the data clustered by learning condition in the two memory tasks for the two groups followed by Duncan's multiple contrasts, main effect of group, F (2,61) = 3.61, p = .03; F (2,61) = 6.15, p = .00, for recognition and completion respectively. Comparisons of overall recognition and completion of incidental words were not significantly different among groups, F (2,60) = .20, $p > .10$; F (2,60) = 2.00, $p >$ .10, for Group differences on the recognition and completion tasks. Also, as revealed by ANOVA, baseline recognition and completion were essentially equivalent across groups, F (2,61) = .05 and 1.59, p > .10, for recognition and completion respectively.

Refer to Figure 4

Word Separation and Instructions to Learn. Figures 5 and 6 show Group scores for incidentally and intentionally learned words on the recognition and completion tasks in the close and far separation formats. These figures show that although memory for incidental words was generally unaffected by separation format for either recognition or completion, there was a task-dependent differential effect of separation on intentionally learned words. An overall MANOVA indicated that there was a significant three-way interaction among memory task, learning condition and separation format, F (1,61) = 10.01, p = .00, for all participants. This interaction reflected a task dependent discrepancy between memory for incidental and intentional scores based on separation format.

Refer to Figures 5 & 6

As shown in Figure 5 and confirmed by related paired t-test comparisons on total scores, recognition scores for intentionally learned words were more accurate in the far format than in the close for all participant groups, t (63) = 3.60, p = .00 (1-tailed). Conversely, as indicated in Figure 6, completion scores for intentionally learned words were higher with words from the close than far format for all groups, t

(63) = 6.25, p = .00 (1-tailed).

Word Separation and Instructions to Learn among Groups. Significant group differences were found when words were learned intentionally within the two separation formats. One-way ANOVAs followed by Duncan's multiple contrasts were performed on the experimental scores clustered according to separation format and instructional conditions using Group as a between subjects variable. As shown in Figure 5, recognition of intentionally learned words from the close format was less accurate in outpatients with mTHI than either of the other groups, F (2,61) = 4.08, p = .02. Recognition scores for intentionally learned words were not significantly different between students with a history of mTHI and normal student controls, $p > .10$.

On the completion task, Figure 6 shows that fewer intentionally learned words were completed in the two separation formats by the outpatient group, F (2,61) = 8.75, p = .00; F (2,61) = 4.09, p = .02, for group differences in the far and close formats respectively. Independent related t-tests were used to further define these group differences. These tests showed that completion of intentionally learned words from the far format was also significantly lower in the group of students with a history of mTHI than in healthy controls, t (41) = 2.39, p = .02 (1-tailed).

The Analysis of Covariance (ANCOVA) procedure with age as a covariate showed no reliable group differences were evidenced for recognition of incidentally presented words in both formats or on the completion task in the far format. However, completion of incidentally learned words from the close format was significantly reduced in outpatients as compared to the student group with mTHI, F (2,60) = 4.54,

$p = .01$.

Group classification using clustered Memory Task Variables. Discriminant analysis using the Wilks' lambda method, SPSS-PC+ was conducted on the experimental task variables collapsed across instructional condition and separation format within each task. As shown in Table 5, an overall classification rate of 62.5% was obtained with 77.3% healthy controls, 42.9 % students with mTHI and 66.7% outpatients correctly classified into their respective groups using the scores from five of the collapsed variables. These variables were completion of intentionally learned words from the far (lambda = .78, $p = .00$) and close (lambda = .63, $p = .00$) formats, completion of incidental words from the far format (lambda = .61, $p = .00$) and recognition of incidentally learned words from the far (lambda = .66, $p = .00$) and intentionally (lambda = .69, $p = .00$) learned words from the close formats. Comparisons of centroid values indicated that the two groups that were best discriminated using the above procedure were students without a history of head injury and outpatients, F (5,57) = 6.06, $p = .00$.

Refer to Table 5

One-way ANOVA followed by Duncan's contrasts indicated that the experimental task variable clustered by separation format and instructions that best discriminated among the three groups was completion of intentionally learned words from the widely spaced format, F (2,61) = 8.75, $p = .00$. Both groups of individuals with mTHI completed fewer words in this condition than normal controls, as indicated by paired t-tests contrasts, $t\ (41) = 4.52$, $p = .00$; $t\ (41) = 2.39$, $p = .01$, (1-tailed), for control comparisons with outpatients and students with mTHI respectively. Outpatients also showed lower completion of intentional words from the far format than students with a mTHI history, $t\ (40) = 1.64$, $p = .05$, (1-tailed).

Anecdotally, outpatients with mTHI tended to make more exaggerated lateral neck movements than unimpaired participants when locating intentionally learned words from the far format. No systematic measurement of this behavior was made in the current study.

Response latencies within Groups. As shown in Table 6, outpatients took more time to complete incidentally and intentionally learned word stems than either of the student groups. An ANCOVA with age as covariate showed that this group difference was significant for completion of incidentally, $F\ (2,60) = 3.98$, $p = .02$ and intentionally learned words, $F\ (2,60) = 4.81$, $p = .01$. Outpatients also recognized intentionally learned words more slowly than the other two groups, $F\ (2,61) = 4.80$, $p = .01$.

Refer to Table 6

With respect to differences in response latency between intentional and incidental targets, healthy controls recognized and completed intentionally learned words more quickly than incidentally perceived words, $t\ (21) = 1.74$, $p = .05$; $t\ (21) = 2.18$, $p = .02$ (1-tailed), for recognition and completion respectively. This difference between response latencies for incidentally and intentionally learned words was not significant in either students with a history of mTHI, t (20) = .93, $p > .10$; t (20) = 1.02, $p > .10$, for recognition and completion respectively, or outpatients, t (20) = .77, $p > .10$; t (20) = .76, $p > .10$, for recognition and completion respectively.

Lateral Position and Separation Format among Groups. Figure 7 shows mean group percentages for lateralized targets. As indicated in the figure and confirmed by an independent groups one-way ANOVA on the data clustered by lateral position followed by group contrasts using Duncan's procedure, outpatients with a mTHI history recognized and completed fewer words that were to the left in a pair than either healthy student controls or students with mTHI, F (2,61) = 4.75, $p = .01$; F (2,61) = 3.29, $p = .04$, for recognition and completion respectively. The outpatient group also completed fewer targets on the right than any of the two student groups, F (2,61) = 4.08, $p = .02$. Recognition of words placed on the right was not significantly different among the groups, F (2,61) = 1.36, $p > .10$.

Refer to Figure 7

As indicated in Figure 8, the outpatient group with mTHI recognized, F (2,61) = 3.65, $p = .03$ and completed, F (2,61) = 2.89, $p = .06$, fewer words from the close format than normals or the student group with mTHI. Completion scores for words from the far format was also lower in outpatients with a history of mTHI than the other two groups, F (2,61) = 4.56, $p = .01$. However, recognition of words from the far format was not significantly different among groups, F (2,61) = 2.16, $p > .10$.

Refer to Figure 8

As in Experiment 1, the overall MANOVA revealed a significant interaction between lateral position and separation format, F (1,61) = 5.67, p = .02. However, as shown in Figures 9 and 10, this interaction was most apparent on the recognition task and in students with a history of mTHI. This interaction indicated that lateral position differentially affected memory for words in the two separation formats. An ANOVA performed on scores clustered by separation format and lateral position for students with mTHI indicated a significant interaction between lateral position and separation, F (1,20) = 9.68, p = .00. In this group, there was trend towards better recognition of left than right positioned words from widely spaced pairs (far), t (20) = 1.57, p = .06 (1-tailed). This effect was reversed for words from the close format where right positioned words were significantly better recognized than left, t (20) = 2.68, p = .01 (1-tailed). The interaction between lateral position and separation was not significant in either healthy student controls, F (1,21) = .86, p > ,10, or outpatients with mTHI, F (1,20) = .14, p > .10. Paired t-tests on clustered lateral position/separation target scores within groups indicated that healthy student controls did not evidence a significant lateralized visual field advantage on recognition when identifying words from either format, t (21) = 1.04, p > .10; t (21) = .69, p > .10, for words from the far and close formats respectively. However, outpatients showed significantly better recognition of right than left positioned words from the far format with no significant lateralized effect for words from closely spaced pairs, t (20) =

1.74, p = .05, t (20) = 1.22, p > .10, for words from the far and close formats respectively.

Refer to Figures 9 & 10

Figure 10 shows that on the completion task, the general trend was towards better or equivalent completion of right as compared to left positioned words in both close and far separation formats. This lateralized preference was significant only for words from the close format and only in students, irrespective of head injury status, t (21) = 2.51, p = .02; t (20) = 1.99, p = .03 (1-tailed), for lateral position effects in the close format for healthy controls and students with mTHI respectively. This lateralized advantage for words from the close format was not reliable in outpatients, t (20) = 1.18, p > .10.

Study List and Order of Memory Test administration. There were no significant effects for study list or memory test used across groups. Neither the study list nor the combinations of study and test lists used affected word recognition or completion, p > .10. However, in all groups the order in which memory tests were given had a significant effect on completion, F (1,62) = 4.53, p = .03, but not recognition F (1,62) = 0.43, p > .10. When the recognition task preceded the completion task, completion was less accurate than if completion preceded recognition.

Standardized Test and Experimental Memory Task Performance among the groups. Table 7 shows the classification of participants using the Wilks' lambda method for the Discriminant Analysis procedure, SPSS-PC+, conducted on subscale scores from the PCL-PHI and Zung, and Digit Symbol (standard and incidental learning) tasks. A combination of six of these scores, PCL-PHI cognitive (lambda = .46, p = .00)/ physical dependency (lambda = .29, p = .00) experience, PCL-PHI affective severity(lambda = .34, p = .00), Zung psychological (lambda = .31, p = .00) /affective (lambda = .30, p = .00) and incidental Digit Symbol A (lambda = .38, p = .00) correctly identified 76.19% of the cases into their respective groups. Using a Wilks' lambda significance level of .05, this combination of variables correctly classified 81.8 % healthy student controls (no $mTHI_{college}$), 90 % of outpatients with mTHI ($mTHI_{clinic}$) and 57.1 % of students with mTHI ($mTHI_{college}$) into their respective groups. Comparisons of group centroid values indicated that outpatients with mTHI were best discriminated from healthy student controls, F (6,56) = 20.63, p = .00. However, students with mTHI were also differentiated from outpatients, F (6,56) = 7.51, p = .00, as well as healthy controls, F (6,56) = 3.98, p = .00, using these variables. Of the six best predictor variables used in this classification the two foremost were the subjective experience of cognitive complaints, lambda = .46, p = .00 and incidental learning of digit symbol pairs, lambda = .38, p = .00.

Refer to Table 7

Table 8 shows the summary table for discriminant analysis using a combination of the experimental task variables clustered across instructions and separation format, and standardized test variables described above. As shown, an average of 76.19% of the cases were correctly identified by eight of these variables with 72.7 % no

$mTHI_{college}$, 85 % of $mTHI_{clinic}$ and 71.4 % $mTHI_{college}$ into their respective groups. If the effect of Age is included in the latter analysis, then the discriminant value of twelve of the combined experimental and standardized tasks is increased to 90.63 %, as shown in Table 9. Here, 90.5% of students with mTHI are correctly classified, and differentiated from outpatients, $F\ (12,50) = 11.23$, $p = .00$, and healthy controls, $F\ (12,50) = 2.77$, $p = .00$. In this instance, the best discriminant variable was the experience of cognitive complaints, lambda = .46, $p = .00$.

Refer to Tables 8 & 9

Digit Symbol tasks. Group differences on Digit Symbol tasks are depicted in Table 3. As revealed by ONE-WAY ANOVA and Duncan's contrasts, regardless of mTHI status, the two student groups had significantly higher scores on the Digit Symbol tasks (SSDSYB, INCDIG A) than outpatients, $F\ (2,60) = 11.49$, $p = .00$; $F\ (2,60) = 11.45$, $p = .00$, for standard and incidental learning Digit Symbol scores respectively. It should be noted that 23 of the 64 cases (3 without mTHI, 7 students with mTHI and 13 outpatients with mTHI) used in the statistical analyses could not recall at least seven of the nine symbols on the incidental Digit Symbol task. The relationship between performance on Digit Symbol and experimental memory tasks was examined in a multiple correlational analysis.

Tables 10 and 11 show correlations among standardized test variables and experimental task variables clustered according to instructional condition and separation format on the completion and recognition tasks. As shown in these tables, better attentional skills as measured by the Digit Symbol task (SSDSYB) were associated with better recognition and completion scores on all but one of these clustered task variables, incidental words in the close format.

Among correlations between incidental learning Digit Symbol scores and the clustered variables, a significant relationship between scores was only evident for completion of intentionally learned words from the far format, $r = .36$, $p = .00$. There was also a trend towards the association of better recognition of incidentally learned words with higher scores on the incidental Digit Symbol task, $r = .21$, $p = .05$, also from the far format.

Refer to Tables 10 & 11

Verbal IQ (VIQ). As seen in Table 10, there was a tendency for higher estimates of VIQs to be associated with better completion of incidental words from the close format, $r = .22$, $p = .04$. However as shown in Table 3, estimates of VIQ were comparable across groups, $F(2,61) = 0.78$, $p > .10$. Table 11 shows that the relationship between estimated VIQ and word recognition was not reliable, $p > .10$.

PCL-PHI and Depression symptoms & Group. Group comparisons using the One-way ANOVA followed by Duncan's contrasts (Table 3) indicated that PCS (PCL-PHI) experienced by both groups with mTHI were reportedly more numerous and severe than those reported by healthy student controls, $F(2,61) = 39.14$, $p = .00$. Of interest, are the comparisons of reported cognitive, physical/dependency and affective complaints of PCS among outpatients, students with mTHI and healthy controls. More specifically, paired independent groups t-tests revealed that both outpatients and students with mTHI complained of more cognitive symptoms on the PCL-PHI than healthy controls, $t\ (41) = 9.36$, $p = .00$; $t\ (41) = 2.76$, $p = .00$ (1-tailed), for control comparisons between outpatients and students with mTHI respectively. The experience of affective and physical/dependency symptoms on the PCL-PHI were more numerous in outpatients than either student group, $F\ (2,61) = 9.90$, $p = .00$; $F\ (2,61) = 20.57$, $p = .00$, for comparisons of affective and physical/dependency symptoms respectively. However, both groups with mTHI reported more severe affective complaints, $F\ (2,61) = 16.26$, $p = .00$ and physically disabling symptoms, $F\ (2,61) = 20.02$, $p = .00$, than healthy controls. More detailed t-test analyses showed that outpatients also complained of more severe cognitive, physical/dependency and affective symptoms than students with mTHI, $t\ (40) = 4.55$, $p = .00$, $t\ (40) = 3.45$, $p = .00$ and $t\ (40) = 2.99$, $p = .00$ (1-tailed), for cognitive, dependency and affective symptoms respectively. The overall Zung depression index, which was also reflective of the four subscale scores of affective, physiological, psychomotor and psychological symptoms of depression, was higher in the outpatient group than either the student group with mTHI or healthy controls, $F\ (2,61) = 8.58$, $p = .00$.

Postconcussive symptoms and completion. The negative impact of affective, cognitively and physically disabling symptom experiences on memory performance was mainly evidenced on the completion task. Table 10 shows that on the completion task, both symptom experience ($\text{PCL-PHI}_{experience}$) and severity ($\text{PCL-PHI}_{severity}$) were associated with poorer completion scores. Overall increases in PCS experience were significantly associated with lower completion of intentional words from the far format, r = .37, p = .00, and closely spaced incidentally learned words , r = .33, p = .00 . The negative influence of PCS severity was particularly apparent in completion of intentionally learned words from the close format, r = -.33, p = .00. There was also a tendency for more severe experiences of PCS complaints to be associated with lower intentional learning scores for completion of words from the far format, r = -.26, p = .02. More specifically, the severity with which affective, cognitive and physical dependency symptoms were experienced were all associated with reduced completion in the intentional condition.

As noted in Table 10, the reported severity of physiological manifestations of depression on the Zung (eating, sleeping, libido, anxiety) was negatively correlated with completion of all but one of the clustered task variables, incidental learning in the far format. There was also a trend for the severity of psychomotor symptoms of depression on the Zung, such as being restless to be associated with reduced completion on all clustered task variables except intentional learning in the close format. Of interest are the relationships between intentional learning task variables and depression symptoms. In the far format, an increased severity in both physiological and psychomotor aspects of depression on the Zung, as reflected in increased occurrences on a 4-point scale were associated with poorer completion of intentionally learned words, r = -.33, p = .00, and r = -.25, p = .02 for correlations with physiological and psychomotor symptoms respectively. In the close format, affective, r = .31, p = .00 and physiological symptoms, r = .25, p = .02 on the Zung Depression scale were correlated with completion of intentionally learned words.

Postconcussive symptoms and recognition. On the recognition task, the relationship between task and overall symptom experience was not significant. However, as indicated in Table 11, there was a trend for overall PCL-PHI symptom severity to be associated with less accurate recognition of incidental words from the far format, $r = -.23$, $p = .04$. More detailed analysis of the specific PCS that contributed to this relationship showed that there was a tendency for the severity of affective, $r = .25$, $p = .02$ and cognitive symptoms, $r = .22$, $p = .04$ to be associated with less accurate recognition of incidental words from the far format. Further examination of the relationship between performance on the recognition task and other subcomponents of the PCL-PHI depicted in Table 11, also revealed that less accurate recognition of intentional words from the close format was associated with more severe affective, $r = -.22$, $p = .04$, cognitive, $r = -.25$, $p = .02$, and physical/dependency symptom experiences, $r = -.24$, $p = .03$. More numerous physical/dependency experiences, such as doing things slowly and apathy were also negatively correlated with intentional learning of words from the close format, $r = -.21$, $p = .05$.

Medication use, PTA and Experimental task performance. Multicorrelational analyses were performed among participant characteristics of PTA, coma duration, medication usage and task performance separately clustered according to learning condition, lateral position and separation format. The use of medication was subdivided into three categories: no usage, use of medications for minor complaints, such as colds, infections (antibiotics) and, occasional use of medications for major complaints, such as subclinical depression and severe pain. More outpatients with mTHI (42.8 %) reported using medications for major complaints than either the student group with mTHI (9.5 %) or normal student controls (0 %). However, use of medication was not significantly correlated with either word recognition or completion, $p > .10$.

Estimates of PTA duration were clustered into 30 minute incremental intervals, ranging from (1 - 30) min to 7 hrs, although it was difficult to obtain PTA estimates for periods less than 1 hour. Posttraumatic amnesia estimates ranged from 1 min to 6 hrs and 1 min to 7 hrs, in students and outpatients with mTHI respectively. Posttraumatic amnesia duration was significantly correlated with only one aspect of memory performance, completion of intentionally learned words from the close format, $r = -.36$, $p = .00$ (1-tailed). Even though more outpatients (eight) than students (two) reported PTA experiences greater than 1 hour but less than 24 hours, overall PTA estimates were not significantly different between student and outpatient groups with mTHI, ($p > .10$). Estimates of coma duration (LOC) were not significantly correlated with recognition or completion of words, $p > .10$ and ranged from 1 - 30 min in both students and outpatients with mTHI. Estimates of mean LOC were not significantly different between outpatient and student groups with mTHI.

Discussion and General Discussion

Task Conditions most sensitive to mTHI. Overall memory performance on the experimental task appeared to be particularly difficult under two conditions for all participant groups: completion of intentionally learned words in the far format and recognition of intentionally learned words in the close. Group differences on the experimental task were also best delineated under these two conditions which support the original hypothesis of residual impairments of mTHI under strained processing conditions. Graded manifestations of impairment also confirmed expectations that performance on cognitively demanding tasks would reflect the degree of persisting effects from mTHI, with outpatients obtaining the lowest scores in both these conditions, followed by students with mTHI, who also had more difficulty on the above-described completion task relative to unimpaired student controls. These difficulties address the issue of impaired deliberate, effortful processing after mTHI which is consistent with the findings of comparable memory scores for incidental words among the three groups but significantly lower scores for intentionally learned words for persons with mTHI, particularly outpatients. Group differences, noted on the two memory tasks, were not related to VIQ or to age, which was covaried in instances where significant age effects were noted in preliminary analyses. Consequently, decrements in memory performance on these tasks reflected the functional outcome of cumulative effects of mTHI, the group of outpatients with mTHI being more impaired than the group of students with mTHI, whose performance was in turn inferior to healthy controls.

Contributions of subjective factors. There were many characteristics which could have accounted for these differences in intentional learning among the groups. Of note were the increased numbers of potentially disabling affective, physical/dependency and cognitive complaints and attentional difficulties reported by outpatients with mTHI. Students with a history of mTHI also reported significantly more numerous symptoms associated with PCS which were experienced with greater severity, particularly cognitive difficulties, than did healthy controls, but these were fewer and less severe than in outpatients. Outpatients reported a higher incidence and severity on all the postconcussive symptom indices that were shown to be significantly negatively correlated with task performance.

Completion was apparently more influenced by overall postconcussive symptom conglomerates, affective, cognitive and physical dependency symptoms, which tended to be associated with lower completion of intentionally learned words in both separation formats and lower completion of incidental words in the close format. Lower completion of intentionally learned words was also associated with longer durations of reported PTA. On the recognition task, PCS severity was associated with less accurate identification of intentionally learned words from the close format and incidentally learned words from the far.

Given the findings of poorer attentional skills in outpatients as reflected on Digit Symbol tasks, the group differences may also be partially accounted for by increased distractibility in outpatients. Performance on the Digit Symbol task is thought to reflect both distractibility and processing speed (Lezak, 1983, p. 241, 273). The length of PTA, an index of severity of mTHI was associated with lower completion of intentionally learned words from the close format (the condition in which interference was considered manifest) although PTA estimates in the two groups with mTHI did not differ significantly from each other. However, this is consistent with the notion of greater distractibility in more severely impaired individuals with mTHI. In the less impaired group with mTHI, completion and recognition of incidentally and intentionally learned words from the close format was essentially equivalent to those of normal student controls. Students with mTHI used in this study also evidenced normal attentional skills as reflected by equivalent Digit Symbol performance between groups of normal students and those with a history of mTHI.

In support of the view that the more severely impaired group with mTHI was more distractible than the other two groups, this group of outpatients evidenced significant difficulties relative to the two other groups on the seemingly less effortful task of completion of intentionally learned words in the close format compared to the far. This difficulty was also evident in the encoding of incidentally learned words in the close format where completion of incidentally learned words was significantly lower in outpatients than healthy controls. The more distractible outpatient group may not have been able to focus attention on either intentional or incidental words in the close format. As such, outpatients may have had to make an increased effort to attend to the targeted word in a pair in this distracting (close) context. This hypothesized exaggerated attentional focus on intentionally learned words in the more impaired group of outpatients with mTHI, may have in turn magnified the role of the left hemisphere. Goldberg and Costa (1981) have suggested that intentional learning promotes left hemispheric function.

The finding of significantly lower recognition scores for intentionally learned words from the close relative to the far format in all participant groups adds credence to the notion of increased interference in that condition. In this case, interference from the incidental word in a pair was thought to make it more difficult to encode and later remember either word. Freedom from distractibility, a factor measured by performance on the Digit Symbol task was also best associated with recognition of intentionally learned words from the close format. This suggests that less distractible persons recognized more intentionally learned words in the close condition than more distractible persons.

Some researchers deem a perceptual representation unit to be an essential feature in priming (Schacter, 1990). In the far format, integration of the word pair into a perceptual representation unit may have been the limiting factor which determined priming on the completion task. Faster processing speeds (Digit Symbol), which may determine how quickly a perceptual representation unit is formed, were associated with significantly higher completion scores of intentionally learned words, particularly from the far format. Faster processing speed/better attention was also associated with better completion of incidental words from the far format. Additionally, completion of intentionally learned words from the far format was significantly below that of intentional words from the close in all participant groups. Hence, slowed processing after mTHI with its concomitant difficulties in integration may have compounded this difficulty, and in this experiment, outpatients (the more impaired group with mTHI) experienced the greatest difficulty in completing word stems of intentionally learned words from the widely spaced format, both in terms of accuracy and response speeds. Students with mTHI also had more difficulty completing intentionally learned words from the far format than healthy control students. These difficulties were also observed behaviorally as participants with mTHI performed the experimental task.

Behaviorally, outpatients with mTHI tended to make more exaggerated lateral neck movements when locating widely spaced intentionally learned words than unimpaired participants. This behavior was consistent with the view that persons with mTHI have difficulty rapidly integrating words in widely spaced displays into holistic units. However, no systematic measurement of this behavior was made in the present study.

Speculations on task and subjective group interactive effects. It is proposed that the strategies used to remember words in perceptually demanding conditions such as when briefly presented word pairs were seen in distracting (close) or integratively difficult (far) displays, may have reflected hemispheric biases based on task demands (Goldberg & Costa, 1981; Heilman et al., 1995). In a visual context, such as the far format which required rapid scanning and integration of specific items into holistic units as well as distribution of attention within those units, the prevailing strategy may have been suggestive of right hemispheric processing. This hypothesis is consistent with the findings by Heilman et al. (1995) that indicated that the right hemisphere directs attention outward while the left hemisphere directs attention inward.

The unfamiliar context of the far format may potentiate processing strategies which emphasize interregional integration. The right hemisphere, with its characteristic neuronal organization in which associative cortex is more extensively represented than in the left hemisphere, is better able to execute such integrative strategies (Gur et al., 1980). However, in this study a left field advantage was not reliably shown on either recognition or completion in any of the groups. Nevertheless, efficient processing of the intentionally learned word may have been dependent on effective location of the word to be learned which may have been initially facilitated by right hemispheric integrative processing, as indicated by the trend for better recognition of left positioned words than right in the far format, demonstrated in the less impaired group with mTHI. Therefore, if Goldberg and Costa's hemispheric hypothesis is an appropriate description of memory processing, proficient processing of words in the far format must also be dependent upon other mechanisms. The absence of a left visual field advantage in the relatively unfamiliar word pair arrangement does not discount Goldberg and Costa's (1981) hypotheses of hemispheric differences. These theorists proposed modulation of the left field advantage when performing novel verbal tasks due to a shift in predominating hemispheric processing from right to left in the later stages of task performance.

In the close format, a familiar yet distracting context, left hemispheric type strategies that emphasized rapid decoding of specific details from well-routinized descriptive lexical systems may have predominated. As expected, in the more familiar close format, words to the right were better remembered on both the completion and recognition tasks than those to the left, which was suggestive of left hemispheric proclivity in decoding and was particularly marked in the less impaired group with mTHI.

It is proposed here, that group differences may be explained using Goldberg and Costa's (1981) hypothesis. Using this theoretical framework, it was hypothesized that healthy controls, students with mTHI and outpatients with mTHI reflect a continuum of memory functioning. In the case of unimpaired student controls, spontaneous rapid integration of information operated alongside lateralized processing to efficiently encode words and may counteract initial lateralized processing biases. Thus, in healthy controls, rapid integration of information may have masked lateralized effects and memory performance in healthy controls was essentially unaffected by lateral position.

Students with mTHI who had not sought rehabilitation (the less impaired group with mTHI) may represent a subset of individuals whose integrative abilities as suggested by reduced completion of intentionally learned words encoded in the far format are somewhat less effective than normal controls. However, overall memory functions in this group may not be impaired because they automatically utilize efficient lateralized strategies which promote learning and memory. In the student group with mTHI, automatic use of right hemispheric strategies may have facilitated integration of the word pair in the far format which may have in turn promoted target location. This group of students with mTHI evidenced fewer PCS than the outpatient group with mTHI and also exhibited normal attentional skills inferred from performance on Digit Symbol tasks which may have allowed this group to adequately focus on task demands without unusual distraction from the incidental word. However, in students with mTHI, completion of intentionally learned words from the far format, which may have required proficiency in integrative processing, was less accurate than healthy controls although overall, memory task performance was comparable to normal controls. Therefore, despite relatively good functional outcome as measured by traditional test measures and enrollment in college, the negative impact of mTHI was evident under conditions which strained information processing capacity, particularly that which required rapid integration of information.

Slowed processing after mTHI may make it difficult to integrate rapidly presented information. Given these limitations, which were mainly apparent in outpatients in this study, persons with mTHI may have experienced significant difficulty in encoding the intentional word in the far format. Outpatients with mTHI may represent a group whose automatic integrative abilities are sufficiently impaired and slowed by PCS that they need to resort to deliberate effortful strategies in difficult encoding situations to encode material. Such deliberate strategies are thought to be the forte of the left hemisphere (Goldberg & Costa, 1981). Consistent with the idea that the more impaired group with mTHI may have used predominantly left hemispheric-type strategies to encode words studied in both formats, the outpatient group correctly recognized words that were encoded in the right visual field as well as the other two groups. However, recognition and completion of words presented to the left of a pair during study were significantly lower in the outpatient group than in the other two groups. In the outpatient group with a history of mTHI, a significant lateralized effect was only evidenced on the recognition task, where in contradiction to expectations, an unusual right field advantage was demonstrated for words from the far format. This possible inflexibility in the tacit use of lateralized strategies in the more impaired outpatient group with mTHI may have partially accounted for less accurate memory.

Clearly, much of the above-described explanation concerning differential hemispheric involvement in memory processing is speculative since the experimental task did not measure either visual fields or hemispheric processing. Despite these limitations, lateralized differences were noted on the recognition and completion tasks that appeared to be based upon the separation format in which word pairs were presented. It is known that in some cases, mTHI reduces attention and information processing capacity by slowing and decreasing integration capacity even in apparently asymptomatic individuals (Ewing et al., 1980; Gronwall, 1989). The results from Experiment 2 demonstrate that more severely impaired individuals with mTHI are indeed slower and report more disabling symptoms than unimpaired controls. However, despite slower responses, responses to nontarget words were statistically equivalent among the three groups, as reflected in their baseline scores. Hence, in the more impaired group, lower scores for intentionally learned words did not merely reflect slower response latencies but rather appeared to be a result of difficulties in encoding-retrieval of presented targets.

The results also indicated that response latencies in recognizing and completing intentionally learned words were faster than responses to incidentally perceived words. These response speed differences in responding to intentionally and incidentally learned words were most reliably demonstrated in healthy students with no history of mTHI and less reliable in individuals with a history of mTHI. Response speeds may have reflected hesitancy/certainty in making responses. In the healthy control group, more rapid (shorter latency) completion and recognition of intentionally learned words than incidental ones may have reflected tacit and explicit certainty in responding to intentional targets. In the two groups with mTHI, the relative equivalence in response speeds to intentionally and incidentally learned words may have reflected a greater degree of uncertainty in responding and the fact that learning was difficult in both intentional and incidental encoding conditions. This uncertainty may have been evident at both an automatic level determining completion responses and conscious level determining recognition.

Outpatients also complained of more numerous and severe PCS than either students with mTHI or healthy student controls. The experience of mTHI also introduces a variety of subjective components which Kay et al. (1992) refer to as the subjective cognitive dysfunction loop. In this model, despite recession of neurological complaints, impaired cognitive function is maintained by psychological factors, like depression, which may influence functional outcome. However, emotional complaints may also have a neuroanatomical substrate. Elson and Ward (1994) suggest that shearing strain between medial temporal and inferior frontal cortices and the anterior and middle cranial fossae may contribute to some of the emotional and memory difficulties observed after mTHI. As such, poor performance by the outpatient group with mTHI may have reflected the cumulative effects of neurological, psychological and physical complaints which determine functional outcome.

Comparisons with other studies/reports. The results of poorer performance on the completion task after mTHI contrast with the findings by Mutter et al. (1990), in which completion was comparable in participants with mTHI and unimpaired participants. In the study by Mutter and coworkers, participants had to complete the stem of a target word presented alongside its paired word stimulus (word cued stem) from the study phase, for example, "TELEVISION-ORG" for TELEVISION-ORGANISATION. In essence, more congruent information from the study phase was provided at testing to prime memory. Therefore, from a transfer-appropriate perspective, the participants with mTHI in the Mutter study had an advantage over similar participants in the current study. Schacter (1990) suggested that interactions between data driven and conceptually driven processes may also operate to facilitate word cued stem completion.

One question which arises in interpreting the findings of the experimental task is whether participants truly used implicit as compared to explicit strategies to perform the completion task. Implicit strategies are defined by a relatively automatic response to an apparently meaningless stimulus. Explicit strategies require deliberate retrieval of material from a prior episode. This concern cannot be wholly dismissed, but the use of explicit strategies was discouraged on the completion task by presenting stems for 0.5 s, as well as instructions to complete the stem with the first word that came to mind. Consistently better recognition as compared to completion of intentionally learned words was also suggestive of different strategy use on the two tasks.

Memory for incidentally learned words in groups with mTHI was not significantly different from healthy controls although marked by slower responses to incidental targets in the more impaired outpatient group with mTHI as compared to the two other groups. This result does not support the anecdotal findings of incidental learning difficulties noted in clinical situations (Kay & Lezak, 1990) or those of Experiment 1. In contrast with the results in Experiment 1 as well as anecdotal reports, incidental learning was not significantly impaired by mTHI in Experiment 2. Although the more impaired outpatient group with mTHI in the current study had lower incidental learning scores on both tasks than either student group, the age-corrected group differences, with the exception of completion of incidental words from the close format, were not significant. It may be that the size of the student sample used in Experiment 1 may have less adequately addressed the issues of sample heterogeneity than Experiment 2. This may have limited generalized interpretation of results of Experiment 1. However, both samples are considered small (Gentilini et al., 1989). Notwithstanding this, there was a tendency for lower recognition scores for incidentally presented words from the far format to be associated with reports of more severe PCS, particularly of cognitive and affective complaints. This finding, albeit somewhat spurious, ($p > .01$ & $< .05$), was similar to that observed in Experiment 1 where the student group with mTHI evidenced lower recognition of incidental words that were far apart. In conjunction with the significant finding of reduced completion of incidental words from the close format in the more impaired outpatient group with mTHI in Experiment 2, this relationship between completion of incidental words from the far format and increases in PCS severity is suggestive of difficulties in passive encoding in perceptually demanding contexts. These difficulties may be related to generalized apathy, increased distractibility and an impaired integrative capacity which are all characteristic of chronic postconcussive difficulties.

Another possible reason for the discrepancy between anecdotal reports of impaired incidental learning (Kay & Lezak, 1990) and the findings of relatively normal incidental learning after mTHI in this study was the difference between the postinjury period within which the samples in the present study, and that in which clinical outpatients, described anecdotally, were tested. The outpatient and student groups with mTHI used in this study were tested past the period of 1-3 months post-mTHI when recovery is considered optimal, a period within which many clinical patients are seen initially. As such, it may be that anecdotal clinical observations are more representative of acute postinjury functioning, still in the recuperative stages. It is also possible that anecdotal reports of impaired incidental learning in clinical settings may have been confounded by slowed performance in older individuals. One other possibility that is forwarded to account for the discrepancy is the augmentation of pronouncing responses by instructions to learn a word as described below. Such augmentation may have resulted in reduced incidental learning in all persons, thereby obscuring potential incidental learning difficulties after mTHI.

The simple effect of instructions to learn words may have been amplified by the requisite to pronounce intentionally learned words. Both instructions to learn material and saying words aloud produce similar enhancing effects on memory performance. Mechanic and Mechanic (1967) found that pronouncing incidentally presented trigrams produced an effect similar to instructions to learn the material on a recall task. Since two memory tasks were used, it was difficult to determine the relative contributions of these two factors on the two memory tasks. To clarify the effect of these two factors, future studies are recommended in which only instructions to learn the underlined word are given. Similarly, the effect of pronouncing words on explicit and implicit memory tasks could be examined.

Applications and limitations of the findings. The experimental task was somewhat useful in discriminating individuals with more severe postconcussive complaints (outpatients with mTHI) from those with fewer, less severe symptoms. Consistent decrements in experimental memory task performance were observed based on mTHI status presumably linked to PCS experience. Participants without mTHI performed best on these tasks and outpatients from the clinic performed most poorly. For the most part, memory performance on the experimental task was not sensitive enough to discriminate persons on the less severe end of the mTHI scale from persons who had never had mTHI. Students with mTHI were found to represent a subset of individuals who were apparently minimally affected by the limitations of reported PCS. In many instances, performance on the experimental task was similar for students with a history of mTHI and healthy student controls.

In hindsight, this finding is not surprising since students with mTHI histories were selected because they had not sought postconcussive rehabilitative services.

However, some features of the experimental task, such as, intentional learning of words in widely spaced formats (where optimal speed of processing may have been paramount), proved to be good discriminants of mTHI history and accurately classified over 60 percent of participants in the current study into their respective groups. This seemed to suggest that under difficult conditions, such as those which require rapid integration of information, limitations imposed by a history of mTHI may predispose individuals to perform poorly relative to normals. Interestingly, encoding difficulties after mTHI were mainly demonstrated in the intentional learning condition. Memory for intentionally learned words was consistently less accurate in outpatients with mTHI than in healthy controls, and in many conditions of the experimental task, outpatients performed significantly worst than the student group with a history of mTHI. Although differences between groups with mTHI were observed on all of the standardized and many of the experimental task measures used in the study, it would have been useful to have obtained corroborating neurological evidence of the functional group differences described since problems were noted in estimating reported PTA. In some instances, the best estimates (even from medical records) of this PTA period, from injury to the return of continuous memory, were descriptions such as, a few minutes, less than 5 minutes, more than 5 minutes but less than 1 hour. These difficulties in accurately measuring PTA have also been noted in other studies (Gronwall & Wrightson, 1980).

Neuroanatomical imaging data were not available for all participants. Therefore, the inferential comparisons made lacked the sensitivity to determine whether or not the two groups of participants with mTHI came from a homogeneous sample of individuals based upon brain injury at the time of the accident. Levin et al. (1992) noted significant neuroanatomical abnormalities in many individuals after mTHI. The inclusion criteria such as LOC and PTA were selected to minimize heterogeneity within groups of persons with histories of mTHI.

Functional neuroimaging studies may also have been useful in trying to refine possible neurophysiological correlates of task performance. Future studies could investigate performance on the experimental task conjointly with neurophysiological correlates such as functional MRI and/or PET techniques. In this way, one could better determine whether lateralized processing is a determining factor in memory for word pairs in the separation format contexts described in this study.

Further investigation of lateralized neck movements observed behaviorally is also suggested to corroborate the inference of possible difficulties in locating intentionally learned words in the far format in the more impaired group with mTHI. This may provide supporting evidence for the integrative difficulties noted after mTHI. As such, objective measurement of these movements need to be documented to confirm anecdotal reports of difficulties. Tests of distributed attention, such as the Distributed Attention Test used by Gentilini et al. (1989) may also have been useful in determining difficulties in distributed attention.

Another interesting research question which arises from the study's findings is that of memory functions in severely impaired individuals with mTHI when performing other tasks which require deliberate, effortful processing but which have a major right hemispheric input. Such tasks may include the spatial versions of the current task in which spatial characteristics are differentially encoded and retrieved. Is performance on such tasks limited by potentially inefficient lateralized strategies?

This study was limited to some extent by constraints in recruitment of participants with mTHI. As such, large numbers of individuals with mTHI who met criteria were difficult to amass. Small numbers of participants (Gentilini et al., 1989) limited the power of the study by making it more difficult to counteract the individual differences which were substantial. Thus, the findings should be interpreted with caution because of the relatively small sample used in Experiments 1 and 2. However, analyses of homogeneity of variance showed no differences among samples. The within-subjects design reduced this complication somewhat by having both encoding conditions and memory test comparisons performed by the same individuals.

Another limitation was the examiner/investigator bias, since the investigator was not blind to the mTHI status of participants. Interpretations of the findings were thus influenced by this prior knowledge. Such biased interpretations were reduced by using standardized test measures to compare group characteristics.

Conclusions and theoretical implications. The findings describe group tendencies and can only be interpreted in that context. Results of neuroimaging tests for participants with mTHI, where available, were "normal" and in no individual instance could the definitive diagnosis of mild traumatic brain injury (which requires neuropathological confirmation) be given, since performance on behavioral tasks reflect the cumulative effect of physical, neurological and subjective factors. Individual differences in memory task performance did occur, as seen by variability in performance within groups. However, it is interesting to note that when symptoms commonly associated with head injury were used in combination with memory factors derived from performance on the experimental task to classify the groups by mTHI history, not one of the outpatients with a history of mTHI who reported the most severe complaints, nor unimpaired individuals with the least complaints, were misclassified. Using these combined variables, classification of the less impaired group was increased to 71.4% as compared to 57.1% and 42.9% if only standardized or experimental task measures respectively, were used.

The results support the characterization of mTHI as an injury in which initial indices of injury severity only partially reflect functional outcome which determines performance on cognitive tasks, such as the experimental memory task. Individuals with mTHI represent a heterogeneous group who complain of more numerous and severe PCS than normals, and persons who seek rehabilitative services appear to be more impaired than those who do not. In this more impaired group, information processing is slowed as evidenced by lower scores on the Digit Symbol and longer response times to target words. This difficulty may be further compounded by the impact of PCS, such as depression, distractibility and possibly reduced inter- and intra-hemispheric integration. The results show that impairments in memory emerge in encoding (learning) situations which appear to be difficult or stressful for all persons. In this study, recognition of intentionally learned words from the close format and completion from the far were found to be significantly more difficult than their counterpart conditions. Explicit memory performance is influenced by conceptual processing which is diminished by interference. Significantly lower recognition scores for intentionally learned words from the close than far format are consistent with this idea. The more distractible group of outpatients with mTHI recognized significantly fewer intentionally learned words in the close format than the other two groups. Attention was comparable between groups of students with mTHI and unimpaired healthy students and in the group of students with mTHI no unusual deficits on the recognition task were noted.

On the other hand, completion was thought to be influenced by speed of processing to form a perceptual representation unit and rapidity in intra- and inter-hemispheric processing. Reduced completion in the far as compared to the close format is consistent with this hypothesis. Therefore, the group of outpatients with mTHI who were slower than either the group of normals or students with mTHI, completed the fewest number of intentionally learned words from the far format. Students with mTHI also performed poorly on this task despite relatively normal processing speeds as measured on the Digit Symbol task and in their responses to targets. Nonetheless, these students complained of more numerous PCS, such as apathy and difficulty planning and organizing, which may have contributed to difficulties in processing word pairs from the far format. (Here, it would have been useful to know whether the group of students with mTHI would have difficulties on tests of distributed attention.) Therefore, subtle cognitive difficulties associated with mTHI may produce residual deficits in stressful situations, such as locating a word to be learned in the far format, even in persons with good functional outcome.

The findings support the idea that persistent effects of mTHI are more apparent on an implicit task, completion, in which words are encoded in an integratively difficult context, the far format than an explicit task. This is consistent with findings by Gentilini et al. (1989) in which a test of distributed attention, requiring simultaneous attention across both visual fields was most sensitive to the effects of mTHI. Differences in task demands between recognition and completion may account for the discrepancy between recognition and completion tasks.

To summarize, this study provided useful information concerning residual deficits after mTHI. First, residual memory deficits were present 1 to 5 years postinjury in the sample of individuals although these deficits were not widespread across the two groups. Individuals with a history of mTHI who had not sought clinical services for PCS outperformed those recruited at outpatient clinics, possibly because the outpatient group presented with increased numbers of PCS relative to a student group with mTHI and normals. Residual memory difficulties in students with a history of mTHI only became apparent on the most difficult aspects of the experimental task. This included completion of intentionally learned words which involved rapid scanning in order to locate the word in an unfamiliar format, where words in a pair were widely separated. This finding is supportive of the view that a comprehensive assessment of memory functions after mTHI should include learning under incidental and intentional conditions as measured by both implicit and explicit memory tasks. In light of reports which implicate mTHI as a predisposing factor to Alzheimer's Disease (Rasmusson, Brandt, Martin & Folstein, 1995) and those that describe the adverse effects of cumulative incidents of mTHI (Gronwall & Wrightson, 1975), it may be that a single incident of mTHI in which brain injury has occurred may permanently compromise the integrity of the brain, resulting in impaired cognitive functions, such as memory, under cognitively-demanding situations requiring rapid, distributed and divided attention, even in instances with good functional outcome. Interestingly, like the more impaired group of outpatients with mTHI, persons with Alzheimer's Disease also perform poorly on both explicit and implicit memory tasks relative to normals (Keane, Gabrieli, Fennema, Growdon & Corkin, 1991). Therefore, it is possible that diffuse axonal injury after mTHI, when it occurs, predisposes neuronal networks to more generalized degenerative processes, such as that seen in Alzheimer's Disease and abnormal functioning under stressful conditions. Consequently, in the instances of mTHI where brain injury has occurred, residual deficits of mTHI may persist, even where good functional outcome is indicated.

The findings of the study are also consistent with an integrative view of memory processing which operates within the specialized milieu of brain systems. In this view, memory is seen as the net output of information processing at various stages which are dependent upon task demands of encoding and retrieval. The specific neuronal network systems responsible for performance on the two memory tasks may not be identical but they appear to share some common features. Implicit and explicit forms of memory or memory tasks were similarly affected by instructions to learn words although the recognition task was more affected by intentional learning than completion possibly because of the congruence between conceptual demands of intentional learning and performance on the recognition task. The two tasks appeared to be differentially affected by perceptual features of word pair arrays, although this appeared to be restricted to intentional learning aspects of the two tasks.

Table 1

Means and standard deviations of demographic & standardized test characteristics as a function of head injury status in students (Experiment 1)[1].

	No mTHI (n = 21)	mTHI (n = 13)
Education (yrs)	13.86 (2.06)	13.92 (1.04)
$VIQ_{NART\text{-}USA}$	116.23 (7.20)	14.64 (6.03)
Age	27.52 (8.21)	21.85 (4.49) *
Digit Symbol	11.52 (2.27)	12.08 (2.56)
INCDIG A	6.58 (1.46)	6.00 (2.09)
PCL-$PHI_{experience}$	0.30 (0.19)	0.26 (0.18)
PCL-$PHI_{severity}$	2.59 (0.94)	2.94 (0.93)
PCL-$PHI_{affective}$	0.35 (0.27)	0.28 (0.20)
PCL-$PHI_{cognitive}$	0.36 (0.30)	0.38 (0.26)
PCL-$PHI_{physical}$	0.19 (0.20)	0.20 (0.17)
SDZUNG(standard score)	40.44 (8.63)	44.23 (12.81)
$ZUNG_{(psychomotor)}$	0.38 (0.14)	0.49 (0.17) *

Note 1. PCL-$PHI_{experience}$ = overall symptom experience; PCL-$PHI_{severity}$ = overall symptom severity; PCL-$PHI_{affective}$ = affective symptoms; PCL-$PHI^{cognitive}$ = cognitive symptoms; PCL-$PHI_{physical}$ = physical dependency symptoms; INCDIG A = incidental Digit Symbol; mTHI = group with mild traumatic head injury.
*p < .05

Table 2

Intercorrelations between performance on standardized tests and experimental task (Experiment 1)[2] (Coefficient / n=34) / 1-tailed Significance)

	Recognition			
	Incidental		Intentional	
Standard/Learning Condition:	Far	Close	Far	Close
$PCL\text{-}PHI_{experience}$	.2803(*p=.05)	.1847	1018	.1275
$PCL\text{-}PHI_{severity}$	.1554	.0911	.1076	1168
SDZUNG	-.1007	.1216	.0428	.0745
Digit Symbol	-.0578	.0171	.0295	.1497
INCDIG A	.1719	.0926	.1325	.1751
VIQ_{NART}	-.0942	.0748	.1449	.3217(*p=.03)
	Word stem completion			
$PCL\text{-}PHI_{experience}$	-.0336	.0698	.0540	.1964
$PCL\text{-}PHI_{severity}$	0114	.1521	.0801	.2216
SDZUNG	-.0894	.4221(*p=.01)	-.0454	.1423
SSDSYB	.1065	-.1276	.1770	.4544(*p =.00)
INCDIG A	-.0667	3447(*,p=.02)	.2213	.3917(*,p=.01)
VIQ_{NART}	.0284	.0360	.1554	.1087

Note. $PCL\text{-}PHI_{experience}$ = overall symptom experience; $PCL\text{-}PHI_{severity}$ = overall symptom severity; $PCL\text{-}PHI_{affective}$ = affective symptoms; $PCL\text{-}PHI_{cognitive}$ = cognitive symptoms; $PCL\text{-}PHI_{physical}$ = physical dependency symptoms; Digit Symbol = standard score; INCDIG A = incidental Digit Symbol; SDZUNG = Zung depression

Table 3

Means and standard deviations for demographic and standardized test characteristics in the three groups (Experiment 2)[3].

	No $mTHI_{college}$ (n = 22)	$mTHI_{college}$ (n = 21)	$mTHI_{Diagnosed}$ (n = 21)
Education(yrs)	15.04 (1.99)	15.05 (1.53)	14.95(3.01)
$VIQ_{NART-USA}$	112.95 (10.58)	109.67 (8.30)	113.89 (10.68)
Age	21.45 (6.63)	20.90 (5.48)	34.43 (7.35)*
Digit Symbol	12.77 (2.52)	11.33 (2.20)	9.20 (2.52)*
INCDIG A	7.77 (1.45)	6.86 (2.26)	4.80 (2.35)*
$PCL\text{-}PHI_{experience}$	0.27 (0.15)	0.39 (0.15)*	0.68 (0.17)(*)
$PCL\text{-}PHI_{severity}$	2.34 (0.91)	3.20 (1.17)*	4.10 (1.09)(*)
$PCL\text{-}PHI_{affective}$	0.35 (0.20)	0.45 (0.24)	0.67 (0.27)*
$PCL\text{-}PHI_{cognitive}$	0.33 (0.21)	0.51 (0.23)*	0.85 (0.15)(*)
$PCL\text{-}PHI_{physical}$	0.21 (0.21)	0.32 (0.18)	0.62 (0.25)*
Zung	46.48 (9.01)	47.01 (8.02)	57.49 (11.87)*

Note. $PCL\text{-}PHI_{affective/cognitive/physical}$ = type of PCS experience reported on the PCL-PHI; $PCL\text{-}PHI_{experience}$ = overall symptom experience; $PCL\text{-}PHI_{severity}$ = overall symptom severity; INCDIG A = incidental learning Digit Symbol; mTHI = group with mild traumatic head injury.
*/(*) $p < .05$
* = group differs from groups without *
(*) = group differs from groups with * & without *

Table 4

Comparison of injury-related demographic characteristics for participants with mTHI (Experiment 2)[4]

	$mTHI_{College}$ (n = 21)	$mTHI_{Clinic}$ (n = 21)
Mean Years Post Injury	2.57 (SD: 1.63)	2.67 (SD: 1.28)
Mean Coma Duration[a]	6.90 (SD: 9.54)	8.64 (SD: 11.08)
PTA > 1 hr[b]	2 (9.5%)	8 (38.1%)
Motor Vehicle (MVA)[b]	10 (48%)	8 (38%)
MVA Pedestrian[b]	1 (5%)	5 (24%)
Assault[b]	1 (5%)	1 (5%)
Falling Object[b]	1 (5%)	5 (24%)
Fall[b]	8 (38%)	1 (5%)
Other[b]	-	1 (5%)

Note. mTHI = group with mild traumatic head injury;
a = approximate duration for loss of consciousness (min);
b = number (percent) of persons in group with mTHI;
PTA = estimated period of posttraumatic amnesia

Table 5

Classification of groups based on Discriminant Analysis using variables clustered according to separation format and instructions for the two memory tasks (Experiment 2)

Predicted Group Membership (%) based on completion of intentional targets in the far and close and recognition in the close intentional & far incidental conditions

Actual Group/Predicted Group	no $mTHI_{college}$ (n=22)	$mTHI_{college}$ (n=21)	$mTHI_{clinic}$ (n=21)
No $mTHI_{college}$	77.3	13.6	9.1
$mTHI_{college}$	33.3	42.9	23.8
$mTHI_{clinic}$	9.5	23.8	66.7

Five best task predictors of Group membership[5]

	Wilks' Lambda	Significance
1 Completion far intentional	.77700	.0002
2 Recognition close intentional	.69081	.0004
3 Recognition far incidental	.66192	.0005
4 Completion close intentional	.63209	.0006
5 Completion far incidental	.60678	.0011

Note. Percent cases correctly classified = 62.5 %
mTHI = group with mild traumatic head injury

Table 6

Mean reaction times (sec) and standard deviations for word recognition and completion scores among Groups[6] (Experiment 2)

	No $mTHI_{college}$ (n = 22)	$mTHI_{college}$ (n = 21)	$mTHI_{clinic}$ (n = 21)
Incidental completion	4.54 (1.32)	4.67 (1.21)	5.66 (2.66)#
Intentional completion	4.02 (1.49)	4.38 (1.25)	5.95 (2.41)+
Incidental recognition	1.44 (.48)	1.48 (.46)	1.79 (.87)
Intentional recognition	1.33 (.50)	1.41 (.50)	1.89 (.86)*

Note. Group differences:

* F (2,61) = 4.80, p = .01 (ONE-WAY & Duncan Procedure)
# F (2,60) = 3.98, p = .02 (ANCOVA, age as covariate)
+ F (2,60) = 4.81, p = .01 (ANCOVA, age as covariate)

mTHI = group with mild traumatic head injury

Table 7

Classification of groups based on Discriminant Analysis of standardized test measures: PCL-PHI subscale, Zung subscale, standard and incidental Digit Symbol scores (Experiment 2)

Actual Group/Predicted Group	no $mTHI_{college}$ (n=22)	$mTHI_{college}$ (n=21)	$mTHI_{clinic}$ (n=21)
No $mTHI_{college}$	81.8	18.2	0
$mTHI_{college}$	23.8	57.1	19.0
$mTHI_{clinic}$	5	5	90

Six best standardized test predictors of Group membership[7]

	Wilks' Lambda	Significance
1 PCL-PHI Cognitive complaints	.46221	.0000
2 Incidental Digit Symbol	.38072	.0000
3 PCL-PHI Affective severity	.34454	.0000
4 Zung Psychological complaint	.31128	.0000
5 Zung Affective complaint	.29842	.0000
6 PCL-PHI Dependency experience	.28744	.0000

Note. Percent cases accurately classified: 76.19 % accuracy; mTHI = group with mild traumatic head injury

Table 8

Discriminant classification of groups based on a combination of standardized test and experimental variables (clustered according to separation format and instructions within the two memory tasks; PCL-PHI subscale scores, Zung subscale scores, standard and incidental Digit Symbol scores) (Experiment 2)

Actual Group/Predicted Group	no $mTHI_{college}$ (n =22)	$mTHI_{college}$ (n=21)	$mTHI_{clinic}$ (n=21)
No $mTHI_{college}$	72.7	27.3	0
$mTHI_{college}$	14.3	71.4	14.3
$mTHI_{clinic}$	0	15	85

Summary Table: Eight best standardized test predictors of Group membership[8]

	Wilks' Lambda	Significance
1 PCL-PHI Cognitive complaint	.46221	.0000
2 Incidental Digit Symbol	.38072	.0000
3 Completion close intentional	.34209	.0000
4 Completion far intentional	.31918	.0000
5 Recognition far incidental	.29794	.0000
6 PCL-PHI affective severity	.28134	.0000
7 Zung Psychological complaint	.25877	.0000
8 Recognition close intentional	.23590	.0000

Note. Percent cases correctly classified = 76.19%; mTHI = group with mild traumatic head injury; PCL-PHI = Personal checklist for the person with head injury

Table 9

Discriminant classification of groups based on experimental task variables clustered according to separation format and instructions within the two memory tasks, PCL-PHI/Zung subscale measures, Digit Symbol scores, & Age (Experiment 2)

Actual Group/Predicted Group	no $mTHI_{college}$ (n=22)	$mTHI_{college}$ (n=21)	$mTHI_{clinic}$ (n=21)
No $mTHI_{college}$	81.8	18.2	0
$mTHI_{college}$	9.5	90.5	0
$mTHI_{clinic}$	0	0	100

12 best predictors of Group[9] based on experimental task, standardized test & Age

	Wilks' Lambda	Significance
1 PCL-PHI cognitive complaint	.46221	.0000
2 AGE	.29952	.0000
3 PCL-PHI affective severity	.24410	.0000
4 Completion far intentional	.21498	.0000
5 Recognition close intentional	.19586	.0000
6 Zung affective complaint	.18016	.0000
7 Zung psychomotor complaint	.16959	.0000
8 Zung psychological complaint	.15676	.0000
9 PCL-PHI affective complaint	.14231	.0000
10 Completion close intentional	.13350	.0000
11 Recognition close incidental	.12747	.0000
12 Completion far incidental	.12113	.0000

Note. Percent cases correctly classified: 90.63 % accuracy
mTHI = group with mild traumatic head injury; PCL-PHI = Personal checklist for person with head injury

Table 10

Intercorrelations between performance on standardized tests and clustered variables on the completion task (Experiment 2)[10] (1-tailed)

	Far		Close	
Standard/Experimental	Incidental	Intentional	Incidental	Intentional
Group	-.1037	-.4707**	-.1721	-.3094**
Digit Symbol	.2671*	.3985**	.1830	.3468**
INCDIG A	.1654	.3569**	.0760	.1738
VIQ_{NART}	.1887	.1677	.2237*	.1933
$PCL\text{-}PHI_{experience}$[a]	-.0473	-.3735**	-.3342**	-.1856
$PCL\text{-}PHI_{severity}$[b]	-.0753	-.2601*	-.0961	-.3284**
$PCL\text{-}PHI_{affective\ experience}$	-.0674	-.3040**	-.3553**	-.1682
$PCL\text{-}PHI_{affective\ severity}$	-.1334	-.2966**	-.1741	-.3941**
$PCL\text{-}PHI_{cognitive\ experience}$	.0139	-.3067**	-.2602*	-.1505
$PCL\text{-}PHI_{cognitive\ severity}$	-.1150	-.2590*	-.2287*	-.3733**
$PCL\text{-}PHI_{dependency\ experience}$	-.1235	-.2918**	-.2648*	-.2033*
$PCL\text{-}PHI_{dependency\ severity}$	-.1934	-.3548**	-.2234*	-.2995**
SDZUNG	-.1048	-.1930	-.1731	-.2450*
$ZUNG_{affective}$	-.0980	-.1610	-.1392	-.3139**
$ZUNG_{physiological}$	-.1613	-.3346**	-.2643**	-.2548*
$ZUNG_{psychomotor}$	-.2225*	-.2497*	-.1994*	-.1641
$ZUNG_{psychological}$	.0029	-.1125	-.0695	-.1285

Note. PCL-PHI = Personal checklist for person with head injury; a = overall symptom experience; b = overall symptom severity; INCDIG A = incidental learning Digit Symbol; SDZUNG = standard score Zung; *$p < .05$; **$p < .01$

Table 11

Intercorrelations between performance on standardized test and clustered variables on the recognition task (Experiment 2)[11] (1-tailed)

	Far		Close	
Standard/Experimental	Incidental	Intentional	Incidental	Intentional
Group	-.1853	-.2034*	-.1280	-.3370**
Digit Symbol	.2992**	.2577*	.1107	.4055**
INCDIG A	.2140*	.1842	.1925	.1759
VIQ_{NART}	.0446	-.0409	.0343	-.0553
PCL-$PHI_{experience}$	-.0163	-.1389	-.0022	-.1431
PCL-$PHI_{severity}$	-.2262*	-.0835	-.0484	-.1565
PCL-$PHI_{affective\ experience}$	.1369	-.0472	.1279	-.0500
PCL-$PHI_{affective\ severity}$	-.2485*	-.1565	-.1661	-.2207*
PCL-$PHI_{cognitive\ experience}$	-.0423	-.1179	.0031	-.1702
PCL-$PHI_{cognitive\ severity}$	-.2211*	-.1918	-.0456	-.2525*
PCL-$PHI_{dependency\ experience}$	-.0595	-.1565	-.0893	-.2123*
PCL-$PHI_{dependency\ severity}$	-.1868	-.1607	-.1956	-.2370*
SDZUNG	-.0362	.0236	-.0456	-.0736
$ZUNG_{affective}$	-.1234	-.1541	-.0647	-.0721
$ZUNG_{physiological}$	.0307	.0534	-.0131	-.0421
$ZUNG_{psychomotor}$	-.1240	.0434	-.0206	-.0170
$ZUNG_{psychological}$	-.0422	-.0714	-.1340	-.1000

Note. PCL-PHI = Personal checklist for person with head injury; a = overall symptom experience; b = overall symptom severity; INCDIG A = incidental learning Digit Symbol; SDZUNG = standard score Zung; *$p < .05$; **$p < .01$

Figure 1. Mean percent words correct and baseline values as a function of task and learning instructions in the two groups of students (Experiment 1)

mTHI = mild traumatic head injury.

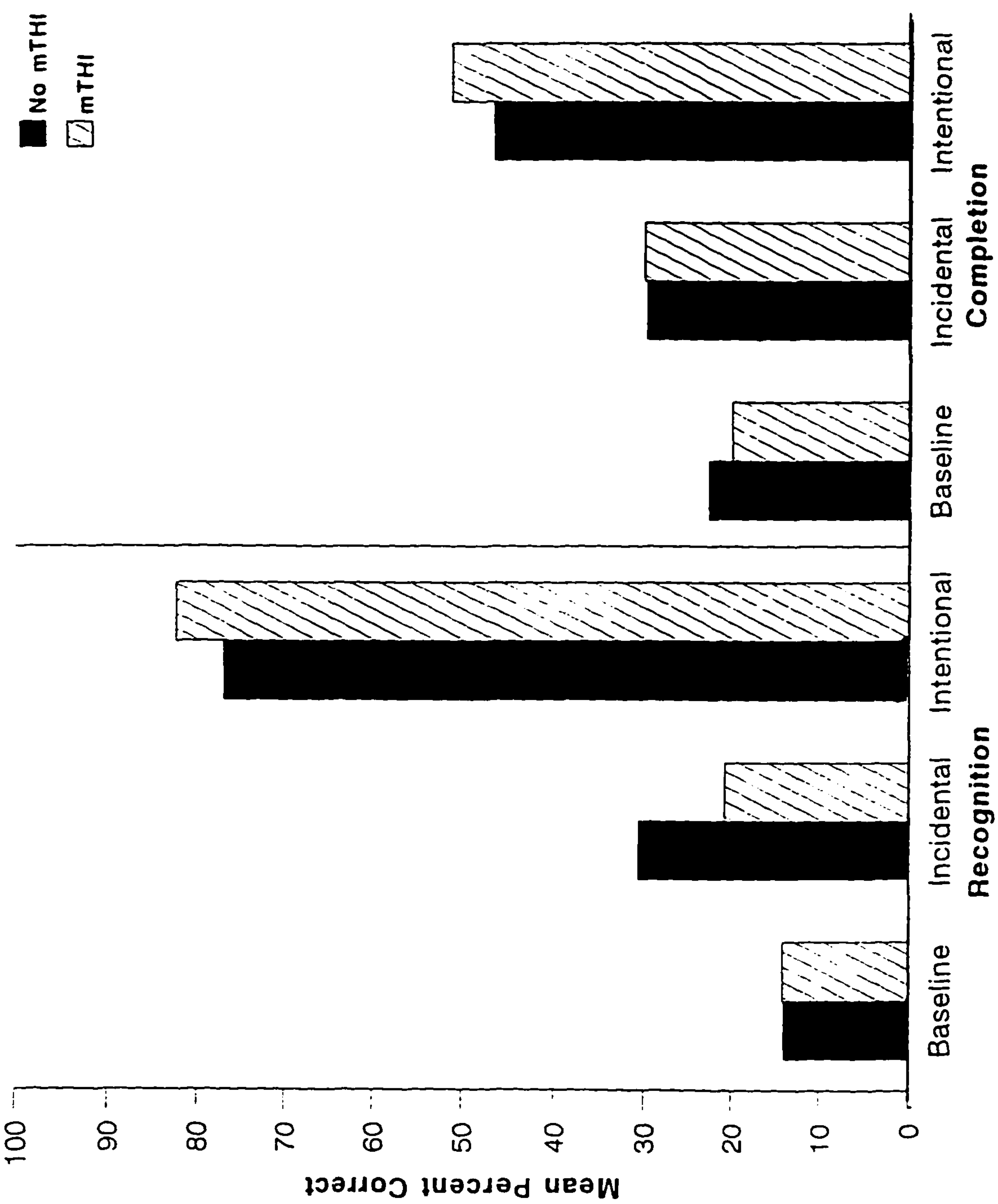

No mTHI
mTHI
Mean Percent Correct
0
10
20
30
40
50
60
70
80
90
100
Baseline
Incidental
Intentional
Recognition
Baseline
Incidental
Intentional
Completion

Figure 2. Mean percent words recognized as a function of separation format and lateral position in students based on mTHI history (Experiment 1).

mTHI = mild traumatic head injury; left = words to the left of a pair; right = words to the right of a pair; far = words from far format; close = words from close format.

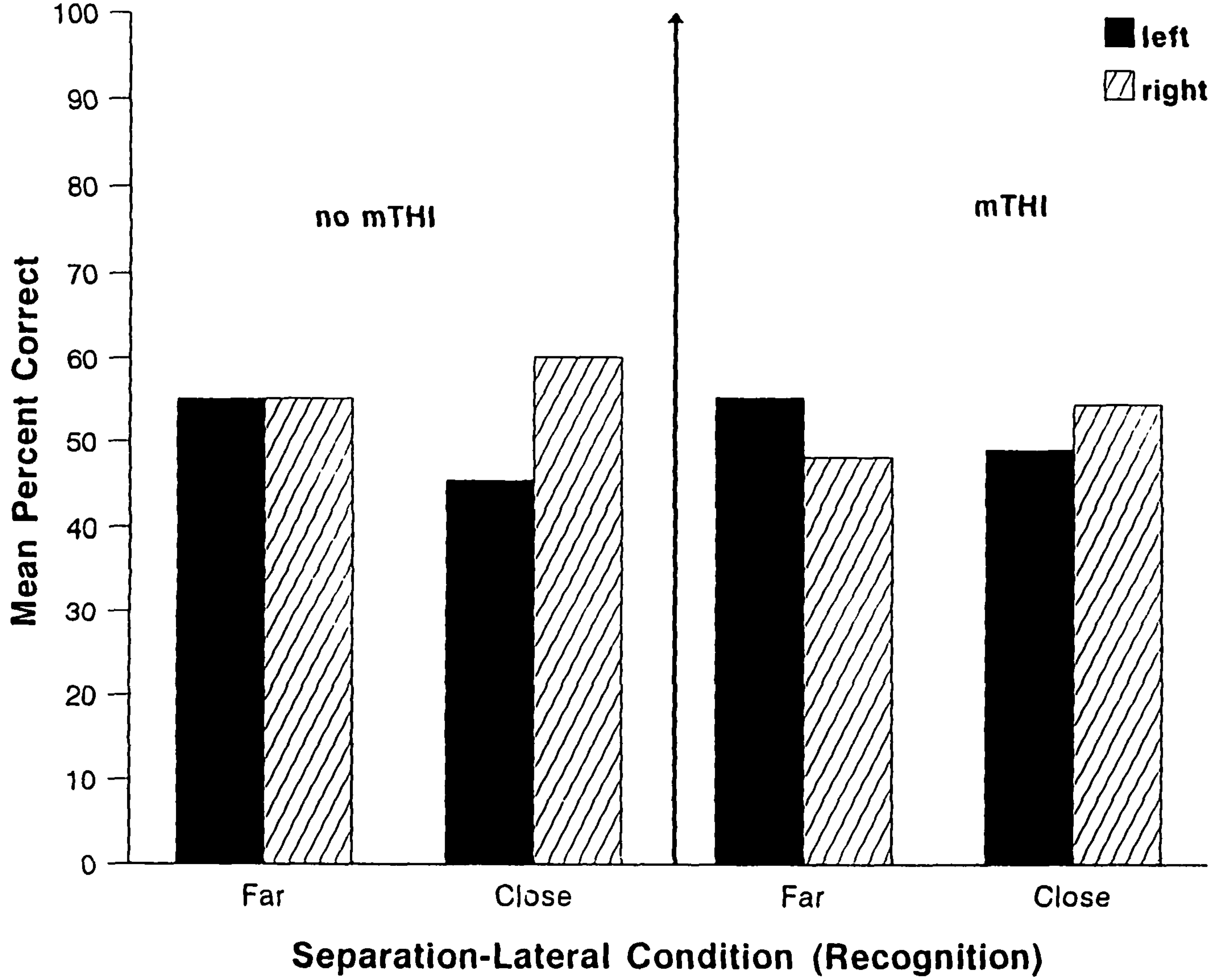
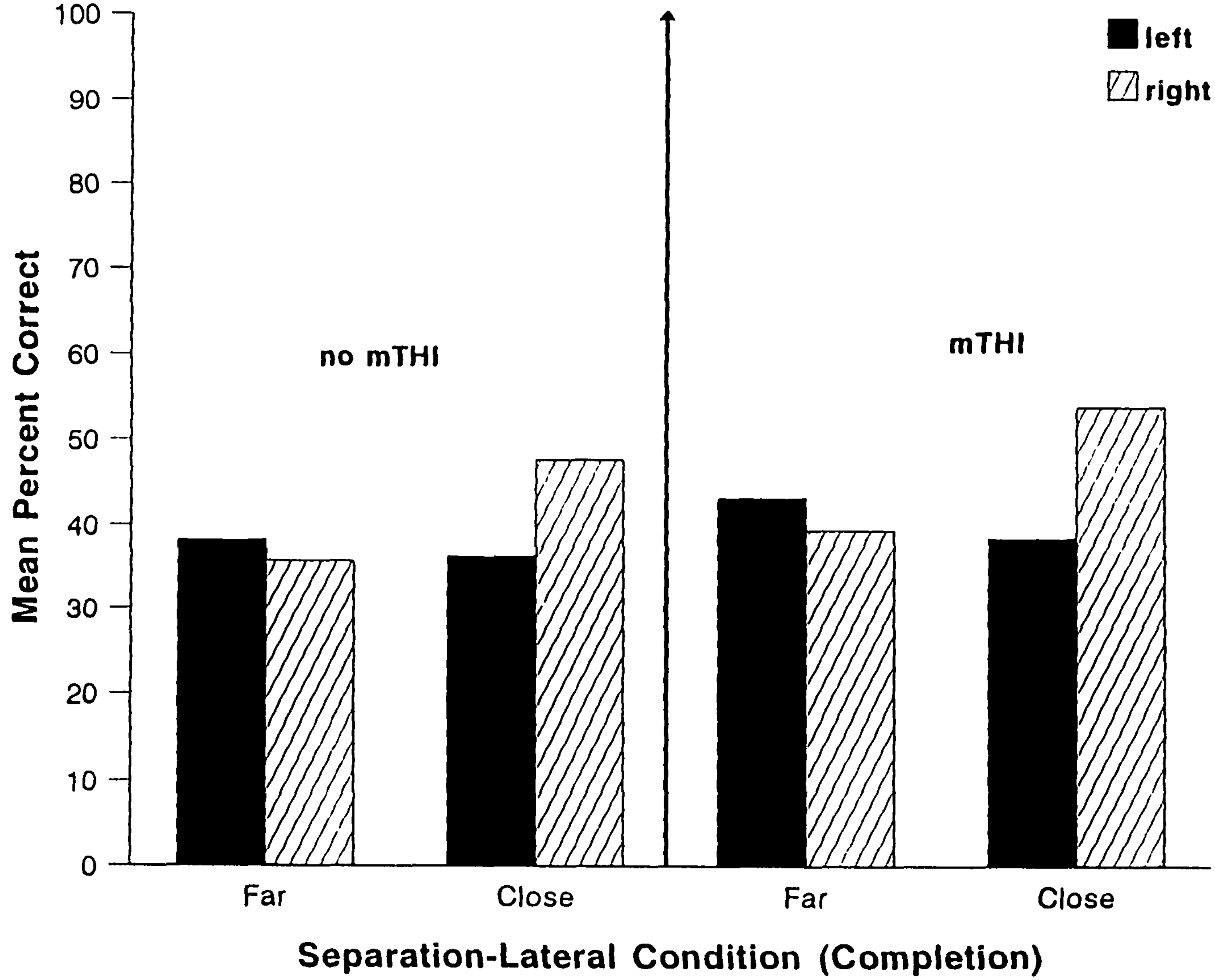

left
right
no mTHI
mTHI
Mean Percent Correct
100
90
80
70
60
50
40
30
20
10
0
Far
Close
Far
Close
Separation-Lateral Condition (Recognition)

Figure 3. Mean percent words completed as a function of separation format and lateral position in students based on mTHI history (Experiment 1).

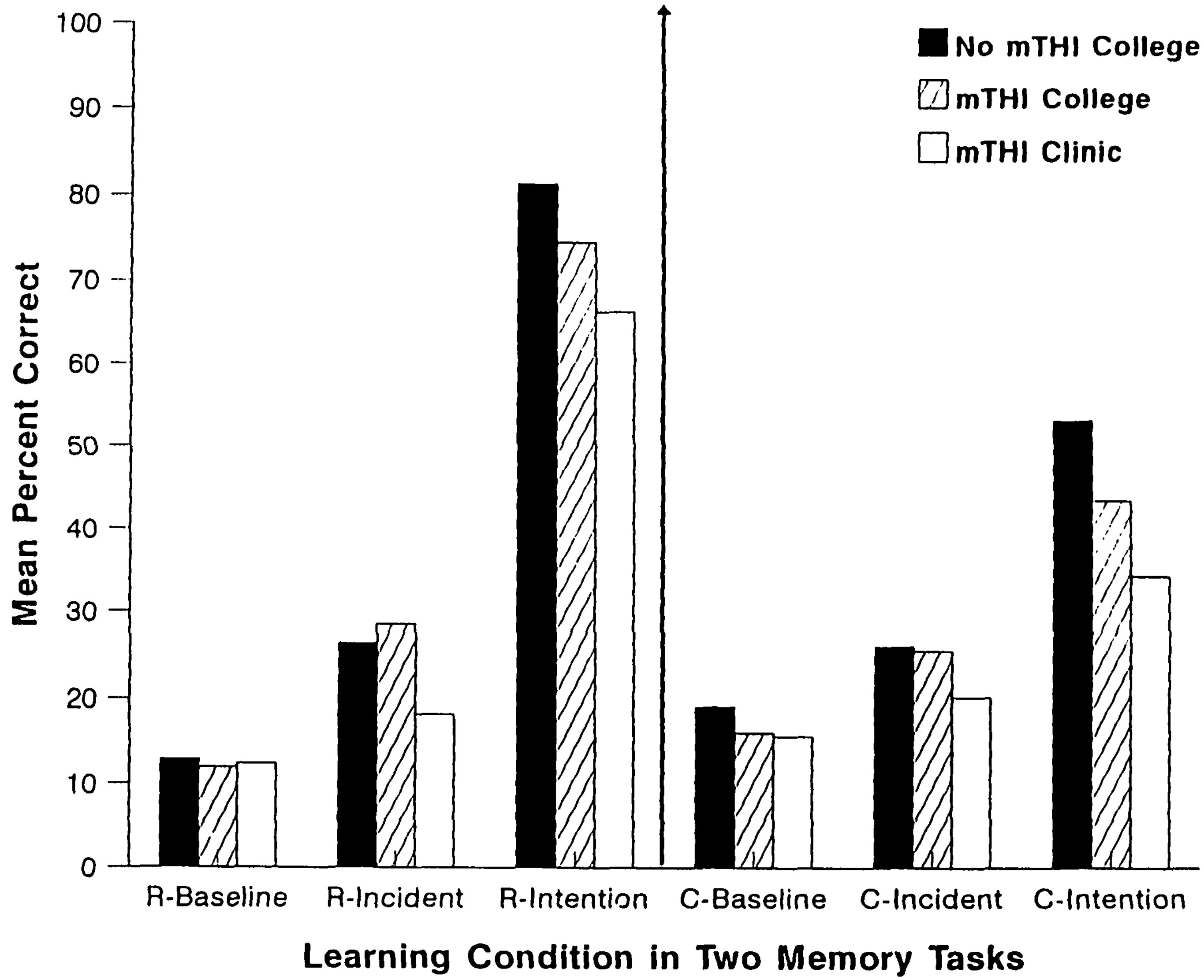
mTHI = mild traumatic head injury; left = words to the left of a pair; right = words to the right of a pair; far = words from far format; close = words from close format.



left
right
no mTHI
mTHI
Mean Percent Correct
100
90
80
70
60
50
40
30
20
10
0
Far
Close
Far
Close
Separation-Lateral Condition (Completion)

Figure 4. Mean percent incidental, intentional and baseline words recognized (R) and completed (C) in the three groups (Experiment 2).

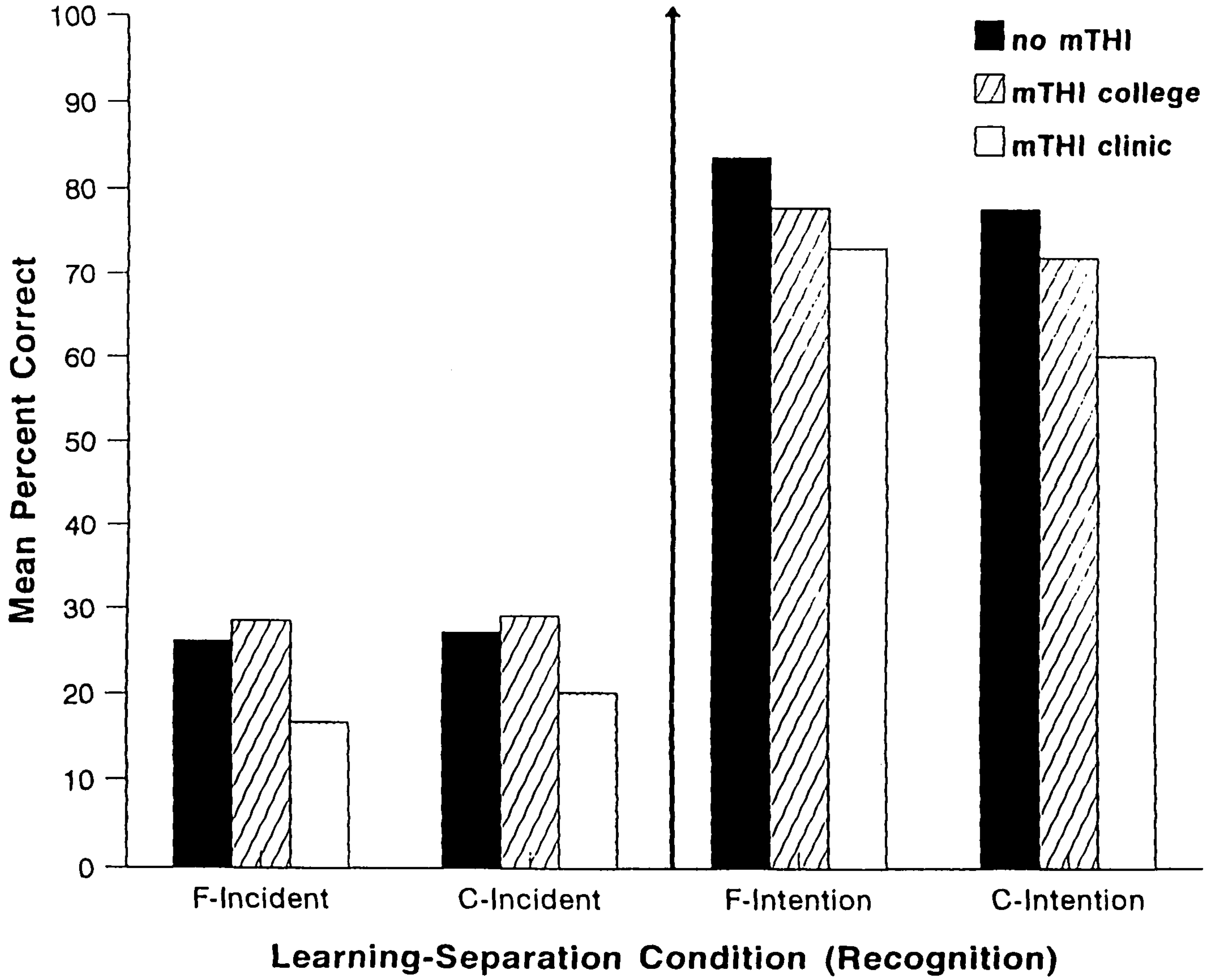
mTHI = mild traumatic head injury.



100
90
80
70
60
50
40
30
20
10
0
Mean Percent Correct
No mTHI College
mTHI College
mTHI Clinic
R-Baseline
R-Incident
R-Intention
C-Baseline
C-Incident
C-Intention
Learning Condition in Two Memory Tasks

Figure 5. Mean percent words recognized as a function of learning instructions and separation format in the three groups (Experiment 2).

mTHI = mild traumatic head injury; F = far, C = close.



no mTHI
mTHI college
mTHI clinic
Mean Percent Correct
100
90
80
70
60
50
40
30
20
10
0
F-Incident
C-Incident
F-Intention
C-Intention
Learning-Separation Condition (Recognition)

Figure 6. Mean percent words completed as a function of learning instructions and separation format in the three groups (Experiment 2).

mTHI = mild traumatic head injury; F = far, C = close.

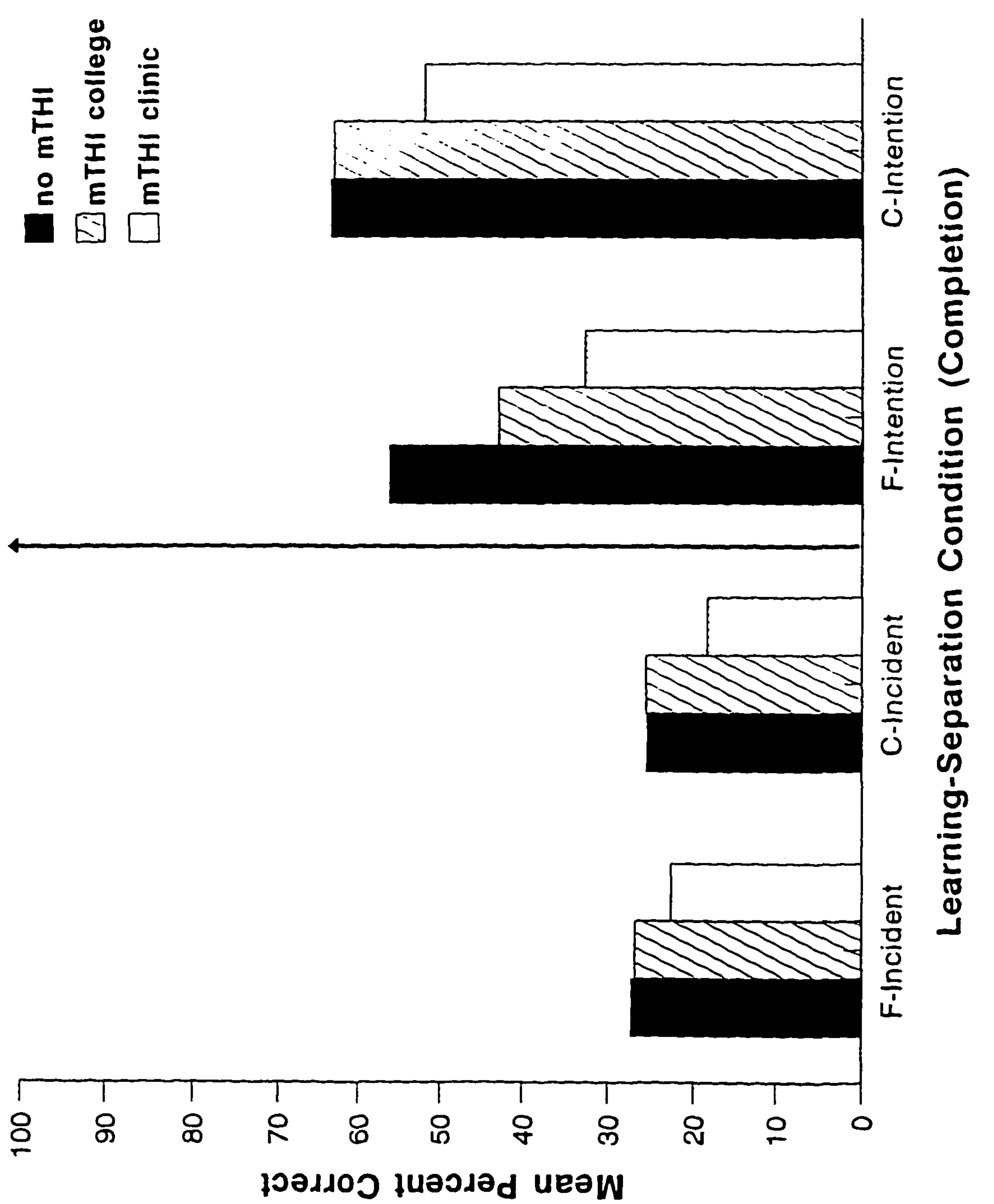

no mTHI
mTHI college
mTHI clinic
Mean Percent Correct
0
10
20
30
40
50
60
70
80
90
100
F-Incident
C-Incident
F-Intention
C-Intention
Learning-Separation Condition (Completion)

Figure 7. Mean percentage words recognized and completed as a function of lateral position in a word pair among the three groups (Experiment 2).

mTHI = mild traumatic head injury; left = words positioned to left of a pair; right = words positioned to right of a pair.

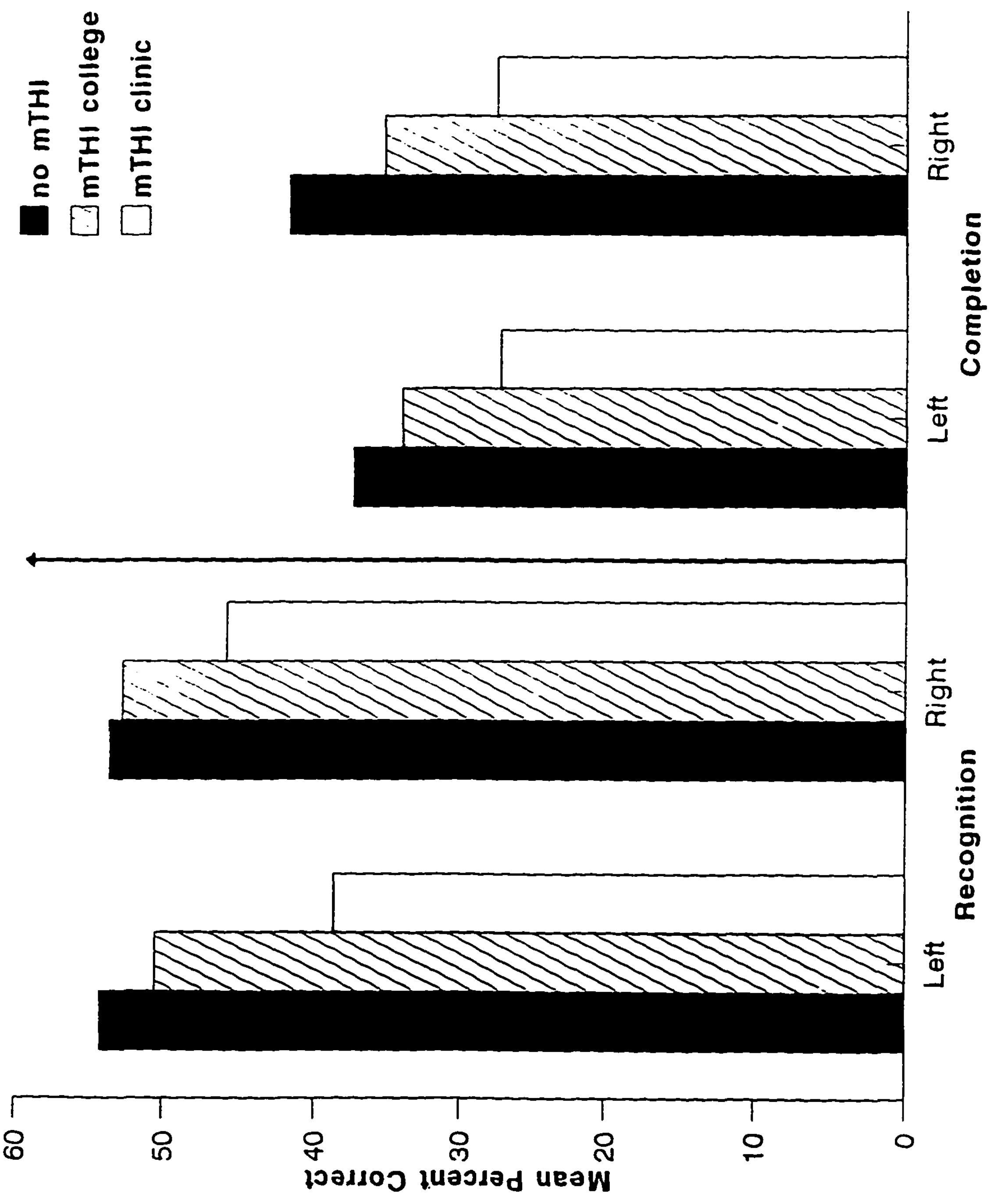

no mTHI
mTHI college
mTHI clinic
Mean Percent Correct
0
10
20
30
40
50
60
Left
Right
Recognition
Left
Right
Completion

Figure 8. Mean percent words recognized and completed as a function of separation format in a word pair in the three groups (Experiment 2).

mTHI = mild traumatic head injury; far = words from far format; close = words from close format.

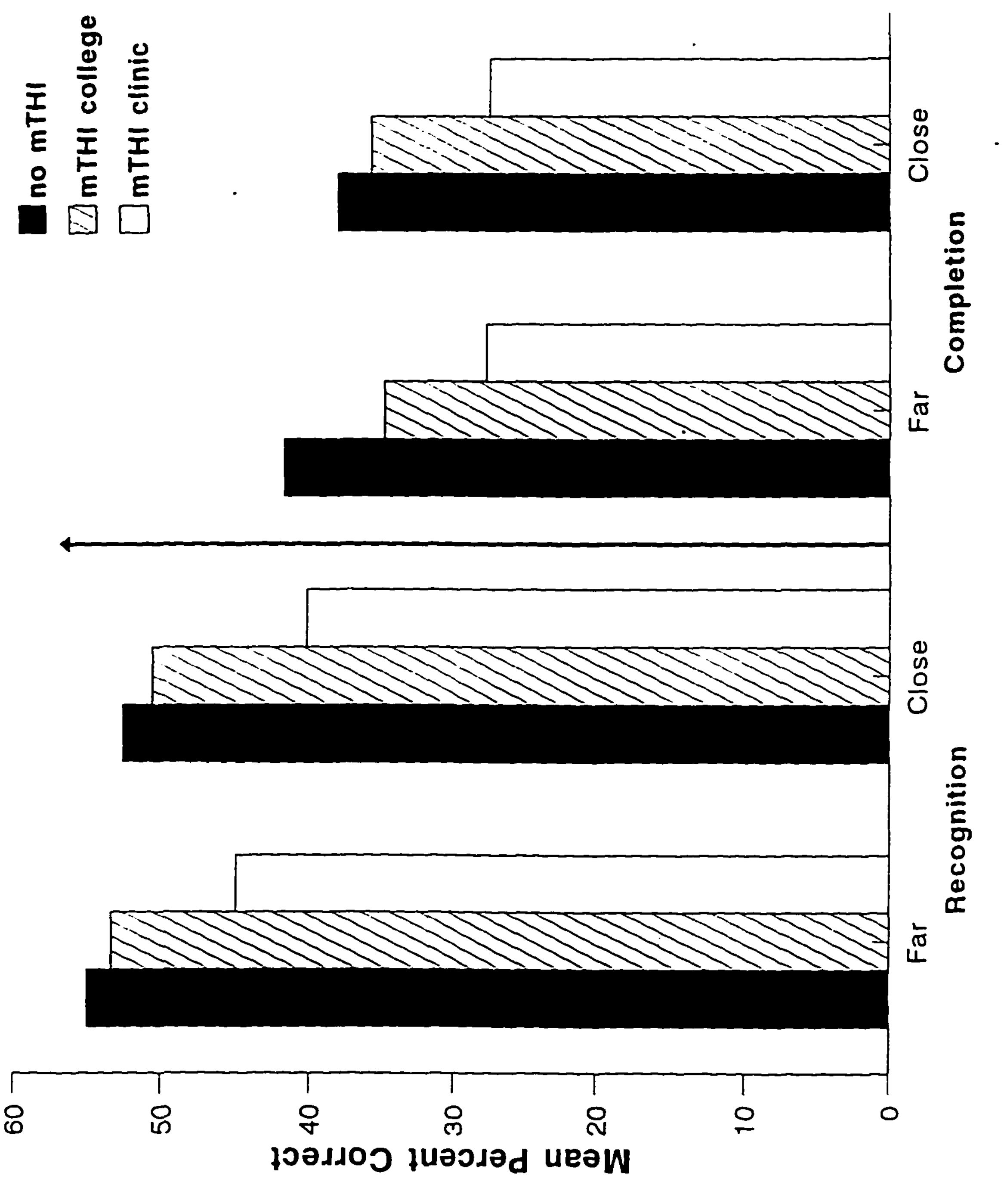

no mTHI
mTHI college
mTHI clinic
Mean Percent Correct
0
10
20
30
40
50
60
Far
Close
Recognition
Far
Close
Completion

Figure 9. Recognition of words as a function of lateral position and separation format in the three groups (Experiment 2).

mTHI = mild traumatic head injury; far = words from far format; close = words from close format; left = words positioned to left of a pair; right = words positioned to right of a pair.

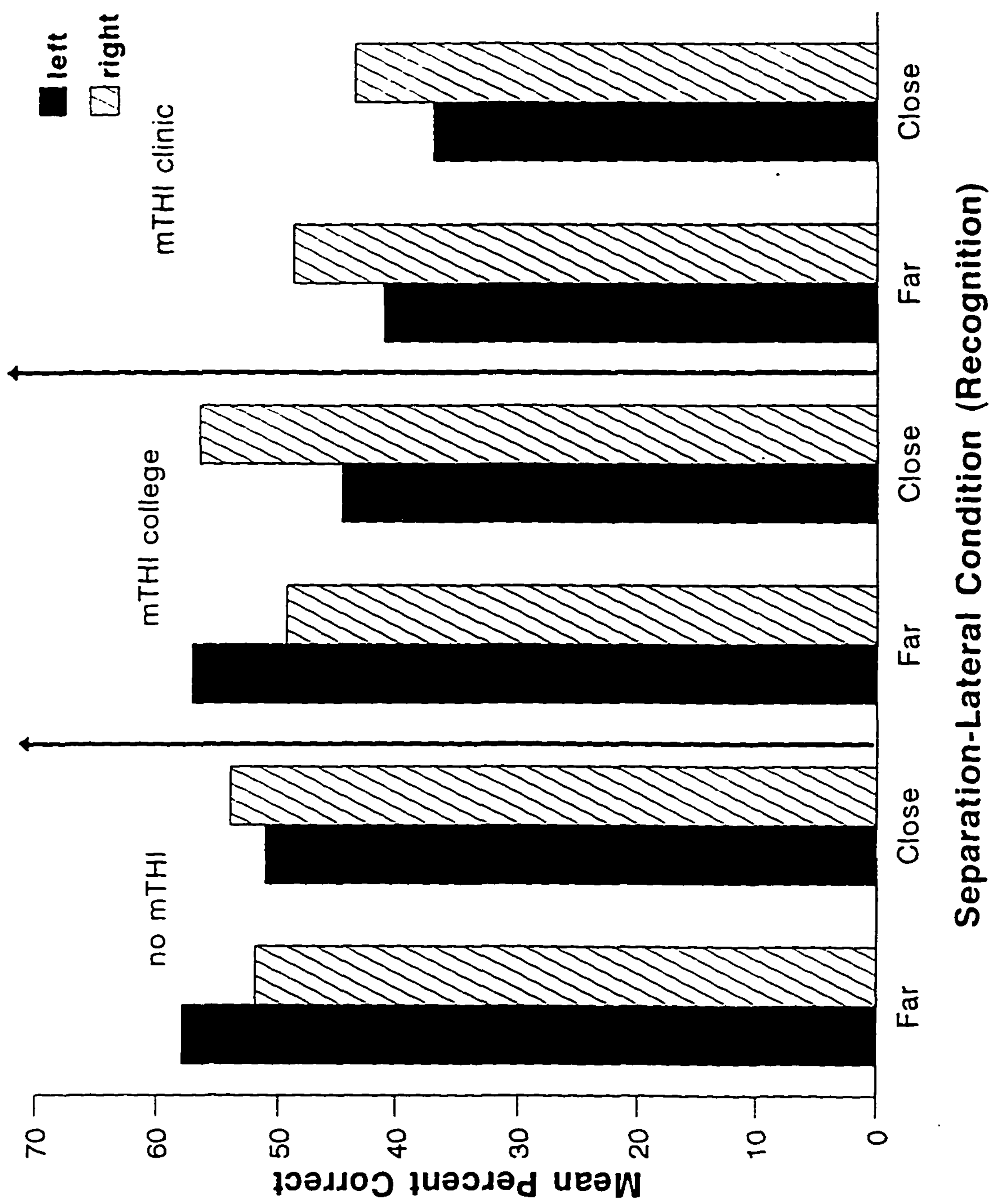
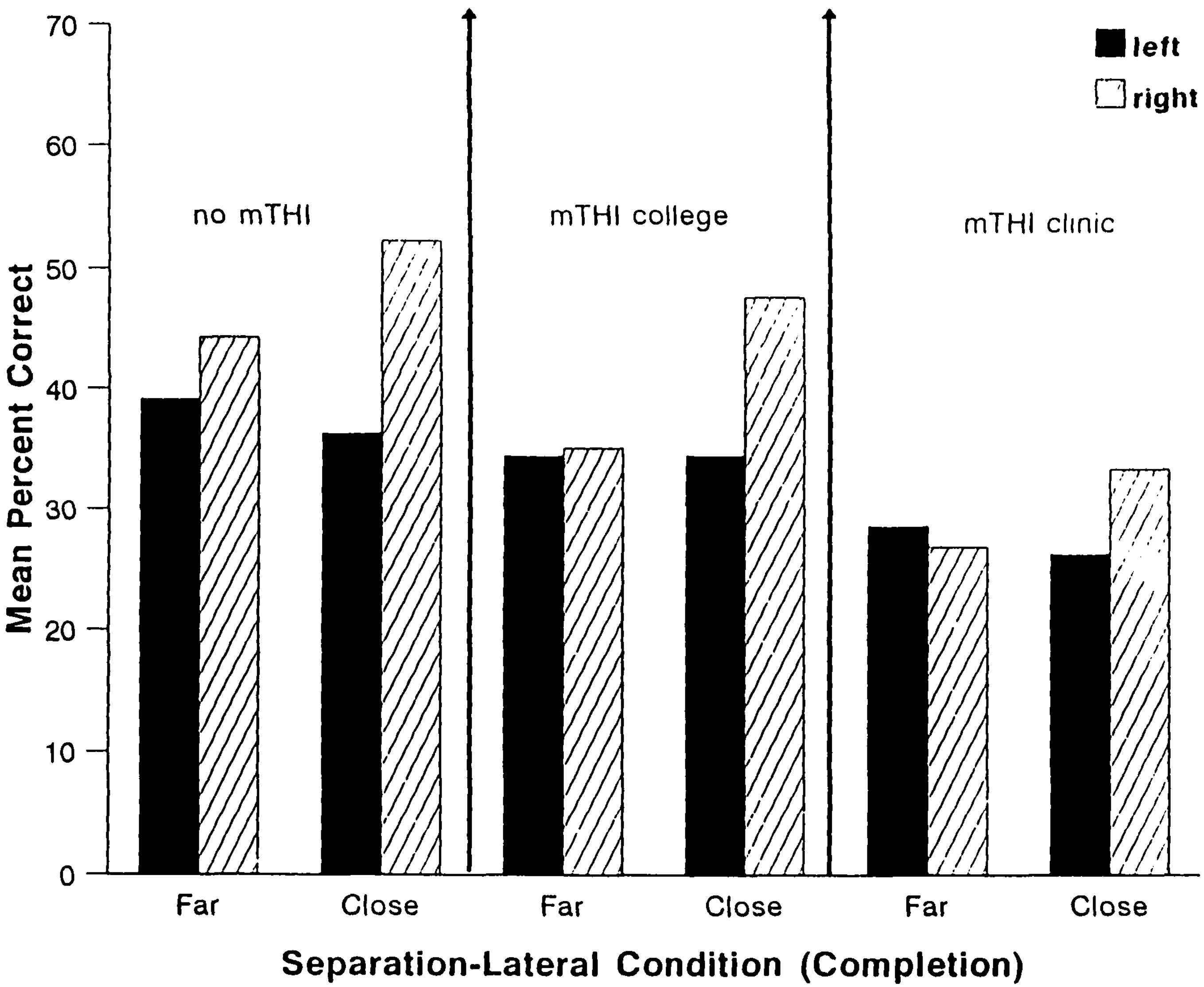

Mean Percent Correct
0
10
20
30
40
50
60
70
Far
Close
Far
Close
Far
Close
no mTHI
mTHI college
mTHI clinic
left
right
Separation-Lateral Condition (Recognition)

Figure 10. Word Stem Completion as a function of lateral position and separation format in the three groups (Experiment 2).

mTHI = mild traumatic head injury; far = words from far format; close = words from close format; left = words positioned to left of a pair; right = words positioned to right of a pair.


left
right
no mTHI
mTHI college
mTHI clinic
Mean Percent Correct
0
10
20
30
40
50
60
70
Far
Close
Far
Close
Far
Close
Separation-Lateral Condition (Completion)

Appendixes

Appendix A. Preliminary data for experimental task (pilot study).

A preliminary study was performed in spring 1993 on Queens College students using the experimental paradigm. Thirty eight students participated in the study. Twenty seven of the participants served as normal controls and eleven students had a history of traumatic head injury. The severity of the head injury for students in the latter group ranged from mild to severe. The Wide Range Achievement Test-Revised (WRAT-R) and Digit Span (WAIS-R) tests were used as neuropsychological measures of academic ability and immediate memory respectively. There were no group differences in age, F (1,37) = .06, $p > .10$; performance on the WRAT-R, F (1,37) = .37, $p > .10$; or Digit Span, F (1,37) = .05, $p > .10$; scores. The results for experimental task performance are given below.

Task. Recognition scores were better than word stem completion scores, F (1,37) = 24.70; p = .00.

Instructions. Instructions to intentionally learn words resulted in better memory for words than incidental perception, F (1,37) = 241.47; p = .00.

The effect of instructions was more pronounced in persons who had a history of head injury, F (1,37) = 4.21; p = .05. This effect was best seen on the recognition task, F (1,37) = 3.83; p = .05 as compared to the completion task which was not significant.

There was a significant interaction between memory task and learning, F (1,37) = 82.25; p = .00. The effect of instructions was more pronounced on the recognition, F (1,37) = 229.15, p = .00 as compared to word stem completion task, F (1,37) = 60.71; p = .00.

Separation Interactions. There was a significant interaction between lateral position and separation such that words that were far apart were best recognized and completed in the left position and vice versa for words that are close together, F (1,37) = 18.91; p = .00.

There was a significant interaction between separation format and learning instructions, such that the effect of intentional learning was best seen in the far condition, F (1,37) = 4.55; p = .04.

Appendix B. Interview form used to assess group placement

. ID # ________

. Age ________

. Gender ___________

. Visual Acuity ______________________

. 1^0 language Is English your first language? Yes ____ No___

Do you speak other languages? Yes ____ No ____

If Yes, which language(s) ______________________________

. What is your highest level of education?

elementary school _______

junior high school _____

some high school but not completed _____

High school diploma or GED ____

Trade school _____

College (# credits or level) _____

Bachelor's degree _____

Graduate degree: Masters _____ doctorate _____

Other _____

For Students: What is your gpa? ________

mTHI Hx:

0. Have you ever been involved in an accident in which you hit your head? [controls only]

Yes _____ No _____

. **If yes then**, [all THI]

(a) How long ago were you involved in the accident?

______

(b) What type of accident was it? ________________

(c) Was this the first time that an accident like that ever happened to you?

______

(d) Did you lose consciousness? _______

(e) For how long? Give an estimate... __________________

(f) Did you have any trouble remembering things soon after the accident?

____

(g) If yes, about how long did this last? ________________

(h) What was the first thing that you remembered immediately after the accident?

____

____

____

.. After the accident, when was the first time that you could remember:

o what time of day it was? ___________________

o what day it was? __________________________

o where the accident took place? ______________

o where you were ____________________

o who you were? _______________________

o who the people around you were? ________________

o what was the last thing you that you remembered before the accident?

____

(h) Do you currently have any difficulties with your memory? _______

0 Did you have any medical or other problems before the accident? __________

If yes: (i) What kinds of problems were they? __________________________

(ii) Do you have any medical or other problems now? ______

Nature _________________________

0 What about drugs & alcohol ..... would you say that you used drugs or alcohol

.....

None of the time _____

About once every 6 months ____

About once every 3 months ____

About once a month ______

About once a week ______

More than once a week _____

0 Do you have seizures? ________

0 Do you receive treatment for any problems, including psychotherapy? Yes _____ No _______

(i) What type of difficulty is it? ____________

0 Are you on any medications? __________

(i) What types of medication & do you know what the dosage is? _______

0 Have you ever been hospitalized before for any other problem?

Yes _____ No _____

. **If so**, what type of problem was it & when did it occur?

____

____

____

0 Are you currently involved in any litigation matter? ________

Appendix C. CONSENT FORM

PART I - RESEARCH PARTICIPANT INFORMATION SHEET

You are being asked to participate in a research study (because you sustained a brain injury and as a result you may have difficulty remembering information)[12]. The purpose of this study is to see if a computerized task of learning and memory can be used to assess learning under two conditions in individuals with brain injury. If you agree to join the study, you will participate in one testing session. The tests will involve learning words presented on a computer, reading words and completing some paper and pencil tasks commonly used to assess possible attention/concentration difficulties (and symptoms which you may have as a result of the brain injury). The session will require about 45 minutes of your time. It is expected that 64 individuals will be participating in this study. Thirty two of the participants will have sustained a mild traumatic brain injury and 32 will not. There are no potential risks in participating in this research.

The information provided by these procedures may be useful to the investigator, as well as members of the rehabilitation team, occupational therapists, psychologists and physical therapists. Furthermore, this information may enhance the understanding and management of other brain injured patients. Your identity will be kept confidential. The computerized task is a novel one and diagnostic assessment comparable to that being proposed in the context of this study is not currently available outside of such a study. However, other neuropsychological tests which measure learning and memory are available.

Should you initially agree to participate in this research, you have the right to withdraw from the study at any point in time without any penalty whatsoever. The principal investigator may stop the testing session if she feels it is too stressful or difficult for you to continue the tasks. You will receive $10.00 or credit in partial fulfillment of course requirements for your time and expenses incurred.

Note. Persons without head injury had clauses in parentheses omitted.

PART II.

Individual's Consent for Participation as a

Subject in Clinical Research

By signing this form I have agreed to participate as a subject in a research study entitled Incidental & Intentional Learning after mild Traumatic Brain Injury to be carried out under the supervision of Wilma Winnick, Ph.D.: Dept. of Psychology, Queens College, 65-30 Kissena Boulevard., Flushing, NY 11367 (718) 997-3200.

Records of this study will be kept confidential and I will not be identified in any written or verbal reports with the following possible exceptions: the Department of Psychology and the Institutional Review Board, Queens College.

I understand that the research does not involve any known potential risks. If I have any questions related to this research project, I can call the supervisor or principal investigator of this study at (718) 997-3200/3254. I have been given a copy of this form upon initial agreement to participate in this study. I have asked all the questions I want to ask, after reading and listening to an explanation of the three paragraphs in Part I of this consent form which describe:

1. The Purpose of the research.
2. The Procedures involved and duration of my participation.
3. The Risks that I will be taking, if any.
4. The Benefits that may result, to me or others.
5. Alternative procedures or treatment.

I have been told by the principal investigator that I may be a subject in this investigation only if I wish, and that I may withdraw from the study at any time.

____________________________________ ______________

Signature of Participant Date

____________________________________ ______________

Signature of Principal Investigator Date

Appendix D. Sample study list used in Experiments 1 & 2.

List 1A (* target words on example recognition list 2a)

CORNER	TOMATO	*
MAGAZINE	NITROGEN	*
FINGER	CABBAGE	*
PRETZEL	SPONGE	*
PRODUCT	BEAVER	
INDUSTRY	AQUARIUM	
GINGER	WELDER	
PACKAGE	DISTANCE	
COSTUME	MESSAGE	*
CENSUS	MIRROR	*
NUMBER	WAITER	*
TRIANGLE	CLIENT	*
REPORTER	FOUNTAIN	
TROUSERS	GALLERY	
TENDENCY	DIMENSION	
CRICKET	CONCERT	
UNIFORM	LEAFLET	*
LIBRARY	COMPASS	*
ADVICE	EMBLEM	*
TURTLE	AVENUE	*
COTTAGE	BORDER	
RAILROAD	LAUNDRY	
NATURE	TRUMPET	
FOOTBALL	PAINTER	
STEAMER	SKILLET	*
ANIMAL	ORANGE	*
FACTORY	RABBIT	*
PARACHUTE	ACCORDION	*
ANCHOR	MORSEL	
MOSQUITO	DIRECTION	
COLUMN	DENTIST	
COBBLER	MOUNTAIN	

Appendix E: Sample recognition/completion list used in Experiments 1 & 2

(underlined words = three letter word stem completion targets)

TARGETS:	FOILS:
CORNER	IODINE
TOMATO	GARAGE
MAGAZINE	BALLOON
NITROGEN	POSTMAN
FINGER	OCCASION
CABBAGE	PLUMBER
PRETZEL	BULLETIN
SPONGE	ELEVATOR
COSTUME	TANKER
MESSAGE	VALLEY
CENSUS	VENDOR
MIRROR	PASSAGE
NUMBER	STRING
WAITER	FOREST
TRIANGLE	CROWBAR
CLIENT	AUTHOR
UNIFORM	WINDOW
LEAFLET	PLIERS
LIBRARY	LUGGAGE
COMPASS	BUTCHER
ADVICE	MONKEY
EMBLEM	TERRACE
TURTLE	SHADOW
AVENUE	SLIPPER
STEAMER	SUBJECT
SKILLET	BASKET
ANIMAL	STATUE
ORANGE	GLACIER
FACTORY	SLUMBER
RABBIT	AGENCY
PARACHUTE	RACCOON
ACCORDION	ECONOMY

Appendix F: Orienting instructions for experimental task (given to all participants at the start of experimental task).

"Before we begin let me tell you about the experiment. You need not worry about remembering everything that I say now because the instructions will be given to you on the computer screen before each phase of the task. The experiment will consist of three phases followed by a few paper and pencil tasks which will be used as a comparison with the experimental task on the computer. In the first phase of the experimental task, you will see a pair of words appear on the computer screen one at a time. One of the words in a pair will be underlined and the other will not. You will be required to say the underlined word aloud and try to remember it. When the last pair has been presented, you will be given two other tasks: a word stem completion task and a recognition task.

Do you have any questions?"

Questions are answered without alerting the participant to the fact that memory for the incidental word will also be evaluated. This is done by repeating task instructions for the learning phase and reminding the participant that the instructions for each task will be given at each stage on the screen.

Appendix G1: Format of Digit Symbol subtest of the WAIS-R

1	2	3	4	5	6
O	X	=	/	+	|

3	1	2	6	5	4

2	3	5	4	1	6

Appendix G2: WAIS-R modification used in Experiment 2.

After 90 seconds, the position on the digit-symbol sheet that was reached was noted. Participants were then allowed to complete the entire test. Upon completion of the last item, a response sheet with only the items from the last line exposed was presented to participants, who were asked to fill in the empty boxes with the appropriate symbols from memory. If participants could not correctly recall at least seven symbols, they were asked to write as many symbols as they could recall in the margin below (Lezak, 1983).

Appendix H. NATIONAL ADULT READING TEST USA version (Grober & Sliwinski, 1991)[13]

Instructions:

I am going to show you a series of words and I would like you to read the words aloud until you finish or until I ask you to stop.

[Discontinue after 5 errors]

Note. $VIQ_{estimated} = 132 - 1.24$ (# pronunciation errors) read column 1 then go to column 2

. ACHE
AISLE
. CAPON
DEBT
. CHORD
HEIR
. DENY
BOUQUET
. CAPRICE
GAUGE
. WORSTED
DEPOT
. NAUSEA
NAIVE
. SUBTLE
PUGILIST
. FETAL
BLATANT
. PLACEBO
HIATUS
. SIMILE
MERINGUE
. SIEVE
CHASSIS
. CELLIST

ALGAE
. SUPERFLUOUS
CHAMOIS
. THYME
APROPOS
. VIRULENT
ZEALOT
. FACADE
CABAL
. ABSTEMIOUS
DETENTE
. SCION
PAPYRUS
. QUADRUPED
PRELATE
. EPITOME
BEATIFY
. HYPERBOLE
IMBROGLIO
. SYNCOPE

Appendix I1 New York University HI-FI, Person with head injury symptom checklist (Version 2.0), Kay, T., Cavallo, M. & Ezrachi, O. (1994).

Instructions:

On the left you will find a list of symptoms. Next to each item, you are asked to indicate - Yes or No - whether this is something you experience. **IF YOU ANSWER YES**, then indicate how much of a problem this presents in your daily functioning. Circle one of the numbers from 1 (no problem) to 7 (severe problem). The higher the number you circle, the more of a problem it is for you. Only rate the problem 1-7 if you answered "Yes" to experiencing the symptom.

PLEASE COMPLETE ALL ITEMS.

Do you experience ... ?			**IF YES,** How much of a problem does this present in your daily functioning?
Symptom	No	Yes	1 2 3 4 5 6 7 No Problem / Moderate Problem / Severe Problem
1. Visual problems; difficulty seeing	N	Y	1 2 3 4 5 6 7
2. Hearing difficulties	N	Y	1 2 3 4 5 6 7
3. Poor balance	N	Y	1 2 3 4 5 6 7
4. Doing things slowly	N	Y	1 2 3 4 5 6 7
5. Difficulty pronouncing words clearly (dysarthria)	N	Y	1 2 3 4 5 6 7
6. Problems with coordination	N	Y	1 2 3 4 5 6 7
7. Fatiguing quickly; getting tired easily	N	Y	1 2 3 4 5 6 7
8. Headaches	N	Y	1 2 3 4 5 6 7
9. Dizziness/vertigo	N	Y	1 2 3 4 5 6 7
10. Sensitivity to noise	N	Y	1 2 3 4 5 6 7
11. Sensitivity to light	N	Y	1 2 3 4 5 6 7
12. Problems with taste or smell	N	Y	1 2 3 4 5 6 7
13. Difficulty remembering the right word (word-finding)	N	Y	1 2 3 4 5 6 7
14. Expressing self in a wordy, roundabout way	N	Y	1 2 3 4 5 6 7
15. Being easily distractible (e.g., in a noisy room)	N	Y	1 2 3 4 5 6 7

Do you experience ... ?			IF YES, How much of a problem does this present in your daily functioning?
Symptom	No	Yes	1 2 3 4 5 6 7 No Moderate Severe Problem Problem Problem
16. Poor concentration for extended periods of time (e.g., reading in a quiet room)	N	Y	1 2 3 4 5 6 7
17. Being forgetful; difficulty remembering things	N	Y	1 2 3 4 5 6 7
18. Difficulty thinking clearly and efficiently	N	Y	1 2 3 4 5 6 7
19. Difficulty planning and organizing things	N	Y	1 2 3 4 5 6 7
20. Difficulty setting realistic goals	N	Y	1 2 3 4 5 6 7
21. Difficulty following through or finishing things	N	Y	1 2 3 4 5 6 7
22. Apathy, lack of interest in things	N	Y	1 2 3 4 5 6 7
23. Lack of initiative, don't start things up	N	Y	1 2 3 4 5 6 7
24. Irritability	N	Y	1 2 3 4 5 6 7
25. Restlessness	N	Y	1 2 3 4 5 6 7
26. Temper outbursts	N	Y	1 2 3 4 5 6 7
27. Mood swings, quick emotional shifts	N	Y	1 2 3 4 5 6 7

Do you experience ... ?			**IF YES,** How much of a problem does this present in your daily functioning?
<u>Symptom</u>	<u>No</u>	<u>Yes</u>	1 2 3 4 5 6 7 No Problem, Moderate Problem, Severe Problem
28. Difficulty bringing emotions under control once expressed	N	Y	1 2 3 4 5 6 7
29. Getting into arguments with others	N	Y	1 2 3 4 5 6 7
30. Being physically violent	N	Y	1 2 3 4 5 6 7
31. Getting bored easily	N	Y	1 2 3 4 5 6 7
32. Complaining about things	N	Y	1 2 3 4 5 6 7
33. Dependency on others	N	Y	1 2 3 4 5 6 7
34. Needing supervision	N	Y	1 2 3 4 5 6 7
35. Anxiety/tension	N	Y	1 2 3 4 5 6 7
36. Depression	N	Y	1 2 3 4 5 6 7
37. Loneliness	N	Y	1 2 3 4 5 6 7
38. Loss of confidence	N	Y	1 2 3 4 5 6 7
39. Changes in appetite	N	Y	1 2 3 4 5 6 7
40. Sleep disturbance	N	Y	1 2 3 4 5 6 7
41. Low sexual drive	N	Y	1 2 3 4 5 6 7
42. High sexual drive	N	Y	1 2 3 4 5 6 7
43. Changed personality	N	Y	1 2 3 4 5 6 7

Appendix I2. New York University PCL-PHI Subscale Score Computation Sheet

Subscale 1 Affective/Behavioral	Subscale 2 Cognitive	Subscale 3 Physical/Dependency
Item EXP SEV	Item EXP SEV	Item EXP SEV
V2.0 (v1.2)	*V2.0 (v1.2)*	*V2.0 (v1.2)*
8 (4) ___ ___	7 (5) ___ ___	1 (1) ___ ___
24 (17) ___ ___	13 (6) ___ ___	3 (2) ___ ___
25 (19) ___ ___	14 (7) ___ ___	4 (3) ___ ___
26 (20) ___ ___	15 (9) ___ ___	5 (8) ___ ___
27 (21) ___ ___	16 (10) ___ ___	22 (15) ___ ___
28 (22) ___ ___	17 (11) ___ ___	23 (16) ___ ___
29 (23) ___ ___	19 (12) ___ ___	33 (27) ___ ___
30 (24) ___ ___	20 (13) ___ ___	34 (28) ___ ___
31 (25) ___ ___	21 (14) ___ ___	
32 (26) ___ ___		
35 (29) ___ ___		
36 (30) ___ ___		
37 (31) ___ ___		
43 (34) ___ ___		
# of EXP items responded to: _____ (1) IF (1) >_ 10: Sum EXP scores _____ (2) Divide (2) by 14 = [ ] (3)	# of EXP items responded to: _____ (1) IF (1) >_ 6: Sum EXP scores _____ (2) Divide (2) by 9=[ ] (3)	# of EXP items responded to: _____ (1) IF (1) >_ 6: Sum EXP scores _____ (2) Divide (2) by 8=[ ] (3)
# of SEV items responded to: _____ (4) IF (4) >_ 9: Sum SEV scores _____ (5) Divide (5) by (4) = [ ] (6)	# of SEV items responded to: _____ (4) IF (4) >_ 6: Sum SEV scores _____ (5) Divide (5) by (4) = [ ] (6)	# of SEV items responded to: _____ (4) IF (4) >_ 6: Sum SEV scores _____ (5) Divide (5) by (4) = [ ] (6)

Appendix J. Zung Depression scale[14]

		None Or a Little of the Time	Some of the Time	Good Part of the Time	Most of the Time
1.	I feel down-hearted, blue and sad				
2.	Morning is when I feel the best				
3.	I have crying spells or feel like it				
4.	I have trouble sleeping at night				
5.	I eat as much as I used to				
6.	I still enjoy looking at, talking to and being with attractive women/men				
7.	I notice that I am losing weight				
8.	I have trouble with constipation				
9.	My heart beats faster than usual				
10.	I get tired for no reason				
11.	My mind is as clear as it used to be				
12.	I find it easy to do things I used to				
13.	I am restless and I can't keep still				
14.	I feel hopeful about the future				
15.	I am more irritable than usual				
16.	I find it easy to make decisions				
17.	I feel I am useful and needed				
18.	My life is pretty full				
19.	I feel that others would be better off if I were dead				
20.	I still enjoy things I used to				

Note. Zung Index = (total raw score/maximum score of 80) X 100
Subscale index = total subscale score/maximum total for subscale
Affect: Items 1 & 3; Physiological: Items 2 & 4 through 10; Psychomotor: Items 12 & 13; Psychological: Items 11 & 14 through 20

References

Arcia, E. & Gualtieri, C.T. (1993). Association between patient report of symptoms after mild head injury and neurobehavioural performance. Brain Injury, 7, 481-489.

Arguin, M., Joanette, Y. & Cavanaugh, P. (1990). Comparing the cerebral hemispheres on the speed of spatial shifts of visual attention: evidence from serial search. Neuropsychologia, 7, 733-736.

Alexander, M. P. (1995). Mild traumatic brain injury: pathophysiology, natural history and clinical management. Neurology, 45, 1253-1260.

Bachevalier, J. (1990). Ontogenetic development of habit and memory formation in primates. Annals of the New York Academy of Sciences, 608, 457-484.

Bassett, S.S. & Slater, E.J. (1992). Neuropsychological function in adolescents sustaining mild closed head injury. Journal of Pediatric Psychology, 15, 225-236.

Beers, S.R., Goldstein, G. & Katz, L.J. (1994). Neuropsychological differences between college students with learning disabilities and those with mild head injury. Journal of Learning Disabilities, 27, 315-324.

Binder, L.M. & Rattok, J. (1989). Assessment of the postconcussive syndrome after mild head trauma. In M. D. Lezak (Ed.), Assessment of Behavioral Consequences of Head Trauma (pp. 37-48). New York: Alan R. Liss.

Blakely Jr., T.A. & Harrington, D.E. (1993). Mild head injury is not always mild; implications for damage litigation. Medical Science Law, 33, 231-242.

Blaxton, T.A. (1989). Investigating dissociations among memory measures: support for a transfer-appropriate processing framework. Journal of Experimental Psychology: Learning, memory & cognition , 15, 657-668.

Blaxton, T.A. (1995). A process-based view of memory. Journal of the International Neuropsychological Society, 1, 112-114.

Blaxton, T.A. (Speaker) (1996). Functional mapping of perceptual and conceptual components of human memory. (Cassette Recording No. J115-29). Chicago, IL: International Neuropsychological Society.

Blumbergs, P.C., Scott, G., Manavis, J., Wainwright, H., Simpson, D.A. & McLean, A.J. (1994). Staining of amyloid precursor protein to study axonal damage. Lancet, 344, 1055-1056.

Bohnen, N., Van Zutphen, W., Twijnstra, A., Wijnen, G. Bongers, J. & Jolles, J. (1994). Late outcome of mild head injury: results from a controlled postal survey. Brain Injury, 8, 701-708.

Bowers, J.S. & Schacter, D.L. (1990). Implicit memory and test awareness. Journal of Experimental Psychology: learning, memory and cognition: learning, memory and cognition, 16, 406-416.

Brown, W.P. & Ure, D.M.J. (1969). Rated characteristics of word association stimuli. British Journal of Psychology, 60, 233-249.

Correll, R.E., Brodginski, S.E. & Rokosz, S. F. (1993). WAIS performance during the acute recovery stage following closed-head injury. Perceptual and Motor Skills, 76, 99-109.

Craik, F.I.M. & Lockhart (1972). Levels of processing: a framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671-684.

Craik. F.I.M. & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 104, 268-294.

Dikmen, S.S. & Levin, H.S. (1993). Methodological issues in the study of mild head injury. Journal of Head Trauma Rehabilitation, 8, 30-37.

Dornbush, R. L. & Winnick, W. A. (1967). Short-term intentional and incidental learning. Journal of Experimental Psychology, 73, 608-611.

Duncan, J. & Humphreys, g. (1989). A resemblance theory of visual search. Psychological Review, 96, 433-458.

Elliott, C.L. & Greene, R.L. (1992). Clinical depression and implicit memory. Journal of Abnormal Psychology, 101, 572-574.

Elson, L.M. & Ward, C.C. (1994). Mechanisms and pathophysiology of mild head injury. Seminars in Neurology, 14, 8-18.

Evans, R.W. (1992). The postconcussion syndrome and the sequelae of mild head injury. Neurologic Clinics, 10, 815-847.

Ewing, R., McCarthy, D., Gronwall, D. & Wrightson, P. (1980). Persisting effects of minor head injury observable during hypoxic stress. Journal of Clinical Neuropsychology, 2, 147-155.

Gabrieli, J.D.E. (1995). A systematic view of memory processes. Journal of the International Neuropsychological Society, 1, 115-118.

Gabrieli, J.D. (Speaker) (1996). Functional magnetic resonance imaging (fMRI) of memory processing in the frontal lobes: evidence for a brain locus for semantic working memory. (Cassette Recording No. J115-29). Chicago, IL: International Neuropsychological Society.

Gale, S.D., Burr, R.B., Bigler, E.D., & Blatter, D. (1993). Fornix degeneration in traumatic brain injury. Brain Research Bulletin, 32, 345-349.

Gentilini, M., Nicheli, P. & Schoenhuber, R. (1989). Assessment of attention in mild head injury. In Levin, Eisenberg & Benton (eds,), Mild head injury(pp. 163-175). NY: Oxford University Press.

Goldberg, E. & Costa, L.D. (1981). Hemisphere differences in the acquisition and use of descriptive systems. Brain & Language, 14, 144-173.

Goldman-Rakic, P. (1987) Circuitry of primate prefrontal cortex and regulation of behavior by representational memory. In Handbook of Physiology: higher functions of the brain (Vol. 5). American Physiological Society.

Grady, C. (Speaker). (1996). The roles of medial temporal and prefrontal cortex in encoding and recognition of visual stimuli. (Cassette Recording No. J115-29). Chicago, IL: International Neuropsychological Society.

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

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

Graf, P. & Ryan, L. (1991). Transfer-appropriate processing for implicit and explicit memory. Journal of Experimental Psychology: Learning, Memory & Cognition,16, 978-992.

Greene, R. (1986). Word stems as cues in recall and completion tasks. Quarterly Journal of Psychology, 38A, 663-673.

Grober, E. & Sliwinski, M. (1991). Development & validation of a model for estimating premorbid verbal intelligence in the elderly. Journal of Clinical & Experimental Neuropsychology, 13, 933-941.

Gronwall, D. (1989). Cumulative and persisting effects of concussion on attention and cognition. In Levin, Eisenberg & Benton (eds,), Mild head injury (pp. 153-162). NY: Oxford University Press.

Gronwall, D. (1991). Minor head injury. Neuropsychology, 5, 253-265.

Gronwall, D. & Wrightson, P. (1975). Cumulative effects of concussion. Lancet, 2, 995-997.

Gronwall, D. & Wrightson, P. (1980). Duration of post-traumatic amnesia after mild head injury. Journal of Clinical Neuropsychology, 2, 51-60.

Gronwall, D. & Wrightson, P. (1981). Memory and information processing capacity after closed head injury. Journal of Neurology, Neurosurgery & Psychiatry, 44, 889-895.

Gur, R.C., Packer, I.K., Hungerbuhler, J.P., Reivich, M., Obrist, D., Amarnek, W.S. & Sackeim. H.A. (1980). Differences in the distribution of gray and white matter in human cerebral hemispheres. Science, 207, 1226-1228.

Hamann, S.B., Squire, L.R. & Schacter, D.L. (1995). Perceptual thresholds and priming in amnesia. Neuropsychology, 9, 3-15.

Heilman, K.M., Chatterjee, A. & Doty, L.C. (1995). Hemispheric asymmetries of near-far spatial attention. Neuropsychology, 9, 58-61.

Hinnant, D. & Tollison, D. (1994). Impairment and disability associated with mild head injury: medical and legal aspects. Seminars in Neurology, 14, 84-89.

Hirsh, R. (1980). The hippocampus, conditional operations and cognition. Physiological Psychology, 8, 175- 182.

Jeret, J.S., Mandell, M., Anziska, B., Lipitz, M., Vilceus, A.P., Ware, J.A. & Zesiewicz, T.A. (1993). Clinical predictors of abnormality disclosed by computed tomography after mild head trauma. Neurosurgery, 32, 9-16.

Jernigan, T.L. & Ostergaard, A.L. (1993). Word priming and recognition are both affected by medial temporal lobe damage. Neuropsychology, 1, 14-26.

Kaplan, E., Fein, D., Morris, R. & Delis, D. (1991). WAIS-R NI manual: WAIS-R as a neuropsychological instrument. NY: The Psychological Corporation: Harcourt Brace Janovich.

Kay, T. (1986). The unseen injury: Minor head injury. Framingham, MA: National Head Injury Foundation Inc.

Kay, T. (1992). Neuropsychological diagnosis: disentangling the multiple determinants of functional disability after minor traumatic brain injury. Physical Medicine & Rehabilitation: state of the art reviews, 6, 109-127.

Kay, T., Cavallo, M. & Ezrachi, O. (1994). Administration Manual, New York University Medical Center Head Injury Family Manual, New York, NY: Author.

Kay, T., Harrington, D.E., Adams, R., Anderson, T., Berrol, S., Cicerone, K., Dahlberg, C., Gerber, D., Goka, R., Harley, P., Hilt, J., Horn, L., Lehmkuhl, D. & Malec, J. (1993). Definition of mild traumatic brain injury. Journal of Head Trauma Rehabilitation, 8, 86-87.

Kay, T. & Lezak, M. (1990). The nature of head injury. D.W. Corthell (Ed.). In Traumatic brain injury and vocational rehabilitation, (pp.22-61). Mnemonie: University of Wisconsin - Stout.

Kay, T., Newman, B., Cavallo, M., Ezrachi, O. & Resnick, M. (1992). Toward a neuropsychological model of functional disability after mild traumatic brain injury. Neuropsychology, 6, 371-384.

Keane, M.A., Gabrieli, J.D.E, Fennema, A.C., Growdon, J.H. & Corkin, S. (1991). Evidence for a dissociation between perceptual and conceptual priming in Alzheimer's Disease. Behavioral Neuroscience, 105, 326-342.

Levin, H. (1990). Memory deficits after closed head injury. Journal of Clinical and Experimental Neuropsychology, 12, 129-153.

Levin, H.S., Williams, D., Eisenberg, H.M., High Jr, W.M. & Guinto Jr, F.C. (1992). Serial MRI and neurobehavioral findings after mild to moderate closed head injury. Journal of Neurology, Neurosurgery & Psychiatry, 55, 255-262.

Lezak, M. (1983). Neuropsychological Assessment. NY: Oxford University Press.

Matthews,A., Mogg, K., May, J. & Eysenck, M. (1989). Implicit and explicit memory bias in anxiety. Journal of Abnormal Psychology, 98, 236-248.

Mechanic, A. (1962a). Effects of orienting task, practice, and incentive on simultaneous incidental and intentional learning. Journal of Experimental Psychology, 64, 393-399.

Mechanic, A. (1962b). The distribution of recalled items in simultaneous intentional and incidental learning. Journal of Experimental Psychology, 63,593-600.

Mechanic, A. & Mechanic. J. (1967). Response activities and the mechanism of selectivity in incidental learning. Journal of Verbal Learning and Verbal Memory, 6, 389-397.

Mishkin, M. & Appenzeller, T. (1987). The anatomy of memory. Scientific

American, 256, 80-89.

Mittenberg, W., DiGiulio, D.V., Perrin, S. & Bass, A.E. (1992). Symptoms following mild head injury: expectation as aetiology. Journal of Neurology, Neurosurgery and Psychiatry, 55, 200-204.

Morris, C.D., Bransford, J.P. & Franks, J.J. (1977). Levels of processing versus transfer appropriate processing. Journal of Verbal Learning and Verbal Behavior, 16, 519-533.

Moss, A.R. & Dowd, T. (1991). Does the NART hold true after head injury? A case report. British Journal of Clinical Psychology, 30, 179-180.

Mutter, S., Howard, P., Howard, J. & Wiggs, C. (1990). Performance on direct and indirect tests of memory after mild closed-head injury. Cognitive Neuropsychology, 7, 329-346.

Neill, W.T., Trammell, W., Beck, J.L., Bottalico, K.S. & Molloy, R.D. (1990). Effects of intentional versus incidental learning on explicit and implicit tests of memory. Journal of Experimental Psychology: Learning, Memory & Cognition, 16, 457-463.

Neimark, W.T. & Saltzman, I. J. (1953). Intentional and incidental learning with different rates of stimulus presentation. American Journal of Psychology, 66, 618-621.

Parasuraman, R., Mutter, S.A. & Molloy, R. (1991). Sustained attention following mild closed-head injury. Journal of Clinical & Experimental Neuropsychology, 13, 789-811.

Pitarque, A., Algarabel, S. & Meseguer, E. (1992). Degree of elaborative processing in two implicit and two explicit memory tasks. Bulletin of the Psychonomic Society, 30, 217-220.

Postman, L. (1964). Short-term memory and incidental learning. In A.W. Melton (Ed.), Categories of human learning. (pp. 145-201). New York: Academic Press.

Postman, L. & Adams, P. A. (1956). The interaction of orienting task and stimulus materials. Journal of Experimental Psychology, 51, 329-333.

Povlishock, J.T. & Coburn, T.H. (1989). Morphopathological change associated with mild head injury. In Levin, Eisenberg & Benton (Eds.), Mild head injury (pp. 37-53). NY: Oxford University Press.

Rasmusson, D.X., Brandt, J., Martin,D.B. & Folstein, M.F. (1995). Head injury as a risk factor in Alzheimer's Disease. Brain Injury, 9, 213-219.

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

Roediger III, H.L. (1990). Implicit memory. American Psychologist, 45, 1043-1056.

Roediger III, H.L., Rajaram, S. & Srnivas, K. (1990). Specifying criteria for postulating memory systems. Annals of the New York Academy of Sciences, 608,572-58.

Ruff, R.M., Levin, H.S., Mattis, S., High Jr., W.M., Marshall, L.F., Eisenberg, H.M. & Tabaddor, K. (1989). Recovery of memory after mild head injury: a three-center study. In Levin, Eisenberg & Benton (eds,), Mild head injury (pp. 176-188). NY: Oxford University Press.

Russell, N.R. (1971). The Traumatic Amnesias. NY: Oxford University Press.

Russell, E.W. & D'Hollosy, M.E. (1992). Memory and attention. Journal of Clinical Psychology, 48, 530-538.

Schacter, D.L. (1987). Implicit memory: history and current status. Journal of Experimental Psychology: Learning, memory & cognition, 13, 501-518.

Schacter, D. (1990). Perceptual representation systems and implicit memory. Annals of the New York Academy of Sciences, 608, 543-571.

Schmitter-Edgecombe, M. (1996). Effects of divided attention on implicit and explicit memory performance following severe closed head injury. Neuropsychology, 10, 155-167.

Schoenhuber, R. & Gentilini, M. (1988). Anxiety and depression after mild head injury: a case control study. Journal of Neurology, Neurosurgery and Psychiatry, 51, 722-724.

Squire, L. (1987a). Memory and brain. NY: Oxford University Press.

Squire, L. (1987b). Memory: neural organization and behavior. In American Physiological Society (Ed.) Handbook of Physiology: higher functions of the brain (Vol. 5).

Teasdale, G. & Jennett, B. (1974). Assessment of coma and impaired consciousness: A practical scale. Lancet, 2, 81-84.

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

Vakil, E. Blachstein, H. & Hoofein, D. (1991). Automatic temporal order judgement: the effect of intentionality of retrieval on Closed-head injury patients. Journal of Clinical and Experimental Neuropsychology, 13, 291-298.

Warrington, E.K. & Weiskrantz, L. (1970). Amnesic syndrome: consolidation or retrieval? Nature, 228, 629-630.

Weldon, M. S. (1991). Mechanisms underlying priming on perceptual tasks. Journal of Experimental Psychology: Learning, Memory & Cognition, 17. 526-541.

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

Winnick, W.A. & Nachbar, S. (1967). Tachistoscopic recognition following paired-associate learning. Journal of Verbal Learning and Verbal Behavior, 6, 95-99.

Woodruff-Pak, D.S., Logan, C.G. & Thompson, R.F. (1990). Neurobiological substrates of classical conditioning across the lifespan. Annals of the New York Academy of Sciences, 608, 174-178.

Zola-Morgan, S. & Squire, L.R. (1990). The neuropsychology of memory: parallel findings in humans and nonhuman primates. Annals of the New York Academy of Sciences, 608, 434-456.

Zung, W. W. K. (1965). A self-rating depression scale. Archives of General Psychiatry, 12, 63-70.